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JORNADAS

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Editors:

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VII CONGRESS OF THE EUROPEAN SOCIETY FOR AGRONOMY

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Foreword

As we approach the 7th Congress of the European Society for Agronomy, it is easy to detect that ESA is now at a crossroads. The Society has been successful in maintaining a scientifically attractive Congress since its creation, and it has sponsored a journal, the European Journal of Agronomy, that has been steadily growing in quality and acceptance among the journals in the agricultural sciences. Both activities have progressed, when the 'climate' for agronomy in Europe has been changing, ever since we met for the first time in Paris in 1990. The initial hopes of creating a pan-european society that would integrate many of the national societies in agricultural science have not materialized and ESA, while maintaining a membership that allows for the maintenance of the Congress and the EJA, has not reached the potential many of us had hoped for 12 years ago.

Most agronomists today, focus their research on the sustainability of agriculture. If ESA is to be sustained, I believe we need a strategic reappraisal of the Society, to define new avenues for developing it as an effective umbrella organization for agronomists in Europe. I encourage all participants in the VII ESA Congress, and in particular the Division Chairs and the National Representatives, to engage in serious talks about the future of ESA while they meet in Cordoba. I believe that if each member contributes to a meaninful debate, helps in defining new actions and acts accordingly in the coming years, the Society has great potential for growing into an organization that will play an important role, not only in european research but in world agricultural sciences as well.

The VII Congress takes place in Cordoba, Spain, and those attending will understand easily why the subject of water-limited agriculture is one of the highlights of the Congress. For the first time, ESA has organized within its Congress, a joint Symposium with the American Society of Agronomy (ASA, CSSA, and SSSA), precisely on the issues around water and agriculture. Thanks are due to to Dr. J. Nicholaides, Executive Secretary of the Tri-societies, and to Prof. M. Singer, President SSSA, for their support. The Congress will host many other contributions from all over Europe and beyond, totalling about 400, that will present the status of agricultural research in an environment that focus less and less on production objectives and more and more on the multiple roles that agriculture plays today in modern society.

Many public and private institutions as well as individuals have contributed to this Congress and they deserve our recognition. This book of Abstracts has been meticulously edited by Prof. Francisco Villalobos with the enthusiastic collaboration of Dr. Luca Testi. They have devoted countless hours, not only to the production of this book but to the miriad of issues raised in the preparation of this Congress. The success of the VII ESA Congress will be in large part due to their tireless efforts.

Elias Fereres Castiel

President
European Society for Agronomy

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Symposium on water limited agriculture

DESIGNING CROPPING SYSTEMS FOR EFFICIENT USE OF LIMITED WATER

David J. Connor

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The conservative relationship between the rates of plant growth and transpiration, that has its origin in gas exchange at the leaf level, need not extend to the seasonal or life-time crop performance, especially when attention is directed to reproductive rather than vegetative growth. The deviation depends upon the ability of individual plants to withstand periods of water shortage, i.e. drought resistance, especially at growth stages that are critical to yield formation and realization. Consequent changes in partitioning of biomass raise the possibility that transient water shortage may even increase harvestable yield.

The best opportunities to maximize water-limited crop productivity are found in management, i.e. in crop selection, preparation of land, sowing times, selection of crop sequences, and where appropriate, supplemental irrigation. A successful cropping strategy will maximize the quantity of water available to each crop by concentrating it in space and time, minimizing losses to drainage and soil evaporation, and selecting appropriate crops and crop sequences. It will also maintain balanced nutrient and water supplies during the cycles of individual crops by sowing cultivars of suitable phenological development at times and densities that best allow expression of their intrinsic water-use efficiency and drought resistance mechanisms.

The design and management of cropping systems is made difficult not by the inadequacy of water supply but by its uncertainty. The semi-arid regions where these challenges exist are characterized by variable rainfall such that some years may allow crops to express their yield potential but in others to fail. The overall performance of a strategy can be improved by tactical variations to observed or anticipated changes in climatic or economic environments. The best economic results are obtained when tactical variations in management are directed to maximize yields in seasons of high rainfall and to minimize costs in seasons of low rainfall. Crop simulation, irrigation scheduling, and decision-support models are becoming available to assist in such decisions by establishing probabilities of outcome to alternative strategies and tactical variations. The value of these decision aids is increased in regions where skill exists in forecasting seasonal rainfall, e.g. that now based on recognition of El Niño cycles.

Where water is available for irrigation, it can be concentrated to fully water an area of crop or be distributed in lesser amounts over a larger area. The decision is influenced by the value of the crop and the probability of rainfall and depends upon an understanding of the effect of transient stresses on crop yield and quality. Reduced-deficit irrigation is used in stone-fruit orchard management to reduce water use during a lull in fruit growth, to control vegetative growth during that period, and to take advantage of compensatory fruit growth when irrigation is resumed. A newer development is partial root drying. In grape vines it is used to control fruit quality and is achieved with two drip lines per plant row to allow alternating wetting and drying of either side of the root system. Crop management of high-value horticultural crops can be improved by measurements of soil, but especially of plant water status, and by predictions of irrigation water demand.

Maintenance or improvement of soil condition is the key to the long-term sustainability of semi-arid, rain-fed cropping systems. Management must be directed to avoid erosion and also to maintain or establish soil physical and chemical conditions suitable for infiltration and root exploration to depth. This maximizes storage of water and its accessibility to the crop.

Reduced and zero-tillage have the capacity to change the patterns of water storage and use to an extent that not only allows greater yields of existing sequences but also introduces the possibilities of change to more attractive cropping options. Increasing demand for crop products is encouraging intensification of cropping systems but sustaining the soil resource in semi-arid rain-fed areas is usually more assured when animal production is integrated with cropping.

It is widely understood that extraction of water from rivers for irrigation can have deleterious effects on riverine ecological systems. It is now evident that cropping management that maximizes the utilization of rainfall can also have significant effects on river flows and the burden of salts that they carry. A more common problem, even in regions where potential evapotranspiration greatly exceeds rainfall, is increased drainage particularly in cropping systems that include fallow. In semi-arid regions, salinization frequently results as rising water tables mobilize salts from depth in the soil profile. The development of optimum cropping strategies must also include these regional ecological issues to establish the sustainable balance between productivity and sustainability.

The principles of efficient water use are well established. The difficulty in their application, apart from social and population pressures characteristic of individual regions, derives from the variability of soils, topography, availability of suitable crops, and especially the variability of rainfall. New techniques are becoming available to assist research and the transfer of technology to farmers. These include automatic weather stations, practical methods to measure soil and plant water status, predict crop water requirement, and make seasonal forecasts of rainfall. There are also geo-spatial techniques to map soil water and salinity and to make yield maps of extensive crop areas. While work on the development of new crops and cultivars of increased drought resistance proceeds, the greatest benefits to productivity and the environment will only flow when the already well-known principles of crop water use are applied using emerging technologies to measure, control, and predict outcomes of alternative management strategies.

CROP MANAGEMENT ADAPTATION TO WATER-LIMITED ENVIRONMENTS

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Agronomic and climatic context of water-limited agriculture

Water stress is the main factor limiting crop production in rainfed farming systems in arid (Precipitation / Potential EvapoTranspiration < 0.2) and semi-arid (0.2 < P/PET < 0.5) environments. In sub-humid (0.5 < P/PET < 0.75) and humid areas (P/PET > 0.75), water shortage is rarer but often affects crops grown on shallow soils and spring-sown crops, both of which may require supplementary irrigation. Increased water needs for agriculture and threats to natural water resources should be considered when assessing different climate change scenarios. High temperatures and water stress are expected, with adverse effects on crop yield.

Depending on climate and soil type, different types of drought are encountered which require specific farming adaptations : (1) early drought affecting the uppermost soil layers and responsible for poor seedling establishment and crop failure ; (2) drought during the vegetative period resulting in a low leaf area index, biomass and grain number ; (3) late drought affecting grain filling. In addition, intermittent episodes of stress with plant recovery or continuous soil drying may be observed. The year to year variation in total rainfall and its monthly distribution characterizing low rainfall areas generates a wide diversity of scenarios although all the situations (but especially the long-season crops) are generally affected by late drought. In the low-rainfall of Mediterranean-type environments, crop growth is restricted to a short winter growing season which starts with autumn rainfall and ends with declining soil moisture and high temperatures in spring.

Chronic water deficit is mainly due to inherent physical conditions, which cannot be alleviated : low soil water-holding capacity (depth, structure, texture, stony soils) and/or rainfall shortage during the winter fallow or growing season in association with a high evaporative demand. Water deficit is often associated with high temperatures and salinity, causing additional stress.

In rainfed environments, cropping systems are based on wheat (or barley)-fallow rotation for water conservation when annual rainfall is less than 300 mm. Cropping systems are more diversified in 400-600 mm areas : cereals are combined with autumn-sown legumes (lentils, chickpea etc.). On the deepest soils, spring-sown crops may be introduced, like sunflower, sorghum and maize, which use water stored over winter. Deficit irrigation may be used for cereals or drought-tolerant spring-sown crops. Fully irrigated systems with high-income crops, such as maize, soybean and sugarbeet are often used on alluvial soils where water is more readily available. In the last decade, the need for quality and yield stability has resulted in the development of irrigation in the northern European great plains under high-input management.

Adaptation to drought-prone environments through crop management

Ludlow (1989) reviewed three strategies of crop adaptation to drought-stressed environments : (a) drought escape, whereby the crop completes its life before the onset of terminal drought, (b) drought avoidance, where the crop maximizes its water uptake and minimizes its water loss, (c) drought tolerance, where the crop continues to grow and function at reduced water contents. These headings are generally used to discuss genotypic adaptation but they can also be applied to discuss adaptation of crop management. Drought suppression (or attenuation) is an additional strategy that can be achieved by irrigation.

To cope with limited, variable and often chronically deficient rainfall, the farmer has to apply the optimal combination of different strategies :

1) maximize the stored soil water at planting, at the beginning of rapid growth and at anthesis but avoid an excess of water in the profile at harvest in order to plant the subsequent crop in good conditions and limit winter drainage ;
2) escape drought by ensuring that key growth stages for grain yield formation do not coincide with periods of strong evaporative demand and/or low rainfall (especially sensitive phases such as emergence or anthesis): quicker and more appropriate crop phenology;
3) tolerate the occurrence of drought by choosing a crop species or cultivar less susceptible to intermittent or prolonged water stress;
4) optimize the use pattern of initial stored water and rain falling during the growing season by reducing the contribution of evaporation to ET and increasing total water extraction but using it sparingly in early growth.
5) supplement the natural deficit by irrigation at the most responsive periods in order to optimize the use of the other inputs.

Genotypic diversity may be used also for strategies 2), 3) and 4) together with the adaptation of crop management.

In the situations where water is the main limiting factor, agronomists frequently assess management practices in terms of water use efficiency (WUE), which is the ratio of harvestable dry matter to crop water use (evaporation + transpiration) (e.g. Cooper and Gregory, 1987)

$$WUE = DM / (T+E) = (DM/T) / (1 + E/T)$$

DM = harvestable dry matter ; T = total amount of water transpired by the crop ;
E = soil evaporation ; DM/T is often called transpiration efficiency (or TE)

In addition, Passioura (1977) proposed that grain yield of cereals in water-limited environments could be analyzed in terms of three factors that are largely independent :
Grain yield (GY) = Water transpired (T) x water-use efficiency (WUE) x harvest index (HI)
Therefore increasing biomass (grain or grain + straw) will be attained through increasing (1) the total quantity of water available to a crop, (2) plant transpiration relative to soil evaporation, and (3) the transpiration efficiency. This approach has been extensively used in assessing the adaptation and grain yield of a range of crops to water-limited environments (e.g.Turner et al., 2001).

Crop adaptation to water-limited environment may be summarized by 4 principles :

- increasing water transpired by a favorable crop phenology (1)
- increasing transpiration efficiency (2)
- reducing the contribution of soil evaporation to ET (3)
- increasing soil water content and its capture by the crop (4)

Principle 1 : Choosing crop species and cultivars adapted to the rainfall amount and monthly distribution
Rainy season and growing season should be matched to optimize the capture of water available for transpiration and to escape water stress during the reproductive phase (e.g choice of autumn-sown crops in Mediterranean regions). Drought escape, whereby a crop completes its life before the onset of terminal drought, is often regarded as the primary strategy of crop adaptation to water-limited environments (Loss and Siddique, 1994). The wide diversity in the length of crop and cultivar growing periods offers ample opportunities for this adjustment. There are many examples where the use of early maturing (or early flowering) cultivars increased and stabilized grain yield, especially in arid and semi-arid areas (Fereres et al., 1993).
The choice of drought-tolerant cultivars (and species) is another means of adaptation to drought-prone environments and of increasing WUE which has been well documented (Ludlow and Muchow, 1990). For instance, the major traits of adaptation for cool season grain legume species in low-rainfall Mediterranean-type environments are early flowering and pod and seed set before the onset of terminal drought. Rapid development together with early ground cover and DM production allow greater water use in the post flowering period: examples are pea and faba bean, as compared with other legumes (Siddique et al., 2001).

Principle 2 : Increasing transpiration efficiency (DM/T)
Transpiration efficiency (ranging from 4 to 9 g of dry matter per kg of water transpired) is a relatively stable parameter for a given crop in a given environment (Tanner and Sinclair, 1983). The value of TE is higher for C4 crops such as maize and sorghum than for C3 crops like sunflower, wheat and legumes. In addition, TE is higher during periods of low vapour pressure deficit (VPD) as in the cool winter months. Fereres et al (1998) found higher values of TE for autumn-sown sunflower. For chickpea in Syria, TE increased from 19 kg $ha^{-1}.mm^{-1}$ in spring to 23 kg $ha^{-1}.mm^{-1}$ with winter sowing (Cooper and Gregory, 1987). By choosing efficient and/or autumn-sown crops, TE could be increased. This could be achieved by using early cultivars tolerating low temperatures. N fertilization generally improves TE through an increase in green area index and RUE (Heitholt, 1989 ; Korentager and Berliner, 1987) while application of P on deficient soil accelerates crop development and hastens maturity, thus ensuring that the crop experiences an environment with a lower VPD (Shepherd et al., 1987).

Discussion : Short or long growing period ? In a Mediterranean climate, crops sown in late autumn or winter receive rainfall which is variable but often sufficient to cover water needs until anthesis, with fluctuations resulting from the degree of recharge during the previous winter. Crop yield is generally limited by the terminal drought associated with high temperatures causing shriveling. Sowing soon after the first autumn rains generally results in increased seed yield potential compared to delayed sowing because of more available water, higher biomass production, earlier anthesis and increased harvest index. These advantages may be offset by the increased risk of fungal diseases and frost damage near anthesis. Sowing date in Mediterranean regions must be sufficiently late to minimize the risk of frost during shooting but early enough to ensure that flowering escapes the terminal drought. This is more true for cereals than for indeterminate species, e.g legumes, which can tolerate intermittent low temperature events. The opportunity to displace the sowing time of sunflower to autumn or winter was studied in southern Spain by Gimeno et al. (1989). Seasonal ET was increased by 30 % and WUE by 79 % for the winter plantings as compared with the spring plantings. The tolerance of sunflower to low temperatures then became the main problem to solve through selection. On the other hand, early sowing of sunflower implies a complete change of current management : new methods of chemical weed control and N fertilization are needed with the change of crop growing period and the new hierarchy of limiting factors.

In the long term, we may not conclude that short-cycle genotypes are always the best choice for water-limited environments. Early cultivars use less water because of their shorter growth duration and their smaller leaf area index (LAI). Hence, in a year of favorable rainfall, they tend to produce less biomass and yield than late cultivars. However, when water supply is limited in the latter part of the growing season, late cultivars produce excessive biomass with a low HI while early ones generally produce moderate biomass with better HI. In Israel, Blum (1993) demonstrated the interaction between water availability and optimal growth duration for wheat : under conditions of water deficit (GY < 3 t ha^{-1}), the correlation between yield and days to heading of 12 cultivars was negative while under well-watered conditions (GY > 6 t ha^{-1}), late flowering cultivars had a yield advantage; under mild stress, mean yield was not related to growth duration. In southwestern France, early maturing wheat cultivars yielded more in the driest years while the opposite was observed in rainy and cool seasons (Debaeke, 1995). Gimenez and Fereres (1986) concluded that late maturing cultivars of sunflower were a better choice than early maturing ones in the conditions of southern Spain, because the former were deeper rooting and obtained more water from the water table. Blum (1993) found that late sorghum and wheat cultivars have a larger root system (root length and growth duration) and that they recover better after drought stress. In conclusion, the optimal growth duration is strongly dependent on the climatic variability and the intensity of water deficit. In arid and semi-arid conditions, shortening the growing period is generally to be preferred (escaping strategy) while in sub-humid conditions, the reduction of potential production is probably more detrimental than the risk of severe yield limitation by water stress. The final decision will depend on the farmer's attitude to the climatic and economic risk.

Principle 3 : Reducing the contribution of soil evaporation (E) to total ET

In Australia, 30-60 % of the seasonal ET may be lost as evaporation from the soil surface (Siddique et al., 1990). This large loss occurs because, during early winter, crops have low LAI and the soil surface is frequently wetted by rainfall in Mediterranean-type environments. ET during this period is dominated by E but if this water could be transpired, growth and water use efficiency of crops might be increased.

One means of reducing E is to use crop residues as mulch in order to reduce the amount of energy reaching the soil surface. The principal effect of mulching is to reduce the rate of evaporation when the soil surface is damp and thereby to extend the duration of the 'first-stage drying' (Ritchie, 1972). For example, Bristow et al (1986) in the Pacific Northwest simulated a 36 % reduction in the total E under residue-covered soils. The availability of crop residues is often restricted in dry areas by its use as fodder, by the reduced biomass or the lack of suitable tillage equipment.

For these reasons, the most feasible way to reduce E is probably to increase the early growth of the crop canopy. Plant characteristics such as early vigor, crop morphology (spreading habit vs erect foliage) and management practices such as early sowing, increased fertilizer input, planting density and reduced row width which increase early growth have been shown to decrease E/ET. Reducing deep drainage losses which contribute to salinity and waterlogging may constitute an additional benefit (Eastham et al., 1999).

Cooper et al (1991) pointed out several difficulties in applying these principles in dry areas. Sowing too soon is risky because early rains are unreliable and crop failure may result from initial germination not followed by sufficient rainfall. Maximizing ground cover during winter months by using high planting densities may conflict with the need to conserve sufficient water to be available during grain filling.

Discussion : Low or high plant population ? Modifying plant population can have large beneficial effects on the reduction of E/ET. But when water is short, low plant populations are generally recommended and practised in order to maximize the available water per plant, in spite of an increase of E/ET. Anderson (1984) showed that the optimum density for triticale varied from 80 to 190 plants/m² for grain yields ranging from 2.1 to 6.9 t ha^{-1} depending upon the season's rainfall. In Toulouse (SW France), optimal plant density was 7.4 plants/m² for irrigated sunflower and 6.3 plants/m² for rainfed sunflower (Debaeke and Nolot, 2000). Connor and Loomis (1991) discussed the choice of plant arrangement. The authors conclude that if the crop relies upon stored water, wide rows are appropriate because E will be small and the stored water can be released slowly; on the other hand, if the crop relies upon rainfall during the growth cycle, a uniform arrangement with appropriate spacing will enable each plant to extract the water available while minimizing the unproductive losses by E.
Myers and Foale (1981) showed that the widest spacing gave the highest yield of sorghum at low-rainfall sites whereas close spacing was best at the most productive sites. Nevertheless, the choice of plant density and row spacing may interact with methods of weed control either by plant competition or mechanical weeding : controlling weeds is vital in water-limited environments to retain sufficient water for grain filling.

Discussion : Low or high fertilization ? Increased N fertilization generally results in a reduction of E/ET (Anderson, 1985 ; Cooper and Gregory, 1987). Application of nitrogen (and phosphorus) may increase root length and rooting depth, increasing water use (Gregory et al, 1984 ; Brown et al., 1987). But excessive N amounts may depress yield in some cases by its influence on early growth and high LAI exhausting limited water supplies before grain filling (Cantero-Martinez et al, 1995). High plant N may predispose the plant to water stress injury (Fischer, 1981). Nitrogen application should be matched to the attainable yield by using balance sheet methods which explicitly consider the main factors reducing the efficiency of nitrogen in such water limited environments (Nolot and Debaeke, 2001). In rainfed conditions, the timing of nitrogen application is guided by soil moisture. Generally N is given at planting and placed at depth to prevent N gaseous losses and maximize its uptake by the crop. This single application is not the best strategy to adjust N amount to seasonal rainfall (Nordblom et al., 1985) ; the risk of N leaching in winter should also be considered. Split applications in cereals are recommended, the second dose being applied at stem elongation with regard to winter rainfall. Supplementary irrigation is a way to increase N use efficiency in such conditions and to improve grain protein content in cereals. The splitting strategy should be decided by considering soil water at sowing, seasonal rainfall and availability of irrigation. In dry areas, N-fertilizer response is largely rainfall-related, loss of nitrate from the rooting zone by deep leaching is rare but ammonia volatilization may be a major source of N loss in calcareous soils (Vlek et al, 1981 ; Harmsen, 1984). N efficiency at harvest may range from 20 to 80 % depending on fertilizer type, application time and method, soil type and climatic conditions (Garabet et al, 1998). Incorporation of N fertilizer while mechanically weeding is a way to increase N use efficiency in row crops.

Principle 4 : Matching crop water requirements and water availability
This strategy modifies the crop water balance by reducing crop water needs to the amount available from rain and irrigation and by increasing the capture of stored water and rainfall. Reducing crop water requirement could be achieved by low plant densities, wide inter-rows, plant thinning (or defoliation) and reducing N fertilization. The term 'crop rationing' has been used to describe this strategy (Debaeke and Nolot, 2000). The objective is to save water early in the season to leave sufficient resources for grain filling or at least during the most sensitive periods, for instance anthesis when water use efficiency is maximum. Encouraging a more

even seasonal water requirement is an effective approach when water is plentiful during the first half of the season and becomes short during the second half of the season. Under such conditions, a dense canopy is developed when water is available, which contributes to early crop senescence when water becomes scarcer. This phenomenon, called 'haying off', is often attributed to high levels of soil N, such as when a legume was the previous crop or N rate is not matched to water availability, stimulating early growth and water use (McDonald, 1989). Genotypic traits were proposed for wheat by Richards and Passioura (1989) to improve the seasonal pattern of water use. Passioura (1976) concluded that the grain yield of wheat growing on a fixed and limiting supply of water can be substantially increased by forcing the plants to save water for post-anthesis growth. HI increased with the fraction of water transpired after anthesis. When LAI is kept below 3, transpiration increases linearly with LAI when the soil surface is dry (Ritchie, 1972). This strategy may be applied by sowing a crop or a cultivar with a low LAI at anthesis, but which covers the soil rapidly, or one with low stomatal conductance, which may conserve soil water during the periods when the soil water deficit is still small. Choosing an early-flowering cultivar or sowing late may result in similar crop rationing. But as suggested by Fischer (1979) for wheat, the choice of a given precocity or a given level of crop rationing is a compromise between attaining a sufficient biomass and grain number at anthesis without reducing soil water content too markedly at early grain filling. Fereres et al (1998) showed that winter sowing of sunflower increased TE (because of higher radiation use efficiency) and T (because of a higher LAI), and that this approach, which increases total biomass but reduces HI, represents the best compromise; they concluded that transpiration should be increased under water-limited conditions.

Increased crop water availability may be obtained by increasing the soil water storage capacity. This is achieved by deep tillage (e.g paraplowing), in short or long fallow periods, with the objective of reducing runoff and increasing infiltration, although the efficacy of this practice is limited in swelling clay soils that crack during the hot summer and because of the maintenance of high evaporative demand in autumn. Compared to shallow tillage or no-tillage, plowing may contribute to deeper soil desiccation during dry periods while more water is stored during wet periods. An example of this interaction with water regime was given by Aboudrare (2001) in the semi-arid conditions of Morocco.
The effects of soil tillage on water conservation have been thoroughly reviewed by Unger et al. (1991). Considerable progress has been made in maximizing soil water storage by stubble-mulch and minimum-tillage techniques in the Great Plains of USA with positive impacts on enhancing water infiltration and suppressing evaporation.
The purpose of fallowing is to conserve water from one season to another. Numerous authors have studied the efficacy of fallowing (duration, management of crop residue, tillage etc.) for storing water for the subsequent crop. The efficacy of fallowing as regards the transpiration of the succeeding crop may be extremely variable depending on soil depth, texture and structure and whether weeds are controlled (McAneney and Arrue, 1993).
In most Mediterranean countries, weeds and volunteer cereals are allowed to grow on the fallow and provide a valuable and cheap source of grazing for livestock (Cooper and Gregory, 1987). However, in some areas, clean fallowing is practised and the increased water storage during the fallow has resulted in substantial yield increases in the subsequent crop (cereals or sunflower). Competition for water should also be prevented during the growing season by controlling the weeds early in the season. WUE of lentil production was increased from 3 to 6.4 $kg.ha^{-1}.mm^{-1}$ by suppressing 90 % of the weed biomass (Cooper and Gregory, 1987).
Soil tillage in optimal conditions of soil moisture increases the soil volume explored by the rooting system thus resulting in higher transpiration (Aboudrare, 2001). Application of fertilizer may also increase the total water use by a small amount, either by increasing the

depth of water extraction, or the amount extracted from specific soil layers or both (Brown, 1971).

As water is mostly localized deep in the profile in dry regions, species and cultivars with deep rooting should be preferred. But two problems may emerge : 1) a rapid exhaustion of stored water and a non-optimal distribution of water transpired over the season ; this was observed in sunflower in Morocco where maximizing soil water storage in March at planting did not result in the highest yield (Aboudrare et al., 2000a) ; 2) as root development follows the wetting front in dry areas, it is unlikely that deep reserves will be exploited each year.

Supplementary irrigation (SI) has been used in water-limited regions to increase the water supply available to crops. When natural contributions by rainfall or groundwater are too scarce to satisfy full crop water requirements only occasionally due to an insufficient amount and/or poor distribution within the season, a continuously optimal water regime can be obtained by SI, i.e by a temporary and discontinuous irrigation regime (Caliandro and Boari, 1996). Such situations are frequently observed in humid and sub-humid regions, generally for spring-sown crops such as soybean, maize, sugarbeet and potatoes. For instance, in southwestern France, most of the maize is grown under SI (up to 250-300 mm). In regions where both rainfall and irrigation resources are too limited for ensuring a permanent optimal water regime to crops, SI is mainly supplied at the critical periods of the crop growth cycle in order to maintain or improve crop production (Caliandro and Boari, 1996). This is the case in arid and semi-arid regions of the Mediterranean basin where supplementary irrigation is practised for species generally grown profitably without irrigation but whose yields are subject to a great deal of year-to year variation because of rainfall variability. These species are winter cereals (wheat), autumn-sown legumes (faba bean, peas) and spring-sown crops with a dense and deep rooting system (sorghum, sunflower, cotton, etc.). In these regions, spring-sown crops (such as maize or sugarbeet) with high water requirements but a restricted rooting system are only grown in intensively irrigated systems in which irrigation amounts (up to 800-1000 mm) greatly exceed the contribution from natural resources.

In temperate humid and sub-humid environments, where water deficits are rare, mostly terminal and/or of short duration, supplemental irrigation is used by farmers to stabilize yield and quality at high levels, and to maintain crop uniformity. In drier environments, SI can be considered to be more a dry farming technique since it helps to optimize the use of limited water resources (Caliandro and Boari, 1996) : its purpose is to prevent complete yield loss (through irrigation at sowing, in exceptionally dry years) or to improve yield in years which are not excessively dry (by irrigation during shooting). In every case, SI is a means of insuring farmers against climatic risks.

Either because irrigation volume (or discharge) is limited because of a dry winter, low storage capacity of the basin or the unavailability of sprinkling equipment, or because the soil water deficit is not very large, supplementary irrigation generally involves a limited number of water applications, either to save the life of the crop or more often to improve the efficiency of the other practices (Oweis et al., 1999). These are: sowing in due time, avoidance of uneven and poor plant emergence, more efficient placement and use of fertilizers, thus limiting N leaching and N residues at harvest, use of high-yielding cultivars and avoidance of crop moisture stress, particularly during the initial stages of its development in semi-arid regions or later (around flowering) in wetter regions. For instance, in the West Asia-North Africa region, cereal yields are low and variable in response to inadequate and erratic seasonal rainfall (350 mm rainfall and above) and related management factors, such as lack of nitrogen and late sowing. It is clear that small amounts of supplementary irrigation water can make up for the deficits in seasonal rain and produce satisfactory yields (Oweis et al., 1998).

A minimum yield of more than 3.5 $t.ha^{-1}$ is guaranteed for wheat with an amount of irrigation varying from 50 to 200 mm, depending on the zone and the amount and distribution of the seasonal rainfall, whereas the average yield is below 1.5 $t.ha^{-1}$ under rainfed management (Arar, 1992). Quite a small amount of irrigation (1/3 full irrigation) may achieve over 60 % of the potential increase in yield obtainable with full SI. In addition, the efficiency of use of both soil water and nitrogen is greatly increased by SI. Oweis et al. (1998) observed a wheat yield increase with up to 100 kg N ha^{-1} under SI management in Syria, while the maximum response under rainfed conditions was obtained with 50 kg N ha^{-1}.

In southwestern France, under a temperate sub-humid climate, grain yield was increased by 17, 27, 37 and 70 % for sunflower, sorghum, soybean and maize respectively with 120 mm of irrigation (given around flowering) when compared to rainfed management over 9 years on a deep silty-clay soil (Debaeke and Hilaire, 1997). This shows the differential sensitivity of spring-sown crops to supplementary irrigation as related to physiological traits such as depth and extraction efficacy of rooting system, drought tolerance mechanisms (sunflower and sorghum), indeterminate reproductive period (for soybean) acting as an escaping strategy.

With limited available water, the challenge is to satisfy crop water demand at the critical (and most responsive) stages. An extensive review of specific periods for optimizing irrigation was made by FAO (Doorenbos and Kassam, 1979). For instance, the most sensitive stages of wheat to water stress are booting and early ear emergence according to some authors and the pre-flowering and ear formation stages according to others, whereas seed germination and crop emergence periods are only rarely considered to be sensitive to water stress (Caliandro and Boari, 1996). The decision to irrigate at a given growth stage depends on the crop sensitivity to water stress, on the weather pattern and on the need to exploit natural water resources. Irrigation of cereals in autumn during dry spells aims to ensure an optimal plant density and satisfactory root establishment in order to fully use soil water reserves later but also to cover the soil surface rapidly to limit soil evaporation and maximize early radiation interception and biomass accumulation. In semi-arid regions, when a single application is available for sunflower, it should be applied either just before sowing to recharge the soil and establish the crop, or between flower bud appearance and flowering, to increase leaf area index. In wetter areas, one irrigation is generally recommended after anthesis to increase the leaf area duration and favour oil production. Irrigation should be stopped early on deep soils to allow a significant contribution from deep water storage.

Supplementary irrigation is a solution which does not usually completely eliminate water deficit. In water-limited agriculture, irrigation is often limited both in volume and delivery rate (deficit irrigation), either because the sources of irrigation (water table, hill reservoirs, rivers etc.) have not been refilled, or because equipment and labor are insufficient to ensure full satisfaction of water requirements, especially during the driest seasons.

Devising a consistent set of techniques for water-limited environments

The package of techniques which was previously described should be combined in a logical and consistent manner to optimize the use of stored soil water and seasonal rainfall.

In water-limited conditions, a sequence of decisions, either tactical or operational, is taken by the farmer :

1) crop planting or fallowing : depending on soil water content in autumn, a decision about the crop pattern (winter or spring-sown, fallowing or not) is taken. In spite of limitations imposed by crop rotation and the limited range of crops, some flexibility generally exists.
2) yield objective : as a function of initial water and the probability of rainfall during the season, drought escaping, crop rationing and (or) tolerance are decided at planting by consistent decisions on sowing date, sowing density, N rate, type of cultivar etc.

3) in autumn, the sowing operations are planned for when a sufficient amount of rain has occurred to prevent crop failure.
4) the yield target is evaluated again in early spring and N top-dressing can be decided for cereals at stem elongation. The crop may be aborted and plowed in if winter rainfall and/or crop establishment prove insufficient; a second crop may be sown in spring or the residual crop may be grazed by livestock.
5) on irrigated crops, the decision to apply water is taken for maximizing N use efficiency ; crop stage, soil water deficit or leaf area index are possible indicators to decide on successive irrigations. Tactical decisions are taken as a function of recent weather and taking into account the probability of rainfall in the next days or weeks.

In rainfed agriculture, but especially in semi-arid and arid conditions, most of the decisions are taken at planting without further opportunity to correct the yield target by top-dressing applications. In the absence of supplementary irrigation, the N rate is reduced and the N fertilizer is incorporated into the soil at planting to make use of residual moisture. Decisions are taken in response to the actual soil water content taking into account the probability of future rainfall. When supplementary irrigation is available, N splitting is possible and crop rationing is probably more successful because crop requirements and inputs can be adjusted.

In such conditions, long-term mean rainfall serves to give a general picture of the potential for crop production in spite of the substantial year-to-year variation in rainfall. It is important to consider rainfall in terms of probability of occurrence to assess the long-term suitability of crop cultivars and crop management strategies (Keatinge et al., 1986 ; Dennett, 1987). Advances in medium-term weather forecasting in some areas give hope that rational within-season adjustments may soon be possible (Fereres et al., 1993).

Tactical decision making should be guided by an optimal growth pattern from sowing to grain filling. Such a pattern was indicated by Passioura (1977) : a partitioning of 2/3 of transpiration before anthesis and 1/3 during grain filling was found to be the best pattern of water use for wheat. In sunflower, for southwestern France, Picq (1990) suggested a pattern based on the fraction of solar radiation intercepted (or LAI). Rules were then devised to decide on supplementary irrigation as a function of pre-anthesis LAI and soil tensiometer readings (Bougel et al., 2001).

Simulation models for improving crop management in water-limited environments

Simulation models are useful for evaluating crop management under water-limited conditions :

- they are based on several decades of knowledge of soil-water and plant-water relationships ; even when running at the process level, a minimum set of physiological detail is sufficient to give useful predictions (Sinclair and Muchow, 2001) ;
- the complex interactions previously described may be explained and optimal decisions may be reached more easily with sound models using long-term weather records while field experiments cannot definitively explore a sufficient range of weather and management combinations ;
- recently, progress has been made in interfacing decisional and biophysical models (Bergez et al., 2001)

Simple but sound water balance models may be enough to assess the risk of water deficit associated with a given crop duration and sowing time. More complete models are necessary to describe N dynamics in soil, N uptake and crop cultivar behavior.

In the last 15 years, on the basis of ecophysiological studies, numerous soil-plant models (either crop-specific or generic) have been developed to simulate water dynamics in soil and the response of major crops to water use: APSIM (McCown et al., 1996), CropSyst (Stockle et al, 1994), Epic-Phase (Cabelguenne et al., 1999), STICS (Brisson et al., 1998) being among the most recent ones. By using long-term weather records as input, these mechanistic models, more or less complex, were used extensively to determine the probability of given responses of grain yield to various combinations of crop management including the amount of soil water at planting, sowing date, cultivar phenology, plant population and supplementary irrigation and to define at field or farm level the optimal irrigation schedules or combination of techniques in various water-limited environments (e.g. Sadras and Hall, 1989 ; Jackson et al., 1990 ; Rosenthal and Gerik, 1990 ; Singels, 1992 ; Fereres et al., 1993 ; Muchow et al., 1994 ; Cabelguenne et al., 1995 ; Aboudrare et al., 2000b). The two following examples illustrate the potential of models for supporting decisions for water-limited agriculture.

Nordblom et al.(1985) compared 3 fertilization strategies for dryland wheat in Oregon on a historical 60-year weather sequence: a blind constant application at sowing time each year, a variable application in early spring based on the simulation of soil mineralization or split applications. The spring application was the most profitable according to the model. But farmers are conservative and use a split application strategy which provides more flexibility for fine tuning of fertilizer amounts according to the current growth conditions.

In Australia, Hammer (2000) analyzed the possibility of improving profitability by manipulating row configuration in dryland cotton in response to a seasonal rainfall forecast. Using a simulation approach and 100 years of historical rainfall data, he determined the most profitable option for row configuration for either all years or those years associated with each Southern Oscillation Index (SOI) phase prior to sowing. Without using the seasonal forecast (fixed management), the 'solid row' option was the most profitable. But when using the SOI-based forecast at the time of sowing (responsive management), either 'single' or 'double skip row' could be the best options. Over all years, the tactical attitude resulted in an extra profit of 11 % compared with fixed management.

Such model outputs should be considered as supports in decision-making but not as rules for best management. Their use for decision-making requires ready access to input variables and an explicit representation of crop management in terms of decision rules. Bergez et al (2001) developed a model where irrigation scheduling was based on the activation of decision rules (if [value of indicator] ... then [action]) in order to realistically represent the decision process of the farmer. These rules were used to decide on the start of irrigation, frequency of application and amount to apply, cessation after a rain event, end of irrigation, etc. It is now a challenge for modellers to represent the indicators used by the farmers to decide on applications in order to produce sound and transferable decision rules for any given water limitation scenario.

References

Aboudrare A. et al., 2000a. Proc.15th Int.Sunf.Conf., ISA, Toulouse (France), C : 115-120
Aboudrare A. et al., 2000b. Sécheresse 11 (1) : 19-27
Aboudrare A., 2001. Thesis, IAV Hassan II, Rabat (Maroc), 175 p.
Anderson W.K., 1984. Field Crops Res 8 : 281-295.
Anderson W.K., 1985. Field Crops Res 12 : 191-202.
Arar A., 1992. International Conference on Supplementary Irrigation and Drought Management, Valenzano-Bari (Italy), CIHEAM, Vol.1 : 1-10.
Bergez J.E. et al, 2001. Ecol.Mod. 137 : 43-60.
Blum A., 1993. In : International Crop Science I, CSSA, Madison (WI, USA), pp.343-346
Bougel F. et al., 2001. Oleoscope (Cetiom) 60 : 15-17.
Brisson N. et al, 1998. Agronomie 18 : 311-346
Bristow K.L. et al, 1986. Agr For Meteor 36 : 193-214.
Brown P.L., 1971. Agron.J. 63 : 43-46.

Brown S.C. et al, 1987. Field Crops Res 16 : 53-66.
Cabelguenne M. et al., 1995. Trans.ASAE 38 : 507-511
Cabelguenne M. et al., 1999. Agric.Syst. 60: 175-196
Caliandro A., Boari F., 1996. Medit 7 : 24-27.
Cantero-Martinez C. et al, 1995. Eur J Agron 4 : 309-316.
Connor D., Loomis R.S., 1991. In : Improvement and management of winter cereals under temperature, drought and salinity stresses, INIA-ICARDA, pp.441-465.
Cooper P.J.M., Gregory PJ, 1987. Soil Use Manag. 3 : 57-62.
Cooper P.J.M et al., 1991. In : Improvement and management of winter cereals under temperature, drought and salinity stresses, INIA-ICARDA, pp.397-419
Debaeke P., 1995. Agr Med 125 : 64-78.
Debaeke P., Hilaire A., 1997. Can.J.Plant.Sci. 77 : 539-548.
Debaeke P., Nolot J.M., 2000. Proc.15th Int.Sunf.Conf., ISA, Toulouse (France), C : 1-8
Dennett M.D., 1987. Soil Use Manag 3 : 47-51.
Doorenbos J., Kassam A.H., 1979. Yield response to water, Irrigation and Drainage Paper 33, FAO, Rome (Italy), 193 p.
Eastham J. et al, 1999. Agric Water Manag 42 : 205-218.
Fereres E et al., 1993. In : International Crop Science I, CSSA, Madison (WI, USA), pp.83-89
Fereres E. et al., 1998. Proc. 5th ESA Cong., Nitra (The Slovak Republic), Vol.I, 317-318.
Fischer R.A., 1979. J.Aus.Inst.Agric.Sci. 45, 83-94.
Fischer R.A., 1981. Plant Soil 58 : 249-278.
Garabet S. et al, 1998. Field Crops Res 58 : 213-221.
Gimenez C., Fereres E., 1986. Aust J Agric Res 37 : 583-597.
Gimeno V. et al., 1989. Field Crops Res 22 : 307-316.
Gregory P.J. et al, 1984. J agric Sci Camb 103 : 429-438.
Hammer G.L., 2000. In : Applications of seasonal climate forecasting in agriculture and natural ecosystems, Kluwer Academic Publishers, Dordrecht (The Netherlands), pp 51-66.
Harmsen K., 1984. Fert Res 5 : 371-382.
Heitholt J.J., 1989. Agron.J 81 : 464-469.
Jackson B.S. et al., 1990. J.Prod.Agric. 3 : 420-425.
Keatinge J.D.H et al., 1986. Field Crops Res. 13 : 239-249.
Korentager L., Berliner P.R., 1987. Agron.J 80 : 977-981.
Loss S.P., Siddique K.H.M., 1994. Adv Agron 52 : 229-276.
Ludlow M.M., 1989. In : Structural and functional responses to environmental stresses, SPB Academic Publishing, Gravenhage (The Netherlands), pp.269-281.
Ludlow M.M., Muchow R.C., 1990. Adv. Agron. 43 : 107-153
McAneney K.J., Arrue J.L., 1993. Agronomie 13 : 481-490..
McCown R.L et al, 1996. Agric.Syst. 50: 255-271.
McDonald G.K., 1989. Aust. J. Exp. Agric. 29 : 455-481.
Muchow R.C. et al., 1994. Field Crops Res. 36 : 235-346.
Myers R.J.K., Foale M.A., 1981. Field Crops Res 4 : 147-154.
Nolot J.M., Debaeke P., 2001. Proc.11th Nitrogen Workshop, Reims (France), 401-402
Nordblom T.L. et al., 1985. Agric.Syst. 18 : 133-153.
Oweis T. et al., 1998. Agron. J. 90 : 672-681.
Oweis T. et al., 1999. Eur.J.Agron. 11 : 255-266.
Passioura J.B., 1976. Aust.J.Plant Physiol. 3 : 559-565.
Passioura J.B., 1977. J.Aust.Inst.Agric.Sci. 43 :117-120.
Picq G., 1990. In : Le Tournesol et l'Eau, Cetiom (Paris), pp.105-124.
Richards R.A., Passioura J.B., 1989. Aust J Agric Res. 40 : 943-950.
Ritchie J.T, 1972. Water Resour.Res. 8 : 1204-1213.

Rosenthal W.D., Gerik T.J., 1990. J.Prod Agric. 3 : 124-131.
Sadras V.O., Hall A.J., 1989. Agric. Syst. 31 : 221-238.
Siddique K.H.M. et al, 1990. Aust J Agric Res 41 : 431-447.
Siddique K.H.M. et al., 2001. Eur.J.Agron. 15 : 267-280.
Sinclair T.R, Muchow R.C., 2001. Agron.J. 93 : 263-270.
Singels A., 1992. Agric. Syst. 38 : 175-184.
Shepherd K.D. et al, 1987. J agric Sci Camb 108 : 365-378.
Stockle C.O. et al., 1994. Agric.Syst. 46 : 335-359.
Tanner C.B, Sinclair T.R, 1983. In : Limitations to efficient water use in crop production, American Society of Agronomy, Madison (WI, USA), pp.1-27.
Turner N.C. et al., 2001. Adv.Agron. 71 : 193-231.
Vlek P.L.G et al, 1981. Plant Soil 58 : 133-176.

AGROECOLOGY OF WATER USE AT THE FIELD, FARM, AND LANDSCAPE LEVELS

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Introduction

Sustainability of agricultural production, incomes of farm families, and viability of rural communities in areas of limited rainfall have been problematic since people first left hunting and gathering. Low precipitation, erratic distribution of rains, and unpredictability of snowfall contribute to high-risk agriculture, yet many such areas are those available for production. Over centuries, farmers have developed strategies to stabilize productivity under harsh conditions and to maximize use of the available precipitation. Most research has focused on genetic improvement of crops, understanding plant survival mechanisms, or efficient capture and storage of scarce rainfall through modifications in tillage practices. Little attention has been given to the integrated activities that lead to greater efficiency of water use at the field, farm, and landscape levels.

Challenges in designing systems for limited rainfall areas include overcoming 1) low soil moisture levels, 2) rapid soil degradation, and 3) low soil fertility due to loss of organic matter (Stewart, 1994). One obvious solution to solve all three problems is to supply irrigation; such a solution is possible only where available surface or underground water, necessary equipment, and adequate infrastructure for exploitation of off-site water resources are available. In the vast majority of rainfed lands, irrigation is not a sustainable option. Agroecology provides an integrated approach that builds on information from natural ecosystems and informs the design of cultivated systems. The efficient capture, storage, and use of water by plants can be accomplished by looking at the mechanisms available at the field, farm, and landscape levels. For long-term sustainability, such systems must be productive, economically profitable, environmentally sound, and socially viable (Francis, 2000). This paper describes the principles and elements of such systems.

Methods

Agroecology builds on an understanding of the structure and function of natural systems to design more productive agricultural production strategies (Gliessman, 1998). Processes that occur across a hierarchy of scale, in nutrient and water cycles, through biodiversity and integration efficiencies, through food chains and trophic structures, and result in emergent properties such as production stability are important characteristics of systems that are well designed to take advantage of scarce rainfall and other resources. The efficient design of systems for biogeochemical function cannot ignore the economic, environmental, social, and political consequences of these farming strategies. Such design is important for the field, the farm, and the landscape and nearby communities.

Results

Efficient water use on the farm can be enhanced by thoughtful design of crop and animal systems in each production field and through the integration of fields across the farm. In a free enterprise and individual farm ownership system there is less attention given to spatial integration at the landscape level and its impact on the local community. These aspects are important to total system water use.

Cropping system and field levels: Each cropping system consists of one or more species planted in sequence (crop rotation) or together in the field (intercropping) to make most efficient use of scarce water resources. Crops can be chosen that are tolerant of drought and that make efficient use of available water (Callaway et al., 1993). Crop rotations of unlike species can make best use of stored water and nutrients in different parts of the soil profile, a function that is performed even better by proper choice of intercropped species (Francis, 1986). Minimum tillage practices that maintain crop residues on the soil surface, cover crops during the main crop cycle and through months when harvestable crops are not in the field, and tight sequential plantings can provide continuous cover on the land and help break the force of rainfall during most of the year. Increased soil organic matter can enhance the water holding capacity of soils, storing scarce rainfall for when it is needed by crops. Contour planting or terraces in sloping fields can prevent rapid rainfall runoff and loss of valuable topsoil, organic matter and nutrients. These are all practices that simulate what happens in a natural system where water is stored, nutrients cycle, and the integrity of function is maintained.

Farm level: Integration efficiencies are achieved on the farm by careful placement of enterprises that can complement each other and enhance total farm function. Contour rows or terraces that lead to water storage areas can provide for potential irrigation of limited areas downslope on the farm. Use of woody perennials as windbreaks can reduce water loss through transpiration and increase yields of most crops in drought conditions. Placing crops with lower water needs on the best drained soils, and those with higher needs in lower areas can make best use of the total farm water resource. Managing a scarce water resource to take maximum advantage of nutrients is essential.

Landscape and community levels: Farm design to complement the function of neighboring farms and efficient water use in the community is an additional approach build on agroecology principles. Sharing the stored water resource across farm boundaries, design of cropping systems and fields that prevents damage to neighbors' fields, and cooperative use of forages, crop residues, and manure from animal enterprises are ways that planning can be done at the landscape level. Likewise, field windbreaks can be more effective if planned beyond the individual farm boundaries. Community issues include storing water so that it does not fill culverts and roads with sediment, mitigating the impacts of concentrated rainfall events, and maintaining plant or residue cover through the year to enhance the overall multifunctionality of the landscape for the community.

Conclusions

Agroecology principles can be applied to help individual farmers and neighbors make efficient use of scarce rainfall in dry areas. Their attention to design at the field, farm, and landscape level can enhance the multiple functions of a rural landscape and ecological integrity of the watershed. This design can also contribute to farm productivity and profits, as well as quality of life for both rural and nearby community residents. This demonstrates the important potentials in ecological design.

References

Callaway, M. B., and C. A. Francis, editors. 1993. *Crop Improvement for Sustainable Agriculture.* University of Nebraska Press, Lincoln, Nebraska, USA

Francis, C. A., editor. 1986. *Multiple Cropping Systems,* Macmillan Publ. Co., New York, USA

Francis, C.A. 2000. Designing a durable and positive future for agriculture. American Journal of . Alternative Agriculture 15(1):44-47

Gliessman, S.R. 1998. *Agroecology: Ecological Processes in Sustainable Agriculture.* Ann Arbor Press, Chelsea, Michigan, USA

Stewart, B.S. (1994) Arid and semi-arid ecosystems: general traits and challenges. *Acquis et perspectives de la recherché agronomique dans les zones arides du Maroc*, M. El Gharous, M. Karrou, and M. El Mourid, editors. INRA, Rabat, Morocco, 24-27 May 1994. p. 1-13

BREEDING FOR ADAPTATION TO DROUGHT: WHAT HAS WORKED AND WHAT HAS NOT WORKED, YET

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Introduction

I will review accomplishments in breeding for adaptation to drought mainly based upon our work with cowpea (*Vigna unguiculata* L. Walp.) but with some consideration of research with other crop species. I will emphasize approaches and selection-traits that have been effective, and discuss some selection traits that are promising but have not yet proven to be effective.

Approaches and selection-traits that have been effective

We bred cowpea cultivars that have produced useful quantities of grain in the Sahelian zone of Africa in years when droughts were so severe that all other cultivars of cowpea and other crops such as pearl millet, sorghum and peanut failed to produce significant quantities of grain. Our approach to breeding included the following four steps.

1. We selected plants with optimal numbers of days from sowing to first flowering and maturity, and appropriate plant habit. However, rainfall in the Sahel is so variable and the droughts are so extreme that we consider it necessary to breed two types of cultivars and recommend that farmers grow both types to try to insure that they achieve some grain production every year. We have shown that varietal intercrops, where these two types of cultivars are grown in alternating rows, can be more effective than sole crops of these types of cultivars (Thiaw et al. 1993).

a) We bred erect cultivars that are extremely early. 'Ein El Gazal' (Elawad and Hall 2002) and 'Melakh' (Cisse et al. 1997) begin flowering about 34 days from sowing and reach maturity within 60 days from sowing. This type of cowpea cultivar escapes late-season drought. 'Ein El Gazal' was evaluated in the Sahel as breeding line 1-12-3 (Hall and Patel 1985). In Louga, Senegal, 'Ein El Gazal' reached maturity 55 days from sowing and produced 1091 kg/ha grain with a rainfall and total water supply of only 181 mm and hot conditions having an evaporative demand of 6 mm/day. In El Obeid, Sudan, this cultivar produced 500 kg/ha with a rainfall of 230 mm while landraces with longer cycles from sowing to maturity only produced 152 kg/ha. Unfortunately, early erect cultivars are very sensitive to mid-season drought (Thiaw et al. 1993).

b) We bred a cultivar that flowers later and is more spreading than either 'Ein El Gazal' or 'Melakh'. 'Mouride' (Cisse et al. 1995) begins flowering about 38 days from sowing and reaches maturity about 70 days from sowing. In Senegal, 'Mouride' has exhibited greater resistance to mid-season drought but less ability to escape late-season drought than 'Melakh". To-date, these new cowpea cultivars have been more successful in the many dry years in the Sahel than the new cultivars of pearl millet, sorghum and peanut that have been developed. The earliest of the new cultivars of pearl millet and peanut reach maturity in about 80 days from sowing, and thus are not well adapted to years when the rainy season is very short. Achieving appropriate phenology by selecting for optimal numbers of days to flowering and maturity is a critical first step in breeding for adaptation to drought for most annual crops as was pointed out by Richards et al. (2002) for wheat.

2. The cowpea cultivars we bred have resistance to vegetative-stage drought. 'California Blackeye No.5' ('CB5') is one of the parents of 'Ein El Gazal' (Elawad and Hall 2002). 'CB5' has exhibited the ability to withstand a vegetative-stage drought that would have killed most other annual crop species, and to recover when re-watered and produce very high grain yields of about 4000 kg/ha that were similar to a weekly irrigated control treatment (Turk et al. 1980). The vegetative-stage drought had been imposed by sowing seed into a dry soil profile, providing a small amount of water to permit the seedlings to emerge, and then growing the plants under

high evaporative demand conditions for 43 days with no further irrigation or rain. In those years in the Sahel when vegetative-stage droughts occurred, I observed that cowpea plants survived while pearl millet and peanut plants growing in the same fields had died. The mechanism for the resistance to vegetative-stage drought of cowpea is not known. Under severe droughts, cowpea maintains leaf water potentials > - 1.8 MPa, while pearl millet, sorghum and peanut can develop leaf water potentials as low as – 4 to – 9 MPa under these conditions. We probably incorporated resistance to vegetative-stage drought by chance, either through choice of parents or through our selections based on trials in water-limited field environments. A simple screening technique has been reported by Singh et al. (1999) that might be effective for selecting for this trait in cowpea.
3. Multiple resistances to pests and diseases of importance in the Sahel were incorporated into 'Mouride' (Cisse et al 1995) and 'Melakh' (Cisse et al. 1997) including resistance to two seed-borne diseases, three insect pests and Striga which is a parasitic weed.
4. Final selections were based on performance tests of advanced lines in many multilocation field trials over several years in the target production zone on experiment station sites and farmers' fields. Also, laboratory and consumer evaluations of grain quality were made.

Selection-traits that have not been effective, yet

We have used a physiological approach to trait selection that is based on the following model from Hall (2001), which is similar in concept to the model proposed by Passioura (1977).

$$Y = \Sigma ET_i \times (T_i / ET_i) \times W_i \times CP_i$$

Summation is conducted over the reproductive period. ET_i is total water use land area $^{-1}$ day $^{-1}$ from both soil evaporation and transpiration (T_i). W_i is water-use efficiency / day, which is the daily net carbohydrate production / T_i. CP_i is the proportion of this carbohydrate that is translocated to the grain / day, and when integrated over time is conceptually similar to harvest index (HI). A simple but erroneous view is that grain yield (Y) might be increased by selecting to maximize the various model components. However, the need to optimize and thus not maximize CP_i (and HI) is obvious, in that when partitioning of carbohydrate is either too rapid or begins too early, plants tend to be too dwarfed. Clearly all of the components should be optimized, together with optimizing other traits, such as the number of days to first flowering and maturity, which interact with them. Daily and seasonal T might be enhanced in water-limited environments, where plants are growing on moisture stored in the soil, by selecting plants that have more rapid development of deeper root systems than current cultivars. Directly selecting for rooting traits is difficult. We developed an indirect method for selecting for rate of root development based on injecting an herbicide band deep in the soil and selecting plants that exhibited herbicide symptoms sooner, as an indicator of more rapid root development (Robertson et al. 1985). This method was shown to select lines that extract more moisture deep in the soil, but it only can be used with stable lines. Genetic lines with differences in rate of root development were detected using this method for cowpea (Hall and Patel 1985) and peanut (Khalfaoui and Havard 1993). The peanut lines with earlier development of herbicide symptoms had later maturity, however, indicating the need to optimize at least three interacting traits: rate of rooting, cycle length and HI. For plants with the C_3 photosynthetic system, breeding to modify W_i can be done by selecting for changes in Δ based on measurements of stable carbon isotope composition of leaves (Hall et al. 1994a). Theory and experimental studies have shown that seasonal W is negatively correlated with Δ (Condon and Hall 1997). A simple view is that grain yield in water-limited environments may be enhanced by selecting to increase W by selecting for lower Δ, but it is not clear whether this approach is valid. Selection studies with cowpea and wheat gave linear positive correlations between grain yield and leaf Δ for well-watered and some water-limited environments (Condon and Hall 1997). Also, the most productive cowpea cultivars in both irrigated systems in California and rainfed water-limited systems in Senegal tend to have high leaf Δ and therefore low W (Hall et al. 1994b). Different cultivars are most productive in California and Senegal so this result indicates that different sets of genes may be responsible for the high Δ in radically different environments. However, we also have observed positive genetic correlations between Δ and both earliness of flowering and HI (Menéndez and Hall 1995, 1996). The new cultivars we developed for both Senegal and California have high HI and are early; consequently, we may have inadvertently selected for high Δ. If this is the case, another increment of grain yield may be achieved in water-limited environments, such as the Sahel, by incorporating lower Δ and thus higher W into the best current cowpea cultivars. Progress has been made for wheat in defining the water-limited environments where selecting for low Δ may result in increases in grain yield, and in breeding a cultivar with improved adaptation to drought using this approach (Condon et al. 2002).

References

Cisse, N., M. Ndiaye, S. Thiaw and A. E. Hall. 1995. Registration of 'Mouride' cowpea. Crop Sci. 35: 1215-1216.

Cisse, N., M. Ndiaye, S. Thiaw and A. E. Hall. 1997. Registration of 'Melakh' cowpea. Crop Sci. 37: 1978.

Condon, A. G. and A. E. Hall. 1997. Adaptation to diverse environments: variation in water-use efficiency within crop species. In: L. E. Jackson (ed.), Ecology in Agriculture, Academic Press, San Diego, CA, pp. 79-116.

Condon, A. G., R. A. Richards, G. J. Rebetzke and G. D. Farquhar. 2002. Improving intrinsic water-use efficiency and crop yield. Crop Sci. 42: 122-131.

Elawad, H. O. A. and A. E. Hall. 2002. Registration of 'Ein El Gazal' cowpea. Crop Sci. 42.

Hall, A. E. 2001. Crop Responses to Environment. CRC Press, Boca Raton, FL, pp. 232.

Hall, A .E. and P. N. Patel. 1985. Breeding for resistance to drought and heat. In: S. R. Singh and K. O. Rachie (eds.), Cowpea Research, Production, and Utilization, John Wiley and Sons, Ltd., New York, pp. 137-151.

Hall, A. E., R. A. Richards, A. G. Condon, G. C. Wright and G. D. Farquhar. 1994a. Carbon isotope discrimination and plant breeding. Plant Breeding Reviews, Vol. 12, 81-113.

Hall, A. E., S. Thiaw and D. R. Krieg. 1994b. Consistency of genotypic ranking for carbon isotope discrimination by cowpea grown in tropical and subtropical zones. Field Crops Res. 36: 125-131.

Khalfaoui, J-L. B. and M. Havard. 1993. Screening peanut cultivars in the field for root growth: a test by herbicide injection in the soil. Field Crops Res. 32: 173-179.

Menéndez, C. M. and A. E. Hall. 1995. Heritability of carbon isotope discrimination and correlations with earliness in cowpea. Crop Sci. 35: 673-678.

Menéndez, C. M. and A. E. Hall. 1996. Heritability of carbon isotope discrimination and correlations with harvest index in cowpea. Crop Sci. 36: 233-238.

Passioura, J. B. 1977. Grain yield, harvest index and water use of wheat. J. Aust. Inst. of Agric. Sci. 43: 117-120.

Richards, R. A., G. J. Rebetzke, A. G. Condon and A. F. van Herwaarden. 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop Sci. 42: 111-121.

Robertson, B. M. A. E. Hall and K. W. Foster. 1985. A field technique for screening for genotypic differences in root growth. Crop Sci. 25: 1084-1090.

Singh, B. B., Y. Mai-Kodomi and T. Terao. 1999. A simple screening method for drought tolerance in cowpea. Indian J. Gentic. 59: 211-220.

Thiaw, S., A. E. Hall and D. R. Parker. 1993. Varietal intercropping and the yields and stability of cowpea production in semiarid Senegal. Field Crops Res. 33: 217-233.

Turk, K. J., A. E. Hall and C. W. Asbell. 1980. Drought adaptation of cowpea. I. Influence of drought on seed yield. Agron. J. 72: 413-420.

WATER PRODUCTIVITY OF PLANTS AND MOLECULAR BIOLOGY: AN ECO-PHYSIOLOGIST POINT OF VIEW

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Introduction

Shortage of fresh water will be one of the most critical agricultural constraints in the coming years. In the next two decades, water use is expected to increase 40% and, even if irrigation efficiency is improved to its potential, an additional 17% in fresh water will be required to meet the agricultural demand worldwide. The strong limitations to enhancing water supplies, either from surface or under-ground sources, along with the high competition for water with other sectors (e.g., growing cities and industries), forces agriculture to necessarily increase water productivity of plants. In addition to best farm-management practices in water use, "classical" genetics contributed, and continues to contribute, toward the increase in water productivity. "Modern" genetics (biotechnology, molecular biology or genetic engineering) is further extending and empowering the opportunities toward such a task. This paper, after highlighting some basic understanding behind the physiological concepts of water productivity (WP), will discuss the perspectives, achievements and expectations involving molecular biology to improve WP and drought tolerance of plants, from an eco-physiologist point of view.

A physiological framework to analyze water productivity of plants

The water consumption by plants is dominated by the amount lost through evapotranspiration. In comparison, the amount of water consumed for physiological needs (photosynthesis, protein metabolism, and other hydrolytic processes) is definitely negligible. In order to properly identify the areas of intervention to increase WP, then, it is worthy to closely follow the path that water "travels", from the soil up to the atmosphere, along with the major physiological and growth processes involved.

Proceeding in a step-wise manner, the water available in the soil is not necessarily fully explored and up taken by the root system, and a water use efficiency (WUE) term can be identified as the ratio "*root_zone_water/soil_water*". Moreover, not all the root-zone available water is used for the evapotranspiration (ET) process, so that an additional WUE term is recognized, over a given period of time, as the ratio "ΣET/ *root_zone_water*". A subsequent consideration is that evapotranspiration (ET) is the result of *evaporation* (E), mostly from the soil, and *transpiration* (T), i.e., the evaporation of water passing through the plant interior and undergoing some physiological control. This distinction is needed since the non-transpired water is strictly considered non-productive for the plant, configuring E as a waste and T as productive. Cumulated over selected periods of time, the ratio "ΣT/ΣET" is another WUE term.

The previous ratios retain the characteristics of *efficiency* since consistent with its definition and framed within the theoretical limits between 0 and 1. When trying to relate the biological outputs of plants with the associated losses by transpiration, the term *efficiency* looses its rigorous meaning since (i) the water transpired does not enter directly in the *biological* processes and (ii) it has no more the previously identified theoretical limits between 0 and 1. That is why at physiological level it is more appropriate to talk in terms of *water productivity* (WP). Three major expressions of WP can be identified: the amount of carbon gain (ΣA) per unit amount of water transpired (ΣT), or *photosynthetic WP* (=ΣA/ΣT); the amount of *biomass* obtained per unit amount of water transpired (ΣT), or *biomass WP* (=biomass/ΣT); the *yield* obtained per unit amount of water transpired (ΣT), or *yield WP* (=yield/ΣT). The *photosynthetic WP* depends on species (C_3, C_4, CAM), gas-exchange conductances, nutritional status of plants, and vapour pressure deficit of the atmosphere (Steduto, 1996). *Biomass WP* implies the conversion of the assimilated CO_2 into biomass. This conversion requires a substantial expenditure of energy (in terms of assimilates) due to growth and maintenance respiration and depends on the final composition of the biomass (e.g., carbohydrates, proteins, lipids). These energy costs are strictly regulated by the bioenergetics of the various processes involved at biochemical level (Penning de Vries *et al.*, 1974) and may also depend on the thermal regimes of the environment where they are taking place. The *yield WP* can be considered the product of *biomass WP* times the "Harvest Index" (HI), where HI represents the fraction of biomass partitioned into the harvestable organs.

Identifying the areas of interventions to improve WUE and WP of plants

Based on the previous framework, improvements on the water use efficiency and productivity of plants may derive by focusing on the following aspects:

(i) Root characteristics. It is evident that the plant-root growth, depth and density distribution, affect the results of the efficiency terms over the segments involving the water stored in the soil and uptake.

(ii) Rapid leaves growth. The reduction of the soil evaporation (E) in favor of the transpiration (T) would improve the ΣT/ΣET efficiency term through a rapid leaf-growth development during the initial crop stages.

(iii) Selective reflectance of leaves. Due to variability in spectral absorptivity among species, in principles, the radiant heat load of leaves, and hence T, could be reduced by decreasing absorptivity in selected short wave bands of the visible spectrum, without reducing A (Stanhill, 1981).

(iv) Carboxylation capacity of leaves. This capacity can be improved by reduction of the photorespiration process in C_3 species. This would lead to a reduction in the ratio of leaf interior CO_2 concentration (C_i) to ambient CO_2 concentration (C_a) with a positive feedback on stomatal conductance, which would be reduced with a corresponding reduction in T (Morison, 1998). However, C_3 species have an advantage in cooler environments (Osmond *et al*, 1982). Thus, the real advantage of suppressing or reducing photorespiration needs to be carefully evaluated in the different environments and species. Beyond suppressing photorespiration in C_3 species, the carboxylation capacity of leaves (in both C_3 and C_4 plants) can be increased by moving up the ceiling of A, provided more efficient metabolic pathways are found.

(v) Reduction in dark respiration. More efficient pathways of biochemical conversion would allow a reduction in dark respiration and a consequent higher biomass production (Amthor, 1989). However, dark respiration is functional to many metabolic processes dealing with growth, maintenance, translocation, etc., and the consequences of its modification on such processes are not easy to predict.

(vi) Time-shifting of plants processes and cycles. There is an advatage in shifting the time period of occurrence of some processes and/or plant cycles in order to avoid conditions of high evaporative demand from the environment. On short-term basis, a typical example is represented by the CAM plants, which *shift* the process of transpiration (and carbon accumulation) during nighttime to avoid the highly transpirative daytime conditions. The drawback is the high energetic costs of such a mechanism. On long-term basis, a *seasonal shifting* of spring and summer species toward winter time would allows plants to grow under lower evaporative demand.

(vii) Harvest index. Partitioning of the biomass into the harvestable organs has been so far the most effective way to improve *yield WP*.

Lessons learned from plant breeding for drought tolerance

In an agricultural context under water scarcity, the ultimate goal is to increase *yield WP*. Therefore, the past experience from the domain of plant breeding for drought-tolerant plants is very instructive to explore the strategies and perspectives to improve WP through current advancement in plant molecular biology. From an eco-physiologist point of view, the major lessons learned can be summarized as follows:

(i) the time-scale of the plant responses is an important implication to consider when a drought-induced water-stress is in progress (Passioura, 1996). Such a time-scale of the different responses are linked to the level of plant organization, i.e., molecular, cells, organs, whole plant, with a wide diversity of traits, or drought tolerance mechanisms. In other words, it must be recognized that drought induces "multi-dimensional" responses (Blum, 1996) and, consequently, there are no single traits that confer global drought tolerance to plants;

(ii) in principle, while none of the plant organizational levels can be excluded in the response to drought, some of them have higher significance than others in terms of final yield. By far, the most important feature of drought tolerant plants is their phenology, conceived as the timing of its development in relation to temporal changes in water supply. Matching the phenology of crops to the environment has been one of the most important successes of breeders;

(iii) leaf area developmental pattern, or modulation, is rather more influential on yield than the modulation of net assimilation rate. In fact, during an intensifying drought, the modulation of leaf area allows the adjustment of the water loss from the canopy to the "size" of the water supply in the soil (Blum, 1996);

(iv) the ability of a crop to grow at low temperature (early vigor) could considerably improve its drought tolerance and reduce the amount of water which would be likely lost by soil evaporation. Notice that such a trait is not directly related to plant water relations in any way;

(v) roots are seen not only for their characteristics (depth, density distribution, etc.) to influence water uptake, but also as primary sensors of water deficit through *feed-forward* mechanisms, via the emission of chemical messages (Tardieu, 1996);

(vi) the positive association between osmotic adjustment and yield, and its stability, under drought has been well demonstrated for a number of crop species (Blum, 1989). The ability of the plant to lower its osmotic potential allows for the maintenance of adequate water content in cells and tissues, with consequent metabolic activities. Unfortunately, osmotic adjustment is time dependent and the progression of water stress has to be sufficiently slow to allow solutes to accumulate (Turner *et al.*, 1986). This feature introduces difficulties in plant breeding programs and implies that osmotic adjustment may not be effective as a mechanism of drought tolerance when the water stress develops very rapidly (Blum, 1989);

(vii) stem reserves for grain filling have particular advantages, for grain crops, when the drought develops strongly during post-anthesis. In this case, the accumulated assimilates in the stems during pre-anthesis growth (when drought was less stressing) can contribute significantly to the final yield (viii) the harvest index is one of the most important components of yield. Breeders have succeeded in increasing this trait to a point that the limits for further genetic improvement cannot be achieved without further advances in understanding the molecular structure of plants (Austin, 1988). The increase in HI has been, so far, the most effective way to improve the *yield WP*.

Molecular biology and water productivity of plants

Analysis of *quantitative trait loci* (QTL), DNA *marker-assisted selection* (MAS), sequencing and mapping genes, cloning, transgenesis, *sense* and *antisense* DNA, on-off switching of latent genes, microarrays, etc. are powerful techniques developed by MB to identify gene actions, investigate their role in the plant metabolism and transfer them into target plants. Through these techniques, successful new varieties resistant to herbicides, pests and deseases have been developed. To a less extent, improved food nutritional value of some varieties has been also

successful (e.g., rice with higher content of vitamin A). Following these significant progresses, there is now a greater impetus towards generating varieties with higher tolerance to drought and greater water productivity. From an eco-physiologist point of view, a first concern toward MB is that works are focusing on processes at cellular scale, while the main processes involved in water productivity interest higher hierarchical scales. In fact, most of the MB progress just mentioned relates to plant characters involving single or few genes, while traits that would increase WP of plants are largely polygenic. Nevertheless, researches have shown cases where single-gene transfer, inducing cell-metabolism modifications, has resulted also in positive whole-plant changes (e.g., osmotic adjustment). MB research on drought tolerance, indeed, has initially concentrated its attention on the concentration of molecules and compounds that are *desiccation* or *dehydratation protectants* (e.g., trehalose) and *antioxidants* (e.g., sorbitol). This approach has its meaning if plants are exposed to extreme water stress for a short time, which has limited relevance for the majority of the drought-prone agricultural systems. A similar approach was used in salt tolerance studies, with protecting osmolytes (e.g., mannitol) the subject of research. This circumstance, however, was more fortunate since there is a strong link between osmoprotectants and osmotic adjustments, which confer to plants a certain degree of drought tolerance. Through osmotic adjustment, compatible solutes (e.g., proline and glycinebetaine) actively accumulate resulting in the maintenance of a higher turgor pressure, known to be associated to stomatal opening and cell growth, and to the most common observation of deeper root growth, or higher root density. Moreover, metabolic costs of storing photosynthates for osmotic adjustment is generally less that the cost of converting them into biomass, and solutes accumulated under stress are efficiently utilized metabolically upon stress relief.
Since conventional breeding has shown that this characteristic is effective in sustaining yield under drought conditions, and because it is amenable at cellular level, through MB it is expected to progress quickly in this research area. The need to investigate polygenic traits, however, is getting overcome by advances in genomics and microarray techniques that allow simultaneous screening of several thousand genes expressing particular responses under specific conditions, as well as examine cross-talk between them and other known metabolic pathways. It seems that with these techniques, in addition to a rapid identification of genes involved in trait expression, break-through the levels of complexity can be studied simultaneously.

A break-through expected by MB is the enhancement of *yield WP* through modification of the plant carbon balance, i.e., increasing the ceiling for maximum photosynthetic capacity and/or reducing respiration. Conventional breeding has not apparently succeeded in increasing plant yield via this avenue. In normal circumstances, though, it seems that respiration does not result wasteful and is almost as efficient as it is theoretically possible, according to the fundamental laws of bioenergetics. On the other hand, photosynthetic assimilation of CO_2 requires many enzymes, processes and syntheses (RuBP, electron transport, carbon reduction cycle, sucrose and starch synthesis, etc.) so that increase in any one of them will likely have little effect on the overall rate of photosynthesis. The requirement of a constant proportion of these enzymes and electron carriers, may suggest that many genes are regulated by the same or similar signals, indicated as "master controls" (Sharkey *et al.*, 1991). Modification of these master controls would allow photosynthesis to be improved without the need to modify all the individual steps involved.

One likely candidate for a master control of photosynthesis in leaves appears to be the phytochrome (Sharkey *et al.*, 1991), which has been found to influence the expression of genes for a wide range of proteins. Experiments in this line have shown that increasing Ribulose bis phosphate (RuBP) was associated with increase of other enzymes in constant proportion, but that operational rates of photosynthesis were reduced because the leaves of the genetically manipulated plants showed also undesired morphological modifications. MB researches on both photosynthesis and respiration would most likely need to investigate chloroplast and mitochondrial genes beyond the nuclear ones. Transforming the DNA of these organelles, in fact, may prove to be more effective, although much more difficult, than transforming nuclear DNA. Moving upward the ceiling of the photosynthetic process seems to be remote at this stage. A closer, though diffcult, breack-thru might be the transfer of C_4 photosynthetic metabolism into C_3 plants. In the news section of the *New Scientist* magazine web-page (April 1, 2000), was reported that, at a conference on rice biotechnology (held by IRRI), there were presented the research results on a transgenic rice in which two basic enzymes of maize (PEP carboxylase and pyruvate orthophosphate dikinase) were inserted. The transgenic rice, tested in the field, has shown 35% yield increase as compared to the control. Up to date, these results have yet to be published.

A further concern from an eco-physiologist point of view is the pedo-climatic environment in which the plant is going to live. The opportunities offered by MB need to be complemented with the basic knowledge of soils, crop and atmospheric water relations. Under actual conditions, pleiotropic effects, when more than one trait is controlled independently by a single gene and they correlate with each other without causal link, needs to be assessed as well. Field-testing, then, is needed not only for the agronomic verification, but also for determining the effect of the gene in the whole plant under natural environment (Bray, 1997). While hundreds of tests of transgenic plants with various alterations have taken place in laboratories, the number of corresponding tests in the field remain low.

Conclusion

There is no question that MB is a powerful tools to hasten the progress in plant breeding for higher water productivity. It may not replace established plant breeding techniques, but, surely will augment them, improve their efficiency, and enable plants to be modified in ways not possible by present methods. Nevertheless, plant improvement for water productivity through MB has had very limited impact, so far. On the one hand, it is true that advances in biotechnology is progressing fast to overcome the limitations of investigating polygenic traits, analyzing complexity of poly-genes expressions, identifying all metabolic pathways involved, looking into the cross-talk of such expression, etc.. On the other hand, it is also true that insights in plant and crop eco-physiology, under proper space-time frameworks, could ensure that suitable high water-productive varieties are effectively developed in the near future. Finally, the advances in the field of MB need to be integrated with current crop breeding programs to allow plants to be studied as a 'whole' and be modified to obtain the desired traits in consonance with the actual pedo-climatic conditions.

References

Amthor, J.S., 1989. Respiration and Crop Productivity. Springer-Verlag inc., New York, p. 215.

Austin R.B., 1988. New opportunities in breeding. *Hort. Sci.*, 23, 41-45

Blum A., 1989. Osmotic adjustment and growth of barley genotypes under drought stress. *Crop Sci.*, 29, 230-233

Blum A., 1996. Crop responses to drought and the interpretation of adaptation. *Plant Growth Regulation*, 20, 135-148

Bray E.A., 1997. Plant responses to water deficit. *Trends in Plant Science*, 2, 48-54

Morison J.I.L., 1998. Stomatal response to increase CO_2 concentration. *J. Exper. Botany,* 48, 443-452

Osmond C.B., et al, 1982. Functional significance of different pathways of CO_2 fixation in photosynthesis. In: Lange O.L., Nobel P.S., Osmond C.B. and Ziegler H. (eds). *Physiological Plant Ecology II. Water Relations and Carbon Assimilation.* Encyclopedia of Plant Physiology, New Series 12B. Springer-Verlag Berlin, Heidelberg, New York, pp. 479-547

Passioura J.B., 1996. Drought and drought tolerance. *Plant Growth Regulation*, 20, 78-83
Penning de Vries F.W.T., et al, 1974. Products, requirements and efficiency of biosynthesis: a quantitative approach. *J. Theor. Biol.*, 45, 339-377
Sharkey T.D., et al, 1991. Carbon metabolism enzymes and photosynthesis in transgenic tobacco (*Nicotiana tabacum*, L.) having excess phytochrome. *Planta*, 185, 287-296
Stanhill G., 1981. The size and significance of differences in radiation balance of plants and plant communities. In: Grace J., Ford E.P. and Jarvis P.J. (eds). *Plants and their Atmospheric Environment*. Blackwell, Oxford, pp. 57-73
Steduto P., 1996. Water use efficiency. In: Pereira L.S., Feddes R.A., Gilley J.R., Lesaffre B. (eds). *Sustainability of Irrigated Agriculture*. NATO ASI Series E: Applied Sciences. Kluwer Academic Publ., Dordrecht, pp. 193-209
Tardieu F., 1996. Drought perception by plants. Do cells of droughted plants experience water stress? *Plant Growth Regulation*, 20, 93-104
Turner N.C., et al, 1986. Response of seven diverse rice cultivars to water deficits. II. Osmotic adjustment, leaf elasticity, leaf extension, leaf death, stomatal conductance and photosynthesis. *Field Crops Res.*, 13, 273-286

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VALIDATING SAP FLOW MEASUREMENT IN CITRUS TREES GROWING UNDER DIFFERENT WATER AND ENVIRONMENTAL CONDITIONS

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Introduction

When lysimeter systems are not available, measurement of sap flow in the stem becomes an alternative method for determining canopy transpiration under field conditions. The compensation heat-pulse method (Green and Clothier, 1988) seems to be an appropriate technique for non-destructive measurements of sap flow in woody stemmed plants. The purpose of this work was to evaluate the heat pulse technique as a means of estimating transpiration from young lemon trees growing in pots. The validity of heat-pulse measurements was tested by comparing sap flow against actual transpiration determined gravimetrically.

Methods

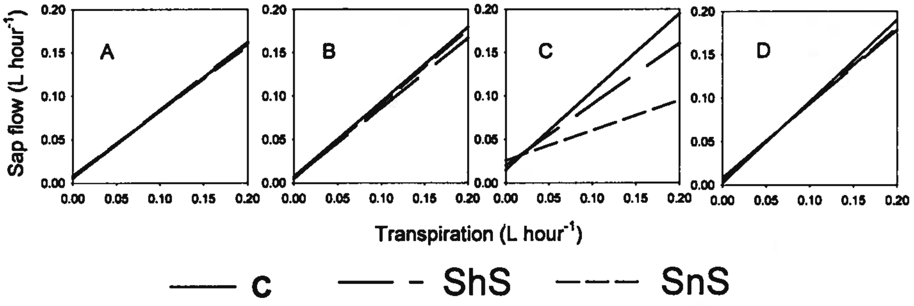
The experiment was conducted in a research field near Murcia, Spain, over a 2-months period between August 13 (Day 225) and October 19 (Day 292) 2001. Two-year-old citrus trees (*Citrus limon* L. cv. Verna) were grown in 70 L plastic pots. Six trees were used in the experiment. At the beginning of the experience (Period A, Day 225-241) all of them were under open field conditions. On August 29 (Day 241), four of them were located under a rectangular shade net of highly reflective aluminized polypropylene (Periods B,C,D). Trees were irrigated once per day with nutrient solution (Periods A,B). On October 2 (Day 275) water was withdrawn for seven days in four trees (two shaded and two of the open field, Period C). After these seven days, pots were re-irrigated to their full water holding capacity (Period D).

According to the previous description, it is possible to distinguish three different treatments (C, well irrigated plants during all the experiment; ShS, water stressed plants under shaded conditions; and SnS, water stressed plants under natural light). Sap flow was monitored in the trunk of the trees described above, using the compensation heat-pulse technique, with one set of heat-pulse probes per tree, following the procedure of Green and Clothier (1988). The sap flow was recorded at 30 min intervals. Each pot was placed on top of a weighing scale (capacity 150 kg and resolution of 5 g, Ohaus), thus the diurnal course of transpiration was measured every half hour. In four days, representative of different environmental and water irrigation periods, the relation between sap flow and gravimetric transpiration (Figure 1), and the evolution of leaf water potentials (Figure 2), were recorded for the three different treatments.

Results

There were close linear relationships between sap flow and actual rates of transpiration, with regression coefficients around 0.80, when the trees were well watered independently of the environmental conditions (Periods A,B,D). However during the water stress period, when the trees were clearly short of water (See ShS and SnS in Figure 2C), measured sap flow underestimated actual transpiration and the slopes of the linear regressions (See ShS and SnS in Figure 1C) decreased respect to the value reached in the control treatment. These underestimations were related with the level of water stress, and thus the slope was lower in SnS than in ShS.

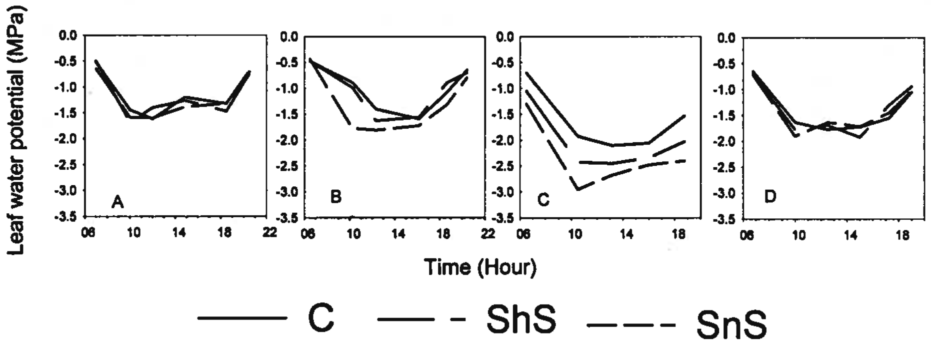
Figure 1



Discussion

Measurements of sap flow underestimated actual transpiration when the trees were droughted. This fact could be explained by the limitations of the compensation heat pulse velocity system at low sap flow reported by Alarcón et al. (2000). However, the determination coefficients for all correlations were highly significant, even those done on plant water stressed (data not shown). For this reason, we consider that results obtained here support the use of the heat pulse technique to estimate the transpiration rate of young lemon trees under several environmental conditions, although different calibration must be done when the plants are droughted.

Figure 2



References

Alarcón, J.J. et al., 2000, Plant and Soil, 227, 77-85.
Green, S. and Clothier, B., Journal of Experimental Botany, 39, 115-123.

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CONTRIBUTION OF CARBOHYDRATES STORED PRIOR TO GRAIN FILLING TO WHEAT GRAIN YIELD IN VARIABLE ENVIRONMENTS.

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Introduction

Wheat grain yields in rainfed agriculture of Australia and other similar environments around the world are often low and vary substantially from season to season. Carbohydrates stored prior to grain filling have been identified as important contributors to grain yield in such environments, but quantifying their general contribution has been hampered by large seasonal variability. A crop simulation model, APSIM-Nwheat, which considers the remobilization of carbohydrates, was therefore linked to long-term historical weather records to analyse yield benefits from carbohydrates stored prior to grain filling under rainfed conditions. Simulation experiments were repeated at a number of locations in the main wheat cropping areas of Australia, all characterised by highly variable seasonal rainfall.

Methods

The Agricultural Production Systems Simulator (APSIM) (McCown *et al.*, 1996) for wheat (APSIM-Nwheat version 1.55s) is a crop simulation model, consisting of modules that incorporate aspects of soil water, N, crop residues, crop growth and development and their interactions within a wheat/soil system that is driven by daily weather data. It calculates the potential yield, which is the maximum yield reached by a crop in a given environment that is not limited by pests, diseases, weeds and lodging, but is limited by temperature, solar radiation, water and N supply. Documented model source code in hypertext format can be viewed at www.apsim-help.tag.csiro.au. APSIM-Nwheat employs a modified routine from CERES-Wheat (Ritchie *et al.*, 1985) for calculating remobilization of carbohydrates stored prior to grain filling to the grain. Source and sink limitations are accounted for by modelling the rate of grain filling as the minimum of either carbohydrate demand or supply on a daily time step. The supply of carbohydrates for grain filling in the model is derived from direct photosynthesis and remobilization from carbohydrates stored prior to grain filling. The potential amount of carbohydrates stored prior to grain filling to be remobilized during grain filling is set to be 75% of all above-ground biomass growth from 150 °Cd prior to the start of grain filling. In cases where photosynthesis during grain filling exceeds the demand of assimilate accumulation of the grain, excess carbohydrates can be stored temporarily in the stem and be used for later periods of grain growth. APSIM-Nwheat has been rigorously tested against field measurements in various studies under a large range of growing conditions (e.g. Asseng *et al.*, 1998). A comparison of observed (van Herwaarden *et al.*, 1998) and simulated data for remobilization amounts showed a good model performance with a RMSD of 12%. To study the yield benefits from carbohydrates stored prior to grain filling in different rainfed environments, simulation experiments were carried out with the model at a number of locations in the main wheat growing areas of Australia using historical weather records from 1950-1990. In addition, the standard remobilization routine of APSIM-Nwheat was compared with a 20% increased storage capacity for remobilization.

Results and Discussion

Simulation results highlighted that carbohydrates stored prior to grain filling contributed a significant proportion to grain yield (Fig. 1a). The simulated contribution of carbohydrates stored prior to grain filling to grain yield amounted up to several tonnes per hectare, however, it varied substantially from 5-90% of grain yield depending on seasonal rainfall amount and distribution, N supply, crop growth and seasonal water use. A large variability in the contribution of carbohydrates stored prior to grain filling to grain yield has also been found in a number of studies summarised by Setter *et al.* (1998), without identifying the cause of the variability. With increasing yield, the absolute amount of remobilization generally increased while the relative contribution to grain yield decreased (Fig. 1b), confirming measurements by van Herwaarden *et al.* (1998). Increasing the capacity to accumulate pre-grain filling carbohydrates for later remobilization by 20% increased yields by a maximum of 10% in terminal drought seasons, but had little effect in poor or very good seasons in which factors that affect the storage of carbohydrates rather than the storage capacity itself appear to limit grain yield. These factors were, little growth due to N or water deficit in the weeks prior to and shortly after anthesis (when most of the carbohydrates are stored for later remobilization), poor sink demand due to little pre-anthesis growth or high photosynthetic rate during grain filling. Increasing the storage capacity for remobilization is expected to increase grain yield especially under conditions of terminal drought.

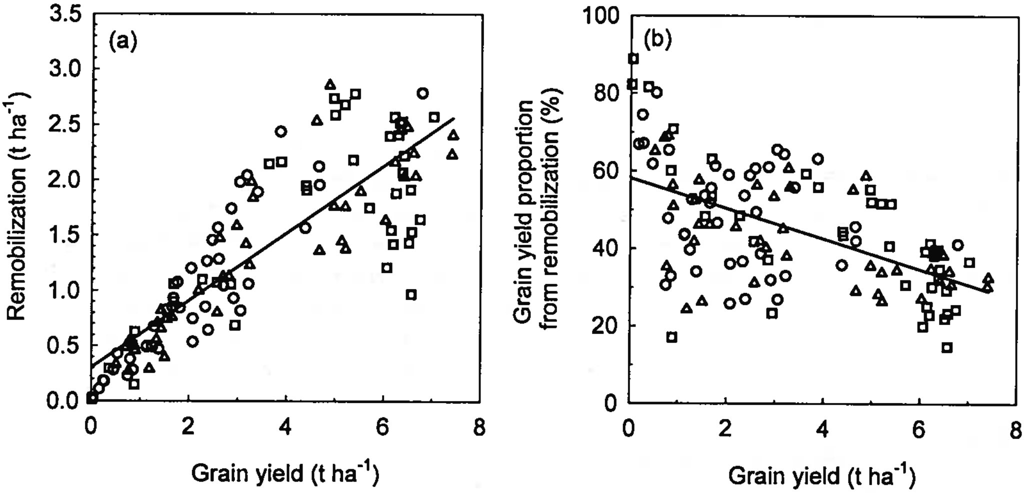

Fig. 1. (a) Simulated remobilization of pre-grain filling stored carbohydrates to grain yield versus grain yield and (b) relative proportion of grain yield from remobilization versus grain yield at Wongan Hills, Western Australia (O), Dalby, Queensland (Δ), and Pucawan, New South Wales (□), Australia, using weather records from 1950-1990 and applying 150 kg N ha^{-1}. Linear trend lines are shown.

References

Asseng, S. *et al.*, 1998, *Field Crops Res.*, 57, 163-179.
McCown, R. L. *et al.*, 1996, *Agric. Syst.*, 50, 255-271.
Ritchie, J. T. *et al.*, 1985, AGRISTARS Publication No. YM-U3-04442-JSC-18892. Michigan State University. East Lansing, USA. 252 p.
Setter, T. L. *et al.*, 1998, In: Wheat: Research Needs Beyond 2000AD. Eds. S Nagarajan *et al.*, pp 237-252. Narosa Publishing House, New Delhi.
van Herwaarden, A. F. *et al.*, 1998, *Austr. J. Agric. Res.*, 49, 1067-1081.

A MODEL SYSTEM SHOWING POSSIBLE REGULATION OF SHOOT FUNCTIONING IN FIELD GROWN MAIZE EXPOSED TO SOIL DRYING

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Introduction

Maize responds to progressive drought with reduction in leaf extension rate and in assimilate production and ultimately with a reduction in yield. The common view is that soil drying results in some types of chemical signalling between roots and shoots. Field-grown plants experience minor drought events daily due to diurnal variation in the top soil moisture. To date, little is known on the timely interaction of multiple signal events and the responses triggered by those in field-grown plants. The present study focuses on a possible sequence of multiple signals, hydraulic and non-hydraulic, regulating leaf growth and stomatal conductance ultimately controlling transpiration of field grown maize in drying soil.

Methods

The study was conducted in a field lysimeter, comprising 16 tanks of 2 x 2 x 1m each. Eight tanks contained loamy sand and 8 tanks contained sandy loam soil. An automated mobile glass roof protected the crop from the rain. Each tank was supplied with an individually operated trickle irrigation system. Plants were exposed to soil drying in sandy loam soil during the vegetative stage. Soil water content was measured daily using the neutron moderation method at 10, 20, 30, 40, 50, 60, and 80 cm depths. Leaf extension rate, stomatal conductance, leaf water potential, leaf ABA and leaf nitrogen content were measured daily during soil drying. Xylem sap was collected daily at root pressure. Xylem sap [ABA], pH, and ionic composition were determined.

Results

- Under drought conditions, morning xylem pH was increased by about 0.2 as compared to the fully watered plants throughout the growing season.
- Xylem sap [NO_3] generally decreased over the growing season, but was about 2-3 mmol lower under drought conditions than in the fully watered plants.
- Xylem sap [ABA] varied with climatic conditions but was significantly increased under drought 10 days into the drying cycle.
- Drought effects on stomatal conductance became significant at about 15 days into the soil drying period.
- Leaf nitrogen content significantly decreased by about 1.2% over the soil drying period.
- Leaf ABA was constant under fully watered conditions but started to increase at about 10 days into the drying cycle.
- Leaf extension rate in droughted plants was lower than well-watered at about 5 days into the soil drying period.
- Midday leaf water potential started to decrease at about 20 days into the drying cycle under drought conditions.
- Significant correlation between LWP and leaf ABA
- Significant correlation between ABA and stomatal conductance.
- Significant correlation between xylem sap [NO_3] and [ABA]
- No correlation between xylem sap [NO_3] and stomatal conductance

Conclusions

- Few days of soil drying result in an increase of pH and [ABA] and a decrease of [NO_3] of xylem sap of maize
- Xylem sap [ABA] is negatively correlated with xylem sap [NO_3]
- Both xylem and leaf [ABA] significantly correlate with stomatal conductance.
- [NO_3] and pH of xylem sap seem to be fairly sensitive parameters which may allow the plant to fine tune transpirational control under non-lethal stress conditions.

Based on these findings the model system given in Figure 1 was suggested.

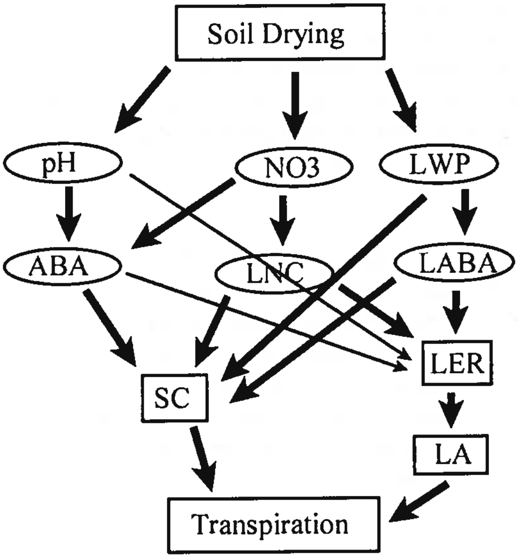

Figure 1. A model system showing possible regulation of shoot functioning in response to soil drying. pH= xylem sap pH; NO3= xylem sap [NO3]; ABA= xylem sap [ABA]; SC= stomatal conductance; LNC = leaf nitrogen content; LWP= leaf water potential; LABA= leaf [ABA]; LER= leaf extension rate; LA= leaf area.

Acknowledgement

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Reference

Bahrun A., Jensen C.R., Asch, F., and Mogensen, V.O. 2002. Drought-induced changes in xylem pH, ionic composition and ABA concentration act as early signals in field grown maize (Zea mays L.). Journal of Experimental Botany, 53, 1-13.

OPTIMIZATION CRITERION OF WATER DISTRIBUTION FOR DEFICIT IRRIGATION SYSTEMS

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Introduction

Water constitutes a principal factor in agricultural production. Every plant needs an adequate water supply for its proper development so that its physiological needs are met. In agriculture water supply must be such so as to allow production of cultivated plants that will produce a satisfactory economic yield (English M.J., 1990; Hargraves G.H. & Samani Z.A., 1984). Efficient management of water supply for irrigation purposes requires the definition of appropriate operating rules, which should consider both the natural variability of the hydrological series and the needs of the different water users (Barbagallo et al., 2001).
The operating rules can be defined by applying optimisation techniques which attempt to determine the optimal releases by maximising or minimising an objective function, subject to various constraints (Yeh W., 1985).
In this paper an optimisation model for planning of multiannual water resources management has been development. In particular, the problems related to the use of water resources for irrigation purposes have been studied when releases occur from an artificial reservoir. The optimal stored water management is based on a dynamic programming procedure with different seasonal objective functions:

- maximise the cumulative sum of the irrigation area maximum profitability (NB_t) over the n season of the time series;
- the cumulative sum of squared deficit from a fixed level of water crop requirement over the n season of the time series.

The comparison between the two criteria, in terms of dynamic programming results, has been made to define the optimal water releases distribution for irrigation purposes.

Methods

Optimal releases from Pozzillo reservoir (the main Catania Plain irrigation district water supply system) during the period 1959-98 have been determined by means of a comparison between the following dynamic programming optimisation criteria:

- maximisation of the sum of the maximum profitability over the n season of the time series, $\sum_{t=1}^{n} NB_t$ (1)
- minimisation of the sum of the squared deficits over the n season of the time series,

$$\sum_{t=1}^{n}(D_t - U_t)^2 \qquad (2)$$

Subject to the constraints:

$$S_{t+1} = S_t - U_t + I_t - E_t \qquad t=1,\dots N-1$$

$$E_t = e_t \cdot (S_t^b + S_{t+1}^b)/2 \qquad t=1,\dots N$$

$$0 \le S_t \le K$$

$$0 \le U_t$$

t is the current time interval (6-month period from November to April, and 6-month period from May to October);
S_t is the storage at the beginning of the interval t;
U_t is the release during the interval t;
I_t is the unregulated inflow during the interval t;
D_t is the irrigation demand during the interval t;
K is the storage capacity of the reservoir;
E_t is the evaporation during the interval t;
N is the total number of optimisation intervals.

The seasonal profitability is expressed by an economic equation in which the profitability is estimated as being proportional to productivity of the main crop of the area (citrus orchard), whilst the costs consists of a fixed component depending on the volume of seasonal irrigation, the number of waterings and the amount of produce (Mannocchi F., Macarelli P., 1994).

The optimisation problem has been solved by means of a discrete backward Dynamic Programming (DP) algorithm, stated in inverted form (Labadie J.W., 1990).

$$f_t^n(S_t) = max(or\, min)[Z_t + f_{t+1}^{n-1}(S_{t+1})]$$

n is the total number of intervals remaining before reservoir operation terminates.
Z_t assumes the form (1) or (2).

The result of the model implementations in terms of optimal releases and economical revenue, during the time series, has been used to determine the best criterion to optimise the reservoir operation. The result has been used to test reservoir operating rules in order to express the optimal release in terms of the main system state variables and hydrological input.

Results

This paper presents a dynamic programming procedure capable of finding the optimal solution (in terms of net economic benefit from irrigation) for planning an irrigated area, taking into consideration parameters of irrigation and the yield response of the crop, whenever shortages of available irrigation water exist.
The optimal reservoir operation criterion gives the optimal irrigation volume to be seasonally allocated to the irrigated area when the overall crop profitability is the greatest possible.

References

Barbagallo S., Cirelli G.L., Consoli S., Rossi G., 2001. "An optimization model for reservoir management under water deficit conditions" 6th Scientific Assembly of IAHS, Maastricht 18-27 Luglio 2001.
English, M.J., 1990. "Deficit irrigation I: Analytical framework". J. Irrig. And Drain. Engrg., ASCE, 116(3), 399-412.
Hargraves, G.H., and Samani Z.A, 1984. "Economic consideration of deficit irrigation". J. Irrig. And Drain. Engrg., ASCE, 110(4), 343-358.
Labadie, J.W., 1990. "Dynamic programming with microcomputer". Encyclopedia of Microcomputers, A Kent and J. Williams (eds.), vol 5, M. Dekker, INC., New York.
Yeh, W., 1985. "Reservoir management and optimisation models: a state of the art reviuw". Water Resources Reseach, vol. 21(12), pp. 1797-1818.

A NEW METHOD FOR QUANTIFYING THE EFFECTS OF WATER STRESS IN SUNFLOWER

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Introduction

One of the first morphological effects due to water stress in sunflower is reduction of leaf expansion (Sadras et al., 1993). As a consequence, reduction in photosynthetic potential is also expected, since this parameter is clearly essential in order to estimate the level of water stress tolerated by sunflower before any reduction in yield may be observed. Furthermore, it is necessary to know the extent of water stress from which the plant is still able to recover.
The effects of progressive water stress and its recovery on the transpiration rate of single plants and leaf expansion were evaluated as functions of FTSW (Fraction of Transpirable Soil Water – Sinclair and Ludlow, 1986). A mathematical procedure for standardization of data is also presented here.

Methods

Sunflower seeds of cv. Marco (AGRA) were sown in 120 pots. The pots were filled with a mixture of sand and silty-loamy soil (ratio 1:1).
At beginning of flowering, the pots were irrigated to saturation and their tops sealed with a plastic sheet, to prevent soil evaporation, only leaving one hole for the plant stem and one for irrigation. The pots were weighed after one night when percolation was considered over and soil at field capacity; then the pots were bottom-sealed with a plastic rubber. The weight measured the following day was considered as reference for the rest of the experiment. In this system, the only way for the plant to lose water was by transpiration, easily measurable daily by weighing the pots.
The 120 plants were randomly divided in 7 groups: group 0, 20 plants (controls) were kept for the rest of the experiment at the reference value; in group 6 for 20 plants (stressed) the FTSW was allowed to decrease daily to a maximum of 150 ml per pot (Sinclair and Ludlow, 1986). The remaining 80 plants were divided into 5 groups of 16 plants each and treated like the stressed ones, but the plants were rewatered when FTSW was about 0.4 for group 1, 0.2 for group 2, 0.1 for group 3, 0.07 for group 4 and 0.05 for group 5.

Results

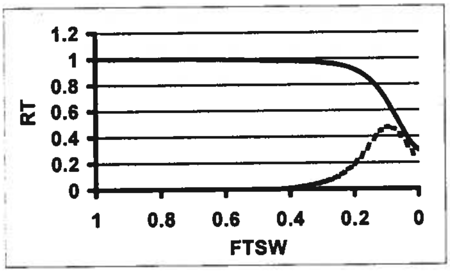

Fig. 1. Amount of Recoverable Relative Transpiration (RRT) (dotted line) and final RT (continuous line) as function of FTSW values at the moment of re-hydration.

Fig. 1 shows the amount of recoverable relative transpiration (dotted line) and the final RT (continuous line), as functions of FTSW values at the moment of re-hydration. A recovery in transpiration rate was possible at any FTSW, even though the maximum (0.47) was observed at an FTSW value of about 0.1. For lower values, permanent damage became more and more prevalent.
Concerning leaf expansion as a function of FTSW, the rate of expansion appeared to be related neither to initial size nor to position on the main stem, and could not be compared at all to the leaves of controls, so that standardization of values was mandatory in this case.

Standardization of leaf area was carried out using the following formula.

$$LAS_{i,j,k} = \frac{LA_{i,j,k} - LA_{0,j,k}}{Inc_{0-2,j,k}}$$

$LAS_{i,j,k}$ = standardized leaf area on day i for plant k and leaf j;
$LA_{0,k,l}$ = leaf area at beginning of experiment for plant k and leaf j;
$Inc_{0\text{-}2,j,k}$ = slope of regression between first 3 days and corresponding leaf area for plant k and leaf j.

Standardization allows a single description curve to be used to estimate potential leaf expansion for water-stressed plants, based on only the first three days of the experiment, as was done for the estimation of transpiration.

Using the following formula it was possible to estimate the potential leaf area of stressed plant.

$$PLA_{i,k,j} = (ab^{\frac{1}{D}}D^{c} + Int_{0-2,k,j}) \cdot Inc_{0-2,k,j}$$

$PLA_{i,j,k}$ = potential leaf area (for stressed plants) on day i for plant k and leaf j;
a, b, c = coefficients
D = days from the beginning of the experiment
$Int_{0\text{-}2,k,l}$ = intercept of regression between first 3 days and corresponding leaf area for plant k and leaf j;
$Inc_{0\text{-}2,j,k}$ = slope of regression between first 3 days and corresponding leaf area for plant k and leaf j.

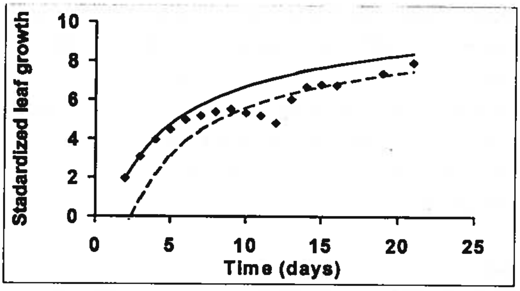

Fig. 2. Potential leaf area in normal water conditions (continuous line), under water stress (filled diamonds) and after re-hydration (dashed-line).

Fig 2 shows a potential leaf area (continuous line) in comparison with that of a water-stressed plant (filled diamonds). In this case, sunflower was re-watered on day 12 (group 3), when not only a reduction in leaf growth but also shrinking were evident. After irrigation, the leaf was restored to its original turgor and then started to grow again. A similar response was observed for the other groups even the same description curve (dashed line) but was horizontally and vertically shifted; both shifts were modeled as functions of FTSW before re-hydratation.

Discussion and conclusions

Transpiration in conditions of progressively increasing water stress was almost similar to that of non-stressed plants, until the point of about 30% of transpirable soil water, thus confirming the great adaptability of sunflower to water stress.

In general, water stress had two different effects on leaves: a reduction in the maximum size attainable and a delay in growth. These two effects worked in parallel as the FTSW decreased.

Single plants showed a large variability in terms of transpiration and leaf area expansion, in both control and water-stressed conditions. This meant that relative indices could not be calculated in the usual manner. This inconvenience was overcome by using a series of standardized data for both transpiration and leaf expansion. The resulting equations express the response of sunflower to both parameters, and they may easily be introduced into sunflower models

References

Sinclair, T.R., Ludlow, M.M., 1986. *Aust. J. Plant Physiol.*, 13, 144-149.
Sadras, V.O., et al., 1993. *Plant and Soil*, 153, 1879-1974.

(Work partially funded by the project PROBIO – MiPAF, Italy)

INTERACTIVE EFFECTS OF ATMOSPHERIC CO_2-CONCENTRATION AND PLANT AVAILABLE SOIL WATER CONTENT ON CANOPY EVAPOTRANSPIRATION AND CONDUCTANCE OF SPRING WHEAT

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Introduction

Global warming caused by increasing atmospheric CO_2-concentration [CO_2] will most probably affect the distribution of vegetation zones on earth with a tendency to increase the areas of arid environments. This will also have implications for crop growth conditions. At the same time [CO_2] is known to directly affect the water status of plants. Thus, knowledge about interactions of [CO_2] and water supply on water status of crops is of increasing interest in agronomy.It is well known that stomatal conductance is decreased by CO_2-enrichment under well watered conditions. Stomatal conductance was found to be unaffected by plant available soil water (PAW) above a critical threshold value (T_{PAW}) of PAW and declining linearily with PAW below this threshold (Sadras et al. 1996). To date, the impact of elevated [CO_2] on T_{PAW} for stomatal and particularly canopy conductance (G_C) is poorly known. The objective of the present study was to investigate such effects at the canopy scale.

Methods

Spring wheat (*Triticum aestivum* cv. "Minaret") was grown in lysimeters with 0.4 m soil depth (1998) or in the field (1999) in open-top chambers under two CO_2-concentrations (ambient, ambient + 280 ppm) and two watering regimes [well watered (WW) with a plant available water (PAW) > 40 mm; droughted, (DS), 0 < PAW < 30 mm beginning after first node stage]. Volumetric soil water content was measured with TDR sensors. Seasonal changes in the absorption of photosynthetically active radiation of the canopy (fAPAR) and H_2O-gas exchange of the canopies (E_C) were measured continuously from first node stage until the beginning of flag leaf senescence using an open chamber system (Burkart et al 2000). Canopy conductance (G_C) was calculated by dividing E_C by vapor pressure deficit of air. In addition, in 1999 root growth was measured at anthesis using the soil core break method (Kücke et al. 1995).

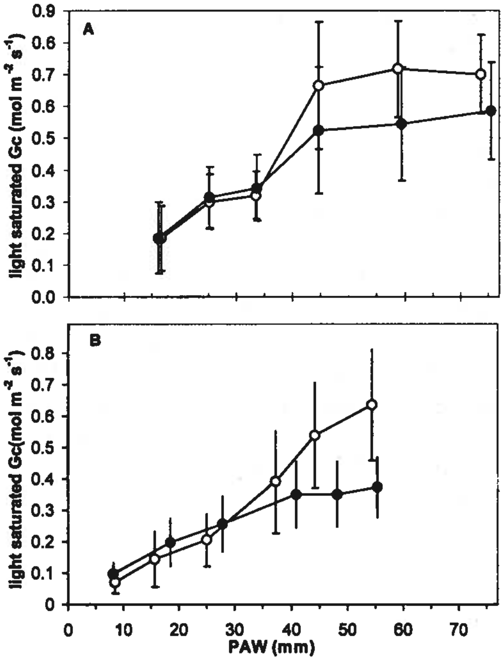

Fig. 1: Light saturated canopy conductance G_C as a function of plant available water (PAW) under ambient (open symbols) and elevated CO_2-concentrations (closed symbols). A Data from 1998. B Data from 1999. Error bars represent standard deviations

Results

Throughout both growing seasons PAW was kept between 30 to 60 mm in the WW plots. In 1998 this required a reduction in the amount of water added to the high CO_2 plots. After onset of drought stress treatment, PAW of the two water regimes diverged and the values of the drought stress plots remained almost always below 30 mm. At the end of the growing season in 1999, there appeared to be a CO_2-effect on PAW: under WW conditions PAW was increased, but under drought stress reduced by CO_2-enrichment. However, these effects could not be statistically proved (data not shown).

G_C showed a non-linear relationship to absorbed radiation (APAR), best explained by saturation curves. Thus, data of light saturated G_C (APAR > 400 µmol m^{-2} s^{-1}) were selected for further analysis. Data were divided in classes of PAW in steps of 10 mm, and means of PAW and G_C of each class were calculated. In the lysimeter experiment, PAW > 40 mm did not affect light saturated G_C (Fig. 1 A), and CO_2-enrichment reduced light saturated G_C by ca 20 % ($p < 0.01$). However, below a threshold value (T_{PAW}) of PAW (<40 mm) light saturated G_C declined with falling PAW, and no CO_2-effect could be found at PAW < 30 mm. Thus, in 1998 elevated [CO_2] only reduced T_{PAW}, with no further impact on the G_C-PAW relationship below T_{PAW}.

	depth		
treatments	7.5 cm	22.5 cm	37.5cm
con WW	4974 ± 281	4427 ± 2151	99 ± 115
CO_2 WW	5919 ± 548	6316 ± 715	298 ± 345
con DS	5819 ± 802	3531 ± 768	149 ± 190
CO_2 DS	5222 ± 441	5322 ± 441	448 ± 768

Tab. 1: Number of roots per horizontal soil area (m^{-2}) as a function of soil depth at anthesis. Numbers represent means ± standard deviations ($n = 4$). "WW" well watered, "DS" drought stress, "con" ambient CO_2, "CO_2" elevated CO_2.

A similar pattern was found in 1999 (Fig. 1 B) as T_{PAW} was again reduced by elevated CO_2. However, the shape of the decline below T_{PAW} was changed by CO_2-enrichment this way that at PAW < 25 mm light saturated G_C was significantly enhanced by CO_2-enrichment ($p < 0.01$). Fitting regression lines through the unclassified data ($0 <$ PAW < 30 mm) revealed that the intercept of the regression line was increased by CO_2-enrichment ($p < 0.01$).

In addition, root number per soil area was significantly affected by soil depth ($p < 0.001$) and CO_2-concentration ($p < 0.01$) but not by water supply ($p > 0.3$, Tab. 1). Root number decreased with soil depth and increased under high CO_2. Analysis of variance revealed no interaction of CO_2-concentration and water supply on root growth. However, there was a positive interaction between CO_2 and root depth ($p < 0.01$), since CO_2 enrichment did not stimulate root growth at 7.5 cm, but at 22.5 cm and at 37.5 cm depth.

Discussion

In both years we found a T_{PAW} below which canopy H_2O-exchange was affected by PAW and that T_{PAW} was decreased by CO_2-enrichment which contrasts to the results of Mitchell et al. (2001). The negative effect of elevated CO_2 on light saturated G_C disappeared at PAW ≤ 30 mm. In the 1998 season, there were no differences between CO_2-treatments below this PAW value, confirming that for PAW < 30 mm G_C is determined only by PAW and for PAW > 30 mm G_C is determined by climatic factors and atmospheric CO_2 concentration. The differences in root growth conditions can explain the fact that in 1998 no CO_2-related effects on light saturated G_C could be observed under drought conditions, whereas in 1999 the CO_2-effect on G_C was reversed at low PAW. In contrast to the 1998 experiments, in the field experiment of the 1999 season rooting volume was not restricted by any soil containers. Both the stimulation of root growth and the decrease in soil moisture under high CO_2 in 1999 support the idea that under drought stress high CO_2 plants may have been able to more fully exploit the available soil moisture as has been found by Hunsaker et al. (1996).

References

Burkart S. et al. 2000, *Journal of Plant Physiology* 157, 31-39
Hunsaker, D.J. et al. 1996. *Transactions of ASAE 39*, 1345-1355.
Kücke M. 1995. *Plant and Soil* 172, 63-71.
Mitchell, R.A.C.et al. 2001. *Global Change Biology* 7, 599-611.
Sadras V.O., Milroy S.P. 1996. *Field Crops Research* 47: 253-266.

WATER AND NITROGEN MANAGEMENT IN THE IRRIGATION DISTRICT Nº V OF BARDENAS (ZARAGOZA, SPAIN) AND ENVIRONMENTAL IMPACT ON WATER RESOURCES

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Introduction

The return flows from intensive irrigated agriculture are considered a major non-point contributor to the pollution of surface and groundwater bodies. This work summarizes the water and nitrogen balance performed during the 2001 hydrological year in three basins located in the irrigation district nº V of Bardenas I (Zaragoza, Spain). The objectives were to diagnose the present management of the production inputs (i.e., irrigation water and *N* fertilization), to quantify the volumes and *N* loads in drainage waters and to recommend best management practices for minimizing the nitrogen contamination induced by irrigated agriculture.

Methods

We measured or estimated during the Oct-00 to Sep-01 hydrological year the main water and nitrogen inputs and outputs in three experimental basins. A tracking of farmer's agronomic practices in these basins was also performed.

The equation defining the simplified water balance was: $\square W = (I + P) - (ETa + D)$, where $\square W$ is the change in the volume of stored water, the inputs are the volume of water in irrigation (I) and precipitation (P) and the outputs are the actual volume of crop's evapotranspiration (ETa) and the volume of drainage water (D).

The equation defining the simplified nitrogen balance was: $O = (NI + NP + NF + NSF) - (ND + NC)$, where the inputs are the mass of *N* in irrigation (NI), precipitation (NP) fertilizers (NF) and symbiotic fixation (NSF), the outputs are the mass of *N* in drainage (ND) and crop harvests (NC), and O stands for other factors not considered in the balance. Since most of the nitrogen in drainage waters is in the form of nitrate, we computed its concentration as $[NO_3^-] = ND/D$.

Results

The water balance performed in the three basins indicate that $\square W$ was irrelevant (i.e., values close to zero) compared with the rest of components (Table 1). Basins XIX-6 and XXX-3 had similar *I* and *ETa* values due to similar cropping patterns (corn and alfalfa in more than 80% of the irrigated surface), soils (shallow soils underlined by gravels and with a low water retention capacity of around 85 mm) and irrigation systems (flood irrigation). However, the volume of drainage was 47% higher in XXX-3 than in XIX-6 (Table 1) due to its lower water use efficiency ($WUE = 100\ ETa/(I + P)$; $WUE = 42\%$ in XXX-3 and 52% in XIX-6) resulting from a lower capacity of the irrigation ditches, larger plots, and a poorer on-farm land levelling in XXX-3.

Table 1. Inputs (irrigation-*I* and precipitation-*P*) and outputs (actual crop's ET-*ETa* and drainage-*D*) of water computed in the three experimental basins for the 2001 hydrological year.

BASIN	*INPUTS (In)*		*OUTPUTS* (Out)		*In-Out*
	I (mm)	*P*(mm)	*ETa* (mm)	*D* (mm)	□*W* (mm)
XIX-6	1112	526	859	756	23
XXV-3	669	526	681	496	18
XXX-3	1396	526	810	1113	-1

On the other hand, *I*, *ETa* and *D* in basin XXV-3 were much lower than in the other two basins due to its larger proportion of uncultivated surface (26% in XXV-3 and negligible values in the other basins), its lower corn and alfalfa acreage (only 29% of the irrigated surface), the higher water retention capacity of soils (around 176 mm) and its higher irrigation efficiency (39% of the surface is sprinkler-irrigated, and the average *WUE* was 57%).

The nitrogen balance performed in the three basins indicates that the inputs were higher than the outputs (Table 2). As expected, the most important *N* input was fertilization (*NF*) (we considered that the *NSF* input was totally extracted by the harvested alfalfa), being influenced by crop patterns and the management of fertilizer nitrogen. Thus, corn received the largest quantities of *N* (they amounted to 80% of the total *N* applied in XXX-3 and XIX-6), they were higher than the *N* extracted by the crop and, besides the regular pre-plant *N* application, only one sidedress application was given, so that the excess soil *N* was readily leached in the drainage waters.

In addition, farmers in basin XXX-3 applied still higher *N* amounts to compensate for their lower *WUE*, so that the amount of *N* exported by the drainage waters was close to 200 kg/ha (i.e., twice the amount of 98 kg/ha exported in XIX-6) (Table 2). Thus, the *ND*/*NF* ratio (an indication of the amount of fertilizer nitrogen exported by the drainage waters) was 44% in XIX-6 and increased up to 56% in XXX-3.

Table 2. Inputs (irrigation-*NI*, precipitation-*NP*), fertilization-*NF* and symbiotic fixation-*NSF*) and outputs (drainage-*ND*) and extraction by crops-*NC*) of nitrogen computed in the three experimental basins for the 2001 hydrological year.

BASIN	*INPUTS (In)*				*OUTPUTS (Out)*		*In-Out*
	NI (kg/ha)	*NP* (kg/ha)	*NF* (kg/ha)	*NSF* (kg/ha)	*ND* (kg/ha)	*NC* (kg/ha)	*O* (kg/ha)
XIX-6	3	1	222	184	98	254	58
XXV-3	2	1	146	67	23	126	67
XXX-3	4	1	349	98	195	203	54

In contrast, the *NF* in XXV-3 was much lower due to the previously mentioned characteristics of this basin and, in particular, to the split *N* applications through the sprinkler systems (i.e., fertigation), so that the amount of *N* exported by the drainage waters was only 23 kg/ha, and the *ND*/*NF* ratio decreased to 16%. In consequence, $[NO_3^-]$ in drainage waters were high in XXX-3 (77 mg/L) and XIX-6 (58 mg/L) and much lower in XXV-3 (21 mg/L).

Conclusions

The results obtained in two out of the three experimental basins located in the irrigation district nº V of Bardenas I indicate that the management of irrigation and nitrogen fertilization was rather poor, provoking high volumes, nitrate concentrations and *N* loads in the drainage waters. In contrast, water and *N* managements in the third basin were more efficient and their negative environmental impacts were much lower. Our results show that the key management strategies for controlling *N* pollution are to (1) increase the efficiency of the flood-irrigated systems, (2) change to pressurized systems in areas with low water-retention soils, (3) decrease the amounts of *N* fertilization given to corn and (4) split the applied *N* through fertigation to better match the crop needs along the growing season.Further management practices not evaluated in this work could be to (1) increase the acreage of crops with low *N* needs (i.e., alfalfa), (2) grow winter cover-crops capable of extracting part of the *N* remaining in the soil, and (3) reuse the drainage waters for irrigation (a current practice in this irrigation district). These strategies will save substantial amounts of water and *N* fertilizers and will reduce the *N* pollution of surface and groundwater bodies.

EFFECTS OF SINK LIMITATIONS ON THE EFFICIENT USE OF WATER AND SOLAR RADIATION IN FLUE-CURED TOBACCO

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Introduction

Crop production can be analyzed in terms of environmental resources availability and use efficiency. The above-ground dry matter (AGDM) produced by a crop can be expressed with the function: $\text{AGDM} = \text{RINT} * \text{RUE}$
where RINT is the time integral of solar radiation intercepted per unit of soil surface, and RUE is the efficiency of radiation conversion into above-ground dry matter (Monteith, 1977). In alternative, crop productivity in water-limited conditions can be conveniently analyzed with the function: $\text{AGDM} = \text{W} * \text{WUE}$
where W is the cumulated crop water use (either transpiration or total consumption), and WUE is the amount of biomass produced per unit of water used (Passioura, 1977). Although the concepts of RUE and WUE are widely applied in system analysis of crop growth, only few studies made a direct comparative assessment of both parameters.

Beside to environmental constraints, however, crop growth may be limited by feedback mechanisms occurring within the plant, in particular by the plant demand for carbohydrates, defined as sink strength (Lambers et al., 1998). Flue-cured tobacco is a sink-limited crop during the post-flowering part of its growing season. This is a consequence of the common practice of inflorescence pruning (topping), performed with the purpose of improving product quality. Ceotto and Castelli (2002) reported a seasonal variation of RUE in response to sink limitations induced by topping in flue-cured tobacco. The objectives of this study were: (i) to investigate WUE response to sink limitations; (ii) to explore relationships between RUE and WUE in case of sink-limited situations.

Methods

The field experiment was conducted in 1998 and 1999 at the Station of Istituto Sperimentale per il Tabacco, in Bovolone (Verona), Northeast Italy (Lat. 45°15' N, Long. 11°07' E). The soil of the site is a coarse-loamy, mixed, mesic fluventic Ustochrept with a plant available water holding capacity of 108 mm, based on maximum root depth for tobacco of 0.6 m. Total above-ground dry matter, leaf area index (LAI) and soil water content were sampled weekly during the growing seasons. Total water use was calculated by summing weekly bookkeeping of soil water balance. The intercepted global radiation was calculated using the Beer's law with daily values of LAI interpolated between measured points. A value of 0.3 for canopy extinction coefficient for global solar radiation, was derived (Squire, 1990) from the extinction coefficient for light estimated on the present experiment. RUE was referred to global solar radiation for consistency with water use.

Results

Figure 1 shows the comparisons between WUE and RUE in 1998 and 1999. Overall, the extent of between-year variability was about 2% for WUE and 24-30% for RUE.

After topping, WUE was not influenced by sink limitations, whilst RUE decreased with respect to the vegetative phase, although with different extent in the two years. It is apparent that the ratio photosynthesis/transpiration remained quite constant in sink limited situation, and the reduction of photosynthesis, that determined lower RUE, was, at least partially, counterbalanced by a higher stomatal resistance, and thus lower transpiration.

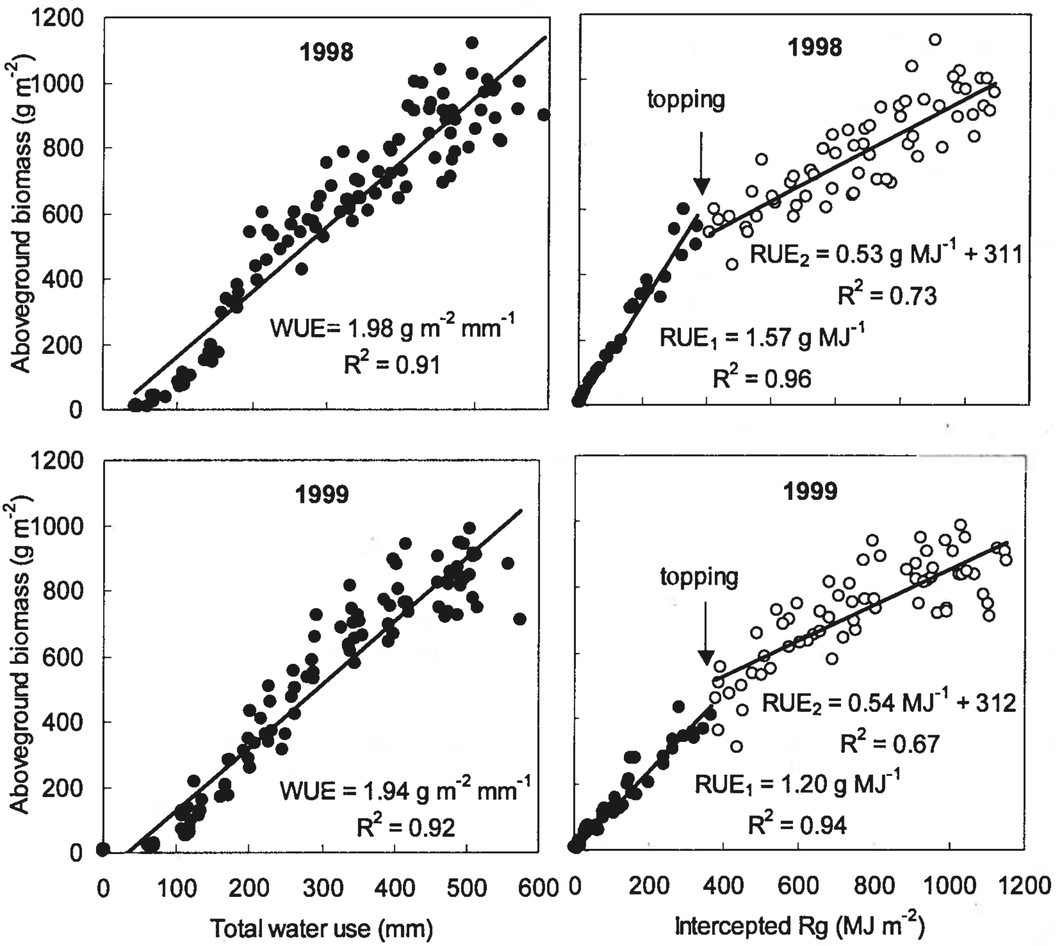

Figure 1. Comparison between WUE and RUE for flue-cured tobacco in 1998 and 1999. The data set includes three treatments (0, 40 and 80 kg N ha $^{-1}$) and two replications.

Conclusions

This experiment indicated that WUE is a more conservative crop characteristic, with respect to RUE, between and within years. However, the comparative assessment of WUE and RUE allowed a better insight on the physiological behavior of flue-cured tobacco growing in sink-limited situation. In fact, the analysis of WUE itself would not allow to detect the occurrence of sink limitations.

References

Ceotto E., Castelli F., 2002. Field Crops Res. 74, 117-130.

Lambers, H., Chapin, F. S., Pons, T. L., 1998. Plant Physiological Ecology. Springer-Verlag.

Monteith, J.L., 1977. Philos. Trans. R. Soc. Lond. Ser. B. 281, 277-329.

Passioura, J. B., 1977. J. Aust. Inst. Agric. Sci. 43, 117-120.

Squire, G.R., 1990. The Physiology of Tropical Production. CAB International,UK, 71-102.

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THE EFFECT OF THE TIMING OF WATER AVAILABILITY ON GRAIN PROTEIN CONCENTRATION OF WINTER WHEAT

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Introduction

The production of breadmaking wheat in the United Kingdom has always been uncertain. Milling standards for grain protein concentration (GPC) are strict, yet despite our ability to manage GPC with variety choice and nitrogen fertilizer there still exists a large inter-annual variation in the protein levels achieved, due to variation in climate. Numerous studies have shown climate during grain filling to influence GPC. However, statistical approaches relating GPC in the UK to climate have also identified rainfall earlier in the season as accounting for significant amounts of annual variation in GPC (Smith *et al.*, 1996; 1999). There has also been increased interest in modelling GPC with more mechanistic approaches (Jamieson *et al.*, 2000). If GPC could be predicted early enough within a season much of the production risk could be alleviated through improved targeting of late season inputs. We report two years of field experiments designed to assess the effects of early rainfall on GPC. The field data is compared with the predictions from two types of model (Smith *et al.*, 1999; Jamieson *et al.*, 2000).

Methods

Experiments were conducted on a fine sandy loam soil (Sonning Series) at the Crops Research Unit, The University of Reading, Sonning 51° 29' N, 0° 56' W (1999-2001). Trickle irrigation was applied at two rates equivalent to the application of an additional 50 or 100mm month^{-1} within three 60-day timings based on the statistical models presented by Smith *et al.*, (1999). Winter wheat (cv. Hereward) received either natural rainfall or additional soil water within each timing i.e. winter (17 Jan. – 17 March), spring (21 March – 20 May) and summer (24 May – 23 July). Two levels of nitrogen fertilizer (0 and 200 kg N ha^{-1}) were applied to each water level within each timing. In both years the crop was drilled in October (11/10/99,17/10/00) and harvested in August (11/08/00, 01/08/01). The crop was conventionally managed receiving nitrogen in the form of prilled ammonium nitrate applied in two halves during stem extension. Irrigation using mains water was applied 10 times per month at a rate of either 5 or 10 mm per application. The mean nitrate concentration of the water was 44.1 mg l^{-1}, which equates to an application of 8.9 and 17.8 kg N ha^{-1} for each water level within each 60 day period. GPC was determined at dry matter by oxidative combustion.

Results & discussion

In 2001 the application of additional winter and spring water reduced GPC (Table 1) as predicted by the statistical model (Smith *et al.*, 1999), but in 2000 GPC was largely unaffected by irrigation. Sirius also predicted reductions in GPC with winter and spring water in 2000 consistent with the statistical model. The increase in GPC in both years by supplying water in the summer is consistent with some statistical models (Smith *et al.*, 1996). The statistical model failed to capture the higher GPC achieved in 2001 compared with 2000. Winter rainfall totals were higher (Fig.1) in 2001 and the magnitude of the associated reduction in GPC was greater than any improvement expected from higher summer temperatures (Fig.1). In both seasons the application of water within any timing increased both grain dry matter and nitrogen yields. Grain nitrogen yields were improved by a greater magnitude than could be accounted for by

Table 1. Comparison of observed and predicted (Smith *et al.*, 1999; Jamieson *et al.*, 2000) GPC responses to the timing of elevated soil water availability for the 2000 and 2001 seasons. SED's are for comparisons with the natural rainfall control only. The model simulations include the nitrogen applied in the irrigation water.

			Grain Protein Concentration (%@DM) Water Treatment						
			Natural rainfall	Winter water (mm month^{-1})		Spring water (mm month^{-1})		Summer water (mm month^{-1})	
	Year	SED		50	100	50	100	50	100
Field results	2000	0.232	11.80	11.58	11.86	11.89	12.20	12.44	12.99
	2001	0.200	12.40	12.16	12.13	11.99	12.11	12.65	13.02
Empirical Model	2000		12.88	12.35	11.82	11.76	10.65	12.86	12.84
	2001		12.69	12.14	11.59	11.57	10.46	12.67	12.65
Sirius	2000		14.50	13.70	13.30	14.30	14.20	14.70	14.80
	2001		11.00	11.20	11.50	11.40	11.70	11.50	11.90

Fig.1. Natural rainfall monthly totals, mean soil moisture deficit and mean air temperatures for the 1999 and 2000 season.

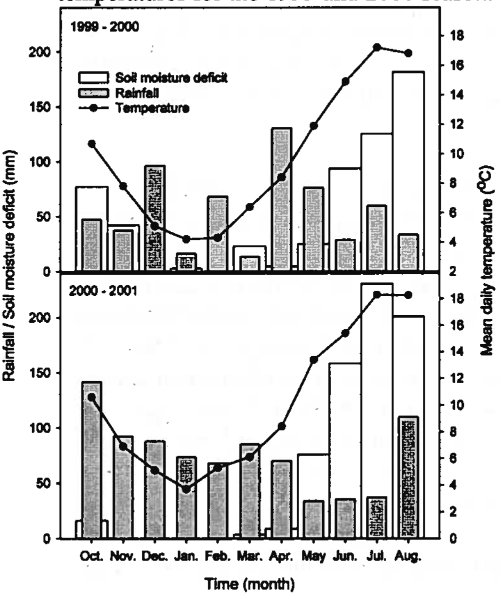
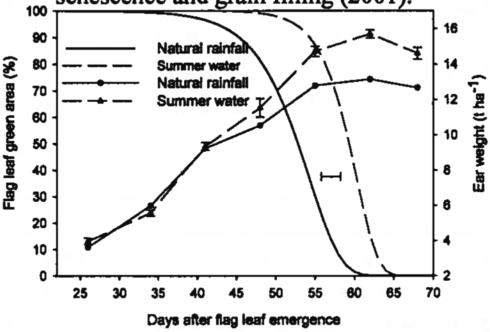


Fig.2. The effect of the application of summer water (100mm month^{-1}) on flag leaf senescence and grain filling (2001).



the nitrogen applied in the irrigation water. Winter and spring water increased yields mostly by increasing grain numbers per m^{-2} whilst promoting the uptake of nitrogen (Clarke *et al.*, 2001). Summer water delayed the build up of a significant soil moisture deficit (Fig.1). This was associated with delayed flag leaf senescence, faster grain filling (Fig.2) and improved nitrogen uptake (Clarke *et al.*, 2001). The Sirius model is being further developed to capture some of these effects. The simulated reduction in GPC from winter and spring water by Sirius in 2000 was due to nitrogen leaching, this mechanism was also cited to explain similar effects in the statistical models. Sirius captured the direction of the effects of summer water in both years although the increase in GPC was driven almost entirely by the nitrogen applied in the irrigation water. Simulated GPC's were lower in 2001 as autumn leaching reduced crop uptake, increasing the model's sensitivity to the nitrogen applied in the irrigation water.

References

Clarke M. P. Gooding M. J. & Semenov M. A. 2001. *Aspects of Applied Biology, Wheat Quality* 64,103-110.

Jamieson P. D. & Semenov M. A. 2000. *Field Crops Research* 68,21-29.

Smith G. P. & Gooding M. J. 1996. *Annals of Applied Biology* 129,97-108.

Smith G. P. & Gooding M. J. 1999. *Agricultural and Forest Meteorology* 94,159-170.

THE EFFECT OF NITROGEN AND THE TIMING OF WATER AVAILABILITY ON ROOT AND SHOOT DEVELOPMENT OF WINTER WHEAT

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Introduction

Despite the success of canopy management the sustainability of current increases in production demands a better understanding of soil-root-shoot interactions (Bingham, 2001). If roots can be managed this may improve the effectiveness of conventional inputs. Two of the ways roots support growth is by channelling nutrients and water to the photosynthetic surface. In this paper we report a one year investigation into the effects of nitrogen and the timing of soil water availability on root and shoot development of winter wheat.

Methods

A field experiment was conducted on a fine sandy loam soil at the Crops Research Unit, The University of Reading, Sonning 51° 29' N, 0° 56' W in 2001. Further details are described in Clarke *et al.*, (2002). Above ground growth was measured on three occasions (21.03.01, 29.05.01 & 19.07.01) by randomly sampling 10 plants for the first two assessments and 10 ear-bearing stems per plot for the final assessment. Root growth was also assessed on three occasions (19.03.01, 22.05.01 & 12.07.01) by mechanical coring to a depth of 1m. Two cores were taken per plot from within and between the rows (row width, 11.5cm) and bulked. Each cylinder of soil was sub-divided into 10cm sections (⌀ 7.5cm) and the roots removed by washing. Root and shoot dry matter was determined gravimetrically after oven drying at 80°C for 48 hours.

Results & discussion

Roots initially accounted for over 15% of total biomass (Table 1). However, spring resource allocation favoured canopy growth for each fertilised treatment reducing the contribution of roots to just 4% by May. Applying nitrogen increased shoot weight by 9.6 t ha^{-1} (Table 1) and grain yield by 4.4 t ha^{-1}. However, root production was much less affected by nitrogen although there was greater mass below 40cm after application (Fig. 1).

Table 1. The effect of time, nitrogen and the timing of soil water availability (+100 mm month^{-1} / 200 kg N ha^{-1}) on root and shoot growth of winter wheat (cv. Hereward).

Treatment	Assessment 1 (2 df)			Assessment 2 (4 df)			Assessment 3 (8 df)		
	Root (kg/ha) 19.03.01	Shoot (kg/ha) 21.03.01	R:S	Root (kg/ha) 22.05.01	Shoot (kg/ha) 29.05.01	R:S	Root (kg/ha) 12.07.01	Shoot (kg/ha) 19.07.01	R:S
Natural rainfall									
200kg N ha^{-1}	264	1760	0.17	697	18600	0.04	747	19300	0.04
0 kg N ha^{-1}							638	9750	0.07
Winter water	231	1640	0.15	755	19200	0.04	861	20800	0.04
Spring water				696	17400	0.04	811	25800	0.03
Summer water							573	20300	0.03
SED	69.9	234	0.044	59.3	994	0.004	97.8	1560	0.008

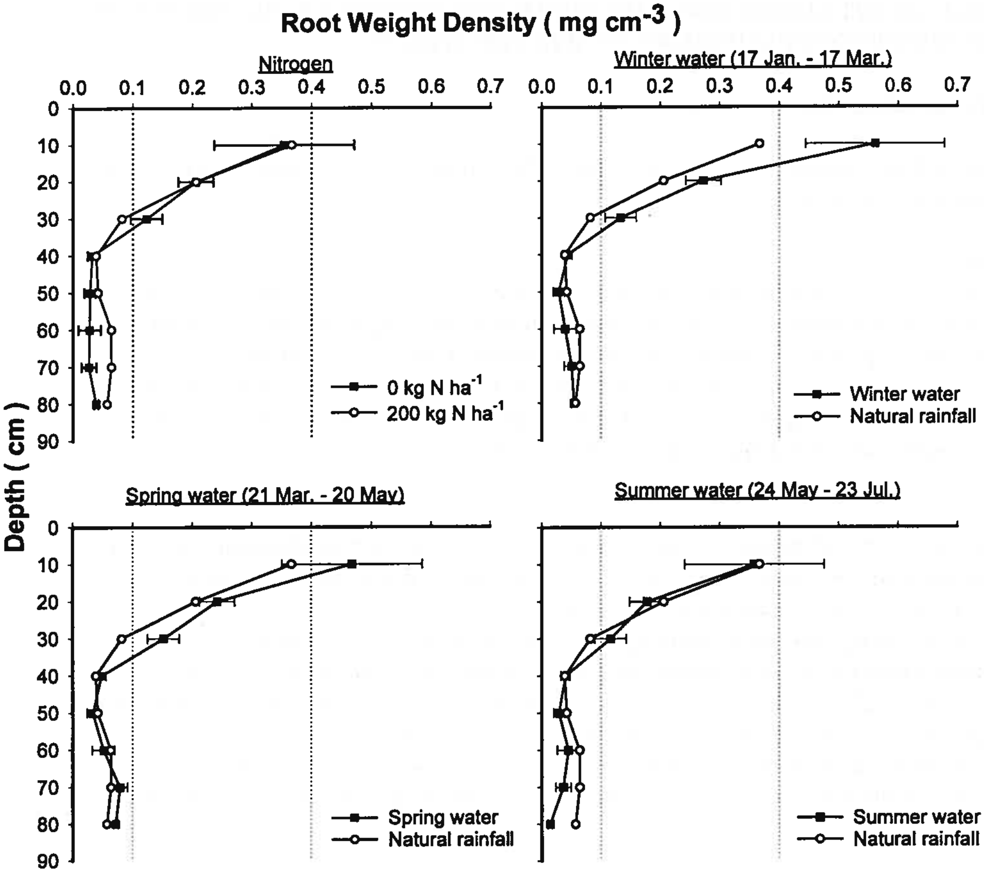

Fig.1 The effect of nitrogen and the timing of soil water availability (+100 mm month^{-1}) on the vertical distribution of root weight density during grain filling (12.07.01). Error bars represent SEDs for individual depth comparisons.

Supplying additional soil water throughout the winter, spring and summer improved grain yields by 1.8, 0.8 & 1.5 t ha^{-1} (DM). Winter water did not affect the root : shoot ratio (R:S, Table 1) whilst spring water applied during stem elongation reduced the R:S (Table 1) by encouraging the proliferation of the shoot. Although total root mass was unaffected the senescence of the surface roots (0-30 cm) was delayed (Fig. 1) by the previous application of both winter and spring water. Summer water reduced the R:S (Table 1) by accelerating the senescence of the root system below 40cm whilst at the same time prolonging canopy life (Clarke *et al.*, 2002).

This work demonstrates how small and unresponsive the size of the root system of winter wheat is to the availability of soil nitrogen and water, despite significant changes in above ground biomass production and grain yield. For conventionally managed crops on sandy soils there seems little scope for the improved targeting of inputs based on mid season root assessments.
We would like to thank Mr N O Smith and Mr S A Jones for technical support throughout this project.

References

Bingham I.J. 2001. *Annals of Applied Biology* 138, 243-251.
Clarke M.P. Gooding M. J. & Semenov M. A. 2002. *This proceedings.*
Clarke M. P. Gooding M. J. & Semenov M. A. 2001. *Aspects of Applied Biology, Wheat Quality* 64,103-110.

IRRIGATION FREQUENCY INFLUENCE IN OPTIMIZATION OF WATER USE IN SUGAR BEET.

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Introduction.

The positive evolution of agriculture rent and the guaranty of an acceptable life level in rural areas are the main reason for the development of the agriculture in many of the regions of our country.

In this aspect, only the irrigated land agriculture is able to fulfil these objectives for small and medium farmers, who are the basis of the sugar beet sector. Sugar beet is the main irrigated land crop in our region.

Castilla and León, is a region with water deficit, thus, it is necessary to concentrate and coordinate efforts to improve the irrigation efficiency, and crop water used efficiency, (Turner, 2001), as it happens in other areas of the world.

One of the strategies to improve the water efficiency in the sugar beet crop is to increase the irrigation frequency, which allows the increase of yield without entirely satisfying the whole crop water supply, as it was demonstrated using different irrigation systems, (García y De Benito, 1996).

On the other hand, the relationship between yield and evapotranspiration in sugar beet depended on the frequency and irrigation number (Howell et al., 1987). The irrigation frequency increase and the wet soil surface decrease have improved the crop water used efficiency, (Sepaskhah and Kamgar-Haghighi, 1997).

The objective of this work was to know the irrigation frequency influence on the sugar beet root and sugar yields in the last years, as well as, to evaluate the efficiency of the applied water.

Methods

The experiments were carried out in a representative field of the sugar beet irrigated areas of this region during 2000 and 2001 campaigns. The trials were located in an alluvial soil of the Pisuerga valley, in the "Finca de Zamadueñas" of the Servicio de Investigación y Tecnología Agraria of Junta de Castilla y León.

The sandy loam texture soil is a Typic Xerofluvent, and the management crop system was the traditional in the two years of the study.

Sowing was carried out in two different dates each year, at the beginning of March (A), and at the beginning of April (B), which is the usual sowing date in the area. The sown variety was KWS´s " Ramona", resistant to rhizomania and stem rising, with density of 90.000 plants ha^{-1}.

A whole cover splinkler irrigation system was used with two frequencies. One was the currently used in the area, which is a weekly irrigation (fn), and the other two times a week (af) regarded as a high frequency. During the growth period, plant sampling was taken to determine leaf area index (LAI) and leave and root biomass.

Harvest was accomplished in three different dates, by the middle of September,(1ª) October (2ª) and November (3ª), respectively. Afterwards, it was determined yield and root sucrose percentage in each sample. The analysis of variance was made by Windows SPSS procedures, (1999).

Results

With year 2000 data, certain parameters of growth, LAI, and leave and root biomass presented significant differences among irrigation frequencies for sampling group, independently of sowing date. These parameters were higher in high irrigation frequency.

Using year 2001 data, these parameters did not present significant differences between irrigation frequencies, although leaf area index and the dry matter of the root was higher in the high frequency irrigated plots.

Yield crop results in each, seeding date, irrigation frequency and harvest date are shown in the Table 1. In 2000, no differences were found in root and sugar yields between harvest dates, however, in September, both of parameters were the lowest. In 2001, root and sugar yields in November were significantly higher than in October and in September harvest, in the last one.

Table 1 Root and sugar yield and sucrose percentage of each harvest dates, seeding date and irrigation frequency High frequency (af), usual frequency (fn).

			Year 2000			Year 2001		
Harvest Dates	Sowing Dates	Irrigation frequency	Root kg ha^{-1}	Sucrose %	Sugar kg ha^{-1}	Root kg ha^{-1}	Sucrose %	Sugar kg ha^{-1}
1ª	A	af	89.600 a	14.4 a	12.902 a	88.426 a	15.9 a	14.060 a
		fn	62.400 b	13.5 b	8.424 b	83.306 a	15.6 a	12.996 a
	B	af	81.600 a	14.3 a	11.669 a	83.330 a	15.6 a	12.999 a
		fn	59.733 b	14.6 a	8.721 b	82.600 a	15.9 a	13.133 a
2ª	A	af	91.400 a	16.0 a	14.624 a	97.386 a	15.4 a	14.997 a
		fn	76.334 b	14.9 b	11.374 b	91.040 a	15.6 a	14.202 a
	B	af	91.133 a	15.9 a	14.490 a	84.054 a	16.0 a	13.449 a
		fn	62.333 b	15.8 a	9.849 b	82.134 a	15.3 a	12.566 a
3ª	A	af	89.869 a	16.6 a	14.918 a	97.174 a	16.2 a	15.742 a
		fn	65.667 b	15.5 a	10.178 b	99.734 a	15.2 a	15.159 a
	B	af	81.866 a	16.8 a	13.753 a	90.886 a	16.1 a	14.633 a
		fn	68.533 b	16.1 a	11.034 a	88.320 a	15.8 a	13.954 a

Values along with different letter between frequencies are significantly different, ($P< 0.05$).

Root and sugar yield presented significant differences between sowing dates. Thus, sowing in March had the highest yield in both years.

There were significant differences in crop and sugar yields among irrigation frequencies, with higher value for high irrigation frequency in 2000 and in 2001, for harvest mean value and sowing date.

The efficiency of applied water with regard to the root and sugar yield, was always better in the irrigated plots with high frequency in the year 2000 data, however, was very similar in 2001.

Conclusions

The best harvest date of the sugar beet crops was November in this Region.

Sugar beet crops could be sown at the beginning of March.

Higher irrigation frequency increases crop growth and yield in sugar beet.

The increase of irrigation frequency can also save an important amount of water which notably affects on production costs.

References

- García Turienzo, M.A. y De Benito Muñoz, A. 1996. Comparación de dos sistemas de riego. Aspersión y goteo, en remolacha azucarera. Ingeniería del agua. Vol 3. nº 4: 37-44.
- Howell, T.A., Ziska, L.H., McCormick, R.L., Burtch, L.M. and Fischer, B.B. 1987. Response of sugarbeet to irrigation frequency and cutoff on a clay loam soil. Irrig. Sci. 8:1-17.
- Sepaskhan, A.R. and Kamgar-Haghighi. 1997. Water use and yield of sugarbeet grown under every-other-furrow irrigation with different irrigation intervals. Agric. Water Manage. 34:71-79.
- SPSS INC. 233 South Wacker Driver, 11 th Floor. Chicago. Illinois.
- Turner, N.C. 2001.Optimizing water use. CAB. International. Crop Science. Pag 119-135. Eds.: J. Nosberger, H. H. Gieger and P. C. Struik..

INFLUENCE OF THE IRRIGATION REGIME AND NITROGEN FERTILIZATION ON MAIZE (*ZEA MAISs* L.) GRAIN YIELD AND RESIDUAL NITROGEN IN THE SOIL

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Introduction

Nitrogen is the most effective among fertility elements to improve crop production when supplies of soil water are adequate. In central and southern Italy, the production of spring-summer crops are greatly dependent on irrigation water availability since rainfall is not sufficient to face crop water needs.

In central Italy regions, where evapotranspiration demand is not excessive, and in soils with high available water content, deficit irrigation has shown good maize grain yield (Quaranta *et al.,* 1988). Since effectiveness of nitrogen fertilization is related to soil water availability during crop growth and excessive residual soil nitrate may be responsible of ground and surface water pollution (Foster *et al.*, 1982), we investigated the effect of irrigation regime and nitrogen fertilization level on grain yield, water use efficiency and harvest index of maize, and on residual soil nitrogen.

Materials and methods

The study was carried out in the years 2000 and 2001 in the experimental farm of the CO.T.IR. on a silty clay-loam soil (Aquic Haploxerert).

The effect of irrigation and nitrogen fertilization was studied on maize hybrid "Tevere" (FAO class 500) using a split-plot design, replicated 4 times. The irrigation (I) treatments (restitution of 0%, 50% and 100% of the maximum crop ET) were assigned to the main plots, while the nitrogen (N) fertilization levels (0, 150 and 300 kg/ha) were allocated in the sub-plots. The source of N was ammonium nitrate; 1/3 was applied at sowing stage and 2/3 at the beginning of fast growth stage. In 2001 the N dose of post-emergence was divided in two sub doses and applied during early and late rapid growth stage. The irrigation applications were made when the cumulative crop evapotranspiration minus precipitation reached 40 mm. The reference evapotranspiration (ET_0) was estimated with the Penman-Monteith method. Soil moisture was measured weekly from sowing to harvesting in the 0-100 cm soil profile. To evaluate the effect of irrigation regime and nitrogen fertilization on grain yield and total dry biomass, the analysis of variance for split-plot design was used. Duncan's multiple test range was used to compare treatment means. Water use efficiency (WUE) and harvest index (HI) were calculated and expressed, respectively, as crop water use for unit of grain biomass and the ratio of grain yield on total biomass. The crop water use was calculated as the difference between soil water content at seeding and harvest plus irrigation and rainfall.

Source of variation	D. F.	year 2000		year 2001	
		Grain yield	Total dry biomass	Grain yield	Total dry biomass
Replication	3	n.s	n.s.	n.s.	n.s.
Irrigation (I)	2	**	**	**	**
Error 1	6				
Nitrogen (N)	2	*	*	*	**
Irrigation x Nitrogen	4	**	*	n.s.	**
Error 2	18				

Table 1 – Analysis of variance results. (** significant at P level of 0.01; * significant at P level of 0.05).

Results

The effects of I and N were statistically significant in both years (tab. 1), while the interaction [IxN] was not significant for grain yield in 2001. No differences were found between years. The grain yield of the treatments $I_{100}N_{300}$ and $I_{100}N_{150}$ were 14.8 t/ha and 13.3 t/ha in 2000 and 13.9 t/ha and 11.6 t/ha in 2001. In both years (tab. 2) significant differences among irrigation regimes for grain yield and total biomass were observed, while no differences were observed between N_{150} and N_{300}. N levels affected WUE; the higher the nitrogen level the better the WUE, while irrigation regime resulted in better WUE with the treatment I_{50} (tab.2). HI was markedly influenced by irrigation and in minor degree by nitrogen level. Looking to the interaction [IxN], the best WUE was obtained with treatment $I_{50}N_{300}$ (0.31) in 2000 and $I_{100}N_{300}$ (0.48) in 2001. The average soil residual N-NO_3 in the 1-m root zone (tab. 3) ranged from 2.5 mg/kg to 26.6 mg/kg in 2000 and from 1.0 mg/kg to 49.3 mg/kg in 2001, with lower values in the irrigated plots and higher values in the not irrigated plots. The average soil residual N-NH_4, ranging from 3.1 mg/kg to 7.5 mg/kg in 2000 and from 1.7 mg/kg to 6.9 mg/kg in 2001, appeared to be less related with the irrigation and nitrogen amounts.

Treatments	year 2000				year 2001			
	Grain yield (t/ha)	Total dry biomass (t/ha)	WUE (l/g)	Harvest Index	Grain yield (t/ha)	Total dry biomass (t/ha)	WUE (l/g)	Harvest index
I_0	3.9 a	10.4 a	0.50	0.37	2.7 a	12.6 a	0.90	0.21
I_{50}	10.8 b	22.0 b	0.34	0.49	8.0 b	23.6 b	0.56	0.34
I_{100}	12.3 c	27.4 c	0.51	0.45	10.9 c	30.4 c	0.61	0.36
N_0	8.0 a	18.5 a	0.49	0.44	5.3 a	17.0 a	0.86	0.31
N_{150}	8.6 ab	18.9 ab	0.46	0.45	7.8 b	24.1 b	0.58	0.32
N_{300}	10.3 b	22.5 b	0.38	0.46	8.5 b	25.4 b	0.53	0.34

Table 2 – Biomass and grain yield, WUE and HI of I and N treatments. Means having a common letter are not significantly different at the 5% level of significance.

Discussion

On the basis of the simple effect of I and N, it can be stated that in the environmental condition of the field trial area the contribution of irrigation on maize grain yield and total biomass is more effective than N fertilization. Since nitrogen improves the WUE (Hsiao, 1993), the highest grain yield was obtained in both years with I_{100} N_{150} and I_{100} N_{300}, respectively 13.3 t/ha and 14.8 t/ha in 2000 and 11.6 t/ha and 13.9 t/ha in 2001. The small difference on maize yield registered in 2000 between N_0 and N_{150} is mainly due to the residual N-NO_3 soil content that, before sowing N fertilization, was 13.7 mg/kg (about 185 kg/ha in the 1-m root zone), while in 2001 residual N-NO_3 was only 5.6 mg/kg (75 kg/ha). The partition of the N dressing application in 2001 could be the reason of the lowest HI and the worst WUE. Maize crop benefits of optimal irrigation and high nitrogen application, but with low irrigation water availability, good grain yield can be obtained by halving the optimal irrigation amount. In fact, it has been observed that grain yield ranged between 8.5 t/ha and 12.0 t/ha with N fertilised treatments I_{50}. Since the difference in grain yield between $I_{50}N_{300}$ and $I_{50}N_{150}$ ranged from 1 t/ha to 0.2 t/ha during the two-year experiment, lower N dose is required with low irrigation amount. High residual soil N-NO_3 at harvest in the N fertilised and not irrigated treatments points out hazard of nitrate leaching during autumn-winter period (characterised by intensive rainfall).

	year 2000		year 2001	
	N-NH4 (mg/kg)	N-NO3 (mg/kg)	N-NH4 (mg/kg)	N-NO3 (mg/kg)
I_0 N_0	3.1	11.2	2.8	3.3
I_0 N_{150}	4.6	26.6	2.6	21.7
I_0 N_{300}	2.0	17.8	6.9	49.3
I_{100} N_0	6.4	2.5	2.1	1.3
I_{100} N_{150}	5.6	15.8	3.0	3.3
I_{100} N_{300}	7.5	8.8	3.4	7.5
I_{50} N_0	6.1	6.4	2.2	1.1
I_{50} N_{150}	4.2	4.2	2.2	1.0
I_{50} N_{300}	5.8	16.2	1.7	6.0

Table 3 – Mean soil residual N in the 0-100 cm depth.

References

Foster, S.S.D.,Cripps, A.C., Smith-Carrington, A., 1982. *Philos. Trans. R. Soc. Lond.* 296, 477-489.

Hsiao T. C. 1993. *Acta Horticultulturae*, 335, pp. 137-148.

Quaranta, F., Monotti, M., Quaglietta, F., Rizzo, V., Di Bari, V., 1988. *L'Informatore Agrario* 14/88.

BREEDING FOR DEEPER ROOTING GRASSES WITH THE HELP OF ^{18}O NATURAL ABUNDANCE IN SOILS.

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Introduction

Water deficit is a major factor of yield variability in Europe. In order of decreasing importance, the main water resistance traits are linked to (1) the phenology, also related to as drought escape strategy, (2) the root depth, (3) the control of transpiration and (4) the cellular adaptation to dehydration. Grassland are generally not irrigated and their persistency depends on their ability to sustain severe drought in summer. By definition, perennial grasses, which are expected to yield for many years, cannot escape dry periods and hence, the main traits are associated to root dynamics. Grasslands are dense canopies made of a complex of genotypes. Intra and inter species competition is particularly strong. Understanding the changes occurring at the canopy level requires understanding the competitive ability of the different genotypes. Measuring the competition between plants for water availability in the field is difficult because (i) root biomass and root depth change throughout the years, (ii) the classical methods of measurement of depth of water extraction do not apply at the single plant level. Roots exhibit contrasted morphology among grasses. The *Lolium multiflorum / Festuca arundinacea* complex, including their hybrids, offers a unique panel of morphologies and root growth dynamics for studying the implication of plant structure on water relations (Durand et al 1997). Soil evaporation at the soil surface brings about higher ^{18}O δ in top layers than in deeper horizons. The results shown here illustrate the use of natural ^{18}O soil gradients in a nursery for assessing the depth of water extraction on large numbers of individuals.

Methods

Determination of the relevant plant compartment for measuring the origin of transpired water.

To measure the isotopic signature of water extracted from the root zone, it is necessary to sample the plant compartment, which mainly reflects the water of the xylem (Bariac et al., 1994). Plants of *Lolium multiflorum* and *Festuca arundinacea* were grown in hydroponics at 20 ° under one 400 watts High pressure sodium lamp. The isotopic composition (^{18}O) of water extracted from leaves, internal and external sheaths and roots sampled when light was on or off were compared to the isotopic signature of the nutrient solution.

Depth of water extraction in the field.

Individual plants of tall fescue, Italian ryegrass and of a population resulting from hybridization between the two species and introgression into ryegrass (*Festulolium*), were grown in a nursery in INRA Poitou-Charentes. TDR water content measurements were made below each plant individual in the top 20 cm of soil. Following 10 days without rain in august 2000, two tillers per plant were sampled between 12 and 14h00 (solar time). Soil samples were collected at different depths and different points in the nursery between plants. Total water was extracted from soil and plant samples and ^{18}O content was determined with a mass spectrometer (Bariac et al, 1994). Lamina area of each plant was measured.

Results

Plant compartment for measuring the origin of water in grass tillers.

The water of the inner sheaths had the same δ as the nutrient solution, whereas transpiring parts of the shoot exhibited enriched ^{18}O content (+7 and +9 °/oo for *Lolium and Festuca,* respectively). These measurement were consistent with the stronger stomatal control in *Lolium* than in *Fescue.* At low transpiration rate, leave still exhibited a slight enrichment in heavy water. δ of inner sheaths was equal to the δ in the nutrient solution.

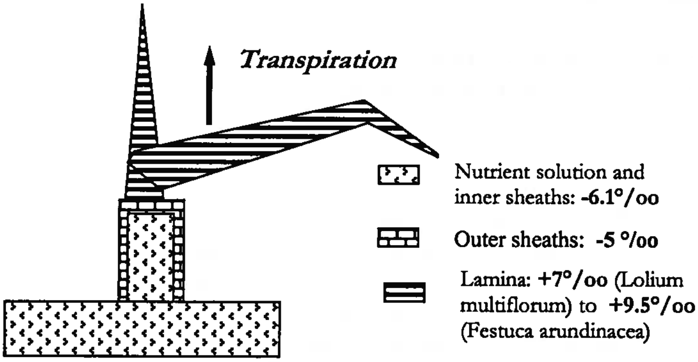

Figure 1. Isotopic signature ($\delta^{18}O$) of different plant compartments showing the enrichment in transpiring tissues.

Depth of water extraction

Plants with low δ ^{18}O had either low transpiration rate and/ or extracted water from shallow horizons The isotopic signature measured in plants collected in a nursery following a period of moderate water deficits varied according to the expected contrasts between *Festuca* (deep water extraction) and *Lolium* (shallow water extraction). The variation within the *Festulolium* population reflected the inter-specific differences observed between the two parent populations (Fig. 2).

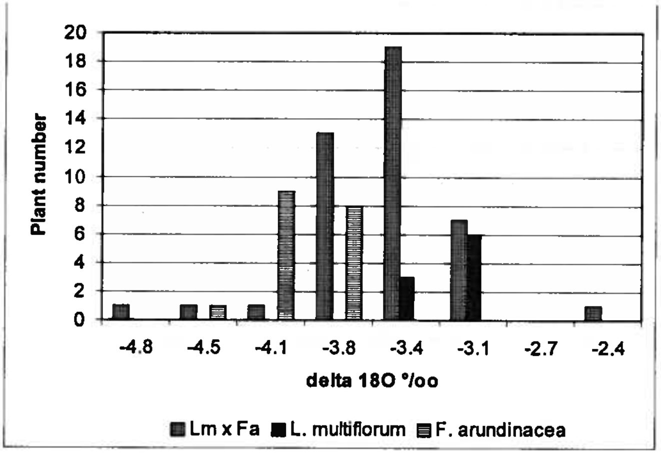

Figure 2. Distribution of individual tillers collected at noon, following a period of moderate water deficits in a grass nursery. A large variability for depth of water extraction appears within the

Conclusion

Natural abundance of ^{18}O gradient in the soil of a plant nursery allowed the discrimination between genotypes within the *Festulolium* population. This was an encouraging result for the search of a new criterion of plant breeding for more persistent grasses in dry environments.

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Durand, Gastal F., Etchebest S., BonnetA.C., Ghesquière M., 1997. European Journal of Agronomy., 7, 99-107.
Bariac T, Gonzalez-Dunia J, Katerji N, Béthenod O, Bertolini JM, Mariotti A, 1994. Chemical Geology, 115: 317-333.

QUANTITATIVE RESPONSE OF GERMINATION RATE TO TEMPERATURE AND WATER DEFICIT IN GRASSES

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Introduction

Breeding for more persistent grasses under oceanic conditions requires drought resistant plants *i.e.* able to use more of the soil water (Durand *et al.*, this volume). This is the aim of a program, based on the hybridisation of *Lolium multiflorum* and *Festuca arundinacea,* combining the high productivity and quality of the former with the persistency under dry condition of the latter (Durand *et al.* 1997). Initial growth rate of *Festuca arundinacea* is however much slower than that of *Lolium multiflorum*, even as far as roots are concerned. The initial elongation rates of seminal roots and leaves determine the rate at which the crop establishes. It also provides a rational for predicting emergence in the field. The paper here reports the results of an experiment aimed at establishing empirical relationships between temperature and soil water potential and the germination rates of *Lolium multiflorum, Festuca glauscescens* and their hybrid. The allometry between roots and leaves of the seedlings is analysed.

Methods

Seeds of *Lolium multiflorum* L. (*cv tonyl), Festuca arundinacea* ssp. *glaucescens* and from a population of a Festulolium hybrid (*LmFg)* were weighed. Seeds were placed in petri dishes on filter paper. The paper was imbibed with pure water, -0.2 or -1.2 MPa PEG solution. Three dishes containing 10 seeds were used for each of the six combination treatments. The dishes were placed in growth cabinets at 10 or 20 °C in full darkness, except for measurements when a dim green light was used. The relative humidity in the growth chambers was 60 %. Every 12 hours, seeds were observed and germination was considered finished as soon as the root or the coleoptile was seen. The growth at emergence of the seedlings was measured. In darkness both the coleoptile and roots exhibit indeterminate elongation, which enables to use their kinetics to compare the initial root/shoot ratio and the relative growth partitioning, *i.e.* the ratio between relative growth rates. On 20 seeds per genotype and treatment, the length of both seminal root and coleoptile were measured using a calliper (0.1 mm resolution).

Results

After 790 hours, the percentage of germinated seeds at 20 °C and 0 MPa was 97, 97 and 93 % for *Lolium multiflorum*, *LmFg* and *Festuca arundinacea,* respectively. Throughout the study, and for all variables measured, *LmFg* was intermediate between the two parent species, but much closer to *Lolium multiflorum.* At -1.2 MPa, many seeds revealed unable to germinate in all species. As expected, the germination rate was much faster for *Lolium multiflorum* than for *Festuca arundinacea* under any condition. (Table 1).

Table 1. Duration, in hours, of the germination of seeds of three grass populations at 10 and 20 °C, imbibed in three osmotic potential solutions. Standard errors are given in parenthesis.

	Lolium multiflorum		*LmFg*		*Festuca arundinacea* ssp. *Glaucescens*	
	10 °C	20 °C	10 °C	20 °C	10 °C	20 °C
0 Mpa	183 (67)	88 (52)	238 (53)	97 (27)	429 (117)	97 (27)
-0.2 MPa	180 (20)	72 (4.3)	259 (85)	100 (36)	401 (73)	181 (91)
-1.2 MPa	416 (55)	289 (58)	484 (102)	293 (33)	527 (*)	367 (115)

*: only one seed germinated

On average, the germination rate of *LmFg* was equivalent to its *L. multiflorum* parent. The germination of *Festuca arundinacea* exhibited a much higher sensitivity to water deficit than *Lolium multiflorum* and *LmFg*. Indeed, germination duration at 20 °C was the same at 0 and -0.2 MPa in both latter species whereas it nearly doubled for *Festuca arundinacea* at –0.2 MPa. This was likely due to the anatomy of the seed, which makes the water travel from the seed surface to the almond much slower in *Festuca arundinacea*.. This was also associated with a large difference in seed mass (approximately 1.9, 3.3 and 4 mg for *Lolium multiflorum, Festuca arundinacea* and *LmFg*, respectively.) However, when considered within each population, the correlation between seed mass and germinations vanished.

The elongation rates of seminal root and coleoptile also differed between both parent species, *LmFg* exhibiting similar growth features as the *Lolium* parent (Fig 1). Using normal spring temperature data of the centre west of France, when sown on 15 May, *Lolium multiflorum* would at latest emerge around 1 June and *Festuca arundinacea* on 23 June.

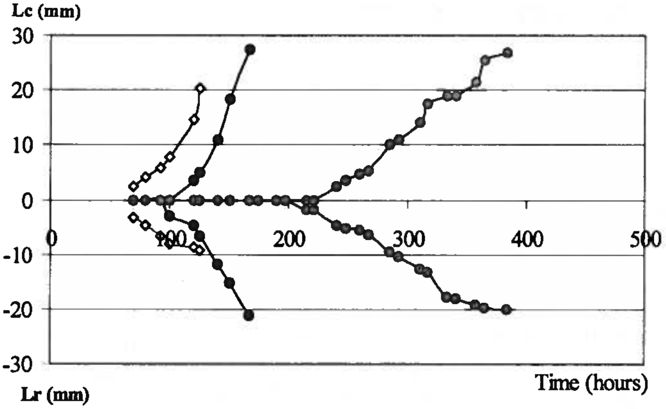

Figure 1. Length of root and coleoptile of one typical seedling of each genotype (grey circles: *Festuca arundinacea*, closed circles: *LmFg*, diamonds: *Lolium multiflorum*) at 20°C and in pure water.

The allometric relationships between root and coleoptile were fitted to power functions, where the power parameter is a measurement of the dynamic partitioning of growth between two organs (Fig. 2). This analysis revealed that the initial root/shoot ratio was higher in *Lolium multiflorum*. But the longer term (extrapolated) trend indicated that root elongation would continue longer relative to coleoptile in *Festuca arundinacea*.

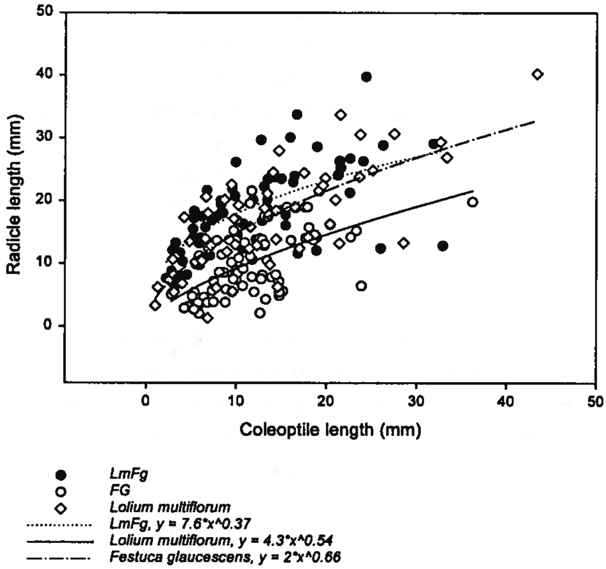

Figure 2. Seminal root length versus coleoptile length in three grass species at 20°C and 0 MPa solution in full darkness.

Conclusion

The action of temperature on *Festuca arundinacea* and *Lolium multiflorum* was similar. Germination of *Festuca arundinacea* was much more sensitive to water status. Hybrid plants were intermediate and closer to the *Lolium* parent. By contrast to the situation in the established sward, the root-shoot ratio was higher in *Lolium*. However, the ratio between root and shoot relative growth rates was higher in *Festuca*, reflecting field situation on the longer term (Durand *et al.* 1997).

References

Durand, Gastal F., Etchebest S., BonnetA.C., Ghesquière M., 1997.. European Journal of Agronomy., 7, 99-107.

Durand JL., Ghesquière M., Bariac T. and Mi Fugui, 2002. Breeding for deeper rooting grasses with the help of ^{18}O natural abundance in soils. (This Volume)

LEAF POTASSIUM AND ITS RELATIONSHIP WITH GAS EXCHANGE AND WATER CONTENT IN COTTON GENOTYPES UNDER DROUGHT-STRESS

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Introduction

There is a limited number of traits effectively related with crop yield for selecting drought-tolerant cotton (Leidi et al., 1999). Interaction between physiological processes, developmental stages and environmental conditions makes difficult the evaluation and the assignment of the contribution of different traits to crop tolerance (López et al., 1995; López, 1998). Traits like photosynthesis, transpiration and stomatal conductance are very much affected by the immediate environment, phenology and their contribution to yield may vary in a time scale (López, 1998; El-Dahan, 2001). Potassium is a main nutrient in cotton because of its high requirement and the low uptake efficiency (Kerby and Adams, 1985). Besides the amount of K required for growth and lint production, K plays a role in turgor maintenance and osmotic adjustment. In plants under drought stress, K accumulation may be more important than organic solutes in the initial phase of adjustment to stress (Hsiao and Läuchli, 1986). Some variation in leaf K accumulation was recorded in three cotton genotypes under terminal drought (López et al., 1993). In this study, we studied the relationships among leaf K, physiological parameters and yield in cotton cultivars subjected to water stress.

Materials and methods

Eight cotton varieties (*Gossypium hirsutum* L.) previously selected for their differential response to drought (López, 1998) were cultivated at Alcalá del Río (Seville) on the available water stored in the soil during the rainy season (713 mm in 1998). The soil type was clayey (Typic Chromoxerert). Sowing was performed on 22nd May. Experimental design was a completely randomized block design with four replications. The main plot consisted of one row 5 m long and 0.95m between rows. After emergence the seedling were thinned to 8-10 plants m^{-1} of row. Measurements of leaf photosynthesis (A), transpiration (E), and stomatal conductance (g_s) were made with an open system using a portable infrared gas analyzer (LCA-2, ADC, Hoddeson, England) equipped with a Parkinson leaf chamber and a data logger. The measurements were made from 11:00 to 12:00 AM at saturating photosynthetic photon flux densities (1000-1500 μ mol m^{-2} s^{-1}) on the youngest fully expanded leaves (four replications). Water-use efficiency was calculated as the relation A/g_s (Leidi et al., 1999). The same leaves were used to determine the following traits: leaf temperature with a hand-held infrared thermometer (Ray R2 Pag, Raytek, Santa Cruz, California, USA); water content (WCT) as the relation (leaf fresh weight–leaf dry weight)/leaf dry weight; water content per cm^2 (WCC) as the relation (leaf fresh weight – dry leaf weight)/leaf area, and specific leaf weight (SLW) as the relation between leaf dry weight and leaf area. All of the physiological characters were determined at early flowering. At the end of the season, seed cotton (seed + fiber) yield was determined by harvesting central rows 3 m long from each varieties. Relationship between traits were determined using Pearson´s simple correlation test.

Results

The concentration of K was positively associated with stomatal conductance, transpiration and photosynthesis but negatively correlated with WUE. This negative association may be basically the result of K affecting mainly stomata and water loss than carbon assimilation (Hsiao and Läuchli, 1986). Leaf K concentration showed significant correlation with traits like SLW and WCC (r=0.76 and r=0.81 respectively, $P<0.05$, n=8). Potassium is a significant contributor to the osmotic potential in cotton (Cutler and Rains, 1978). The negative correlation between leaf K and leaf temperature may reflect the effect of leaf K on leaf water status and stomatal conductance: greater K concentration may improve osmotic adjustment and leaf water status maintaining stomatal aperture and evaporative cooling. In cotton, K deficiency increased stomatal and non-stomatal limitations of photosynthesis (Bednarz et al., 1998). More interesting is the significant association between leaf K concentration and cotton seed yield (r=0.75, $P<0.05$, n=8). It suggests a role for K in the adaptation of genotypes to drought stress and/or differences in the K uptake under stress. No correlation was found between osmotic potential and physiological parameters. Significant differences in leaf K concentration were found when studying a range of 36 cotton genotypes under similar drought conditions (data not shown).

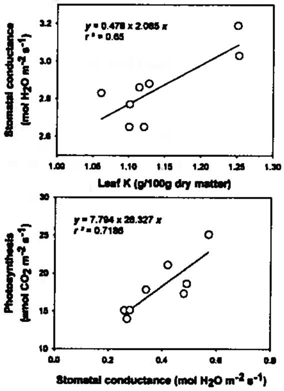

Figure 1.

Conclusions

The relationships between K and main physiological determinants of cotton yield deserves further research. Strategies for increasing K uptake might increase yield under terminal drought. Similarly, the apparent genotypic variation in K uptake capacity under drought should be explored further.

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References

Bednarz C.W. et al. (1998) Environ. Exp. Bot. 39: 131-139.
Cutler J.M., Rains D.W. (1978) Physiol. Plant. 42: 261-268.
El-Dahan M.A.A. (2001) PhD Thesis, ETSIA Córdoba, Spain.
Hsiao T.C., Läuchli A. (1986) In: Advances in Plant Nutrition, vol 2 (B. Tinker, A. Läuchli, eds.) pp. 281-311. Praeger, New York.
Kerby T.A., Adams F. (1985) In: Potassium in agriculture (R.D. Munson, ed.) pp. 843-860. American Society of Agronomy, Madison, Wisconsin, USA.
Leidi E.O. et al. (1999) Field Crops Res. 61: 109-123.
López M. (1998) PhD Thesis, ETSIA Córdoba, Spain.
López M. et al. (1993) In: Relaciones Hídricas en las Plantas, Proc. 1er Simposio Hispano-Portugués, UIB-CSIC, Palma de Mallorca, pp. 189-192.

THE RESPONSE OF LUPIN YIELD TO SOWING DATE IN A MEDITERRANEAN ENVIRONMENT: A SIMULATION EXPERIMENT

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Introduction

Narrow-leafed lupin (*Lupinus angustifolius* L.) is the major grain legume crop in Western Australia, with over 1 million hectares sown every year. It is grown in rotation with wheat (*Triticum aestivum* L.) and canola (*Brassica napus* L.). The Mediterranean climate of Western Australia is characterised by high seasonal variability and therefore the variability of yields is one of the main concerns of growers. In such an environment, a large number of experiments would be required to study and improve crop management. A crop simulation model is a powerful tool, which can be used to extrapolate knowledge of crop performance and management responses across sites and seasons, thereby minimising the number of experiments required.

The Agricultural Production Systems Simulator (APSIM) enables modules of crop, soil water, soil nitrogen and residues to be linked to simulate agricultural systems. The soil water, soil nitrogen and residue modules are common to all crops. The wheat and the canola crop models of the APSIM family have been tested for Western Australian conditions (Asseng *et al.*, 1998; Farre *et al.*, 2001). In the current work, the generic APSIM-legume model is being parameterised for a lupin crop using existing datasets and parameters from the literature. A simulation experiment was performed linking the model with historical weather data. The model will be used in the future to assess yield expectations and risk of alternative management decisions regarding yield, water and nitrogen use efficiency.

Methods

The APSIM-Lupin model being developed is based on an existing APSIM legume template (Robertson *et al.*, 2002). The new lupin model has been parameterised using existing datasets in Western Australia and from values in the literature (Dracup and Kirby, 1996). The cultivar-specific parameters for phenology were obtained for 7 narrow leaf cultivars using observed flowering dates from 2 years, 4 locations and 4 sowing dates (R.J. French, unpublished) by using an optimisation program (Carberry, 1996). Initial testing of the model, using independent observed data (R.J. French, unpublished), was performed for 2 cultivars.

The model was used in simulation experiments with long-term weather data from 1960 to 1999 to simulate grain yield. Two major soil types in the lupin growing area were used, a sand and a loamy sand (55 mm and 130 mm plant-available soil water in the root zone, respectively). Simulations were done for the cultivar Merrit (mid maturity type) at Wongan Hills, Western Australia. The soil water profile was re-set at the lower limit at 1 January (DOY 1) each year. Sowing time was controlled by a sowing rule. A sowing window was set between 15 April and 30 June. The first sowing opportunity occurred when at least 15 mm of rainfall had accumulated within 5 days. Two sowing dates were simulated for every year: a) sowing occurring in the first sowing opportunity, and b) sowing occurring 14 days later.

Results and discussion

Initial testing of the lupin model for 2 cultivars on a duplex and a sandy soil in Western Australia, showed a reasonably good performance of the model for phenology (flowering date) and yield, with Root Mean Squared Deviation of 4.9 days and 0.8 t/ha, respectively.

Simulated lupin yields were highly variable over the 40 years studied, reflecting the climate variability (Fig. 1a). There was no significant interaction between soil type and sowing date, with yields on loamy sand being on average 17-21% higher than on the sandy soil, due to the higher soil water holding capacity. The sowing rule produced a range of sowing dates in the different years, depending on rainfall distribution. Any delay in sowing date reduced the simulated yields (Fig. 1b). Sowing at the first sowing opportunity had a yield advantage over sowing 14 days later in most of the years (Fig. 1a), due to the avoidance of water deficit and heat stress during the grain filling period in spring. The risk of heat stress has been also emphasized by Reader *et al.* (1997), who found yield reductions in lupin caused by hot temperatures during grain filling. The simulation results also agree with findings by Eastham *et al.* (1999), who found that early sowing in lupin was associated with increased early growth and larger canopies giving higher yields.

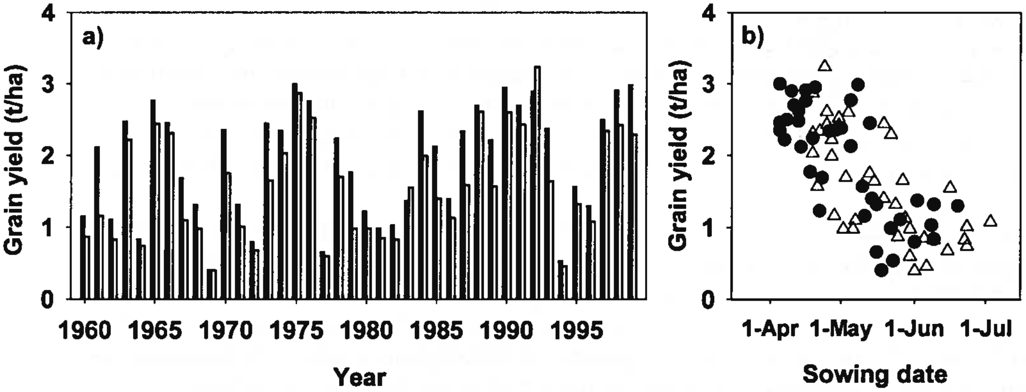

Fig. 1. Simulated yields for lupin cv. Merrit for the period 1960-1999 versus (a) years and (b) sowing date. Yields for sowing at the first sowing opportunity (solid bar, •) and sowing 14 days later (open bar, ☐) are shown for a sandy soil at Wongan Hills, Western Australia.

Conclusions

A new lupin model has been developed using the APSIM-legume template. Initial testing of the model has shown a reasonably good performance for phenology and yield. The application of the model indicated the potential yield loss due to delayed sowing opportunity and an additional loss in relation to the 14 days delay. In the Mediterranean environment of Western Australia, late sowing often results in unfavourable grain filling conditions with high temperatures and water deficit, which reduces yield and crop profitability. The modelling approach allowed the effect of variable growing conditions and its interaction with sowing decisions on lupin yield to be quantified.

References

Asseng, S. *et al.*, 1998, Field Crops Research, 57,163-179.
Carberry, P. S, 1996, Final Report to Grains Research and Development Corporation, Project CSC9, 33pp.
Dracup, M and Kirby, E.J.M, 1996, Lupin Development Guide. Nedlands, Australia: University of Western Australia Press, 97 pp.
Eastham, J. *et al.*, 1999, Agricultural Water Management, 42, 205-218.
Farre, I. *et al.*, 2001, Proceedings of the 10th Australian Agronomy Conference, Hobart.
Reader, M.A. *et al.,* 1997, Australian Journal of Agricultural Research, 48, 1169-1178
Robertson, M. J. *et al.*, 2002, Australian Journal of Agricultural Research, 53, 429-446.

POTENTIAL APPLICATION OF STEM DIAMETER MEASUREMENT FOR IRRIGATION MANAGEMENT IN GREENHOUSE VEGETABLE PRODUCTION

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Introduction

Improved irrigation scheduling (IS) of intensively produced vegetable crops will contribute to maximising production and fruit quality, and to the more efficient use of scarce water resources in arid regions. The incorporation of measures of plant water status into IS procedures will assist in optimising irrigation to the particular requirements of individual crops.

Stem diameter (SD) has been shown to be a sensitive indicator of water stress in some fruit tree species (Goldhamer et al., 2000); protocols are being developed to apply SD measurement to IS in these species (Goldhamer and Fereres, 2001). In transpiring plants, SD normally undergoes diurnal fluctuations, having maximum values shortly before sunrise, and minimum values in the afternoon. Contraction occurs as a result of water from stem phloem tissue being incorporated into the transpiration stream.

Maximum daily contraction (MDC) of SD has been identified as being very sensitive to water stress in fruit trees (Goldhamer et al., 2000). Currently, there are very few data on the application of these measures to vegetable species grown under greenhouse conditions.

Methods

Two studies were conducted, one with tomato, another with melon. The crops were grown in plastic greenhouses at the Estación Experimental "Las Palmerillas", in El Ejido, Almería province, Spain. Both crops were grown in soil, with drip irrigation. The tomato was transplanted on 7/09/00, the melon on 22/02/01.

In tomato, plants were grown in plots, 10 x 4.5 m; there were two treatments, each of four randomly-distributed plots. The "well-watered" treatment was managed with the EnviroSCAN system (Sentek, Australia) to maintain adequate soil moisture. Additionally, the plants with SD sensors had manual tensiometers, and received additional water, if necessary, to ensure that soil matric potential was 10–30 kPa. The "un-watered" treatment was managed similarly until the treatment was imposed; irrigation was withheld for the period 3/4/01 to 10/4/01. One plant in each of two plots, from each treatment, was monitored for SD.

In the melon, plants were grown in a single line of 14 plants located centrally within a crop. The line was divided into four groups of 3–4 plants; two groups were randomly allocated to each treatment. One plant, within each group, was monitored for SD and with a manual tensiometer Prior to imposing the treatments, the plants were watered on the basis of matching crop evapotranspiration. During the treatment period, the drip lateral was disconnected. The "well-watered" plants were watered manually, several times a day if necessary, to maintain soil matric potential at 10–30 kPa. The "un-watered" treatment period was 17/5/01 to 23/05/01.

Stem diameter was measured with linear variable displacement transducer sensors (LVDT; SD-5, Phytech Ltd., Israel). Air temperature and relative humidity were measured with an aspirated psychrometer. All data were recorded every 10 minutes with a data logger (Phytech Ltd., Israel).

Results

In both tomato and melon, within one day of withholding irrigation, there was an increase in MDC of "un-watered" plants compared to that of "well-watered" plants (data not presented). These differences were maintained until the day after resuming irrigation, when MDC in "un-watered" plants decreased to values very similar to that of the "well-watered" plants.

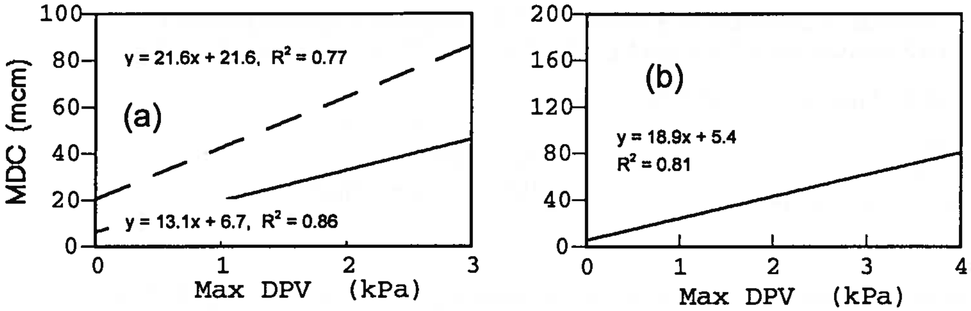

Fig 1. MDC vs. max. daily DPV for (a) tomato and (b) melon. ★ well-watered, ▨ un-watered

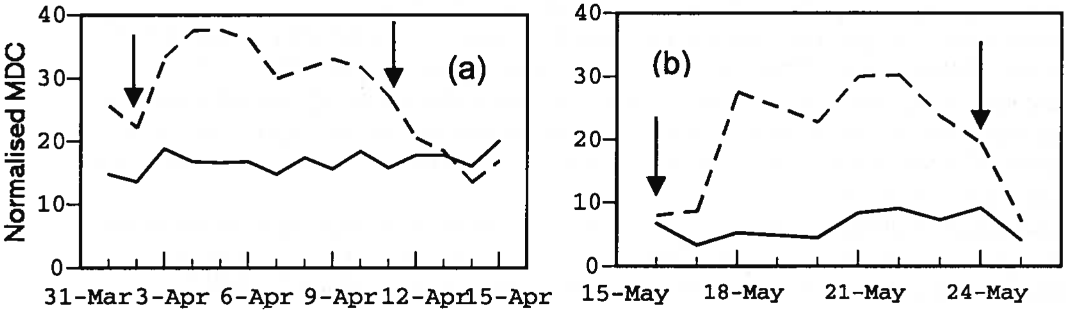

Fig 2. Normalised MDC during treatment periods for (a) tomato and (b) melon. ★ well-watered, ▨ un-watered. Arrows indicate irrigations immediately prior to and after treatment period

For "well-watered" plants, in both tomato and melon, there was a strong linear relationship between MDC and VPD (Fig. 1). In the moderately-stressed plants of the "un-watered" tomato treatment (VPD's mostly <2.5kPa), this linear relationship was maintained, but with a larger slope and higher intercept (Fig 1a). In the more severely stressed plants of the "un-watered" melon treatment (VPD's mostly >2.5 kPa), there was no discernible relationship (Fig. 1b). Normalised MDC (*i.e.* MDC divided by DPV) was relatively constant in "well-watered" plants, for both melon and tomato (Fig. 2). Values were 14–20 mcm kPa^{-1} for tomato, and 3–9 mcm kPa^{-1} for melon. In "un-watered" plants, normalised MDC values increased rapidly, within 1 day of withholding water. The maximum values were 40 and 30 mcm kPa^{-1} in tomato and melon, respectively. Similar values were obtained within 1 day of withholding water in both crops.

Discussion

In tomato and melon, MDC was sensitive to both evaporative demand (*i.e.* VPD) and soil water depletion. When normalised for DPV, normalised MDC was very sensitive to soil water depletion in both species. These data suggest that normalised MDC has considerable potential for use as an indicator of plant water status for vegetable crops grown in greenhouses. The envisaged application to irrigation scheduling involves firstly defining threshold values of normalised MDC for individual species at particular growth stages, in a given environment. Once defined, these values could be used to alert farm managers to a possible stress, or even to automatically activate irrigation.

References

Goldhamer D.A., Fereres E., Cohen M and Girona J. 2000. Acta Horticulturae, 537:431-445.
Goldhamer D.A. and Fereres E. 2001. Irrigation Science, 20:115-125.

GENETIC IMPROVEMENT EFFECTS ON DURUM WHEAT YIELD AND YIELD COMPONENTS IN THE MEDITERRANEAN REGION

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Introduction

Genetic improvement of grain yield in wheat has been the result of selecting for grain yield *per se*, but also for some characters considered to contribute to a high yield, as reduced plant height, more erect leaf posture and larger grain sink size (Leihner and Ortiz, 1978; Waddington et al., 1987; Slafer et al., 1994). Two complementary approaches have been used to analyse the genetic gain in crops, the classical division of yield in numerical components (namely grain-yield components) and the determination of dry-matter accumulation and partitioning (Fischer, 1984). The aim of the present contribution is to examine the progress made in improving the yield of durum wheat cultivars released in Italy and Spain during different periods since 1900.

Methods

For this study, 24 cultivars of durum wheat (*Triticum turgidum* L. var. *durum*) released from the 1900's to the 1990's in Italy and Spain, were grown under rainfed conditions in Lleida (northern Spain) and Granada (southern Spain), during two years. The experimental design was a randomised complete blocks with three replications. For measuring the yield components, plants were taken from 1 m long row in each plot before harvest, which provided the number of spikes per m^2, spikelets per spike, grains per spike, yield per plant, harvest index and plat height. Grain yield was obtained with a harvester and corrected to 12% humidity. Mean kernel weight was measured on a sample drawn randomly from the bulk grain sample from each plot. For statistical analysis, cultivars were grouped into three categories: old (released before 1930), medium (released around 1960's) and modern (released after 1980).

Results

Grain yield and yield per plant markedly improved from the old to modern cultivars, although no significant differences were found between intermediate and modern cultivars. This increase could mainly attributed to a higher number of kernels per unit of land (i.e., a greater sink size), as a result of higher spike density and greater number of kernels per spike in modern cultivars (Table 1). Nevertheless, change in grain yield with time of release showed no statistical differences between intermediates and modern cultivars (Table 1).

Table 1. Mean values for grain yield per ha and per plant, yield components, harvest index and plant height in old, medium and intermediate durum wheat cultivars released in Italy and Spain and grown during 2000 and 2001 seasons.

	Grain yield (kg ha^{-1})	Yield per plant (g)	Spikes m^{-2}	Spikelets spike^{-1}	Kernels spike^{-1}	Kernel weight (mg)	Kernels m^{-2}	Harvest index (%)	Plant height (cm)
Released									
Old	2559b	2.21b	226b	16.5a	28.2b	46.2a	5458c	30.6b	103a
Medium	3387a	2.59a	253ab	16.4a	32.6a	46.9a	7134b	37.3a	77b
Modern	3768a	2.66a	267a	15.9a	34.2a	45.3a	8142a	40.1a	70b
Origin									
Italy	3334a	2.44a	252a	15.9a	31.2a	46.5a	7040a	37.4a	80a
Spain	3142a	2.54a	245a	16.6a	32.2a	45.8a	6782a	34.7a	87a

Values within column and division followed by the same letter are not significantly different according to Duncan's test ($p<0.05$).

Throughout the breeding efforts during the last 90 years, spikelets per spike and kernel weight remain without significant modification. Harvest index, however, increased by more than 23% from old to modern cultivars, due mainly to a parallel reduction in plant high (32%, Table 1). No significant differences were observed in grain yield and its components between cultivars released in Italy and Spain (Table 1).

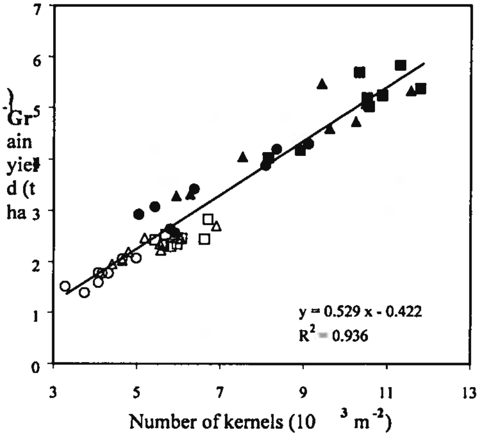

Fig. 1. Relationship between grain yield and number of kernels per m^2 for old (circles), medium (triangles) and modern (squares) cultivars released both in Italy and Spain and grown in Granada (open symbols) and Lleida (closed symbols).

A highly significant association between grain yield and number of grains per unit of land was found for the whole of cultivars and periods studied (Fig. 1). To the best of our knowledge, no data are available comparing series of historical cultivars of durum wheat in Mediterranean environments. Nevertheless, our results agree, in general terms, with those published by Waddington et al. (1987) in CIMMYT-Mexico and McCaig & Clarke (1995) in Canada. In this way, it seems valid to extrapolate to durum wheat what has been widely demonstrated for bread wheat and barley grown in different environments. *i.e.*, grain yield appears more frequently limited by the size of the sink than by the strength of the source during grain filling (e.g. Riggs et al., 1981; Slafer and Savin, 1994).

Conclusions

From the results obtained in this study with 24 cultivars released in Italy and Spain from the 1900's to the 1990's and cultivated during two years under two different environmental conditions in Spain, it can be concluded that gains in grain yield were brought about by consistently increasing the number of kernels per unit area, while mean kernel weight has remained virtually unchanged. Hence, future improvement in grain yield could be attained by increasing mainly the number of kernels per unit of land area, as was already suggested for bread wheat.

References

Fischer, R.A. 1984. Wheat. In: (W.H. Smith, J.J. Banta, Eds.) Potential Productivity of Field Crops under Different Environments. Los Baños: IRRI, pp. 129-154.
Leihner, D.E. ; Ortiz, G. 1978. Euphytica 27, 785-799.
McCaig, T.N. and Clarke, J.M. 1995. Canadian Journal of Plant Science 75, 55-60.
Slafer, G.A. and Savin, R. 1994. Field Crops Research 37, 39-49.
Slafer, G.A., Satorre, E.H. and Andrade, F.H. 1994. Increases in grain yield in bread wheat from breeding and associated physiological changes. In: (G.A. Slafer, Ed.) Genetic Improvement of Field Crops. New York: Marcel Dekker, Inc., pp.1-68.
Riggs, T.J., Hanson, P.R., Start, N.D., Miles, D.M., Morgan, C.L. and Ford, M.A. 1981. 1980. Journal of Agricultural Science 97, 599-610.
Waddington, S.R., Osmanzai, M., Yoshida, M. and Ransom J.K. 1987. Journal of Agricultural Science 108, 469-477.

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VINEYARD RESPONSE TO DIFFERENT IRRIGATION STRATEGIES. FIRST YEAR (2001) RESULTS.

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Introduction

Vineyards for wine, in Spain, were normally conducted without supplemental irrigation water because was not allowed by laws. From 1996 it's allowed to irrigate vineyards, but it exists a large disparity of criteria based on different information that goes from the idea that irrigation water should be applied "*ad libitum*" to the people who believes that irrigation is always negative for wine production. The main objective of this research is to evaluate different scheduling irrigation approaches

Methods

The experiment was conducted in 2001 in a commercial vineyard (*Vitis vinifera* L.) of 12 year-old "Pinot-Noir" vines (1.7 x 3.10 m spacing)(1900 vines/ha) located in Raïmat-Lleida (Spain). The soil was a clay loam with an effective rooting depth between 90 and 110 cm. Annual rainfall for 2001 was 414 mm. Daily maximum temperature was about 36 °C.

Irrigation water was supplied through a drip irrigation system with two 2.3 L/h drippers per vine located in the row and equally distributed trough the pipe. The system was operated with one general controller that individually manipulates each one of the selenoid valves located in each experimental unit. The irrigation schedule was introduced daily to the controller.

Four irrigation treatments were applied: Water budget (WB) and three vine water status irrigation (VWSI) strategies. WB was irrigated following the water budget approach (Goldhamer and Snyder, 1989), with data from a weather station close to the experimental field which determine the reference evapotranspiration (ETo) using the FAO modified Pemman equation (Doorenbos and Pruitt, 1977) and the estimated crop coefficient (Kc) adapted from Williams et al., (1994). Additionally three VWSI treatments were imposed based on to irrigate with 4 mm/day the vines of one experimental unit each time that midday leaf water potential (Ψ_{md}), daily measured, was lower than the established threshold defined for each one of the VWSI treatments: 1) Control (VWSI-C) (C) irrigated when Ψ_{md} was lower than –0.8 MPa for the full season , 2) Control - Stress (VWSI-CS) (CS) irrigated like VWSI-C from bud-break to middle of June (about middle of fruit growth stage II), and from that to harvest when Ψ_{md} was lower than –1.2 MPa, and 3) Stress (VWSI-S)(S) irrigated when Ψ_{md} was lower that –1.5 MPa from bud-break to middle of June and thereafter to harvest when Ψ_{md} was lower than –1.2 MPa. After harvest the three VWSI treatments were still irrigated until early October following the lasted guidelines (Figure 1).

The statistical design was a randomized complete-block with five replicates per treatment. Each one of the 20 experimental units consisted of four adjacent vines rows with twelve vines per row. The center 8 vines of the two central rows were monitored while the other ones served as a guard vines. A total of 960 vines were used in this experiment, 320 of them were monitored.

Midday leaf water potential (Ψ_{md}) was measured almost daily using the pressure pump technique with the plant water status console 3005 (SoilMoisture Corp. Sta. Barbara, CA, USA). To accomplish the full plot control in less than one hour, 2 leaves per experimental unit were measured (one in each row of the experimental unit). A total of 90 controls were performed during this first year.

Harvest was done on July 27th. Experimental vines were hand harvested, clusters for each vine were counted and total vine yield was weighted. One sample of 100 berries per experimental unit was taken to the laboratory to perform the same controls described for weekly berry growth.

Results

Seasonal evolution of Ψ_{md} showed the existing differences between treatments (Figure 1A) and how controlling Ψ_{md} is possible to arrive to clear differentiated irrigation treatments (Figure 1B) with absolutely different amounts of applied irrigation water (Table 1).

The effects on yield were related to the amount of applied irrigation water, with very low decreases for treatments C and CS, and a significant reduction for treatment S (Table 1). The main affected yield component was the average berry weight (Table 1).

With these treatments vegetative growth was reduced in different ways (data not shown) and final yield was related to the degree of vegetative growth reduction early in the season.

Table 1. Applied irrigation water, yield and yield components for each irrigation treatment.

	Irrig.	Yield	NCV	ACW	ABFW	ABDW	NBC
Significance	------	0.0001	0.0015	0.0001	0.0001	0.0001	0.0077
C	300	13.26 b	68.5 b	96.2 b	1.37 b	0.364 b	70.1 c
CS	208	14.56 ab	77.8 a	92.5 b	1.28 c	0.343 c	72.2 ab
S	101	8.62 c	65.9 b	65.4 c	0.96 d	0.271 d	67.7 c
WB	410	15.81 a	71.4 b	111.0 a	1.48 a	0.376 a	75.4 a

Mean separation analysis by Duncan at $\alpha = 0.05$. Irrig. = Applied irrigation water to harvest (mm). Yield = Weight of harvested vines (Tm ha^{-1}). NCV = Number of clusters per vine. ACW = Average cluster weight (g). ABFW = Average berry fresh weight (g). ABDW = Average berry dry weight (g). NBC = Number of berries per cluster.

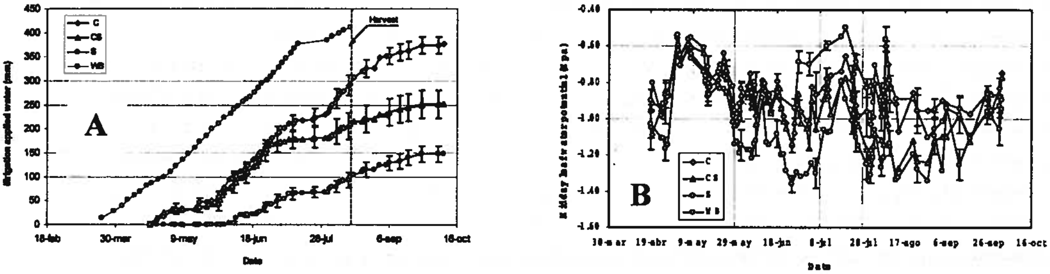

Figure 1. Seasonal patterns of applied irrigation water (A) and midday leaf water potential (B) for each irrigation treatment.

Conclusions

To use daily controls of Ψ_{md} to schedule irrigation in vineyard is a useful approach because it clearly differentiated irrigation treatments when using different Ψ_{md} thresholds, with clear effects on yield. The used thresholds for this first year were probably too low, especially early in the season. Adjusting these early thresholds should be the first objective for next year season work.

References

Doorenboos, J., and Pruitt, W.O., 1977.. Irrigation and Drainage paper n°24. FAO-Rome.

Goldhamer, D.A., and Snyder, R.L., 1989. Irrigation scheduling. A guide for efficient on-farm water management. University of California, 66 pp.

Williams, L.E., Dokoozlian, N.K., and Wample, R., 1994. Grape. In: Handbook of Environmental Physiology of Fruit Crops, Ed. B. Schaffer and P.C. Anderson. Vol.1. Temperate Crops. CRC Press, Florida:85-133.

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USE OF THREE IRRIGATION STRATEGIES IN A GREENHOUSE-GROWN GREEN BEAN CROP IN THE ALMERIA COAST

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Introduction

The Mediterranean greenhouse horticulture is a very competitive sector in Spanish and European agriculture, but it is facing a severe competition within and outside the EU market. Thus, in Mediterranean areas with limited water resources such as the Almería coast, the development of irrigation scheduling practices for minimising water use and lixiviates, and improving vegetables yield and quality is of primary importance.

For improving the irrigation scheduling practices, evapotranspiration of the main horticultural crops of the region was determined using the FAO method (Fernández *et al.*, 2001). Later, models for estimating daily values of crop evapotranspiration using real-time (ET_c) or historical climate data (ET_h) were developed (Fernández *et al.*, 2001). Irrigation of green beans, one of the main greenhouse crops in Almería, occupying an area of about 4800 ha, is mainly based on local farmers' experience without a scientific basis. This work was aimed to study the influence of three irrigation strategies on growth and production of a greenhouse green bean crop.

Methods

The experiment was conducted at "Las Palmerillas" research station (Almería), in an unheated greenhouse (58 m by 24 m) of metallic structure and symmetrical roof (12.5 % slope), covered with 0.2 mm-thick thermal polyethylene sheet. Green bean seeds (*Phaseolus vulgaris* L. ssp. Volubilis, cv. Donna) were sown on 12/09/2001 and the crop cycle finished on 2/01/2002. Plants, in rows 2 m apart and 0.5 m within rows, were vertically supported to a height of 2 m. Irrigation water (electrical conductivity of 0.4 dS m^{-1}) was supplied through a drip system. The soil was the typical "enarenado" soil, commonly used in greenhouses of the region. Three irrigation strategies, arranged in a randomised complete-block design, were studied:

Reference irrigation scheduling (C): Irrigation started when the soil water potential (SWP) was around -25 kPa. The water applied was calculated as the real-time green bean evapotranspiration accumulated from the previous irrigation ($ET_c = ET_o \times K_c$). The reference crop evapotranspiration (ET_o), was calculated with a radiation method (Fernández *et al.*, 2001) using real time data of daily solar radiation and greenhouse transmissivity estimates. The crop coefficient (K_c), was calculated from leaf area index values (LAI), which were estimated as a function of thermal time.

High frequency irrigation (HF): Irrigation started when the SWP was within -10 and -15 kPa. The amount of irrigation water was calculated like that of the reference irrigation treatment. Local growers used this irrigation strategy for improving water and nutrients availability.

Phenology-based irrigation (P). Irrigation started at progressively lower SWP within the vegetative phase, ending at 50 kPa when first fruits were set. Hereafter, the SWP was kept within -10 and -15 kPa. Data of historical green bean evapotranspiration accumulated from the previous irrigation were first calculated ($ET_h = ET_{oh} \times K_{ch}$). Daily values of historical reference evapotranspiration (ET_{oh}) were calculated using average solar radiation from a data set of 14 years, and greenhouse transmissivity estimates (Fernández *et al.*, 2001). Historical daily values of crop coefficient (K_{ch}) were calculated from LAI values, estimated as a function of thermal time, calculated using average temperatures from a data set of 11 years. Finally, the water applied at each irrigation event was chosen within the $ET_h \pm SD$ (standard deviation of ET_h data) interval in order to keep the SWP within the fixed thresholds. Local growers use this irrigation strategy for controlling plant vigour.

Soil water potential was measured with four tensiometers per treatment, installed at 0.12 m below the sand layer near the plant. Total and marketable fruit production, and vegetative, generative and total aboveground biomass were collected in 6 m^2 surface per experimental plot.

Results

Soil water and applied irrigation water

For the three irrigation strategies, the SWP values remained within the fixed threshold values along their whole crop cycles (Fig. 1). The lowest SWP values, of –50 to –60 kPa, were measured in the P irrigation strategy when first fruits setting occurred (Fig. 1).

Total irrigation water applied throughout the crop cycle was similar for the three irrigation management strategies: 99 mm, 102 mm and 111 mm for the C, HF and P irrigation strategies, respectively.

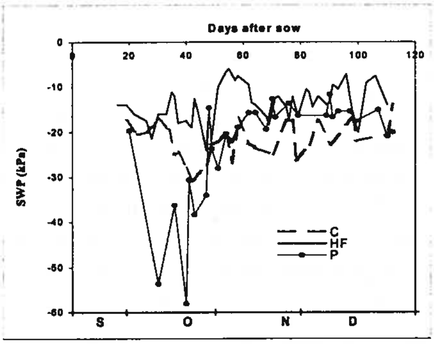

Figure 1. Seasonal evolution of soil water potential (SWP) at 0.12 m depth for a greenhouse green bean crop under three irrigation strategies.

Aboveground dry matter and productivity

No significant differences in total and marketable yields were found between irrigation treatments (Table 1). The fresh weight of marketable green bean fruits ranged from 2713 to 2834 g m^{-2}, values within the optimal range for the region. No significant differences in vegetative, generative and total aboveground biomass were found between irrigation strategies (Table 1), although the total and vegetative biomass of the HF irrigation strategy was slightly higher than those of the two others treatments, and the opposite occurred for the generative biomass (Table 1). Finally, the harvest index for the C and P irrigation strategies was significantly higher than that of the HF treatment (Table 1).

Table 1 – Total and marketable fresh weight of green bean fruits; vegetative, generative and total aboverground dry matter and harvest index of a greenhouse green bean crop. Almería. 2001/2002.

	Yield (g m^{-2})		Aboveground biomass (g m^{-2})			Harvest index (g g^{-1})
	Total	Marketable	Vegetative	Generative	Total	
Reference irrigation scheduling (C)	2714 a	2619 a	450 a	197 a	647 a	0.30 b
High frequency irrigation (HF)	2713 a	2601 a	400 a	208 a	608 a	0.34 a
Phenology-base irrigation (P)	2834 a	2710 a	416 a	209 a	525 a	0.33 a

Means values followed with the same letter are not significantly different ($P<0.05$)

Conclusions

The phenology-base irrigation strategy, used for local growers to induce more generative growth, produced similar fresh weight of green bean fruits than the reference irrigation strategy.

The high frequency irrigation produced similar fresh weight of green bean fruits than the reference irrigation strategy, but allocated relatively less dry matter to the fruits and more to leaves.

References

Fernández, M.D.; Orgaz, F.; Fereres, E.; López, J.C.; Céspedes, A.; Pérez, J.; Bonachela, S.; Gallardo, M. 2001. Programación del riego de cultivos hortícolas bajo invernadero en el sudeste español. Edita: Cajamar (Caja Rural de Almería y Málaga). 78 pp.

EFFECTS OF WATER DEFICITS ON THE PRODUCTIVITY OF PEPPER FOR PAPRIKA.

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Introduction

The production of pepper for paprika under irrigation is quite common in areas of the Mediterranean region, where water supplies for irrigation are dwindling. Irrigation is essential for pepper production as this crop is considered one of the most susceptible to water stress in horticulture (Doorenbos et al, 1986). Biomass production and commercial yield of pepper are affected by irrigation regime (Beese et al., 1982).

The most important feature in pepper for paprika production is the production of color, i.e., the dry weight of fruits with full color at harvest. Water stress is known to hasten maturity in many crops (Orgaz et al., 1992), thus an experiment was designed to evaluate the effects of deficit irrigation regimes on the production of pepper for paprika.

Materials and Methods

A field trial was carried out in a split-plot design with three replications of three different irrigation regimes. Pepper plants (cv. Sonora) were transplanted on 15 April 2001 at a density of 60.000 plants/ha in a farm located about 15 km away from Cordoba (Spain). In treatment 1 (T1), applied water was equivalent to the crop evapotranspiration (ET) until day 127 after transplanting. After that date, only 75% of ET was applied. Treatment 2 (T2) consisted in a 70% reduction of T1. Finally, Treatment 3 (T3) applied 100% ET throughout the season. The total amount of water applied was 426, 316 and 452 mm for T1, T2 and T3, respectively.

Midday stem water potential (Ψ_x) was used as a plant stress indicator. Ψ_x was measured weekly on six covered leaves located near the stem on different plants. Flowers, fruits and buds were tagged and fruit color was measured weekly using a visual scale. Biomass, yield and harvest index (HI) were determined for all treatments.

Results

Figure 1 depicts the seasonal evolution of Ψ_x for all treatments. Inserted in the graph, the correlation between biomass at harvest (kg/ha) and the integral of the Ψ_x, i.e., the area below the Ψ_x seasonal curves (MPa·day). The deficit irrigation induced lower Ψ_x values one week after applied water was reduced. The cutoff in T1 and T2 also was reflected in lower Ψ_x values (Figure2).

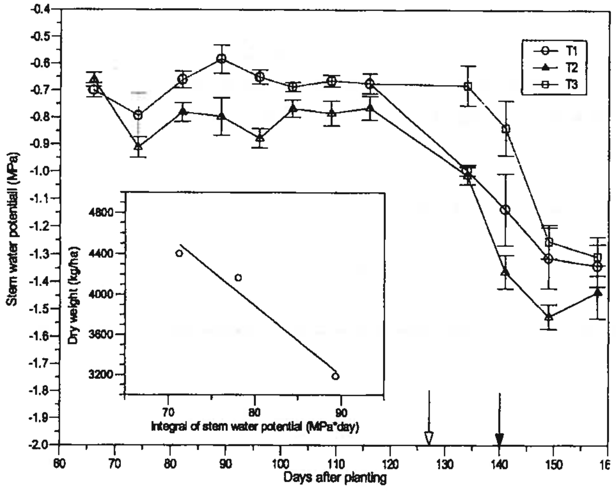

Figure 1: Evolution of the Ψ_x (MPa) for all treatments. The bars represent standard errors (n=6). White arrow shows irrigation cutoff on the day 127 for T1 and T2.Black arrow indicates the end of irrigation. Insert, relation between biomass (kg/ha) and the integral of Ψ_x (MPa·day).

Total fruit number and the number of fruits with full color at harvest were not affected by the irrigation regime (Table 1). Figure 2 shows the production of colored fruits for T1, T2 and T3. After day 120, water stress delayed fruit formation in T2. However, this treatment recovered at the end of the cycle. Colored fruit production in T3 was greater than in T1 after day 130, when applied water was reduced in T1.

Yield results are presented in Table 1 where fruit number and dry weight are presented along with commercial yields. Deficit irrigation reduced yield significantly in T2 by reducing individual fruit weight. Irrigation cutoff in T1 also affected yields (Table 1; Figure 2).

Table 1: Fruit number, weight and commercial yield of pepper under irrigation treatments. *N.S.*: Not significant. ♣: Significant at P<0.05.

Treatment	Fruits number	Fruit dry wt (g)	Nº of colored fruits at harvest	Commercial yield (t/ha)
T1	132,0	3,64	80,3	9,801
T2	121,3	2,76	79,3	6,986
T3	134,6	3,78	91,6	10,810
	N.S	♣	*N.S.*	♣

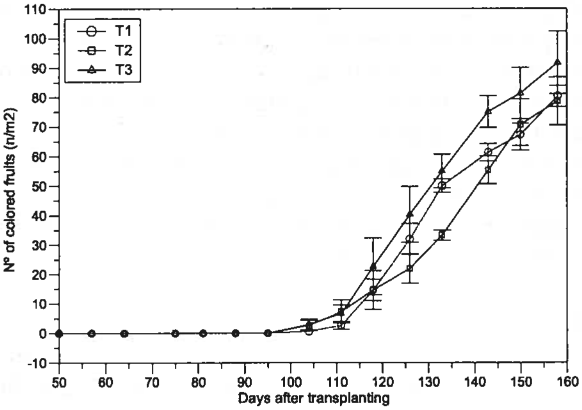

Figure 2: Cumulative production of colored fruits. The bars indicate the standard error (n=9).

Conclusions

Water deficit did not hasten fruit maturation in pepper for paprika production; on the contrary, a deficit irrigation treatment (T2) delayed fruit maturation in relation to a control and an extension of the irrigation in the last phase of the crop increased yields without delaying maturity date.

References

Beese F., R. Horton and P.J. Wierenga. 1982. Growth and yield response of chile pepper to trickle irrigation. Agronomy Journal, 74: 556-561.

Doorenbos J. and A.H. Kassam. 1986. Yield response to water. Food and Agricultural Irrigation Organization (FAO). Irr. Drainage Paper 33.

Orgaz, F., L. Mateos and E. Ferreres. 1992. Season length and cultivar determine the optimum evapotranspiration deficit in cotton. Agronomy Journal 84: 700-706.

WATER USE AND WATER USE EFFICIENCY OF MORPHOLOGICALLY AND PHYSIOLOGICALLY CONTRASTING MAIZE-PEA SOLE AND INTERCROPS.

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Introduction

Research to quantify the effects of mechanisms postulated as being responsible for positive changes in water use efficiency is needed (Morris *et al.*, 1993). Jena *et al.* (1988) suggested that differences in water use by sole and intercrops may be large when species contrast in root distribution as in pigeon pea and rice. The identification of appropriate crops and cultivars with optimal physiology, morphology, and phenology to match environmental conditions particularly water availability is, one of the most important research areas in cropping systems management of water use efficiency (Van Duivenbooden, *et al.*, 2000).

Methods

Two pea cultivars, Maro (M) and Princess (P) and two maize cultivars Nancis (N) and Sophy (S) were grown in all combinations of sole and intercrops at the Field Unit of the School of Plant Sciences, Reading (lat 51°25'N, 0°56W 40m a.s.l.) in 2000 (Kanton *et al.*, in press). Soil moisture content was determined using a Neutron Soil Moisture Probe Type I.H. III, (Didcot Instruments Company Limited, Abingdon, Oxon, England). The soil was a clay loam. Soil measurements were taken at 10 cm depth intervals from 10 cm to 100 cm, normally once per week. The means of 3 readings per depth were used to calculate the volumetric water content (VWC) using the standard equation calibrated for the soil (Alhabeeb, 1997). Soil water content (mm) was obtained by multiplying VWC by the depth of the layer. Soil water use was calculated from the difference in total soil moisture (0-90 cm) between readings and adding rainfall, starting at 20 days after sowing (DAS). There was no drainage from the soil profile. The total rainfall from 20 to 131 DAS was 234.2 mm.

Results

At the beginning of the season (37, 44 and 52 DAS), sole peas had higher cumulative water use compared to the intercrops and sole maize crops (Fig.1). The sole maize crops up to 78 DAS used little water compared to the other treatments except for Nancis-Princess (Fig.1). Nancis-Princess consistently used the least water throughout the season and was similar to the sole maize crops. In contrast Nancis-Maro used the highest amount of water at 59 to 131 DAS. At 52 DAS when peas were in full bloom and had just initiated pods the sole peas had used 14 % more water compared to the intercrops and 65 % more water compared to the sole maize crops. However after 92 DAS when peas had matured, the intercrops and sole maize treatments were using more or similar amounts of water. At the end of season intercrops and sole maize had used relatively similar amounts of water as presented in Table 1. The intercrops produced higher dry matter and therefore higher water use efficiencies (Table 1).

Fig. 1 Cumulative water use as affected by morphologically and physiologically contrasting maize/pea sole and intercrops.

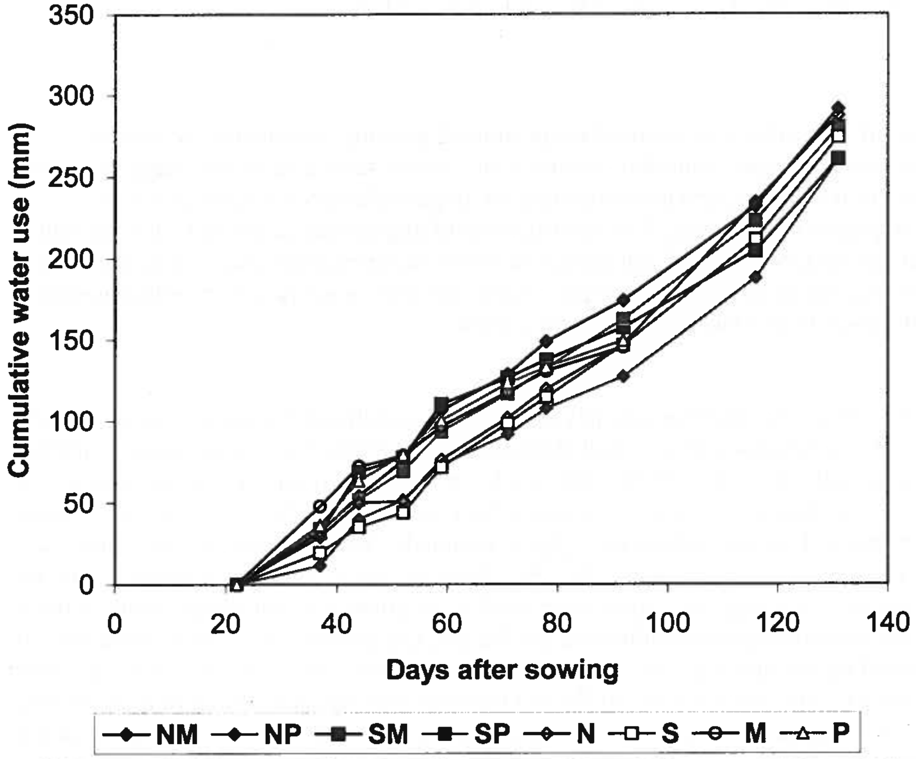

Table 1. Total water use (WU mm), dry matter (DM g m^{-2}) and water use efficiency (WUE g mm^{-1}) of morphologically contrasting maize-pea cultivars (2000)

	Intercrops				Sole crops			
	Nancis	Nancis	Sophy	Sophy				
	Maro	Princess	Maro	Princess	Nancis	Sophy	Maro	Princess
WU	291	260	260	280	287	274	124	128
DM	1519	1279	1406	1243	1332	1245	311	479
WUE	5.21	4.92	5.40	4.44	4.63	4.43	2.52	3.75

Conclusions

- The sole maize crops had lower water use from the beginning to mid-season compared to the intercrops and sole peas, peas tended to use more water than the intercrops.
- The intercrop had higher water use except Nancis-Princess which had consistently lower water use compared to the other treatments
- The intercrops had higher water use efficiencies than the sole crops.

References

Alhabeeb, A.S.I. 1998. Effects of irrigation and plant density on growth and yield of Faba bean (*Vicia Faba* L.). Ph.D. Thesis, Univ. Reading, Dep. Agric. Botany, pp 22-25.

Morris, R.A. and D.P. Garrity. 1993. *Field Crops Res.*, 34, 303-317.

Jena, D and C. Misra. 1988. *Expl. Agric.*, 24, 385-391.

Van Duivenbooden *et al.*, 2000. *Neth. J. Agric. Sci.*, 48, 213-236.

IDENTIFICATION OF POTENTIAL GRAIN GROWTH CHARACTERISTICS FOR BREEDING DURUM WHEAT FOR DRY MEDITERRANEAN ENVIRONMENTS

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Introduction

Durum wheat (*Triticum turgidum cv, durum Desf*) is one of the cereals that are specific to the Mediterranean basin and Morocco is considered as the first producer of this crop in North Africa. In this country, an average of around 1.2 million hectares of durum wheat, which represents 25 % of the total cereals area is grown annually. Nevertheless, most of the crop (83 % of the area reserved to durum wheat) is conducted under rainfed regime which is characterized by a low average rainfall and high fluctuations of the precipitation. Terminal drought is a phenomenon that occurs frequently in the region. Water stress after anthesis usually shortens the duration of grain filling period and hence reduces 1000-kernel weight. Nevertheless, this kernel weight reduction can be compensated for by the selection of genotypes that have the ability to fill the kernels quickly before stress and to have high grain filling rates. In fact, it was shown that kernel weight (Sofield et al., 1977) was more related to grain filling rate than to grain filling duration. Moreover, genotypic variation of both grain filling rate and duration were shown by many scientists in wheat (Darroch and Baker, 1990, Van Sanford, 1985).

The objectives of this study are the evaluation of the genotypic variation of Moroccan old and new cultivars of durum wheat for the grain growth rate, the compensation between kernel weight and seed number and the choice of parents that can be used in breeding programs for improving grain filling rate and grain yield under rainfed conditions in Morocco.

Methods

Fourteen Moroccan old and new cultivars of durum wheat (Keyperounda, Oued Zenati, Marzak, Oum Rabai, Belbechir, Anouar, Sarif, Massa, Isly, Sebou, Yasmine, Jawhar, Ourgh, Amjad). were chosen for this experiment. They were grown in Merchouch experiment station (33° 47'N) in a randomized complete block design with 4 replications. To expose the plants to different climatic conditions, the genotypes were sown twice a year (early November and early December) during 1997/98, 1998/99, 1999/2000 and 2000/2001. Taking into consideration the amounts of rainfall directly received by wheat, we can distinguish seven different environments which are Early-1998/99 (344.5 mm), Early 1997/98 (313 mm), Early-2000/2001 (241 mm), Late-2000/2001 (224 mm), Early-1999/2000 (158.7 mm) and Late-1999/2000 (121.9 mm). The seventh environment was Late-1998/99 that received the same amount of water as Early-1999/2000 but with different temperature regime. In fact, the late plantings were, in general, exposed to higher temperatures, during the grain filling, than the early ones.

The parameters measured are grain yield, 1000 seed weight, kernel numbers per square meter and grain filling rate. Anthesis and physiological maturity stages were recorded for each genotype.

Results

Correlation analysis showed that the number of kernels per spike and per square meter and the grain growth rate per square meter were closely associated with grain yield and the correlation coefficients were 0.71, 0.91 and 0.89, respectively. In fact, varieties that took advantage from soil moisture availability before anthesis (from early season rainfall and water conservation) produced more kernels and hence more grain yield. Yield stability analysis was performed on selected varieties differing in their dates of release. These genotypes are Keyperounda (1956), Oum Rabia (1988), Massa (1988), Jawhar (1993) and Amjad (1995). This analysis showed that there was more variation in yield under good environments than for bad environments. The old genotype Keyperounda gave similar yields than Massa and Jawhar and outyielded Oum Rabia in the environments where the average yield was less than 2000 kg ha^{-1}. Under these conditions, only Amjad gave better results than Keyperounda. When the environment became more favorable (average yield higher than 2000 kg ha^{-1}), all cultivars yielded better than the old variety. Varieties that are more adapted to wet conditions are Jawhar and then Amjad. This last cultivar tended to have the ability to be more stable since it maintained its yield high under both wet and dry environments.

The association between growth rate per kernel and other parameters was investigated. Grain growth rate was positively linked to kernel weight and negatively to grain growth duration meaning that the rate of grain growth was the major parameter controlling the kernel weight establishment. Growth rate per kernel was also negatively associated with kernel number per square meter. This means that there was some compensation between growth rate and kernel number. To improve kernel growth rate and then seed weight without affecting too much kernel number and hence grain yield, the best strategy is to take into consideration, in breeding, simultaneously the two kernel characteristics (kernel rate and number) and use the best combination to identify adapted genotypes. Consequently, to identify potential genotypes, their growth rates per kernel were compared to kernel numbers per square meter. This comparison was illustrated using two cluster groups for growth rate per kernel. The genotypes Ourgh and Anouar had high growth rates an kernel numbers in group 2 and Ourgh and Sebou had high growth rate and medium kernel number in group 1. Oued Zenati and Keyperound tended to have the highest values of growth rate per kernel and low kernel numbers per square meter. Jawhar and Sarif tended to have high kernel numbers but low grain growth rate in group 1. In group 2, Jawhar and Amjad had high kernel numbers but medium to low grain filling rates.

Conclusions

From this study, we can conclude that kernel weight and grain yield can be improved if both kernel number and grain growth rate are taken into consideration when breeding for dry environments of the Mediterranean basin. Moreover, crossing old genotypes of Moroccan durum wheat that have high kernel growth rates with the new ones, like Jawhar and Amjad, which have high kernel numbers could be a strategy to create better adapted materials to dry environments.

References

Darroch, B. A. and Baker, R. J., 1990. Grain filling in three spring wheat genotypes: Statistical analysis. Crop Sci. 30:525-529.

Sofield, I., Evans, L. T., Cook, M. G. and Wardlaw, I. F., 1977. Factors influencing the rate and duration of grain filling in wheat. Aust. J. Plant Physiol. 4:785-97.

Van Sanford, D. A., 1985. Variation in kernel growth characters among soft red winter wheats. Crop Sci. 25:626-30.

EVAPOTRANSPIRATION – YIELD RELATIONSHIP IN ROMANIAN PEDOCLIMATICAL CONDITIONS

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Introduction

Natural resources, especially climate, water and soil, play an essential part in the development of Romanian agriculture. Thus, from the thermic regime point of view, in the southern part of the country the accumulated average is 4,000°C and in the eastern Transylvania and northern Moldavia – up to 3400°C during the vegetation period.

Regarding the precipitation regime, Romania is characterized by 3 humidity zones: (i) the humid zone, with annual rainfalls of 600-1000 mm and annual potential evapotranspiration (ETP) of 550-700 mm; (ii) the sub-humid zone, with annual rainfalls of 450-700 mm and annual ETP of 650-750 mm; (iii) the semi-arid zone, with annual rainfalls of 350-550 mm and annual ETP of 700-800 mm, covering the fields from the South, South-East and South-West of the country.

The water resources corresponding to the internal hydrography network are modest – 37 billion m^3/year on average, Romania being situated on the 21st place in Europe considering the water quantity per inhabitant. These resources are showing a deficit during summer, especially in the field zones. The Danube is an important water resource, with an annual average flow of about 170 billion m^3 which, added to the interior water sources, ensures annually about 9,800 m^3/inhabitant.

The soil resources of Romanian agriculture consist in a great variety of soils, from the most fertile to the very poor ones in nutritive elements, falling on average into the middle productivity class. Presently, agricultural fields represent 62.07% of the total territory of Romania, respectively 0.65 ha/inhabitant. Arable lands represent 63.1% of the total agricultural surface, pastures 22.8%, hayfields 10.1%, vineyards and orchards 4%.

In order to ensure constant high agricultural productions, during the period 1970-1990 irrigation arrangements were built on 3.1 million ha, drainage works on 3.2 million ha, soil erosion control on 2.3 million ha and protection against floods for about 0.6 million ha. However, on about 12 million ha of agricultural fields, of which 7.5 million ha arable land (about 80% of the total arable surface), the production capacity of soils is affected by one or more restrictions, from which the frequent droughts, leading to fluctuations of crop production are noticed.

Methods

The researches concerning the determination of crop water consumption are made in the network of experimental fields, located in different pedoclimatical zones. The total area of such a polygon is about 1 ha and it is cultivated with the most important crops: wheat, maize, soy beans, beans, alfalfa, sun-flower, sugar beet, potatoes, in four irrigated variants and one non-irrigated control. Water delivery is ensured by an underground network of pipes and measured by means of calibrated metallic basins. In the frame of protection zone, sown with alfalfa, is a meteorological station endowed with all necessary equipment to record the main climatic elements. The result of these researches mainly refer to the determination of crops water requirements, including their covering sources and the relationship between evapotranspiration and yields at various water supply levels (Grumeza et al, 1992).

Results

The research data resulted on an average period of 15 years show the favorable effect of irrigation on the drought control, especially in South and South - East of the country. The total water consumption varies between 3000 – 4000 m³ ha⁻¹ for wheat, 5000 - 7000 m³ ha⁻¹ for corn and 6500 – 8000 m³ ha⁻¹ for alfalfa. This water consumption in the semi-arid zone is satisfied only 40 – 50 % by rainfalls and in the same percentage by irrigation, the difference coming from the soil water reserve. The crop yields in irrigation conditions varied between 3 – 5 t ha⁻¹ for wheat, 10 – 14 t ha⁻¹ for corn and 70 – 80 t ha⁻¹ for alfalfa. In natural conditions, crop yields are lower, depending very much to on variation of climatic factors. Evapotranspiration and yield experimental data were statistically processed, resulting significant and very significant correlation coefficients, standing out the importance of the water factor in yield increase. As an example, in figure 1 the statistical processing results for two crops in Mihail Kogalniceanu experimental plot, located in the South - East of the country are presented (Kleps et al, 1994, 1996, 1998).

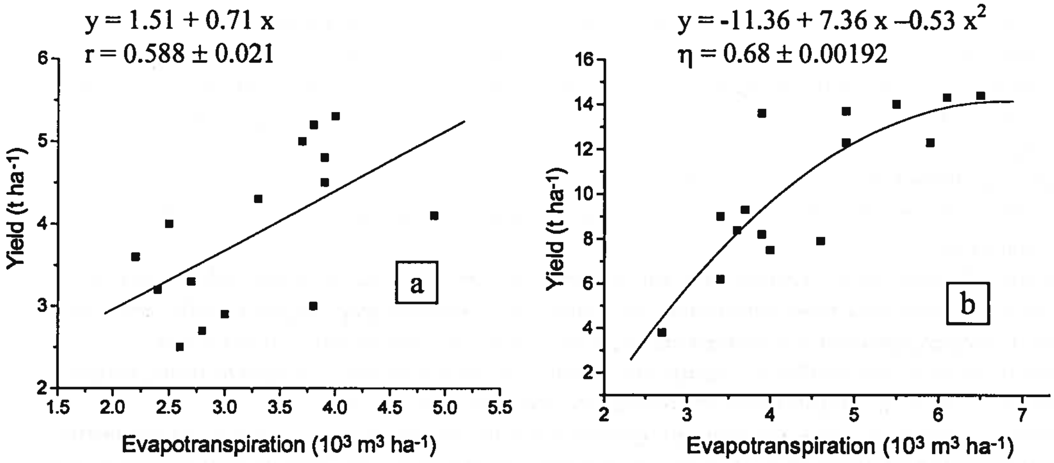

Fig. 1. The total water consumption – yield correlation for wheat (a) and corn (b) in the Northern Dobrogea pedoclimatical conditions.

Conclusions

Romanian agriculture is partially dependent on irrigation, because more than half of agricultural land needs to be irrigated. The researches have shown that the differences of the obtained production between the irrigated and non-irrigated surfaces are substantial for majority of crops, irrigation usually doubling the yields.

References

Grumeza, N. et al, 1992. Proceeding of the 16th ICID Conference. Budapest: 151-159.
Kleps, C., et al., 1994. Proceeding of the 3rd ESA Congress. Abano-Padova: 378-379.
Kleps, C., 1996. Proceeding of the 4th ESA Congress. Veldhoven: 98-99.
Kleps, C. et al, 1998. Proceeding of the 1st Environment-Water Conference. Lisbon: 148-155.

INTERFERENCE EFFECTS WITHIN LEGUME-GRASS ASSOCIATION IN THE FIELD UNDER DROUGHT

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Introduction

Forage legume-grass mixtures are important components of animal production systems (Lazaridou 2001) because of their many benefits. The value of mixed practices of alfalfa-grass associations is still under consideration, not only from the agronomic point of view, but also from the stand of the nature of the interference effects produced within the associations themselves (Zannone *et al.* 1986).

The objectives of this study were to investigate the response of the binary mixtures of alfalfa, and tall fescue plants and to screen domination vs. vigor as it reflects the association effects. The plastic responses, as they express the nature of the interference effects, were also measured. The responses of the component species to drought conditions were also taken in account.

Material and methods

The experiment was conducted at the farm of the Tobacco Institute of Drama (41°09□ N lat, 24°09□ E long, 130 m alt), Northern Greece. The mean annual temperature in the area is 15.2°C and the mean total annual precipitation is 589.4 mm. The soil was shallow and infertile. The species *Medicago sativa* v. *Yliki*, produced by the Forage Institute of Larisa, Greece and *Festuca arundinacea* cv *festorina*, introduced from U.S.A., were used.

Pure and mixed (1:1) field plots (1m x 1m) were established in autumn 1995 at a sowing density of 4.5 g/m^2. The completely randomized design with four replications was used. No fertilizers were applied. All stands were irrigated until the plants established well. After the first cutting in spring of 1996, no water was applied on the half of the plots (treatment: H_0). The rest were well irrigated by sprinkler to maintain field capacity (treatment: H_1). The plants were cut at 7 cm from the soil surface, four times during the growing period. The sampled plants were oven dried at 75°C for 48 h and the above ground biomass (g/m^2) was determined.

The nature of interference effects was expressed by the «plastic responses» (Zannone *et al.* 1986), and was calculated by the formula:

$$PR=[n(Y_{ij}/Y_{ii})]-1 \quad (1)$$

where n is a multiplication factor relating the population in mixture to the same unit area of monoculture and in our case it equals 2 (Zannone *et al.* 1986).

The relative domination (RD) was calculated by the formula:

$$RD= Y_{ij}/Y_{ji} \ (2)$$

and the vigor ratio (VR) by the formula:

$VR= Y_{ii}/Y_{jj}$ (3), as suggested by Zannone *et al.* (1983).

Results

The seasonal plastic responses patterns are illustrated in Fig. 1. Positive values for both species, obtained by formula 2, indicate cooperation, while negative values opposition. Values close to 0, indicate neutralist interference effects. When species i responds to positive values while j to negative ones, there is a strong evidence that species i competes with species j for water which is the specific depleted resource (Zannone *et al.* 1986). Thus, in H_1 treatment (Fig. 1) the seasonal plastic responses patterns illustrate the existence of a scaled and strongly asymmetric competition that the tall fescue plants appear to have on alfalfa plants, at least at the first three cuts. Conversely, in H_0 treatment (Fig. 1), the cut by cut sequence resulted in neutralism.

The proportional relationship that exists between the relative domination and the vigor ratio was also examined in order to illustrate the association effects that the mixed stand appears to have over the pure one (Zannone *et al.* 1983). The relationships between associating (or dominating) ability and pure stand performance (formula 2 and 3) provide indications on the possibility of predicting the associating performance of plants (Zannone *et al.* 1986). This relationship seems to exist between the relative domination in the associations and the ratios of population vigor in the pure stands, where the associations effects are presented (Fig. 2) considering alfalfa as the reference species. In H_1 treatment negative association effects exist between the two species, as the corresponding line is located under the isocline (competition), while in Ho the association effects led to neutralism as the line is located above.

Figure 1. Plastic responses of alfalfa and tall fescue in irrigated (H1) and rainfed (Ho) treatments

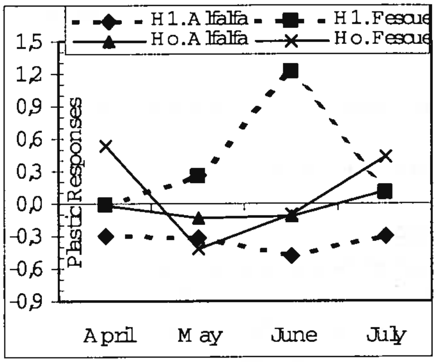
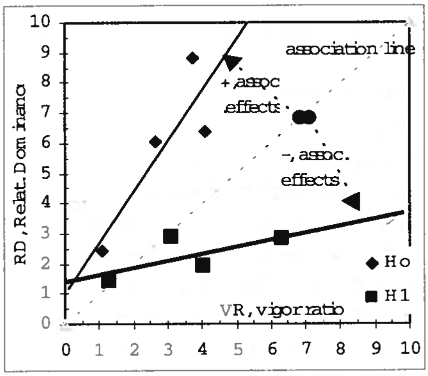


Figure 2. Association effects on alfalfa plants, obtained in irrigated (H1) and rainfed (Ho) treatments



Discussion

These results show the effects of water depletion upon the competitive behavior of the constitute plants of the mixture. When these responses are measured at the stage of fruit formation (fourth cutting) the results suggest neutralism, probably due to the contribution that alfalfa fruits have, in yield terms. Conversely, in H_0 treatment (Fig. 1), the cut by cut sequence resulted in neutralism. Thus, when water is in excess the tall fescue strongly competes with alfalfa, while when water is limiting, this competitive effect turns to neutralism. The differentiation of watering regime, from H_1 to H_0, resulted in higher RD values, while the VR values are kept rather constant. So the association performance in H_0 treatment was more sensitive to the water effect than the pure one, but the simultaneous overcompensation effect of the pure stand (lower RD values than VR) led the association to neutralism. In the excess of the water (H_1) there is no such overcompensation effect and further competition established (Fig.2). The results suggest that the competitive ability of the mixture components changes according to season and in water depleted situations, this plasticity is expressed as neutralism and when water is in excess, as competition.

References

Lazaridou, M., 2001. Effect of cutting intensity on productivity and on water relations of the leaf tissue of rangeland herbage forage species. Ph.D. Thesis, Aristotle Univ. of Thessaloniki, Dep. of Range Science, Thessaloniki, Greece, p. 1-15.

Zannone, L. et al., 1983. An experimental study of intraspecific competition within several forage crops. *Agronomie* 3(5):451-459.

Zannone, L., et al., 1986. Experimental studies of grass-legume associations. *Agronomie* 6(10):931-940.

DROUGHT EFFECTS ON SEASONAL CHANGES OF WATER-USE OF ALFALFA

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Introduction

Nowadays problems regarding water supply, irrigation, water use efficiency have become increasingly important, because in large areas water is scare and/or of a poor quality. Thus, the efficient water use by the crops plays a predominant role particularly in the areas where the water is a limited factor of production. In addition, the WUE could be used as selection criterion, to improve yield in a dry environment (Tardieu 1997).
The objective of the present study is to determine effects of drought on WUE.

Material and Methods

The experiment was performed in Drama (41°09□ N lat, 24°09□ E long, 130 m alt), in northern Greece, where the climate is semi-arid, with mean annual temperature 15,2^{0}C, and mean total precipitation 589,4mm. The dry period is from middle of June to September.
The soil is medium textured with pH 7.5. The studied species was *Medicago sativa* var. Yliki. The applied treatments were two water regimes: irrigated up to field capacity (H) and rainfed (Ho). The measured parameters were: above ground dry biomass, leaf surface (Area measurement system, Delta-T-Devices) and transpiration rate (Li-1600, LiCor, Nebraska U.S.A.). The experimental design was completely randomized, with field plot size of 1 x 1m, and four replicates. The measurements were performed from April to July of 1996 and 1997. The cutting was performed at 20-day intervals, at 3 cm above the ground.
The yield of a forage crop (CGR), as alfalfa, is the above ground biomass accumulated (W) per surface area (E) during a time interval (Δt). It is estimated using the equation,

$$CGR = \frac{W}{E}\,\frac{1}{\Delta t} \qquad (\mathrm{g\ m^{-2}\ day^{-1}})$$

Plant modulates the water transpired by reducing transpiration rate, plant size and leaf area. The latter two affect leaf area index. It is noticeable that for crops with closed canopies and abundant litter, as alfalfa, the soil evaporation could be ignored and water use is equal to transpiration by the canopy. As a consequence, the transpiration water losses were estimated as Canopy Transpiration (CT) (Lazaridou 2001), using the equation,

$$\mathrm{CT} = \text{transpiration rate x leaf area index}\ (\mathrm{mmol\ m^{-2}\ s^{-1}}).$$

Water Use Efficiency (WUE) was estimated as CGR/CT (g day^{-1}/ mmol s^{-1}).

Results

Seasonal changes of Canopy Transpiration are illustrated in Figure 1. As is shown in Fig. 1, when plants were irrigated canopy transpiration remained constant during the dry period. On the contrary, CT declined when plants were rainfed. The irrigation effect was obvious from May to July. Similar was the irrigation effect on CGR as presented in Figure 2. The Crop Growth Rate in the rainfed treatment decreased after May, while under irrigation it remained constant during the season. The effect of drought on yield in comparison with water used is analyzed with the WUE (Fig. 3), which seemed higher in the rainfed treatment, with significant differences from May to July.

Discussion

Seasonal changes of canopy transpiration (Fig. 1) could be affected by the season's climatic conditions. The lack of differences between irrigated and rainfed treatments, during early spring, are due to sufficient soil water. During the summer soil water is in depletion, and when irrigation is not applied the stomatal conductance and leaf area index declined (Lazaridou 2001), resulting in decreased CT. Furthermore, the above decreases result in reducing the CO_2 uptake and photosynthesis. Consequently, during the summer the growth rate decreases in the rainfed treatment (Fig.2).

The seasonal changes of WUE are of great importance, because this is related to better use of the available water for biomass production. During early spring, high productivity per transpired water unit by the canopy (Fig.3), is attributed to allocation of photosynthetic products from the roots to shoot (Carter and Sheafer 1983). On the contrary, during the summer, low productivity per unit of transpired water by the canopy is attributed to allocation of photosynthetic products to the storage organs.

Figure 1. Seasonal changes of Canopy Transpiration. H under irrigation, Ho rainfed

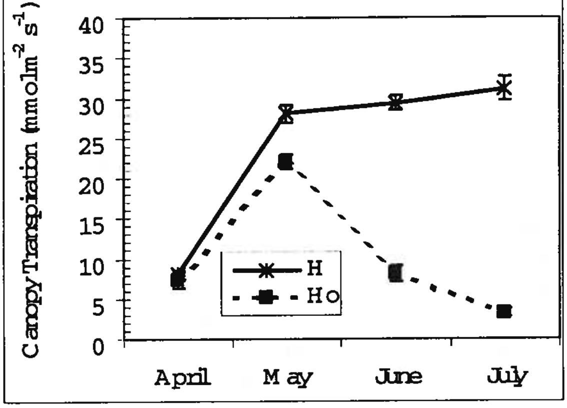


Figure 2. Seasonal changes of Crop Growth Rate. H under irrigation, Ho rainfed

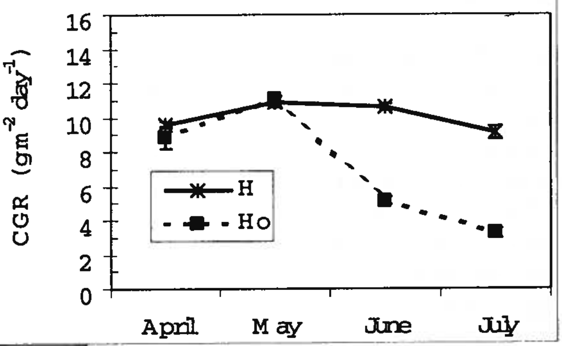
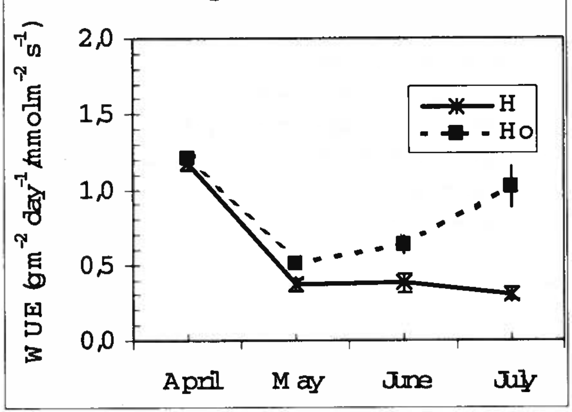


Figure 3. Seasonal changes of Water Use Efficiency. H under irrigation Ho rainfed



The high values of WUE in rainfed culture were due to greater decrease of the total canopy transpiration losses than the reduction of the above ground production. The preservation of a higher WUE, in the rainfed treatment, is considered to be an adaptive mechanism to drought.

References

Carter, P.R.,and C. C. Sheaffer, 1983. *Crop Sci.* 23:669-675.

Lazaridou M., 2001. Effect of cutting intensity on productivity and on water relations of the leaf tissue of herbage forage species. Ph.D. Thesis, Aristotle Univ. of Thessaloniki, Dep. of Range Science, Thessaloniki, Greece, p.26-51.

Tardieu, F., 1997. In: Belhassen E. (ed). *Kluwer Academic Publishers.*

COTTON AND SUNFLOWER IRRIGATION PERFORMANCE WITHIN THE GENIL – CABRA IRRIGATION SCHEME, SPAIN

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Introduction

Performance indicators are needed to characterize irrigation system performance. Traditionally, these indicators are determined using average values for the whole irrigation scheme (Kloezen and Garcés-Restrepo, 1998) or for specific crops. However, such performance indicators do not capture the degree of variation in irrigation management among individual farmers and thus, do not give an accurate assessment of the quality of irrigation practiced in the area. We have used individual farm information to characterize irrigation performance for cotton and sunflower in an irrigation scheme in Southern Spain.

Methods

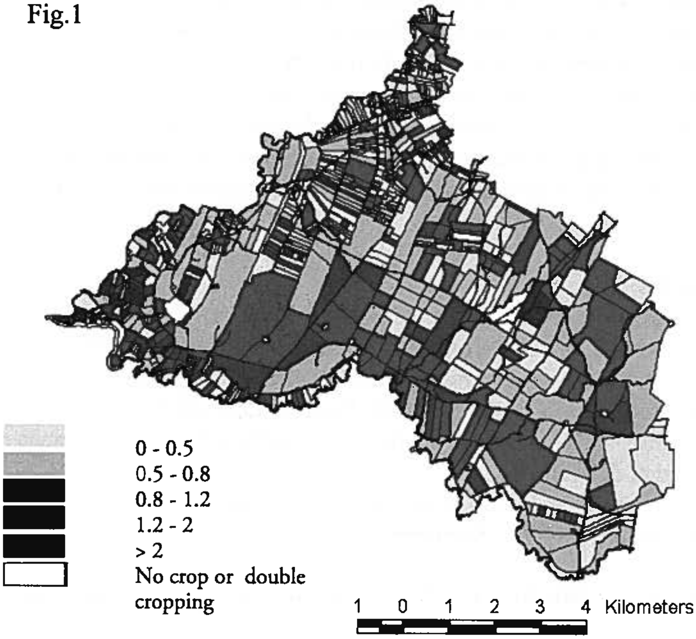
The study area is located in the Genil – Cabra irrigation scheme, in the Cordoba province (Spain). It covers 6989 ha divided in 844 plots. The study presented here is for the irrigation season 1999/2000. Seasonal rainfall was 499 mm and the reference evapotranspiration 1276 mm.

We investigated the management of irrigation in sunflower, a spring crop, and in cotton, a summer crop with higher ET demand. In 1999/2000, cotton was planted in 907 ha and sunflower in 1342 ha, representing 13.0% and 19.3% of the whole planted area respectively. The prevailing irrigation method was hand-move sprinkler.

A water-balance model was developed to calculate the soil water balance components for each plot on a daily time step. The model generates optimum irrigation schedules that avoid crop water stress and deep percolation losses. The model calculates ET using the dual crop coefficient (Allen et al., 1998), surface runoff affected by slope and soil water content, plant water uptake by soil layer and drainage losses due to irrigation ununiformity. A description of the model is presented Lorite (2002).

We used the Annual Relative Irrigation Supply (*ARIS*) as a performance indicators. The *ARIS* was computed as the ratio of applied irrigation to the optimal requirement as computed by the model (Malano and Burton, 2000).

Fig.1



Results

There was substantial spatial variation in the *ARIS* within the irrigation area (Fig. 1), mainly due to the crop. The average *ARIS* for the whole area in 1999/2000 was 0.66 indicating that irrigation was insufficient to meet the demand.

The average seasonal irrigation applied depths for cotton and sunflower were 585 mm and 82 mm, respectively.

For cotton, the average *ARIS* was 0.89, with a coefficient of variation (CV) of 0.37, while for sunflower it was 0.22 with a CV of 1.32.

The frequency distribution of *ARIS* was clearly different for the two crops (Fig 2.). For sunflower, a high proportion (almost 50%) of plots were rainfed and hardly any plot received its maximum requirements (Fig. 2).

In cotton, about half of the plots (53%) had *ARIS* between 0.8 and 1.2, which may be considered at near optimal irrigation. Thirty percent of the fields were underirrigated and only about 16% were irrigated in excess (Fig. 2).

Discussion

The average *ARIS* for cotton (0.89) for the area suggests that irrigation management for this crop is nearly adequate; however, about half of the farmers either underirrigate or overirrigate, too high a proportion to accept current performance as adequate. Similarly, the high CV in sunflower indicates substantial variation in irrigation performance among farmers.

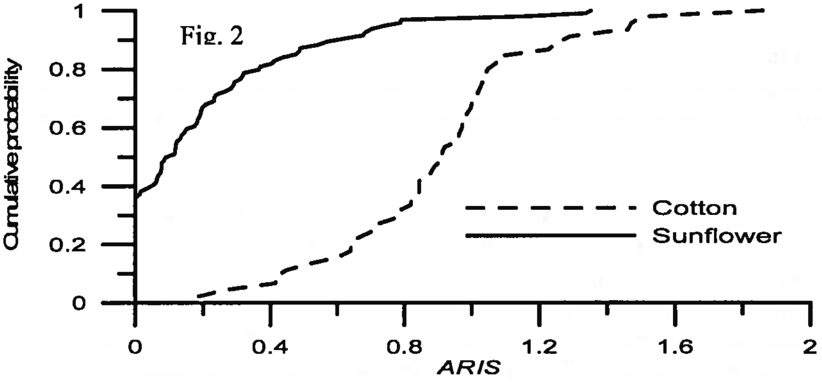


Fig. 2

Comparing with other irrigation areas located in Spain, the average *ARIS* values for sunflower in our study were slightly less than those in “La Loma de Quinto de Ebro” , Zaragoza, (Dechmi et al., 1999) but were much lower than those in “Almudevar “ , Huesca, (Faci et al., 2000). The main difference between the two areas in Aragon was the irrigation method: in the first the most common method was sprinkler, while in the second was surface.

Much of the variation between the two crops may be attributed to differences in subsidy policies. While sunflower is subsidized on the basis of planted area, subsidies for cotton are based on productivity.

References

Allen et al., 1998. Irrigation and Drainage Paper 56. FAO.
Dechmi et al., 1999. XV Congreso Nacional de Riegos. AERYD. 227-234
Faci et al., 2000. Agricultural Water Management 42, 312-334
Kloezen and Garcés-Restrepo, 1998. Research Report 22. IWMI.
Lorite, 2002. Modelo para el análisis de la gestión del agua en zonas regables. Tesis Doctoral. Universidad de Córdoba.
Malano and Burton, 2000 Guidelines for benchmarking performance in the irrigation and drainage sector. IPTRID Secretariat. FAO

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THE INFLUENCE OF HETEROGENEITY IN FRUIT DISTRIBUTION ON WATER RELATIONS OF PEACH TREES.

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Introduction

Water lost from one branch is commonly thought to impact little the water potential of other branches of the tree (Sprugel et al 1991). Evidences for this are based on the hydraulic isolation of branches produced by vascular constrictions. Currently, branches are concieved as small independent units rooted in the main bole (Tyree, 1988). During certain periods of the year, fruit sinks in a peach tree can increase photosyntheisis, leaf conductance and thus decrease leaf water status (DeJong, 1986; Mimoun et al., 1996; Marsal and Girona, 1997). Joining the above mechanisms, an extreeme change in fruit load between two main branches of a tree, should produce a variation in leaf conductance between these branches and a concomitant change in branch water potential. The latter, in the end will depend on the degree of isolation among branches. This study was undertaken to evaluate the previous hypothesis.

Methods

Twenty-four trees from eleven rows of 10-year old 'Elegant Lady' peach (*Prunus persica* L.) trees, on 'Lovell' rootstock, were selected for uniformity, in a block at the UC Davis Wolfskill Experimental Orchard, Winters, California. The orchard was planted in a high density formation (5.5 x 2 m spacing) and trained to a Kearney perpendicular-V with two main scaffolds per tree. The trees were irrigated twice weekly by microjet sprinklers, receiving 100% replacement of reference evapotranspiration (ETo, data obtained from the California Irrigation Management System for Winters). Rainfall was absent during the experimental period.

The thinning treatments were applied just prior to the start of Stage III of fruit development (phase of the final exponential growth) on May 15. Three main bearing pattern treatments were established according to differences in fruit distribution in the tree: 1) fruits distributed evenly with maximum crop, not thinned (EVEN-Max), 2) fruits distributed evenly with minimum crop (<50 fruit tree^{-1}) (EVEN-min) and 3) fruits distributed unevenly by totally defruiting one of the two available main branches (scaffolds) per tree (uneven distribution with defruited scaffold, UNEVEN-DS), and leaving the other one unthinned (uneven distribution with fruited scaffold, UNEVEN-FS). Because scaffolds were used as the reference unit for comparisons, the number of trees in the UNEVEN treatment was doubled (12 trees) compared to EVEN treatments (6 trees).

Stem water potential (Ψ_{stem}) (McCutchan and Shackel, 1992) was measured with a pressure chamber (Soil Moisture Equipment Co., Santa Barbara, CA). Measurements were made at solar noon on shaded leaves located in the lowest portion of each scaffold. Leaves were bagged for at least one hour before measurement. The leaf bags were plastic sheaths covered with aluminum foil. Midday leaf conductance (g_l) was measured under light-saturated conditions, using a portable steady state porometer (Model LI-1600, LI-COR Inc. Lincoln, Nebraska, U.S.A.). Ψ_{stem} and g_l were measured on one and two leaves per scaffold, respectively, in all trees. These measurements were taken on three different days during stage III of fruit growth: just after fruit thinning (May 19), mid-Stage III (June 6) and a week before fruit harvest (June 24).

Results

Trees unthinned (EVEN-Max) had an average of 640 fruits·tree^{-1} and UNEVEN trees had about half of the previous load (360 fruits·tree^{-1}). Fruit load at scaffold level affected g_l, with defruited scaffolds in UNEVEN trees having consistently lower values (about 25 mmol m^{-2} s^{-1}) than fruited scaffolds (Fig 1A). However, Ψ_{stem} did not varied in accordance with these changes in g_l (Fig 1B). On the other hand, fruit load on tree basis seemed to have stronger influence on g_l than on scaffold basis (Fig 1A). In this case, differences in g_l between thinning levels were consistent with changes occurred in Ψ_{stem}; the highest g_l were corresponded with the most negative Ψ_{stem} (Fig 1A and B).

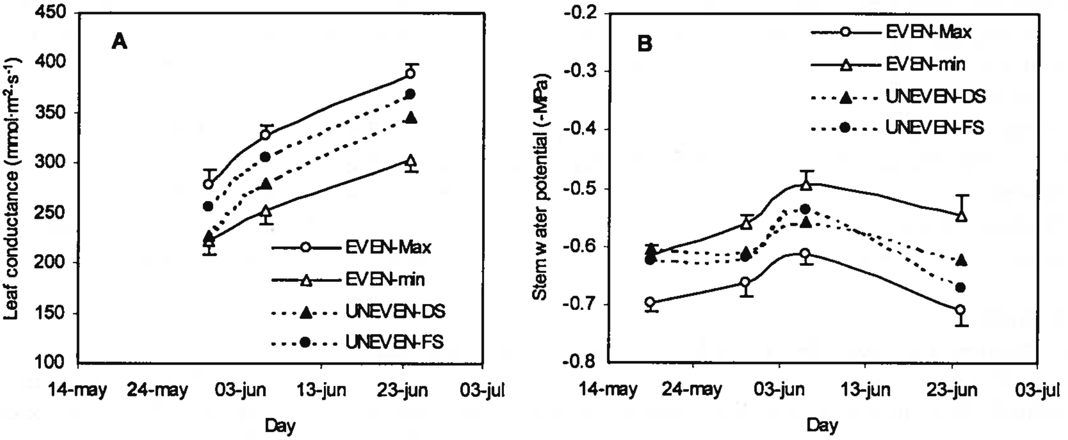

Fig 1. Daily pattern in leaf conductance (A) and stem water potential (B) measured on scaffold basis as a response to the thinning treatments (n=12; error bars indicate standard error).

Conclusions

In peach trees, changes in leaf conductance from scaffolds with extreeme fruit load conditions, did not produce a similar change in stem water potential. This may indicate little isolation between the main stems in a peach tree, or a possible increase in hydraulic conductance for large branches with a heavy crop load when compared to defruited branches.

References

DeJong, T.M. 1986. Effects of reproductive and vegetative sink activity on leaf conductance and water potential in Prunus persica (L) Batsch. Scientia Hort. 29:131-137.

Marsal, J. and J. Girona. 1997. Relationship between leaf water potential and gas exchange activity at different phenological stages and fruit loads in peach trees. J. Amer. Soc. Hort. Sci. 122:415-421.

McCutchan, H. and K.A. Shackel. 1992. Stem water potential as a sensitive indicator of water stress in prune trees (*Prunus domestica* L. cv French). J. Amer. Soc. Hort. Sci. 117:607-611.

Mimoun, M Ben, Longuenesse, J. and M. Genard. 1996. Pmax as related to leaf:fruit ratio and fruit assimilate demand in peach. J. Hort. Sci 71:767-775.

Sprugel, D.G., Hinckley, T.M. and W. Schaap. 1991. The theory and practice of branch autonomy. Annu. Rev. Ecol. Syst. 22:309-334.

Tyree, M.T: 1988. A dynamic model for water flow in a single tree: evidence that models must account for hydraulic architecture. Tree Physiol. 4:195-217.

DOUBLE HARVEST: AN AGRONOMIC STRATEGY TO INCREASE THE WATER USE EFFICIENCY OF BIOMASS CROPS IN MEDITERRANEAN EUROPE

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Introduction

In sustainable agriculture, irrigation aims to increase the water use efficiency (WUE). Since WUE represents the ratio between harvested dry matter of crops and consumptive water use, in the case of graminaceous plants (sugar and fibre sorghums, Sudan-grass, *Arundo* spp., and *Miscanthus*) grown in southern Europe, this ratio can be increased if a double harvest is carried out, with equal quantities of supplied water.

Methods

This hypothesis was verified in an experiment conducted in the field in Rutigliano (Bari) over the course of the year 2001, with fibre sorghum (hybrid H 128). Two sowing periods were compared: Spring (May 17), with irrigation carried out every time the soil profile reached wilting point; and Summer (July 9), in which, after having regularly guaranteed water during the phenological stages of "emergence" and "jointing", irrigation water was supplied only at the beginning of flowering, which is considered a critical stage. An experimental split-plot design was adopted and repeated three times with elementary plots of 30 m^2.

Results

On the basis of the "normal" meteorological pattern, rainfall should have favoured the second part of the cultivation cycle, but in 2001 the sorghum sown in the spring benefited from rains only in the first part of the cultivation cycle and the summer sowing received a single significant rainfall near harvest. The temperatures were higher than the yearly average.

The plants which derived from the summer sowing were of greater height and diameter than those of the first period (table 1). The greater size of the plants did not, however, determine positive variations in the yield of green biomass, which was statistically greater in the "spring" sowing time due to the greater specific weight of the plants.

An analogous situation was found in the production of fresh stalks, the percentage of dry matter was about 24% for the stalks of both sowing times. The final yield in dry stalks varied from the 7.58 t ha^{-1} of the crop sown in the spring, to the 6.73 t of the summer cycle.

After the harvest of the spring sorghum on August 6, the plots were irrigated and 50 kg ha^{-1} of N were distributed to favour sprouts regrowth. This was left to vegetate until the middle of October, when, in correspondence with the complete emission of the panicles, the field was harvested.

This second crop had no further input, besides the modest precipitation that fell in early autumn. The plants harvested in the second harvest showed a yield lower than those of the main harvest. However, this was a production obtained with extremely reduced costs that, when added to that of the first harvest, allowed for the gathering of 12.3 t ha^{-1} of dry stalks (in all, 84% more than the yield of the sorghum sown in the summer).

A double harvest is not an unusual event for a test environment, one had already been tried in 1999 with sorghum hybrids with a different industrial purpose, but in a season more with more favourable. Climate. The "H 128" hybrid had produced 116% more than that cultivated in 2001, and this percentage remains practically constant if we also consider the yield obtained by the regrown sprouts.

In the sorghum sown in spring, the daily water consumption was greater, so much so as to reach peaks of 7-8 mm d^{-1} during the phase of fastest vegetative growth and the emission of the panicles. Subsequently, they tend to reduce to as little as 4 mm d^{-1} in correspondence with the waxy maturation of the grain, the time for which the harvest was planned. In 2001, the seasonal consumption of this crop was 471 mm. With the summer sowing, instead, lower levels of evapotranspiration were recorded, because the crop was subjected to fewer irrigation events (as foreseen by the experimental protocol), and almost nothing was recorded for precipitation: the maximum ET was 5-6 mm d^{-1} and the seasonal consumption was 317 mm.

year	sowing time	I harvest		II harvest		biomass (t ha^{-1})		
		date	height (cm)	date	height (cm)	I harvest	II harvest	Total
2001	Spring	Aug 6th	248	Oct 15th	215	42.6	28.2	70.8
2001	Summer	Oct 2nd	264	-	-	35.0	-	35.0
1999	Spring	Aug 11th	349	Oct 23rd	244	92.2	60.2	152.4

Table 1 – Fibre sorghum plant height and biomass yield.

year	sowing time	consumptive water use (mm)			WUE (g l^{-1})		
		I harvest	II harvest	Total	I harvest	II harvest	Total
2001	Spring	471	127	598	1.61	3.74	2.06
2001	Summer	317	-	317	2.12	-	2.12
1999	Spring	512	243	755	5.23	7.47	5.95

Table 2 – Fibre sorghum consumptive use and WUE.

The values that determined the second cycle of the crop sown in the spring were even lower. The maximum daily consumption was about 2 mm and the seasonal total was only 127 mm. The WUE values are also shown in Table 2, calculated as the ratio between the dry matter produced by the sorghum stalks and consumptive water use. WUE in 2001 is low in the two main productions, due to the modest yields. The second harvest of sorghum sown in spring is more interesting; it rises to 3.74 g l^{-1}, similar to the WUE obtained with the summer sowing. In 1999 the consumptive water uses were greater, but the WUE increased as well: 5.23 and 7.47 g l^{-1}, respectively for the first and the second harvest.

Conclusions

The WUE values of the sorghum sown in the spring are shown to be extremely dependent on the seasonal meteorological conditions. The second harvest showed higher WUE values both years. If, finally, the global values of production and consumption obtained in the two consecutive harvests are taken into consideration, efficiency increases noticeably.

Considering that in the same test environment in past years WUE values of 2.8 for soybean and hemp, 3.7 for grain sorghum and 5.2 g l^{-1} for sweet sorghum have been obtained, in the case of fibre sorghum a double harvest should be aimed for annually so as to obtain greater efficiency values that are comparable to those of other competitive crops.

Acknowledgement: the research was partially founded by CNR (project n° C0000FF "Ricerche sul risparmio idrico nella coltivazione del sorgo per una produzione di energia rinnovabile", co-ordinated by Prof. S. Foti).

PEPPER (*CAPSICUM ANNUUM* L.) CROP RESPONSE TO DIFFERENT IRRIGATION AMOUNTS. I. ANALYSIS OF PLANT INTERNAL WATER STATUS.

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Introduction

It is evident that crop growth and productivity are closely related to the internal water status of the plants. Water shortage in leaves results in a decrease in their water potential, a change in turgor pressure and perhaps an increase in stomatal resistance, thereby reducing water vapour losses. This state of stress leads to underdevelopment of plant organs and has indirect effects on different physiological processes and on plant growth (Horton et al., 1982; Hsiao, 2000).
The aim of this study was to analyze the internal water status response of pepper crop cv. Infantes to different irrigation doses, by measurements of leaf water potential (ψh) and leaf stomatal resistance (Rs) throughout the day.

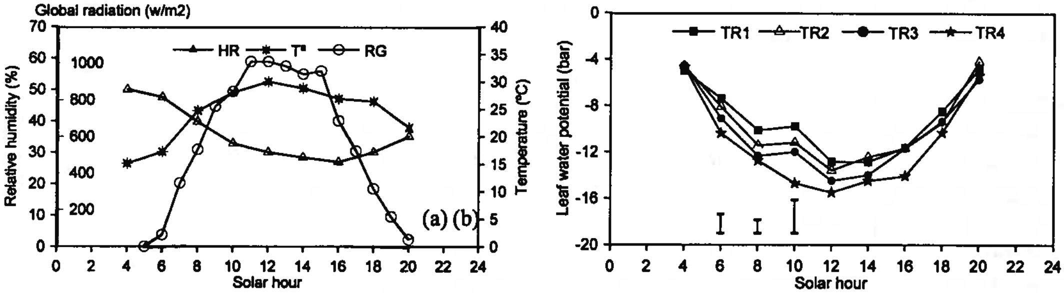
Materials and methods

The trial was carried out in 1999 in Ciudad Real, Spain (3°56' W, 39°0' N, altitude 640 m).
A randomized complete block design was adopted with four irrigation treatments and four replications. Each basic plot had an area of 180 m^2 (15 x 12 m) and 480 plants.
Planting took place on 14 May, using nursery seedlings with 4-6 mature leaves, under black polyethylene mulch. A drip irrigation system, which consisted of one drip line for crop row and emitters of 3 l/h separated by 0.35 m, was employed. Irrigation treatments were applied daily from 28 May to 23 September. Prior to 28 May, all plots received the same amount of water, 20 mm, to favor crop establishment. The weekly irrigation requeriments were made to meet the crop evapotranspiration (ETc), measured with a lysimeter placed on the trial plot, due to the null rainfall during the irrigation period. Irrigations levels were 1.25 ETc (TR1), 1.00 ETc (TR2), 0.75 ETc (TR3) and 0.50 ETc (TR4). The irrigation amounts to be applied to each treatment were calculated considering a 0.81 system efficiency.
ψh and Rs were measured on 27 July (during the strongest growth period of the first set fruits), from sunrise to nightfall and at intervals of approximately 2 hours. Young, healthy and completely developed leaves from the top of the plant (not shaded) were chosen.
Rs was determined for both the adaxial and abaxial surfaces with a diffusion porometer (ΔT Devices LTD.), calibrated in each series of measurements. The total Rs was calculated as the inverse of the sum of the inverses of the adaxial and abaxial resistances (Reid y Renquist, 1997).
The measurements of ψh were performed on the same leaves with a pressure chamber following the methodology of Schölander et al. (1965).
The data were subjected to analysis of variance and a Duncan's multiple range test ($P \leq 0.05$) was applied to the significant results.

Results and discussion

The ETc registered during the irrigation period was of 523 mm. Total water applied in each treatment was: 834 mm (TR1), 648 mm (TR2), 518 mm (TR3) and 364 mm (TR4).
Figure 1a shows the evolution of relative humidity, air temperature and global radiation during the day. ψh evolved in response to the climatic demand of the atmosphere (Fig. 1b), behaving like relative humidity and unlike global radiation and air temperature. However, this last parameter seems to have been the most influential since the minimal ψh coincided with the maximum temperature. ψh approached equilibrium at sunrise and at nightfall in all treatments, when radiation and temperature decreased and relative humidity increased, which probably provoked a decrease in transpiration rates and the rewetting of the leaves. During the midday hours, the atmospheric evaporative demand reached the maximum values, leading to a fall in

potential, even in the treatments without water deficit. This agrees with Begg and Turner (1976), who state that ψh shows marked diurnal fluctuations and very little dependence on soil water potential, which only sets the upper limit of recovery possible by the plant during the dark period. Differences in ψh between treatments occurred at 6:00, 8:00 and 10:00 hs ($P \leq 0.05$). Throughout the day, the ψh varied according to the water amount received. Rs evolved as a function of the incident radiation (Fig. 1c), the principle climatic factor responsible for stomatal opening (Chamont et al., 1995). After sunrise, this parameter declined rapidly, reaching its minimal values at midday hours (maximum radiation). Rs showed a sharp rise at mid-afternoon as a consequence of the rapid fall in radiation and the low relative humidity (Chamont et al., 1995). No effect from the decrease in ψh at midday hours was found on stomatal closing. This means that stomatal behavior only depended on climatic conditions, probably due to the fact that in no case the threshold level of ψh, below which stomatal closing takes place and leaf resistance increases, was reached.



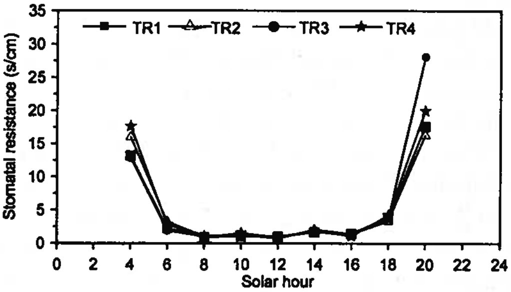


Figure 1.- Evolution of relative humidity (HR), air temperature (T°) and global radiation(RG) (a), leaf water potential (b) and total stomatal resistance of pepper leaves (c) in the different irrigation treatments on 27 July 1999.

Vertical bars represent LSD within treatments (P ≤ 0.05). TR1=125% ETc, TR2=100% ETc; TR3=75% ETc; TR4=50% ETc.

The results indicate that the plants did not suffer a severe water stress during the cycle, since irrigation was applied daily. The small variations in these parameters were due, in general, to the climatic conditions and not to the soil water content, since daily drip irrigation guarantees a wet soil volume where roots develop, only varying in size (not in state of humidity) in function of the quantity of water supplied.

Conclusions

- In pepper, ψh is more sensitive to differential watering and to climatic conditions than Rs.
- ψh does not affect stomatal behaviour, since a moderate decrease in potential does not modify the degree of stomatal opening.
- Measurements of ψh and Rs are not an appropriate method for quantifying the effect of different amounts of water on pepper crops with daily drip irrigation.

References

Begg J.E., Turner N.C., 1976. Adv. Agron., 28, 161-217.
Chamont S., Strainchmps D., Thunot S., 1995. Ann. Bot. 75(1), 39-47.
Horton R., Beese F., Wierenga P.J., 1982. Agronomy Journal, 74, 551-555.
Hsiao T.C., 2000. HortScience, 35(6), 1051-1058.
Reid J.B., Renquist A.R., 1997. Aust. J. Plant Physiol., 24, 685-692.
Schölander P.F., Hammer H.T., Bradstreet E.D., Hemmingsen E.A., 1965. Science, 148, 339-346.

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PEPPER (*CAPSICUM ANNUUM* L.) CROP RESPONSE TO DIFFERENT IRRIGATION AMOUNTS. II. ANALYSIS OF PRODUCTION.

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Introduction

The public concern about the high water consumption for crop irrigation is increasing, making necessary the development of more efficient irrigation techniques for the use of this public resource.

Irrigation control is crucial in pepper because these plants are especially sensitive to both under-watering and over-watering. Incorrect water supply can lead to a decrease in both quality and quantity (Pardo and Suso, 1995; Moreno et al., 2000a, 2000b).

Therefore, the present study was undertaken to determine the yield response of pepper crops cv. Infantes to different irrigation amounts.

Materials and methods

The trial was carried out in 2001 in Ciudad Real, Spain (3°56' W, 39°0' N, altitude 640 m), in a loamy-sand, basic and non-saline soil. It presents a normal C/N ratio, medium levels of organic matter and total nitrogen, high contents of assimilable potassium and calcium and very high levels of magnesium.

A randomized complete block design was adopted with four irrigation treatments and four replications. Each basic plot had an area of 180 m^2 (15 x 12 m) and 480 plants.

Planting took place on 24 May, using nursery seedlings with 4-6 mature leaves, under black polyethylene mulch. A drip irrigation system, which consisted of one drip line for each crop row and emitters of 2 l/h separated by 0.50 m, was employed. Irrigation treatments were applied daily from 6 June to 23 September. Prior to 6 June, all plots received the same amount of water, 25 mm, to improve crop establishment.

The weekly irrigation requirements were calculated to meet the crop evapotranspiration (ETc), measured with a lysimeter placed on the trial plot, due to the null rainfall during the irrigation period. Irrigations levels were 1.1 ETc (TR1), 0.9 ETc (TR2), 0.7 ETc (TR3) and 0.5 ETc (TR4). It has been demonstrated that a 10% decrease in ETc does not significantly alter the final yield and, however, it may imply a significant reduction in water use (Moreno et al., 2000a; Moreno et al, 2000b). The water amounts to be applied to each treatment were calculated considering a 0.81 system efficiency.

A total of six harvests were made over the cycle (7 and 23/VIII, 10 and 27/IX, 15/X, 9/XI), controlling marketable, unmarketable and total yield, as well as their components (number of fruits and mean fruit weight).

Results and discussion

The ETc registered during the irrigation period was of 687 mm. Total water applied in each treatment was: 950 mm (TR1), 758 mm (TR2), 581 mm (TR3), 415 mm (TR4).

The highest marketable yields were reached in treatments TR1 and TR2 (Table 1), especially due to an increase in number of pieces. There were no statistically significant differences between these two groups, which means that over-watering does not result in an increase in yield.

The lower output of treatment TR3 was due to the lower number of fruits produced, although the fruit weight was not affected. Treatment TR4 was the least productive, with a significant reduction in both components.

Drastic water restriction led to a decrease in marketable yield and an increase in unmarketable yield (Fig. 1). Therefore, the decrease in total yield was not so pronounced in the more restrictive treatments. The same results were observed when expressing the results as percentages with respect to total yield (Fig. 2), so that marketable yield decreased about 20% when irrigation was reduced by 50% of the crop requirements. This leads to the conclusion that the most efficient uses of water corresponded to the most restrictive treatments (Table 1), with yield decreasing less than the water supply reduction. The water use efficiency increased with decreasing the irrigation water amount, very little from TR1 to TR2. In relation to the water use efficiency with respect to the total yield, a greater increase is observed in response to the water deficit, as a result of the important increase in the unmarketable component.

Table 1.- Marketable and total production: number of fruits, mean fruit weight, yield and water use efficiency according to the different irrigation treatments.

Treatment	No. of fruits (×1000 ha^{-1})		Fruit weight (g)		Yield (t ha^{-1})		Efficiency (kg m^{-3})	
	Marketable	Total	Marketable	Total	Marketable	Total	Marketable	Total
TR1	259.2 a	329.7 a	234.6 a	222.9 a	60.8 a	73.5 a	6.4 a	7.7 a
TR2	247.0 a	329.2 a	226.9 a	215.2 ab	56.1 a	70.8 a	7.4 b	9.3 b
TR3	209.5 b	332.7 a	228.7 a	205.9 b	47.9 b	68.4 a	8.2 bc	11.8 c
TR4	168.6 c	336.3 a	215.5 b	177.3 c	36.3 c	59.3 b	8.7 c	14.3 d

For each parameter, treatments followed by different letters differ at $P \leq 0.05$.

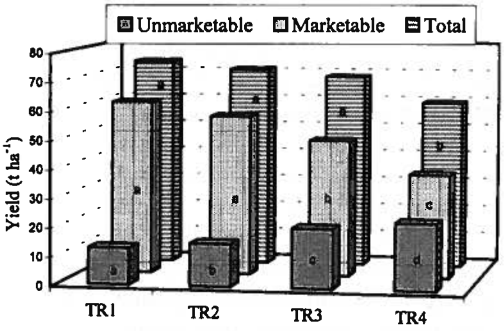

Figure 2.- % Pepper yield according to irrigation treatment. Different letters for diff. at $P<0.05$

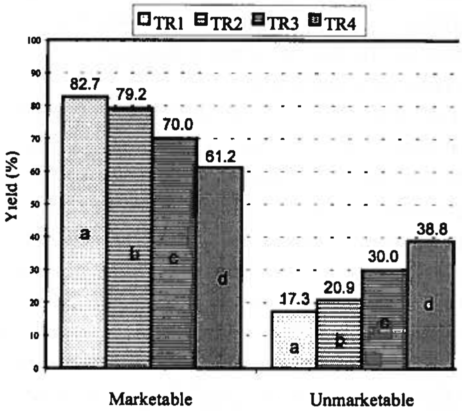

Figure 1.- Pepper yield according to irrigation treatment.Different letters for diff. at $P \leq 0.05$

Conclusions.

- There are no differences in marketable yield of pepper crops when watered between 90% and 110% ETc.
- Over-watering does not result in greater production and may result in waste of water.
- The best yield-water use efficiency relationship is reached when watering is slightly deficient.

Pardo A., Suso M.L., 1995. Hortoinformación, 4, 48-50.

Moreno M.M., Cabello M.J., Moreno A., Ribas F., 2000a. VII Jornadas del Grupo de Horticultura de la SECH (Villaviciosa, Asturias), 28, 159-166.

Moreno M.M., Cabello M.J., Moreno A., Ribas F., 2000b. XVIII Congreso Nacional de Riegos (Huelva), 29-30.

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FRUIT LOAD EFFECTS ON THE WATER RELATIONS OF OLIVE TREES.

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Introduction

Olive (*Olea europaea* L.) is a subtropical fruit tree, which is harvested during winter. The harvest process of olive trees in Spain is still very traditional, requiring significant manpower for an extended time period. The harvest period normally extends from November through February and thus, it is not uncommon to maintain the fruits on the tree until the end of winter in many orchards. Chilling-induced dehydration is a process that occurs in the range of 0 to 12 ºC in many subtropical species. Although olive is considered one of the frost resistant subtropical species(-12ºC of lethal temperature, Bongi and Palliotti 1994), chilling may affect the tree water relations and it is not known if the presence of fruits has interactive effects on the water relations and on the initial growth in spring of the olive tree.

This work was undertaken to evaluate the effects of the presence of fruit on young olive trees during most of the winter period. Measurements of leaf conductance and water potential were used to quantify the chilling-induced dehydration in the presence and absence of fruits. In addition, shoot growth was monitored between Autumn, 2000 and Spring of 2001.

Material and Methods

The experiment was performed in an irrigated three year-old olive orchard (cv. Arbequino) in the CIFA Experimental Station, Cordoba, Spain (38º N., 4.8º W., 110 m. altitude) during 2000. The soil is Typic Xerofluvent of alluvial sandy loam texture and over 1.5 m deep. Tree spacing was 3.5 x 6 m and the trees were irrigated, five days a week, by the drip method with two emitters per tree (4 $l\ h^{-1}$). The irrigation program was designed to avoid water deficits at all times. Two groups (heavy and light fruit load) of four trees were selected. The light trees were defruited completely on the 6th of September (day 249).

Stem water potential (Ψ_x) measurements were used to evaluate tree water status. Fully expanded leaves located in branches near the main trunk were covered with aluminium foil at least 1 hour before excision and the water potential was measured at midday with a pressure chamber (Soil Moisture Equip, Santa Barbara, Calif., USA). Midday leaf conductance (g_l) was determined with a transient porometer (AP4, ΔT, UK) on three sunny and fully expanded leaves per tree. The length of two randomly selected shoots per tree was measured twice a week from September to December and from April to mid-June.

Results

Figure 1 depicts the evolution of Ψ_x during autumn and winter in trees with heavy (HF) and no fruit (NF) load. Significant treatment differences in Ψ_x were detected before defruiting (Figure 1 day 249). After this date (day 249), the Ψ_x differences were maintained within a rehydration trend, probably caused by the reduction in evaporative demand as winter approached. On day 310, Ψ_x of both treatments started to decrease. Treatment differences in Ψ_x reached a maximum by day 350 and amounted to over -0.6 MPa. From day 350 on Ψ_x of both treatments started to increase. Similar Ψ_x values between treatments were reached a few weeks after harvest, on day 94.

The evolution of g_l is presented in Figure 2 where no clear differences were found between NF and HF, although there seems to be a trend of higher g_l in HF. During autumn, g_l was higher than in winter until day 74 when it started to increase as air temperatures increased. The winter g_l values were around 66 % of those measured in autumn. Shoots of HF did not grow during autumn and winter, while NF trees presented a linear increase in shoot extension until day 300 (Figure 3). During spring, shoot growth was similar at the beginning between both treatments, but after day 130 NF trees grew at a slower rate than HF trees.

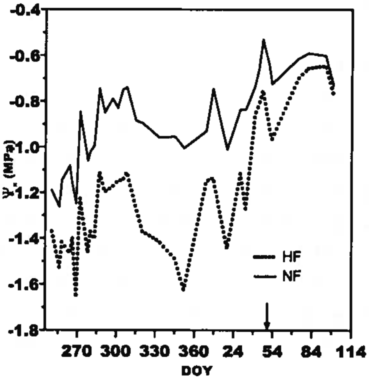

Figure 1. Evolution of Ψ_x during the experiment. Arrow indicates the date of harvest

Discussion

The presence of fruit in the trees during autumn and winter decreased tree Ψ_x and reduced shoot growth. Water deficits were likely due to chilling conditions, because the soil moisture was not limiting during this period of time (data not shown). Chilling-induced dehydration has been reported in potted olive trees (Pavel and Fereres 1998) but they did not identify any effects due to the presence or absence of fruits. The lower Ψ_x of HF may be caused by higher g_l resulting from greater assimilate demand, thus higher photosynthetic rates. Data of Figure 2 was analyzed by comparing individual data of g_l of HF against that of NF. The resulting regression differed significantly from the 1:1 relationship indicating that g_l of HF was abou 13% higher, on the average, than that of NF. DeJong (1986) found a similar trend in peach trees. In the other hand, chilling reduced sharply leaf conductance even though evaporative demand was lower and the Ψ_x values were higher (in NF trees) or almost equal (in HF trees) than in autumn. In olive trees, chilling produced a photoinhition and photoxidation that may decrease leaf conductance (Bongi et al. 1987). The differences in shoot growth during autumn have been related to an increase in assimilate demand by the fruit (Rallo and Suarez, 1989). In addition shoot growth during spring must have been affected by the beginning of the fruit development, that occurred only in the NF trees since no flowers were produced in the HF trees.

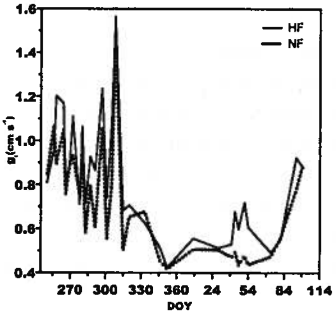

Figure 2. Evolution of g_l during the experiment.

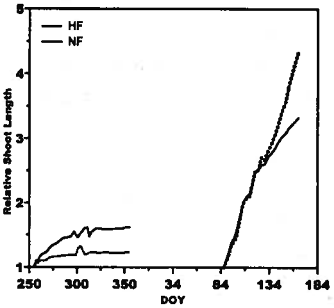

Figure 3. Evolution of the relative shoot length during autumn-winter and spring period.

References

Bongi G and Long SP (1987) Plant, Cell and Enviroment 10:241-249

Bongi, G. & Palliotti, A. (1994) Temperate crops. (eds. B. Schaffer & P.C. Andersen), pp 165-187. CRC Press, Boca Raton.

DeJong, TM (1986) Scientia Horticulturae 29:131-137

Pavel EW and Fereres E (1998) Physiologia Plantarum 104:525-532

Rallo L and Suarez MP (1989) Advances in Horticultural Science 3:55-59

SOIL WATER DEFICIT EFFECTS ON LEAF EXPANSION AND TRANSPIRATION OF GARLIC

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Introduction

Soil water deficits are common in the production of most crops, and they can have substantial negative impacts on growth and development (Sadras and Milroy, 1996). Plant processes that depend on increases in cell volume are particularly sensitive to water deficits. Two important examples of these sensitive processes are leaf gas exchange, which depends on guard cell volume, and leaf area increase, which depends on cell expansion (Lecoeur and Sinclair, 1996). Inhibition of these processes under drought can result in substantial losses in yield.

Modeling plant responses to soil water deficit requires not only an understanding of, but also quantitative relationships for the effects of water deficits on leaf growth expansion and gas exchange rates (Sadras and Milroy, 1996). Ritchie (1981) suggested that physiological processes such as photosynthesis, transpiration or leaf growth would show similar responses across a wide range of enviromental conditions when they were evaluated as a function of soil water content. Plant-available-water (PAW) is a variable that is widely used to describe soil water status (Ritchie, 1981). The value of PAW is calculated from the difference between the water content of the profile when drained after a thorough wetting (field capacity) and the water content of the profile after healthy plants have extracted all the water possible (permanent wilting point). PAW is often related to the leaf expansion and transpiration, with the PAW threshold at which either process declines being PAW_t (Rosenthal et al., 1987).

The objective of this study was to derive the relationship between PAW and leaf growth and transpiration at different developmental stages of garlic (*Allium sativum* L.).

Methods

A glasshouse and an open-field experiment were conducted in the facilities of Instituto de Agricultura Sostenible at Cordoba, Spàin (38° N, 4.8° W, 110 m a.s.l.).The glasshouse experiment had four drought treatments each of them consisting of six well-watered pots used as control and six water-stressed pots. The drought treatments started when the garlic plants had 3-4, 6-7, 8-9, 11-12 leaves. The open-field experiment had four drought treatments and a control. Each open-field treatment consisted of fifty plants in pots distributed in five rows, with 40 cm between rows and 16.5 cm between plants within a row. Only the six central plants were measured while the others acted as guard rows. The open-field treatments started when the plants had 3-4, 9-10, 11-12 leaves and the last treatment started after the end of the vegetative phase. Leaf length and width were measured twice a week from all the leaves of a plant. Destructive measurements of leaf area were conducted to obtain a relation between length×width and leaf area. Leaf expansion rate was calculated as the difference in leaf area per plant between two successive measurements (Sinclair, 1986).

The pots were weighed twice a week to determine the transpiration and the Relative Soil Water Deficit ($RSWD$), defined as:

$$RSWD = \frac{SWC_{fc} - SWC_{a}}{SWC_{fc} - SWC_{pwp}}$$

where SWC is the volumetric soil water content and subscripts a, fc, pwp stand for actual, field capacity and permanent wilting point.

The pots from the open-field experiment were covered to avoid direct soil evaporation. Transpiraton was measured only in the open-field experiment and was calculated as the difference in weight of successive measurements.

Pots were watered twice a week to field capacity until the beggining of the drought treatments. Field capacity and permanent wilting point, expressed as volumetric soil water content, were 0.33 and 0.05 cm^3/cm^3, respectively.

The responses of leaf expansion and transpiration were modelled according to Ritchie (1981). Leaf expansion rates and transpiration of the droughted plants were expressed as ratios to those of well watered plants. To reduce variation among plants, the leaf expansion and transpiration ratios were normalized relative to the average ratios for the period when there were not significant differences between water-stressed and well-watered plants.

Results

At the time of writing this paper only data of the effect of soil water deficit in leaf expansion rate in the glasshouse experiment were available.

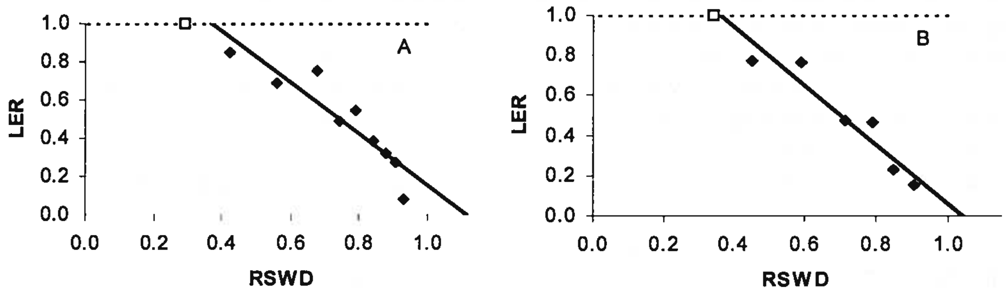

Figure 1. Responses of garlic leaf expansion rate (LER) to relative soil water deficit (RSWD) in the glasshouse experiment. The drought treatment started when the plants had 6-7 (A) or 8-9 (B) leaves. The dashed line is the y=1 line. Each data point is the mean of measurements made in 6 plants. The symbols □ and ◆ represented a non-significant or significant difference ($P<0.05$) in LER between drought-stressed and well-watered plants, respectively.

The RSWD threshold for which the droughted plants showed a response to water stress was 0.36 (Fig.1A) and 0.37 (Fig.1B) for the treatment initiated when the plants had 6-7 and 8-9 leaves, respectively. Mean reference evapotranspiration was 1.25 (StDev=0.44) and 1.46 (StDev=0.62) for the treatments initiated when the plants had 6-7 and 8-9 leaves, respectively.

Discussion

There are not differences in the response of LER to RSWD between both developmental stages. Further information will be available soon about other developmental stages and about the effect of different evaporative demands.

References

Lecoeur, J., Sinclair, T.R., 1996. Field pea transpiration and leaf growth in response to soil water deficits. Crop Science, 36, 331-335.

Ritchie, J.T., 1981. Water dynamics in the soil-plant atmosphere system. Plant and Soil, 58, 81-96.

Rosenthal, W.D., Arkin, G.F., Shouse, P.J., Jordan, W.R., 1987. Water deficit effects on transpiration and leaf growth. Agronomy Journal, 79, 1019-1026.

Sadras, V.O., Milroy. S.P., 1996. Soil-water thresholds for the responses of leaf expansion and gas exchange: A review. Field Crops Research, 47, 253-266.

Sinclair, T.R., 1986. Water and nitrogen limitations in soybean grain production. I,. Model development. Field Crops Research, 15, 125-141.

MANAGEMENT OF WATER RESOURCES USING INTEGRATED TECHNIQUES PROJECT MERIT (EVK1-CT-2000-00085)

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Introduction

In the last years the demand of water has increased, decreasing also its quality. Due to this the management of water resources has became a challenge for the European Union (EU). In 1997, the EU encouraged national and regional governments to develop integrated water policies including all the implicated factors.

- The decisions making about using water management should not be based only on aspects affecting water but also on social, economic and political repercussions. Water is not a resource like the others but an heritage that must be protected and defended.
- It is necessary to include the stakeholders, thus they can claim and participate in the decision making.

Scientific objectives.

The European project MERIT will create a tool for helping to implement integrated policies for resources management. The methodology will be generic and applicable to whole Europe. Three main elements constitute the methodology:

- Structure that involves the stakeholders in the construction and analysis of the Bbn.
- Model supported in the probabilistic theory (Bayesian belief network).
- Set of quantifiable indicators that will be variables within the Bbn.

The Project tries to improve the management of hydrologic basins and get an economically optimum , socially equitable and environmentally sustainable use of the resources.

Methodology and partial results obtained.

a. Techniques of stakeholders involvement.

The processing of Bbn needs to include the claims of the stakeholders. The represents of these groups are been consulted to identify their problems and the solutions that they propose. After that we will organise meetings to discuss the proposed model and later other meetings to get arrangements from confronted groups (Petts, 1997). At this moment we have sent and received more than twenty polls from the stakeholders. The main problems are the volume of water available for irrigation, water quality and current legal aspects.

b. Bayesian belief networks.

This methodology is been recently used to solve environmental problems, because these presents a complicated structure, with high uncertainty grades and great difficulties for getting data (Simonovic and Fahmy, 1999).

A Bbn consists of a series of nodes, representing random variables, which interact with each other (Jensen 1996). The variables within the Bbn are related with other, for this reason a change in the state of any variable produces a change in the state of the variables related. The probability that a variable will be at a particular state is expressed with a table of conditional probability. These tables can be obtained from set of data, from the result of complicated models or from experts opinions.

Figure 1 shows the current state of the Bbn for the quantitative management of water resources at the Hydrological System 08.29 Mancha Oriental. The next step will be that the stakeholders approve this Bbn..

c. Indicators.

Within the Bbn a set of quantifiable multicriteria indicators is been developed. Indicators will be those variables that integrate the effect of a great number of related factors (ecological flows, water quality...) (Crabtree and Bayfield, 1998).

d. Study areas.

- *The Wye catchment (England):* Urban needs not assimilated by the river.
- *Abruzzo area (Italy):* Recreational demand against traditional uses.
- *Aquifer 08.29 (Spain):* High extractions for irrigation that decrease piezometric levels.
- *The Zealand catchment (Denmark):* Extractions and wastes that decrease water quality.

References

Crabtree, R., Bayfield, N., 1998. Developing sustainability indicators for mountain ecosystems: a study of the Cairngorms. *Journal of Environmental Management*, 52: 1-14.

Jensen, F.V., 1996. An introduction to Bayesian Networks. 1 Edition. *UCL Press*. 178 pp.

Petts, J., 1997. The public-expert interface in local waste management decisions: expertise, credibility and process. *Public Understanding of Science*, 6: 359-381.

Simonovic, S.P, Fahmy, H., 1999. A new modelling approach for water resources policy analysis. *Water Resources Research*, 35 (1): 295-304.

NITROGEN FERTILIZATION EFFECTS ON BIOAGRONOMIC AND QUALITATIVE CHARACTERISTICS OF CASTOR BEAN (RICINUS COMMUNIS L.) UNDER LIMITED IRRIGATION

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Introduction

Renewed interest for alternative "no food" crops, seems to be favorable for Castor been (*Ricinus communis L.*), to be used as set-aside crop in hot – arid environments characterized by limited water availability for irrigation.

A wide use of Castor bean cannot do without a complete agronomic setting up mainly related to new genotypes availability and their higher productivity, and also related to crop mechanization needs, mainly harvest.

Together with varieties choice, seeding time and rate (Poma et al. 1995; 1996a; 1996b) and nitrogen fertilization seems to be very important for Castor been management.

In the hot-arid environment, nitrogen use efficiency knowledge is very important because it is strongly linked to genotypes nutritive needs and soil water availability (Copani et al. 1995).

Because of the lack of information from the South of Italy, this trial was carried out to investigate nitrogen fertilization and limited irrigation effects on bioagronomic and qualitative characteristics of Castor bean (Ricinus communis L.)

Methods

The trial was carried out during 1997-98 in the soil of inland of Sicily (Cammarata, Agrigento – 37° 37' N, 13° 42' E) (450 m asl), on a regosoil characterized by average-low fertility (N 1.1‰; P 17.7ppm; K 332 m). Using a split plot design with three replications, two Castor bean genotypes (dwarf and normal) combined with three nitrogen rates (0, 75, 150 kg ha^{-1}) were compared; nitrogen distribution was splitted at seeding and at 5-7 leaves stage. During preparatory plowing 60 kg ha^{-1} P_2O_5 were applied. Castor bean sowing, after durum wheat, was carried out at the end of March and at mid April in the first and second year, respectively.

During Castor bean biological cycle, manual weed control (twice) and three irrigations during critical physiological stages (seeding, 5-7 leaves and beginning of flowering) using a total amount of 1200 m^3 ha^{-1} of water were carried out.

Only biometric characters better correlated with results are reported (tab 1).

Thermopluviometric trend resulted similar to Mediterranean hot-arid climate characterized by high temperature during all the biological cycle (April – August) and by rain deficiencies during maturity.

Results

Sowing-emergence period (average 27 days in the two year trial) was affected by year effect. Castor been Emergence - maturity stage, on the contrary, varied with genotype; in fact, cv. Castor was 4 days earlier (about 94 d) than cv. Negus. Plant height was strongly determined by genotype, by year and by nitrogen fertilization (tab 1, 2).

Plant height statistically different in two year trial, was double for cv. Castor (120 cm) as compared to cv. Negus (67 cm). Also fertilization statistically affected plant height, ranging from 86.0 to 99.6 cm, respectively for 0 and 150 kg ha^{-1} of nitrogen.

Grain yield did not varied with to genotype. On the other hand, annual thermopluviometric trend determined a high yield variability, probably because of some rainfall at the end of April during the second year trial; also fertilization rate affected grain yield but only until 75 kg ha^{-1} of N; the higher fertilization rate (150 kg ha^{-1}) was not statistically different from the 75 kg N ha^{-1} one (tab

2). Plant seed number did not statistically vary because year and 1000 seeds weight did not varied because interaction genotype and N, but strongly determined grain yield.

Charac. Factors	Plant height (cm)	Grain yield (t ha^{-1})	Plant seeds (n°)	1000 seeds weight (g)	Oil (%)
Year (Y)	**	**	*ns*	**	*
Genotypes (G)	**	*ns*	**	**	**
Nitrogen (N)	**	**	**	**	**
Y x G	*ns*	*ns*	**	**	**
G x N	**	**	*	*Ns*	*
Y x N	**	**	**	**	**
Y x G x N	**	*ns*	*	*Ns*	*Ns*

**, significative for P≤1%; *, significative for P≤5 %; *ns,* not significative

Table 1 - ANOVA (1997-98)

Also seeds oil content (% dm) was influenced by studied factors (Genotype, Year and N rate) and by their interaction.

On the average, seeds oil content was lower in the first year (52.3%) and decreased from N 0 rate (54.2%) to N150 (52.4%) (tab 2);
the highest values (55.3%) resulted from "98 x N0" treatment. Grain moisture was generally low (6.2 %), very suitable for grain conservation.

Characters Factors	Plant height (cm)	Grain yield (t ha^{-1})	Plant seeds (n°)	1000 seeds weight (g)	Oil (%)
Year: 1987	88.9 B	1.54 B	100.0	266.6 B	52.3 b
1998	98.2 A	1.91 A	102.5	317.4 A	54.1 a
Gen: Negus	67.1 B	1.74	104.6 A	283.9 B	52.5 B
Castor	120.0 A	1.71	98.5 B	300.1 A	54.2 A
N rate 0	86.0 cC	1,36bB	88.8 cB	270.7 cB	54.2 aA
75	95.0 bB	1.88 aA	109.8 aA	296.6 bA	53.4 bB
150	99.6 aA	1.93 aA	106.1 bA	308.7 aA	52.4 cC

Values with similar letters, in the same column, are statistically for P≤ 0.05 (small letters) and for P≤ 0.01 (capital letters)

Table 2 - Mean effects. (1997-98)

Discussion and Conclusions

The results showed the important role of these trials for euforbiacea agro technique improvements; the trial pointed out that in the semi-arid Mediterranean environment nitrogen fertilization must be reduced, especially if water availability is low and crop management depend on irrigation at the physiological stage only.

Table 3 shows, in fact, that nitrogen use efficiency at 75 kg ha^{-1} rate determined a crop yield statistically similar to that obtained using a 150 kg ha^{-1} rate, with a better nitrogen utilization index.

N Kg ha^{-1}	Yield Kg ha^{-1}	Efficiency
0	1360	6.93 (N0, N75)
75	1880	0.67 (N75, 150)
150	1930	3.80 (N0, N150)

Table 3 - Nitrogen use efficiency (kg of seeds/ kg of nitrogen)

References

Copani V., Cosentino S., Abbate V., 1995, *Supplemento a L'informatore Agrario* 46: 12-13.
Mieli S., 1989, *Terra e vita* 8:109 – 113.
Poma I., Gristina L., 1995, *Supplemento a L'informatore Agrario* 46: 6-8
Poma I., Sarno R., Frenda A., Monti M., 1996, *Sementi elette*, 2:21-25
Poma I., Gristina L.., Frenda A., Monti M., 1996, *Sementi elette*, 2:27-31

CASTOR BEAN GENOTYPES (RICINUS COMMUNIS L.) PRODUCTIVE AND QUALITATIVE EVALUATION UNDER LIMITED WATER AVAILABILITY

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Introduction

Castor bean (Ricinus communis L.) is a tropical plant with a 55 % seeds oil content mainly constituted by rinoleic acid (>85%); high viscosity and high lubricate properties at low temperature are the main Castor bean characteristics. However several industrial applications (plastic colouring, cosmetic and textile) determine a strategic relevance for this vegetal oil. During 2001 total world yield was about 1.3 millions of tons.

India is the major productive country (64.5 %) followed by China (22%) and Brazil (6.5%). Since 1996 (876,000 t) yield increased of about 66% because of unit yield improvement (0.6 t ha^{-1} on 1966 and 1.05 t ha^{-1} on 2001). On the contrary castor bean areas (1,240,000) decreased of about 200,000 ha.

Germany and Thailand are the most important castor bean importer because of provided of industrial factory, while India is responsible of about 2/3 of total castor bean seeds export. Furthermore India (271,000 t), China (127,000 t) and Brazil (41,000 t) produce about 80% of world castor bean seeds oil.

Methods

The trial was carried out (after durum wheat cultivation) during 1996-'97 in the clayey inland of Sicily (Cammarata, Agrigento – 37° 37' N, 13° 42' E) (450 m asl). The soil at the site was a vertisoil, characterized by an average-low fertility (N 1.0 ‰; P 17.5 ppm; K 330 ppm). During preparatory plowing(30 cm depth), the experimental site received a maintenance dressing of 60 kg ha^{-1} P_2O_5, 50 kg ha^{-1} K_2O, and 40 kg ha^{-1} of N.

The experimental design was a randomized block with three replications. 8 Castor bean varieties were compared using a seed density of 5,7 plants m^{-2} and 70 cm rows apart. Sowing, because of seasonal climatic trend, were made on 18/5/96 and 27/3/97 in the first and second year. During the manual operation, necessary to exactly arrange seeds density, 40 Kg ha^{-1} of N were also top-dressed.

Two weeding and three irrigations (at seeding stage, at 6-8 leaves stage and flowering stage), using a total water amount of 1200 m^3 ha^{-1}, were done.

Main biological stage, grain yield, and means of production were recorded; oil seeds content was determined only in the second year.

Characters Treatment	Yield	Height	100 seeds weight	Flowering	Maturity
Variety (V)	**	**	n.s.	**	**
Year (Y)	**	**	**	n.s.	**
V X Y	n.s.	n.s.	n.s.	**	n.s.

Tab.1 – Analysis of variance

Results

Seeds emergence, during the two-year trial, varied depending on seasonal climatic trend. In the first year, sowing delay, caused a fast seeds emergence (ten days after sowing); in the second year more than 30 days needed for seeds emergence..

Flowering stage lasted (two – year period) 55 – 60 days; 99 days on 1996 and 91 days on 1997 were the whole plant cycle.

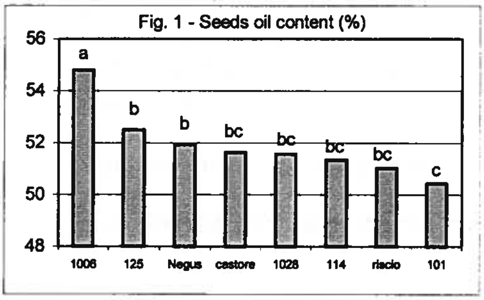
Late maturity varieties were "1028" and "125"; on the contrary variety "1026", in both year, showed an earlier reproductive stage (tab. 2).

Average plants height, generally correlated to yield, was higher in the second year (+17%); varieties Castore, "1006" and "1028" showed the maximum height.
100 seeds weight (meanly 24.7 g during 1996 and about 30.7 g in 1997) was strongly correlated to yield. Cv "1006", "1028" and Negus reached the higher weight ranging between 32 and 35 g.
In the two-year trial, seed yield was determined by "year" effect ; in the first year because of sowing delay (second decade of May) the mean productivity was 1.06 t ha^{-1}; on 1997 the early sowing (third decade of March) allowed a regular vegetative-productive cycle development determining an yield increase (+60% respect to1996) and an average productivity of 1.7 t ha^{-1}.
Cv "1028", "1006" and "101" (tab.2), in both year, always overcame the field mean.

Varieties	Emergence flowering (d)		Emergence maturity (d)		Plant height (cm)		Yield (t ha^{-1})		100 seeds Weight (g)	
	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997
101	57.0 a	57.0 a	98.0 b	90.7 ab	53.7 b	72.7 c	1.27 A	1.89 ab	25.4 b	31.5 ab
114	57.0 a	58.0 a	98.0 b	92.0 a	60.9 b	73.1 c	0.69 C	1.58 d	24.4 bc	22.9 b
125	55.0 ab	53.7 b	100.0 ab	92.0 a	56.4 b	72.4 c	0.94 Ac	1.61 d	22.6 cd	31.1 ab
1006	54.3 ab	52.3 b	100.0 ab	90.3 b	104.1 a	102.3 b	1.23 A	1.97 a	26.4 ab	36.0 a
1028	57.0 a	58.0 a	102.0 a	92.0 a	88.3 a	109.5 a	1.24 A	1.80 bc	28.3 a	32.6 ab
Castore	53.0 c	57.0 c	99.0 b	90.7 ab	93.7 a	101.3 b	1.06 ac	1.68 cd	21.7 d	28.1 ab
Negus	56.0 ab	57.0 a	98.0 b	91.3 ab	58.9 b	71.9 c	1.20 ab	1.61 d	28.5 a	33.0 ab
Riscio	53.0 c	57.0 a	99.3 b	91.3 ab	55.5 b	69.4 c	0.83 bc	1.41 e	20.6 d	30.5 ab
Mean	**55.29 a**	**56.25 a**	**99.29 a**	**91.29 b**	**71.45 b**	**84.08 a**	**1.06 B**	**1.70 a**	**24.73 b**	**30.71 a**

Tab.2 - Varieties bioagronomic characters in the two-year trial

Oil seeds content (meanly 52%), determined only in the second year, was inversely correlated to the flowering stage (Fig.1). Cultivar "1006" (54.8%) and cv "101" (50.43%) showed the highest and the lowest values respectively.



Conclusions

Genotype "1006" seems to be very suitable to the trial conditions both for grain yield and seeds oil content. Cv "1006" was characterized by a medium size, a sufficient first fertile raceme height, a good 100 seeds weight, an early flowering maturity stage, an excellent seeds oil content and a good yield stability.
Also cv "101" and cv "1028" showed sufficient productive performances, even if characterized by different bearing.
Castor bean, in spite of limited water availability, yielded sufficiently showing a good suitability for the semi arid Sicilian environment.

References

Faostat Agriculture Data, *www.fao.org*.
Koutroubas S.D., Papakosta D.K., Doitsinis A.,1999, *European Journal Agronomy* 11:227-237.
Poma I., Gristina L., 1995, *Supplemento a L'informatore Agrario* 46: 6-8
Poma I., Sarno R., Frenda A., Monti M., 1996, *Sementi elette*, 2:21-25

GRAIN YIELD FORMATION IN DURUM WHEAT UNDER MEDITERRANEAN CONDITION WITH EMPHASIS ON MAIN STEMS AND TILLERS

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Introduction

Grain yield is the product of three major yield components (number of spikes per m^2, number of kernels per spike, and mean weight per kernel), which develop sequentially along the plant cycle simultaneously on main stem and tillers. Tillering dynamic is an important feature in understanding grain yield variations that can be predicted by simulation models (Day and Atkin, 1985). Nowadays, there is a relative controversy on the importance of tillering as a selection index, particularly under drought stress. Some authors suggest that high tiller proliferation can increase spike number per area and then grain yield (Hadjichristoudoulou, 1985). Others, on the contrary, reported that although profuse tillering was associated with an elevated number of spikes, they were small and up to 75% or more of the tillers were unproductive (Bremner, 1969). Moreover, release of uniculm varieties appears to improve grain yield particularly under rainfed conditions (Islam and Sedgely, 1981). The objective of this work was to evaluate the contribution of grain production and its components on main stems and tillers to total grain yield under different moisture regimes in southern Spain.

Methods

25 durum wheat (*Triticum turgidum* L. var *durum*) genotypes were grown under two moisture regimes (irrigated and rainfed) in southern Spain during the 1997 and 1998 seasons. The experimental design was a randomised complete block with four replications and plot size was 12 m^2 (6 rows, 20 cm apart). Grain yield was determined on the basis of the harvested plot in all trials and corrected to a 12% moisture level. In order to determine the yield components in detail, individual plants were cut, at maturity, from a sample area of 0.2 m^2 and separated into main stems and tillers. Within these two shoot categories, tillers per m^2, number of spikes per m^2 (NS), yield per plant, number of kernels per spike, number of spikelets per spike, and mean kernel weight were recorded. In addition, the maximum number of tillers per m^2 at the end of tillering (MNT) was also recorded. Percentage of tiller mortality was then calculated as:

$$[(MNT - NS)/MNT] \times 100$$

Results

Grain yields per ha and per plant were higher in the irrigated than in the rainfed trials. This was associated also with significant variations in all yield components particularly tillers per m^2 that was significantly higher in the irrigated treatment (Table 1).

Table 1. Mean values for grain yield, grain yield per plant (Yp), grain yield on main stems (Yms) and tillers (Yt), total tiller number and tiller mortality in 25 durum wheat grown under two moisture regimes during 1997 and 1998 seasons.

	Grain yield kg ha^{-1}	Yp g $plant^{-1}$	Yms g $plant^{-1}$	Yt g $plant^{-1}$	Total tillers n° m^{-2}	Tiller moratility %
Irrigated	3544	2.59	1.65	0.94	1006	47.0
Rainfed	2003	1.39	1.11	0.20	529	13.4
Lsd	92	0.09	0.06	0.06	24	1.8

Lsd: least significant difference.

Under irrigated conditions, tiller mortality was more pronounced probably due to an unproductive use of resources, thus aggravating interplant and inter-component competition in later growth stages (Maidl et al., 1998). Main stems contributed by 63% and 80% to grain yield per plant under irrigated and rainfed conditions, respectively. The contribution of tillers was small in comparison to main stems and was estimated to be only 27% and 20% in the irrigated and rainfed trials, respectively (Table 1). These results agree with those reported by Bremner (1969) who find that main stems contributed between 50 and 70% to grain yield per plant. Similar results were also encountered in other works (Clements et al., 1974; Maidl et al., 1998).

Under irrigated conditions, grain production on main stems and tillers was significantly higher than those of the rainfed trials, due mainly to heavier kernels and greater number of kernels per spike conditioned by high number of spikelets per spike (Table 2). The contribution of tillers to spike density was much lower under rainfed conditions mainly due to water shortage that reduced tiller proliferation.

Table2. Yield components on main stems and tillers of 25 durum wheat genotypes grown under two moisture regimes during 1997 and 1998 seasons.

	Spikes per m^2		Kernels per spike		Spikelets per spike		Kernel weight (mg)	
	MS	T	MS	T	MS	T	MS	T
Irrigated	235	276	36.1	20.6	15.4	12.4	45.3	34.8
Rainfed	258	188	27.6	9.9	12.1	8.7	42.8	27.9
Lsd	8	13	1.0	1.0	0.2	0.3	1.0	1.5

Lsd: least significant difference.

The relationships between the yield components in main stems and tillers and grain yield per ha were, in general, not significant under irrigated conditions, with the exception of the number of fertile tillers, which was positively correlated to grain yield per ha. Under rainfed conditions, however, the kernels per spike and the spikelets per spike on main stems had a significant positive association with grain yield per ha (Table 3).

Table 3. Correlation coefficient between grain yield per ha and yield components on main stems and tiller of 25 durum wheat genotypes grown under two moisture regimes during 1997 and 1998 seasons.

		Spike per m^2	Kernels per spike	Spikelets per spike	Kernel weight
Irrigated	MS	-0.12	0.17	0.05	0.16
	T	0.66***	0.25	0.07	0.34
Rainfed	MS	-0.01	0.43*	0.53**	0.38
	T	0.36	0.37	0.04	0.37

*,**,*** : significant at 0.05, 0.01, and 0.001 of probability level, respectively.

Conclusions

In this study, main stems exerted the highest contribution to total grain yield although a high number of fertile tillers can also increase grain yield when water availability is a not limiting factor. Moreover, an elevated number of spikelets per spike and high fertility of florets on main stems are also very important determinants of grain yield under drought stress conditions.

References

Bremner, P.M. 1969. Journal of Agricultural Science 72, 281-287.

Clements, R.J.; Cross, R.J.; Sanders, P. 1974. New Zealand J. Exp. Agriculture 2, 139-144.

Day, W.; Atkin, R.K. 1985. Wheat Growth and Modelling. Plenum Press, New York, 407 pp.

Hadjichristodoulou, A. 1985. Euphytica 34, 641-649.

Islam, T.M.; Sedgley, R.H. 1981. Euphytica 30, 277-283.

Maidl, F.X.; Sticksel, E.; Retzer, F.; Fischbeck, G. 1998. J. Agron. and Crop Science 180, 15-22.

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PATH COEFFICIENT ANALYSIS OF CORRELATIONS BETWEEN GRAIN FILLING, GRAIN YIELD AND PROTEIN CONTENT IN DURUM WHEAT UNDER TWO MOISTURE REGIMES IN SOUTHERN SPAIN

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Introduction

Grain growth and development is one of the most critical phases in the cycle of plant wheat, because the final kernel weight (and consequently the grain yield) are mainly established at the end of this period. Kernel size depends both on the rate of grain growth as well as on the duration of the grain filling period. Therefore, understanding the processes that control the grain development could be helpful for durum wheat breeding. Grain yield is known to have a negative relationship with protein content, due to the dilution of protein by non-nitrogen compounds in the grain (Campbell et al., 1981). Protein deposition and starch accumulation during grain filling period do not always appear synchronous; the rate of protein deposition may reach its peak before to that of starch, and it may decline earlier. This difference in accumulation patterns may explain higher protein content under environmental conditions that shorten the duration of grain filling period (Jenner et al., 1991; Fernandez-Figares et al., 2000).

Methods

A total of six field trials were conducted both under irrigated and rainfed conditions in southern Spain during three growing-seasons (1998, 1999, and 2000). Ten durum wheat genotypes, including 4 Spanish commercial varieties and 6 advanced lines from the CIMMYT/ICARDA breeding programs, were used in this study. The experimental design was a randomized complete block with four replications and plots of 12 m^2 (6 rows, 20 cm apart). Traits studied were: grain yield, grain protein content, grain filling parameters (duration, rate, and final kernel weight), number of kernels per m^2, and days from sowing to anthesis (vegetative period). Path coefficient analysis was performed on the base of correlation coefficients between each pair of these characters. The causal system assumed (as described in Garcia del Moral et al., 1991) was based on the ontogeny of the wheat plant and is shown in Figure 1.

Results

Direct effects displayed on the diagram of the Figure 1 show that grain yield had been determined mostly by the number of kernels per m^2. Grain filling duration had a positive direct effect on grain yield. In the same way, final kernel weight influenced positively grain yield, although at a small degree in comparison with the former two traits. Protein content was negatively affected by final kernel weight, but responded positively to longer vegetative period. The positive association between protein content and days from sowing to anthesis could be mainly attributed both to the inverse relationship of this last character with grain yield, and to the negative correlation of grain yield with protein content ($r = -0.724^{***}$). Final kernel weight was predominantly affected by grain filling duration and, at a lesser extent, by grain filling rate. In addition, a high rate of grain filling had negative effect on its duration.
In agreement with similar works carried out in southern Spain (Garcia del Moral et al., 1985; Garcia del Moral et al., 1991), this study showed that the number of kernels per m^2 was the component that most influenced grain yield. Variations in the final kernel weight were mainly determined by the duration and the rate of grain filling, in accordance with the results of other authors (Motzo et al., 1996; Royo et al., 2000). Protein content was negatively influenced by grain yield and kernel weight due probably to a dilution effect, which increases the amount of starch in the endosperm. This relationship had been found in many previous works in durum (Novarro et al., 1997; Rharrabti et al., 2001) and bread wheat (Pleijel et al., 1999).

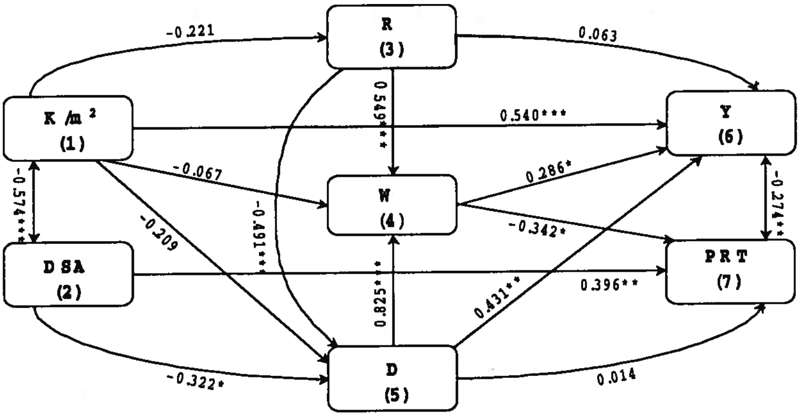

Fig. 1. Path diagram of the interrelationships between seven traits of 10 durum wheat genotypes grown under two moisture regimes (irrigated and rainfed) during three seasons (1998, 1999, 2000). Double-headed arrows indicate correlation coefficients; single-headed arrows indicate path coefficients. *,**,*** significant at 0.05, 0.01, 0.001 probability level, respectively. K/m^2: kernels per m^2; DSA: days from sowing to anthesis; R: grain filling rate; W: final kernel weight; D: grain filling duration; Y: grain yield; PRT: protein content.

Conclusions

Path analysis appeared to be an efficient tool to understand the interrelationships between the studied characters, being particularly useful in estimating the magnitude of direct effects between them. Protein content and grain yield were differently influenced by the other traits. While number of kernels per m^2 and kernel weight has a positive effect on grain yield, lengthening the period from sowing to anthesis (vegetative period) increased grain protein content. Moreover, this study confirmed the general rule of the inverse relationship between grain yield and protein content.

References

Campbell, C.A.; H. R. Davidson; Winkelman, G. E. 1981. Canadian J. Plant Sci. 61, 549-563.

Fernandez-Figares, I.; Marinetto, J.; Royo, C.; Ramos, J.M.; García del Moral, L.F. 2000.Journal of Cereal Science 32, 249-258.

García del Moral, L.F.; Ramos, J.M.; Recalde, L. 1985. Canadian J. Plant Sci. 65, 523-532.

García del Moral, L.F.; Ramos, J.M.; Garcia Del Moral, M.B.; Jimenez-Tejada, P. 1991.. Crop Science 31, 1179-1185.

Jenner, C.F., 1991. Australian Journal of Plant Physiology 18, 179-190.

Motzo, R.; Giunta, F.; Deidda, M. 1996. Field Crops Research 47, 129-142.

Rharrabti, Y.;Villegas, D.; García del Moral, L.F.; Aparicio, N.; Elhani, S.; Royo, C. 2001.. Plant Breeding 120, 381-388.

Royo, C.; Abaza, M.; Blanco, R.; García del Moral, L.F. 2000. Australian Journal of Plant Physiology 27, 1051-1059.

Pleijel, H., Mortensen, L.; Fuhrer, J.; Ojanpera, K.; Danielsson, H.1999. Agriculture, Ecosystem and Environment 72, 265-270.

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AGRONOMIC RESPONSE OF A MELON CROP (*CUCUMIS MELO* L.) TO DIFFERENT VOLUMES AND FREQUENCIES OF IRRIGATION

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Introduction

The main horticultural crop of the province of Ciudad Real is melon, which occupies a surface area of 10,000–15,000 ha, and is mostly cultivated with drip irrigation. In spite of that, a lot of farmers around the area do not irrigate daily; they make use of fewer frequencies, not being rare those cases with a weekly application. According to Tapia *et al.* (1995*)* frequent irrigation reduce the fruit sugar content and do not imply a significant increment in yield, whereas according to Bogle *et al.* (1986) and Mannini (1988) higher yield is produced when irrigation frequency is increased. Warriner *et al.* (1989) did not get variations neither in the flesh firmness nor in the sugar content. The aim of this experiment was to evaluate the effect of the frequency and the quantity of water applied, on melon’s quality and yield.

Methods

The experiment was carried out in 2000 in the experimental field of “La Entresierra”, of the Agriculture and Environment Department of Castilla-La Mancha, located in Ciudad Real (3°56’ W, 39°0’ N, altitude 640 m). The soil is sandy-loam, with an average depth of 50 cm; it is limited by a fragmented petrocalcic horizon, with 60 mm of total available water. It has alkaline pH, a normal hydraulic conductivity, middle level of organic matter and total nitrogen, and a normal C/N ratio. Moreover, it is poor in phosphorus and rich in potassium, calcium and magnesium assimilated. The experimental design was developed in split-plot with full blocks at random and four replications, being the volume of irrigation the main factor of variation with three treatments (R_1 = 125 % of the crop evapotranspiration [ETc], R_2 = 100 % ETc and R_3 = 80 % ETc) and its frequency the secondary factor (D = daily and W = weakly). Every elemental plot (48 m^2) included four planting rows placed 1.5 m apart with a distance of 1.0 m between plants. The planting of melon (cv. Sancho) was carried out outdoors on May the 24th with transparent mulching. An irrigation depth of 11 mm was applied in order to favour its establishment, starting differential irrigation on June the 7th and finishing on September the 26th. The drip irrigation was applied with compensating emitters of 4 l h^{-1} with a spacing of 1.5 x 0.5 m. The irrigation depth was calculated weekly, providing the water consumed by the crop the week before, measured with a weighing lysimeter of 1.5 m^2 placed in the experimental field. The gross water applied was controlled with volumetric counters. Irrigation system efficiency was estimated as 0,85. Six harvestings were carried out 78, 86, 96 104, 117 and 125 days after transplanting (DAT). The following parameters were determined for each date: yield, fruit weight, fruits number m^{-2}, flesh thickness, flesh ratio, flesh firmness, sugar content and, finally, the water use efficiency (WUE), defined as the ratio between units produced and volume of irrigation water applied.

Results

Table 1 shows the total water applied and the ETc in the period 24/V-26/IX. Irrigations were adjusted successfully to the initial scheduling, so deviations could never exceed 3 %.

Table 1. Volume of water applied in each irrigation treatment and crop evapotranspiration (ETc).

Treatments	R_1		R_2		R_3	
Frequency	D	W	D	W	D	W
Net irrigation (mm)	667.1	665.2	553.8	554.0	442.0	443.1
Net irrigation/Etc	1.23	1.23	1.02	1.02	0.82	0.82

ETc (mm)	541.2

Daily irrigation increased yield significantly (Table 2). It varied from 43.6 t ha^{-1}, mean of the weekly treatment to 52.5 t ha^{-1}, mean of the daily frequency one. This is in concordance with the results obtained by Bogle *et al.* (1986) and Mannini (1988) who obtained an increase in production when increasing irrigation frequency. Weight of fruits and flesh firmness were also significantly affected, increasing with daily irrigations. The rest of the parameters were not influenced by the irrigation frequency. Water quantity supplied with the irrigation affected yield significantly, with the R_1 treatment, the one that received the greatest amount of water, producing the highest yield. However, that production was not really different from the one obtained with R_2 treatment, whose water requirements were also met. The harvest increase was mainly due to a weight increase of the fruit when the crop satisfied its water requirements. There were significant differences among R_1, R_2 and R_3 treatments. However, the quantity of irrigation did not affect neither the fruits number, nor the flesh thickness, its firmness, or the sugar content. On the other hand, the flesh ratio was affected significantly, but not strongly, in the more restrictive treatment. In none of the parameters analysed a significant interaction was obtained between the frequency of irrigation and the quantity of water applied.

Table 2. Values of the production and quality parameters analysed.

Factor	Treatments	Yield (t ha^{-1})	Fruit weight (kg)	Fruits number m^{-2}	Flesh thickness (cm)	Flesh ratio	Flesh firmness (kg)	Sugar (°Brix)
Frequency (F)	D	52.5 a	2.9 a	1.8 a	4.28 a	0.56 a	2.8 a	13.4 a
	W	43.6 b	2.6 b	1.6 a	4.41 a	0.56 a	2.6 b	13.2 a
Amount (A)	R_1	52.3 a	2.9 a	1.8 a	4.37 a	0.55 a	2.6 a	13.1 a
	R_2	48.9 ab	2.9 a	1.7 a	4.34 a	0.55 a	2.7 a	13.4 a
	R_3	42.9 b	2.5 b	1.7 a	4.31 a	0.57 b	2.8 a	13.4 a
Interaction	FxA	ns	ns	ns	ns	Ns	ns	ns

The values with the same letter are statistically homogeneous in Duncan's test. ns: not significant (P □ 0.05).

Table 3 shows the values of water efficiency in the different frequency and quantity treatments of water applied. Irrigation daily applied had an efficiency of 1.6 kg m^{-3} higher than the one provided weekly, being this difference significant (P □ 0.05). Besides, the higher the efficiency was, the less quantity of water applied, being significant the differences found between R_1 and R_3 treatments. The interaction between quantity and irrigation frequency was not significant.

Table 3. Water use efficiency in the different treatments.

	Frequency (F)		Amount (A)			Interaction
	D	W	R_1	R_2	R_3	FxA
Efficiency (kg m^{-3})	9.6 a	8.0 b	7.8 a	8.8 ab	9.7 b	ns

The values with the same letter are statistically homogeneous in Duncan's test. ns: not significant (P □ 0.05).

Conclusions

Daily irrigations are necessary to obtain the maximum production, with a good quality of the fruit. This irrigation frequency increases the WUE. The amount of water needed to obtain the maximum productions should be the one that meets the water requirements of the plant, in that case, fruits of similar quality to those obtained with deficit irrigation may be produced.

References

Bogle, C.R. and Hartz, T.K., 1986, *HortSci.*, 21(2), 242-244.
Mannini, P., 1988, *Acta Horticulturae*, 155-161.
Tapia, L.M., Alcantar, J.J. and Vega, A., 1995, *Terra*, 13(2), 174-184.
Warriner, S.A. and Henderson, R.D., 1989, *Acta Horticulturae*, 239-242.

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TESTING OF NEAR-FEASIBLE CROPPING OPTIONS WITH DRYLAND FARMERS

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Introduction

As commonly understood, the concept of sustainability in agriculture has three dimensions: the economic, the environmental, and the social. Of these three, the economic is central. If farming is profitable, then practices that are environmentally and socially sustainable, but have an economic cost, have a chance of being implemented. The economic sustainability of dryland cropping enterprises in Australia is currently under threat due to the cost-price squeeze, stagnating productivity in some systems and an increasing regulatory environment that places restrictions on farming practices. One strategy that farmers have traditionally used to overcome such problems is diversification into new crops and cropping options. For dryland farmers the development of new crops or cropping options carries with it special risks – uncertainty in markets, unforeseen production costs, and production risk associated with climate variability. As researchers we have been exploring with dryland cropping farmers in NE Australia ways to test near-feasible cropping options. The region is characterised by high climatic variability and a diverse range of cropping choices. In a traditional mode of research and development, this feasibility of new cropping options would be tackled by conducting a program of experiments on research stations, manipulating the main agronomic variables of interest (*e.g.* sowing date, variety), and then extending the results to farmers as recommendations. This paper describes an alternative process where a participatory research approach is used, involving researchers, farmers, grain traders and commercial agronomists. The aim of this paper is to describe three examples (mungbean, canola and maize) where this approach has been carried out and the draw out the underlying themes.

Mungbean: new role for an established crop

In the northern Australian cropping region, mungbean is commonly sown as an opportunity crop, usually on low soil water after a winter cereal, and consequently has a reputation for being a low yielding, high-risk crop. Yield prospects could be improved and risks reduced if it was sown on soils with higher soil water content, for instance in spring after a winter fallow. However, there is a lack of experience and confidence in alternative roles for mungbean in the farming system. We initially identified the possible option of spring-sowing through simulation of scenarios and then went about testing the new practice with innovative farmers. This involved monitoring of the management and performance of commercial crops and comparing yields with benchmarks estimated with a model. The monitoring results in conjunction with simulation showed that discrepancies between potential and attainable yield could be traced to known constraints, such as pest damage. However, it was notable that many crops were achieving attainable yields close to the potential, indicating satisfactory control of potential biotic constraints. A remarkable result of the study was the large gap in many crops between attainable and actual yields at harvest, indicating harvest losses as an important source of the yield gap. After two years of on-farm testing, spring-sown mungbean has been shown to have a potential for high returns in the northern cropping systems (Robertson et al. 2000).

Canola: new crop with new problems

The second option involves the introduction of the winter-grown oilseed, canola, into wheat-based rotations, whose productivity is under threat from the build up of soil-borne diseases under monoculture. Canola has been shown to reduce levels of disease inoculum and boost following wheat yields. One of the major risks of growing canola involves a trade-off between sowing early to avoid end-of-season high temperatures and water deficit, and sowing later to lessen the risk of damaging frosts. The threat of frosts that cause major yield loss has been cited as a key reason why canola has not been grown widely in our region (Robertson et al. 2001). In our interactions with growers, the question of optimal time for sowing was raised, some expressed the inclination to sow early (late April to mid May), while others thought that it was best to leave sowing until later, to minimise the risk of frost damage around flowering. Simulation analysis of the long term risk of experiencing a minimum screen temperature of 0 ^{0}C or below, showed that if canola crops could finish flowering (the frost-sensitive stage of crop development) after late August, then a frost would occur in less than 15% of years. We tested this issue on-farm by sowing early three cultivars contrasting in maturity time, and we monitored phenology, biomass and grain yield and daily air temperature in the field. The consequences of the cultivar differences in susceptibility to frost were evident after a –1.4 °C frost on August 15. Follow-up simulation analysis showed that the risks of an early-flowering cultivar being frosted if sown early are quite high – about 50% for a -1°C frost and around 20% for a -2°C frost, whereas the risk of a later flowering cultivar were lower at 20% and 10%, respectively. The consequence of this experience is that new canola growers have a greater appreciation of sowing date, cultivar choice and frost: "Frost is an issue and varieties need to be chosen carefully when a sowing opportunity presents."

Maize: an established crop re-discovered

Highly variable rainfall in the maize-growing areas of NE Australia has resulted in a shift away from maize production towards crops such as sorghum and cotton. Farmer confidence has also suffered due to fluctuating market prices. There is increasing demand for maize as a feed grain and for silage from the expansion of the feedlot beef industry and intensification of dairy production. In addition, there is a demand from farmers to evaluate a wider array of summer crop options following the recent downturn in sorghum, sunflower and cotton prices, and the problems with diseases in irrigated cotton lands. Hence, there has been a re-awakening if interest in dryland maize, in a region where traditionally it has been regarded as much riskier than alternatives such as sorghum. Farmer groups in collaboration with us in 1999 used simulation analysis to identify the fact that high and reliable dryland maize yields were possible on their soil types with a full soil water profile at sowing. On the basis of these simulations, maize was then grown commercially the following season and monitored by us, the researchers. Yields were greater than 8 t/ha and benchmarking showed that these yields were close to potential for the climatic conditions that season. This experience as boosted the confidence of farmers in maize as a dryland option and the area of production has increased markedly in the subsequent three years.

Conclusions

Changed farming practice as a result of research is often hampered by the perception that research results do not conform with on-farm reality. The value of the research approach described in this paper over traditional on-station agronomic experimentation is that it allows farmers to evaluate a new agronomic practice in their own commercial situation. Monitoring by researchers provides insights into crop and soil process influencing productivity and simulation allows identification of opportunities through scenario analysis, benchmarking of crop performance and extrapolation to other soil types, seasons and management regimes (Carberry et al. 2002).

References

Carberry PS et al. 2002. Agricultural Systems (submitted).
Robertson MJ et al. 2000. Australian Journal of Agricultural Research 51:1-12.
Robertson MJ et al. 2001.10th Australian Agronomy Conference, Hobart, Tasmania.

INFLUENCE OF SIZE OF RAINFALL EVENTS ON WATER BUDGET COMPONENTS AND NITROGEN MINERALISATION

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Introduction

Power laws relating the number of events *N (s)* and their sizes *s*, ie. $N(s) \sim s^{-\tau}$, verify general scaling relations for non-equilibrium phenomena[1] and are, by definition, self-similar[2]. Theoretical and empirical studies support the notion of statistical self-similarity in the spatial and temporal variation of rainfall[3,4]. Self-similarity is a central concept in hydrological studies, e.g. floods. The implications of rainfall self-similarity for rain-driven agricultural processes have been largely unexplored.

Soil evaporation, runoff and drainage beyond the root zone need to be minimised to maximise crop water-use efficiency. Reduction of runoff and drainage can also contribute to soil conservation. Patterns of rainfall and evaporative demand, topography, soil properties and management practices all influence the relative importance of the crop's water budget components. For a given amount of rainfall, more soil evaporation and less drainage and runoff could be expected in locations or seasons with high frequency of small rainfall events. Likewise, being a process that is driven by top-soil water content, the rate of nitrogen mineralisation could be expected to increase with increasing frequency of small rainfall events.

This study tested the following hypotheses. *H1)* Power laws can be used to characterise rainfall patterns irrespective of the amount, seasonality and underlaying mechanisms of rainfall. *H2)* High τ is indicative of high frequency of small rainfall events, thus processes which depend on top-soil water content, including soil evaporation and nitrogen mineralisation, are positively associated with τ. *H3)* Runoff and drainage are negatively associated with τ.

Method

H1) Long-term rainfall records for 114 Australian locations (12-43 °S, 115-154 °E, 113 to 3437 mm year^{-1}) were split in 5 mm intervals, and lineal regression was used to fit the relationship between log *N (s)* and log *s*, where *N (s)* is the number of rainfall events, and *s* is the upper limit of each interval. *H2-3)* A simulation model (APSIM) was used to estimate the rate of nitrogen mineralisation and water budget components of wheat crops in a range of locations (n = 39, 33-36 °S, 134-147 °E) and seasons (n = 44). Fixed soil type (sandy loam) and sowing date (1 May) were assumed. The model was run with the non-limiting nitrogen option. Runoff was calculated assuming a USDA's curve number = 80.

Results

H1) Coefficients of determination of the lineal regression between log *N (s)* and log *s* ranged from 0.90 to 0.99 ($P < 0.0001$) and were independent on the total amount of rainfall. A single value of τ provided a good description of the rainfall patterns in 50 out of the 114 locations, whereas some degree of curvilinearity indicated a multidimensional fractal approach would be more suitable in the other locations[3]. A trade-off could be envisaged between the large number of parameters in multi-scaling models[4] and the practical value of a single parameter to capture agronomically relevant features of rainfall patterns, as shown below.
H2-3) Seasonal rainfall accounted for most of the variation in water budget components and N mineralisation (Fig. 1, left panels). Sites with rainfall around 350 mm/season had, for instance, a two-fold variation in frequency of drainage events, and a three-fold variation in runoff; τ accounted for part of the variation unaccounted for rainfall (Fig. 1, right). With increasing τ – ndicative of higher frequency of small rainfall events - soil evaporation and N mineralisation

were greater than expected from seasonal rainfall, whereas runoff and drainage were less than expected (Fig. 1, right).

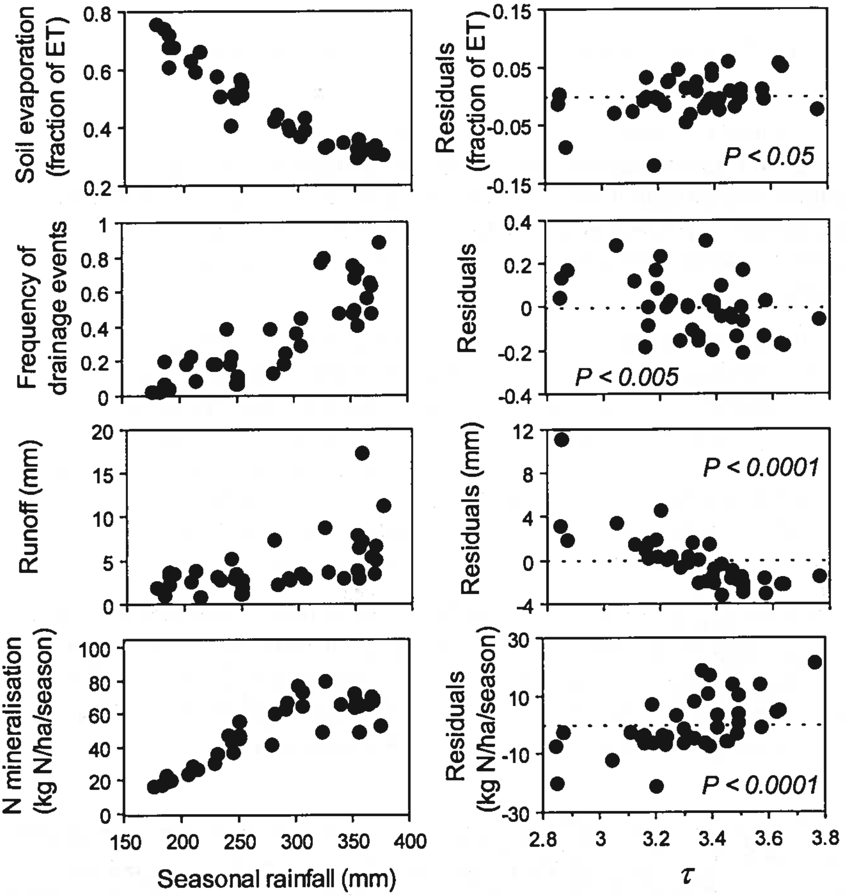

Fig. 1. Influence of amount of seasonal rainfall and relative size of rainfall events, as quantified by τ (dimensionless), on water budget components and N mineralisation of wheat crops in 39 locations.

Conclusion

Despite departure from linearity in some locations, power laws provided an agronomically meaningfully description of the frequency distribution of size of rainfall events. For a given amount of rain, more drainage and runoff, less soil evaporation, and lower mineralisation rates can be expected in locations with low τ.

References

1. Boettcher, S. & Paczuski, M. *Phys Rev Lett* **76**, 348-351 (1996).
2. Schroeder, M. *Fractal, chaos and power laws* (W.H. Freeman & Co, New York, 1991).
3. Olsson, J et al. *J Geophys Res* **98**, 23265-23274 (1993).
4. Burlando, P. & Rosso, R. *J Hydrol* **187**, 45-64 (1996).

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SOIL-PLANT WATER RELATIONS, GROWTH AND YIELD ABILITY OF LENTIL (*LENS CULINARIS* MEDIK.)

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Introduction

The role of grain legumes in the framework of Mediterranean agriculture is widely known as well as the factors that limit their productivity (Carrouee, 1995; Howieson et al., 2000). In lentil, specifically, drought escape and tolerance are both considered strategies involved in its ability to adapt to semi-arid environments where water deficit and high temperatures during the reproductive phase of growth are the main climatic conditions affecting production level. In fact, earliness, high dry matter accumulation and harvest index as well as osmoregulative ability have been found to be associated with high grain yields of the above species grown in south-western Australia and also southern Italy (Silim et al., 1993; Monti et al., 1999). However, little research has been carried out on the relative contribution of the above bio-physiological traits on the behaviour of different genotypes of the crop under drought. In this research, therefore, the adaptability and yield capacity of two contrasting lentil genotypes under rainfed conditions were analysed in terms of soil water availability, plant water status and source-sink relationships.

Methods

The experiment was carried out during the 1999-2000 growing season in the hilly area of Gallina (38°10'N., 15°45'E., 232 m a.s.l.), Reggio Calabria, southern Italy.
The early Italian landrace 'Ustica' (*microsperma*) and the late Canadian cultivar 'Laird' (*macrosperma*) were compared in a randomised-block design with three replicates. The crop was sown on 12 December in plots of 5 m^2 and subjected to appropriate agronomic management. During the crop cycle, plant samples of each plot were periodically collected and their leaf area, above ground dry biomass and its partitioning into leaves, stems, pods and seeds were determined for growth analysis. Changes in predawn osmotic water potential (ψ_π) of the samples of terminal fully expanded leaves per plot were also measured using the psychrometric method. Evapotranspiration was calculated by summing rainfall and variations in soil moisture content in the 0-0.6 m soil profile, measured gravimetrically.

Results

Weather conditions conformed to those typical of semi-arid Mediterranean regions: mean minimum and maximum air temperatures and total rainfall were 11, 18 °C and 576 mm, respectively between October and June. As expected, the duration of the crop cycle differed between genotypes as a consequence of the difference in time to flowering, which occurred at

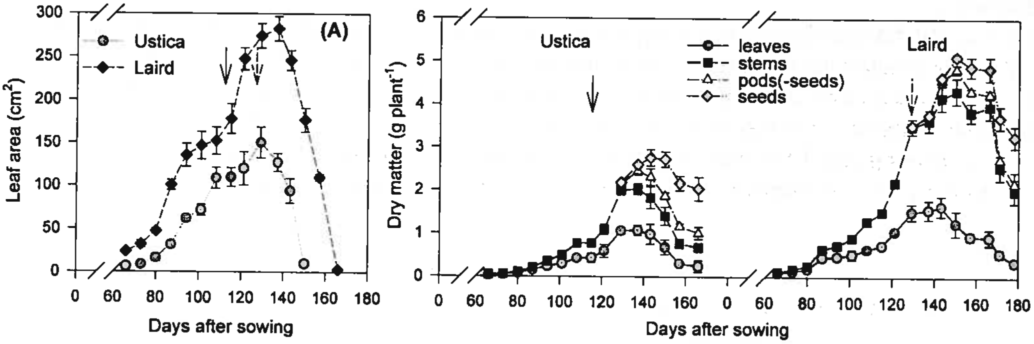

Fig. 1 – Changes in (A) leaf area and (B) dry biomass and its partitioning of lentil genotypes (means±s.e.). The arrows indicate the onset of flowering

113 and 123 DAS respectively in 'Ustica' and 'Laird'. The plant population at harvest was similar for the two cultivars, 193 m^{-2} on average.

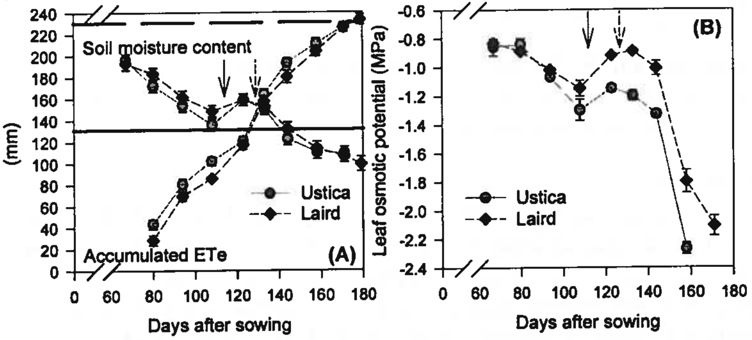

Fig. 2 – Changes in (A) soil moisture content (reference lines=field capacity and wilting point), water use and (B) leaf osmotic potential of lentil genotypes (means±s.e.). The arrows indicate the onset of flowering

Leaf area increased with time up to 129 and 137 DAS with a maximum of 150 and 283 cm^2 respectively in 'Ustica' and 'Laird', then rapidly decreased to about zero at maturity (Fig. 1, A). Total biomass had a similar time course to that of biomass, but increased up to 143 and 150 DAS reaching the highest values of 2.8 g plant^{-1} in 'Ustica' and 5.1 g plant^{-1} in 'Laird' (Fig. 1, B). Thereafter, plant dry weight of the early and late genotype declined by about 26 and 36% respectively at maturity. The dynamics of dry matter partitioning among plant structures quantitatively differed between genotypes especially for leaves and stems, whereas for pods and seeds there were mainly differences in duration. Indeed, while the duration of grain filling of 'Ustica' and 'Laird' was 37 and 41 d, their grain weight reached a similar value at maturity (1.1 g plant^{-1}, on average), although the latter accounted for 50.5 and 33.5% of the above ground biomass, respectively. Total water use was slightly higher in 'Laird' (233 mm) as a result of its greater growth cycle duration in comparison to 'Ustica' (226 mm), although different daily evapotranspiration rates were found for the two genotypes (Fig 2, A). Also the variations in soil water content were quite similar for the two cultivars. In contrast, during the early phases of growth up to 94 DAS, the genotypes had a similar predawn ψ_π (Fig 2, B). Instead, throughout the subsequent period, during reproductive development, 'Ustica' evidenced lower values of predawn ψ_π. This different behaviour of the genotypes, particularly at the lower water availability levels, was also supported by the curvilinear regression of predawn ψ_π on soil moisture content (Fig. 3).

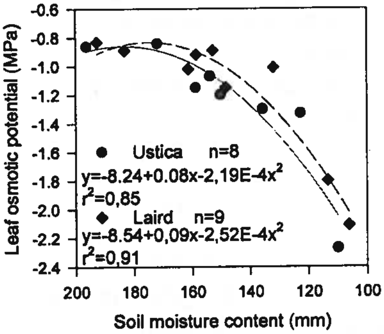

Fig. 3 – Relationship between soil moisture content and leaf osmotic potential of lentil genotypes

Conclusions

The results confirm that there was no single trait responsible for optimal agronomic performance of lentil under drought Mediterranean environments. Early flowering must be associated to adequate leaf area expansion and dry matter accumulation also during the reproductive phase of the crop cycle together with the ability of the plants to reduce their leaf osmotic potential. However, further studies of drought tolerance mechanisms are required with specific emphasis towards the behaviour of different lentil genotypes within micro and macrosperma subspecies.

References

Carrouee B., 1995. Proceedings of 2nd AEP Conference, Copenhagen, 9-13 July: 2-3
Howieson et al., 2000. Field Crops Res., 65: 107-122.
Monti et al., 1999. Atti 5° Convegno nazionale Biodiversità, Caserta, 9-10 settembre: 550-555
Silim et al., 1993. Exp. Agric., 29: 9-19

STRESS TIMING EFFECTS ON SUNFLOWER HARVEST INDEX.

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Introduction

The accurate prediction of crop yields in water-limited situations is increasingly needed as the possibility of climatic change may increase the frequency and severity of droughts even in areas where crop production is seldom limited by water deficits. Additionally, competition for water resources in the semi-arid areas demands the use of deficit irrigation strategies to reduce water consumption while increasing water productivity in agriculture. To predict crop response to limited irrigation, models of crop performance in response to water supply are needed. Crop yield is simulated in the simplest models by partitioning a fixed fraction of biomass (B) to yield, (the harvest index; HI). Empirical data support the hypothesis that HI is constant for many crops when subjected to mild to moderate water deficits (Stewart *et al.*, 1977; Fereres, 1984), even though the concept of critical periods has been very popular in the water stress literature, suggesting that yields, and therefore HI, are very sensitive to irrigation timing. The objective of this work was to quantify the effects of timing and severity of water deficits on sunflower (*Helianthus annuus* L.) harvest index (HI) in Southern Spain.

Material and Methods

The experiment was performed at the Agriculture Research Center, in Cordoba, Southern Spain (37.5° N, 4.8° W). The soil is a sandy loam, classified as a Typic Xerofluvent. Soil depth in the experimental plot was 1.5 m. Sunflower hybrid 'Arbung E-353' was sown on 7 June. Plant population was 7.1 plants m^{-2} and individual plot size was 6.3 m x 6.0 m. Nine irrigation treatments were applied in a complete randomized block design with four replicates, using a drip irrigation system. Water deficits were applied at different phenological stages in the following treatments: 100-100, 100-50, 100-0, 50-100, 50-50, 50-0, 0-100, 0-50, 0-0, where the two numbers indicate the percentage of the maximum crop evapotranspiration (ET) supplied by irrigation, before (first number) and after (second number) anthesis. Soil water content was measured before and after each irrigation using a neutron probe (Campbell Nuclear Pacific) which was previously calibrated for the experimental soil. Crop evapotranspiration (ET) for each plot was calculated using a water balance procedure. Aerial biomass and yield were determined by sampling five plants per plot at harvest.

Results

The different irrigation treatments were an effective way of inducing different levels of water stress during the pre and post-anthesis periods. Crop ET before anthesis was 211, 163 and 98 mm for the 100-x, 50-x and 0-x treatments (Table 1), and seasonal crop ET ranged between 114 and 451 mm for the 0-0 and 100-100 treatments, respectively. Harvest index (HI) was strongly affected by the irrigation treatments, ranging from 0.22 (treatments 0-0 and 100-0) to 0.42 (0-100), (Table 1). HI showed the lowest values when severe water stress occurred during the post-anthesis period, irrespective of the level of water supplied during pre-anthesis period (HI=0.22, 0.24 and 0.22, for the 100-0, 50-0 and 0-0 treatments, respectively), while HI was directly related to irrigation supply after anthesis (HI was 0.22, 0.39 and 0.42 for the 0-0, 0-50 and 0-100 treatments, respectively), (Table 1). Figure 1 depicts the response of the relative HI (HI relative to the HI of the treatment 100-100, which produced the maximum B) to reductions in dry matter production (relative B reduction) caused by the water deficits. Three distinct patterns of HI responses to water deficits emerge from Fig. 1. In the progressive stress treatments (50-50, 50-0, 0-0), the HI remained constant over a range of biomass reduction from 100 to 60 %. As water deficits reduced biomass below 60%, HI declined to less than 70 % of maximum HI for B reductions of 50 to 70 % of Bmax. When water stress was applied during the post-anthesis period, the decrease in HI occurred sooner, at B reductions of 20 to 30 % of Bmax. (Fig. 1). A third pattern was observed when water stress was applied during the pre-anthesis period and no water deficits occurred during the grain filling period. In this latter case, HI was not reduced below the maximum observed when water stress was avoided (treatment 100-100), even though the crop experienced severe water deficits during pre-anthesis (Fig. 1). Actually, HI increased by 25 % under severe water deficits in the vegetative stage relative to the value under full ET. In this latter case, biomass distribution measurements indicated that stem/leaf ratios increased with water deficits in the vegetative period. Presumably, dry matter accumulated in the stem was translocated to the grain under the favorable conditions of the post-anthesis period, thus increasing HI relative to that of the full ET treatment.

Conclusions

Our results provide a range of sunflower HI values that may be manipulated by deficit irrigation. It is apparent that deficit irrigation programs that reduce B by less than about 30% of Bmax, hardly affected HI. If water supplies are less than those required for such level of biomass production, strategies must be designed to concentrate the water deficits in pre-anthesis and to avoid water stress in the post-anthesis period.

Table 1. Average values for pre- and post-anthesis ET (mm) and for HI under the different irrigation treatments.

Treatment	100-100	100-50	100-0	50-100	50-50	50-0	0-100	0-50	0-0
ET preA	228	215	190	176	165	148	97	102	94
ET postA	223	153	82	231	128	46	165	101	20
HI	0.34	0.30	0.22	0.37	0.33	0.24	0.42	0.39	0.22

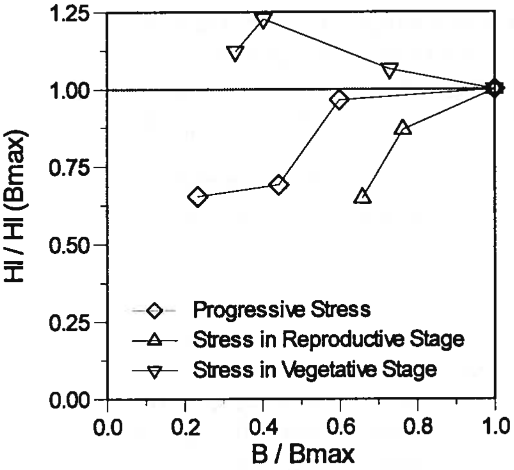

Figure 1. Responses of harvest index to reductions in biomass production due to water deficits expressed relative to maximum values observed under full ET.

References

Fereres, E. 1984 Bull. Soc. bot. Fr. 131, Actual. bot. 1984(1):17-32.

Stewart *et al.* 1977 Utah Water Lab. PRWG: 151-1, Utah USA.

ADAPTATION OF CHICKPEA TO WATER-LIMITED ENVIRONMENTS

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Introduction

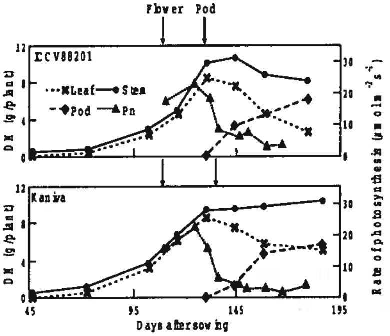
Chickpeas are grown on incoming rainfall in the mediterranean-type climates of the Mediterranean Basin and West Asia and also on stored soil moisture in the subtropical climates of South Asia. In Australia, the same cultivars are grown across this complete range of environments. In all situations chickpea is subjected to terminal drought, but may also be subjected to water deficits at any stage during the growing season. This paper reports on studies that have been conducted over several years to determine the factors involved in the adaptation of chickpea to this wide range of environments.

Methods

Studies were conducted at a low-rainfall site (annual average rainfall of 311 mm, average growing-season rainfall of 229 mm) at Merredin in Western Australia that has a Mediterranean-type climate of hot dry summers and cool wet winters. Using irrigation, rainout shelters and rainfed plots the growth, development and physiological characteristics of chickpea genotypes were followed over several years. Additionally, up to 76 genotypes of chickpea were grown at five sites in Australia from Merredin in Western Australia to Warwick in southern Queensland and seven sites in India from Gulbarga in the south to Hisar in the north. At each site, the phenological development, yield and yield components were measured over two years. Additionally, glasshouse studies have complemented the field studies.

Results

Studies at the Merredin site have shown that rainfed chickpeas fill their seed after leaf photosynthesis has decreased due to the development of water deficits (Leport *et al.*, 1998,1999). Figure 1 shows the rate of leaf photosynthesis (Pn), dry weight (DM) changes in the leaf, stems and pods of two genotypes of chickpea (ICCV88201 a small-seeded desi type and Kaniva a large-seeded kabuli type) in rainfed plots (Leport *et al.*, 1999). In both genotypes, pod development occurred up to 30 days after flowering by which time leaf photosynthesis was low. Seed development occured about 10 days after pod development (Davies *et al.*, 1999). While the pods stay green during seed filling, external gas exchange is low (Leport *et al.*, 1999, Ma *et al.*, 2001). The decrease in dry weight of leaves and stems during pod growth in Figure 1 suggests that assimilate remobilization may contribute to seed yield under terminal stress and labeling with the stable isotopes of carbon and nitrogen showed that while up to 93% of the nitrogen in the vegetative parts was transferred to the seed, only 13% of the carbon was transferred to the seed (Davies *et al.*, 2000). Subsequent glasshouse studies showed that chickpea recycled the carbon dioxide respired inside the pod wall and transferred some of this fixed carbon to the seed and that the rate of internal recycling of carbon was unaffected by the development of water deficits in the remainder of the plant (Ma *et al.*, 2001). These results were consistent with the observation that the turgor of the seed was unaffected by water deficits in the



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remainder of the plant (Shackel and Turner, 2000).

The studies with 39 genotypes of chickpea over 2 years in India showed that yields and maturity increased as the chickpeas were grown from southerly to northerly sites and that in this situation where the crop is grown primarily on stored soil moisture phenology was a key attribute influencing yield. At the southern site of Gulbarga, early flowering and early podding genotypes had higher yields than late genotypes, whereas at the northern site of Hisar, high yields were associated with late flowering and podding. (Table 1). Similar results were obtained with 72 genotypes of chickpea in Western Australia in a very dry season (131 mm growing-season rainfall) with terminal drought. However, in a similarly dry season (175 mm) in South Australia, earliness was not an advantage as rainfall was evenly distributed throughout the growing season. In this case physiological traits such as osmotic adjustment appeared to play a more significant role.

Gulbarga	*n*	Yield (t/ha)	End flower (DAS)	Maturity (DAS)	Flower phase (days)	Pod fill(days)	Filled pod (%)
High yield	8	1.1	64	94	14	24	84
Intermediate	25	0.8	71	97	19	26	80
Low yield	6	0.6	76	105	25	37	76
Hisar							
Low yield	8	2.1	141	156	60	36	32
Intermediate	25	3.1	142	159	49	38	44
High yield	6	4.2	145	162	40	38	58

Discussion

The results suggest that chickpea has several physiological and phenological characteristics that assist in the maintenance of yield in water-limited environments. Because chickpea is grown over a wide range of environments, it is unlikely that a single trait will provide adaptation to all environments and breeders need to maintain a broad germplasm base for future breeding strategies.

References

Davies, S.L. *et al.*, 2000, *Aust. J. Agric. Res.*, 51, 855-866.
Leport, L. *et al.*, 1998, *Eur. J. Agron.*, 9, 295-303.
Leport, L. *et al.*, 1999, *Eur. J. Agron.*, 11, 279-291.
Ma, Q., *et al.*, 2001, *J. Exp. Bot.*, 52, 123-131.
Shackel, K.A. *et al.*, 2000. *J. Exp. Bot.*, 51, 895-900.

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WATER AND NITROGEN MANAGEMENT IN DRIP IRRIGATED TOMATO

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Introduction

High inputs of water and N fertilizers are commonly used for tomato production in the Ebro Valley (Spain). These practices may contribute to increased production costs and the risk of groundwater pollution due to the inefficient utilization of water and N. Drip irrigation allows the use of alternative water management practices that may lead to an improvement of water and nutrients use efficiency. The goal of this study was to optimise water use and to reduce nitrate leaching in drip irrigated tomato (*Lycopersicon sculentum* Mill) cropped with plastic mulch.

Methods

A field experiment was conducted over a fine clayey soil in Valdegon (La Rioja, Spain). Tomato, cv. Brigade, was cultivated under four different irrigation strategies: large water application at planting followed by daily irrigation equal to the ET during the cropping period (T1R1), large water application at planting followed by daily irrigation equal to 80% ET (T1R2), reduced water dose and high frequency at planting followed by high frequency during the cropping period (T2R3 if water applied was 100% ET, and T2R2 if it was 80% ET). Drainage was calculated by weekly measuring the water content of the soil profile and applying the water balance equation. The soil solution at 1 m depth was extracted by porous ceramic cups and was analysed for nitrate. To evaluate nitrate leached to 1 m depth, the drainage volume was multiplied by the nitrate concentration of the soil solution at that depth. Drainage and nitrate leaching were evaluated for two different cropping periods: planting, and cropping. Water use efficiency related to yield (WUE_y) was calculated dividing tomato yield by the total amount of water applied (irrigation+yield). Leachates and soil extracts were analysed for inorganic N by the Griess-Ilosvay method (Keeney and Nelson, 1982), and plant nitrogen was determined by Kjeldahl (AOAC, 1990).

Results

Reducing the amount of water applied did not decreased tomato yield. The treatment that received the larger amount of water had less commercial fruits of a larger weight (Table 1). The higher WUE_y was obtained in T2R2 (Table 2), in which water application at planting was greatly reduced, and the amount of water applied during the cropping period was 80% of ET. Nitrate leaching for all treatments was only significant during the planting period, except for T1R1 were 27% of the total nitrate leached took place during the cropping period (Tables 3 and 4).

Table 1. Crop parameters at harvest. Within a column, means followed by the same letter are not significantly different according to Tukey test at a 0.05 probability level.

Treatments	Yield t/ha	Commercial fruit weight g/fruit	Commercial fruits fruits/m2
T1R1	112,9 b	67,1 a	168 b
T1R2	126,7 ab	58,7 b	216 a
T2R3	134,0 a	62,6 b	214 a
T2R2	121,5 ab	60,0 b	203 a

Table 2.- Water applied, crop evapotranspiration (ET), and water use efficiency related to yield (WUE_y) for the different treatments.

Treatment	Irrigation mm	Rain mm	ET mm	(Rain+Irrigation) / ET	WUE_y kg. mm^{-1}
T1R1	613,0	101,2	472,1	1,5	158,1
T1R2	527,8	101,2	476,0	1,3	201,4
T2R3	532,2	101,2	477,7	1,3	211,6
T2R2	435,5	101,2	484,0	1,1	226,4

Table 3. Initial and final inorganic-N content in the soil profile (1 m depth), and nitrate leached during the whole cropping period.

	Fertilizer	Initial		Final			
Treatment	kg N/ha	$N\text{-}NO_3^-$ kg/ha	$N\text{-}NH_4^+$ kg/ha	$N\text{-}NO_3^-$ kg/ha	$N\text{-}NH_4^+$ kg/ha	Plant-N kg/ha	$N\text{-}NO_3^-$ leached kg/ha
T1R1	50	116 ± 7	18 ± 8	37 ± 35	15 ± 4	445 ± 58	135 ± 56
T1R2	50	116 ± 7	18 ± 8	57 ± 51	17 ± 6	423 ± 40	111 ± 49
T2R3†	50	116 ± 7	18 ± 8	32 ± 8	19 ± 2	441 ± 100	--
T2R2	50	116 ± 7	18 ± 8	34 ± 23	18 ± 3	437 ± 28	51 ± 32

† It was not possible to establish the final $N\text{-}NO_3^-$ leached due to a technical problem

Table 4. Water balance and nitrate leached (1 m depth) during the planting period.

Treatment	Irrigation† (mm)	Rain (mm)	ET (mm)	Drainage† (mm)	N-NO3 leached (kg/ha)
T1R1	160,6	4,2	25	84,1	98,7 ± 73,3
T1R2	162,4	4,2	25	86,3	110,8 ± 49,3
T2R3	78,8	4,2	25	23,1	18,4 ± 8,9
T2R2	73,9	4,2	25	24,9	51,0 ± 31,7

† Irrigation started on may 13th, and drainage determination started on may 18th

Conclusions

Most of the water applied at planting was lost by percolation, probably due to the high soil permeability. Increasing frequency irrigation allow to reduce water application, maintaining yield and optimising water and nitrogen use

References

Keeney, D.R. and Nelson D.W. 1982. Nitrogen-Inorganic forms. pp.643-689. In A.L. Page (ed.) Methods of soil analysis, Part 2. Agron. Monogr. 9. ASA and SSSA, Madison, WI, USA.

AOAC. 1990. Official methods of analysis. pp. 127-129. 15th ed. Harwitte W. (ed.). Association of official analytical chemist. Washington DC, USA.

THE RELATIONSHIP BETWEEN CARBON ISOTOPE DISCRIMINATION AND YIELD IN DURUM WHEAT AS AFFECTED BY GROWING CONDITIONS

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Introduction

Carbon isotope discrimination (Δ) measured on dry mass has been proposed as a selection criterion for increasing yield in many crops, because it's an integrative measure of water use efficiency (Richards and Condon, 1993). Nevertheless, understanding how the growing environment affects the relationship between Δ and yield may be an important goal for breeding purposes (Acevedo, 1993; Richards, 1996).This study was undertaken to assess how the growing conditions affect the strength and sign of the relationship between Δ and yield.

Methods

Twelve field trials were performed from 1997 to 1999 under irrigated and rainfed conditions on four sites of Spain (two in the North, in the Ebro valley and two in the South, in Andalucía). In each trial, 25 durum wheat (*Triticum turgidum* L. var *durum*) genotypes were grown in randomised complete block design with 4 replicates and plots of 12 m^2. The agronomical practices were the usual ones in each site. At anthesis time, leaf area index (LAI) was determined by destructive sampling. Plots were harvested at ripening and grain yield (t ha^{-1}) was determined and expressed at 10% moisture level. In mature grains, δ^{13}C was determined for each plot and carbon isotope discrimination (Δ) was further calculated according to Farquhar *et al.*, (1989). For each trial water input was calculated as the sum of rainfall plus irrigation (if the case) for two periods: from sowing to anthesis and from anthesis to maturity.

Results

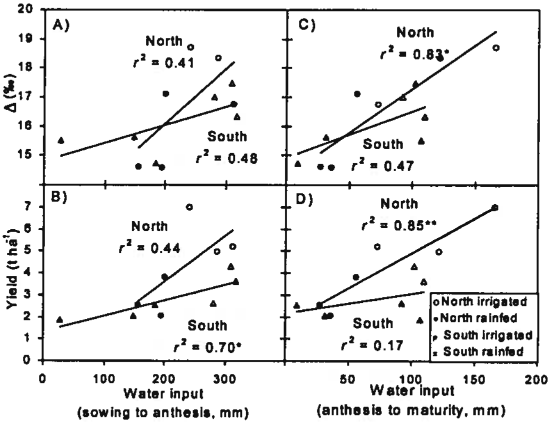
The environmental effect on grain yield and Δ was much higher than variation due to genotype. The analyses of variance (ANOVA) revealed that the site was the most significant effect. Other important sources of variation were year for yield, and the year x site interaction for Δ (Table 1).
Significant linear relationships were found between water input and yield or □ (Fig. 1), in agreement with Stewart et al. (1995). Grain yield and □ were positively correlated, with Pearson's coefficients ranging between 0.02 and 0.70 depending on the trial. Mean LAI values measured at anthesis ranged from 1.1 to 4.5, and were plotted against the Pearson's correlation coefficient of the phenotipic relationship between yield and □ within the same trial. The relationship fitted an asymptotic function and correlation coefficients were significant in the environments with LAI ≥ 2 (Fig.2)

Factor	Yield	Δ
Year	10.4	2.8
Site	59.4	55.8
Genotype	2.1	1.7
Block	2.9	1.7
Year x Site	5.7	25.9
Year x Genotype	1.3	0.9
Site x Genotype	1.8	1.1
Year x Site x Genotype	3.8	1.9

Table 1: Percentage of the sum of squares of the ANOVA. Δ: carbon isotope discrimination on mature grain.

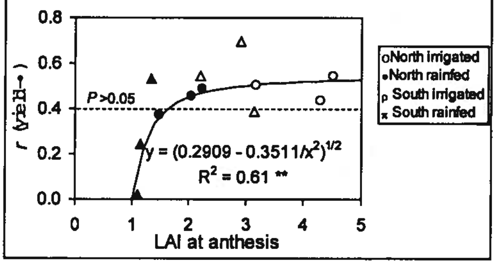
Discussion

Fig. 1. Relationship across trials between water input and both yield and carbon isotope discrimination (Δ).



Better correlation coefficients between grain yield and □ were obtained when considering separately the North and the South trials. Water input from sowing to anthesis was strongly correlated with yield in the trials conducted in the South (Fig. 1B), suggesting an important contribution of pre-anthesis reserves to fill the grain in this zone. On the other hand, in the north trials the best correlation was obtained between yield and water input from anthesis to maturity (Fig. 1D). This may indicate that in the North zone transient photosynthesis plays an important role on grain filling. This hypothesis is supported by the fact that the only significant relationship between water input and □ was attained in the North trials, when considering water input from anthesis to maturity (Fig. 1C).

Fig. 2. Relationship between LAI and the Pearson's correlation coefficient (*r*) of the relationship between yield and carbon isotope discrimination (Δ)



Under the limiting growing conditions of the South rainfed trials, a high contribution of preanthesis reserves to the grain filling may affect the isotope signature of the mature kernels, thereby explaining the weakness of this relationship.

Breeding for higher yields could be supplemented by selecting for higher □ only in favourable environments (for example under irrigation) where LAI ≥ 2 at anthesis. Contrarily, □ is not suitable as a selection criterion for the drought-prone environments.

References

Acevedo, E., 1993, In: Ehleringer, J.R., Hall, A.E., Farquhar, G.D. (ed.) pp. 399-417, Academic Press: NY.

Farquhar, G.D.; Ehleringer, J.R and Hubick, K.T., 1989,. *Ann. Rev. Plant Physiol. and Plant Mol. Biol.*, 40, 503-537.

Richards, R.A. and Concon, A.G., 1993, In: Ehleringer, J.R., Hall, A.E., Farquhar, G.D. (ed.) pp. 451-462, Academic Press: NY.

Richards, R.A., 1996, *Plant growth Regul.* 20:157-166.

Stewart, G.R.; Turnbull, M.H.; Schmidt, S. and Erskine, P.D., 1995, 13C *Aust. J. Plant Physiol.*, 22:51-55.

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CHANGES IN LAI OF DURUM WHEAT GROWN UNDER CONTRASTING WATER REGIMES IN A MEDITERRANEAN ENVIRONMENT

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Introduction

Durum wheat (*Triticum turgidum* L. var *durum*) is mainly grown under rainfed conditions in the Mediterranean region, where water stress is a major production constraint (Simane *et al.*, 1993). The importance of leaf area development through time has been stated by Ludlow and Muchow (1990), since a fast leaf area development early in the season is essential for greater biomass production and early ground cover (Van Oosterom and Acevedo, 1993). Understanding how changes in photosynthetic area may be affected by environmental conditions, particularly drought stress, could enhance the value of many agricultural experiments, and provide a basis for evolving superior high yielding varieties.

Methods

Two field experiments were conducted in two contrasting sites (irrigated and rainfed) of North-Eastern Spain in 1997. Total water received by crop was 230 mm and 408 mm in the rainfed and irrigated sites, respectively. Irrigation started in March. Eight genotypes (Altar-Aos Haurani, Jabato, Mexa, Korifla, Sebah, Waha and Vitron) were sown at a density of 550 seeds m^{-2} in a randomised complete block design, with plots of 12 m^2. Samples consisting in 50-cm-long row were taken at stages 12, 21, 31, 45, 55, 65, 75 and 87 of the Zadocks' scale (Zadocks *et al.*, 1974). Leaf area index (LAI) was determined on a sub-sample of five representative plants per sample. Data of LAI for each combination of genotype and environment were fitted to the logistic curve: $y=a+(b/e)(1+n)^{-(e+1)/e}n(e+1)^{(e+1)/e}$, where $n=\exp((x + d\ln(e) - c)/d)$ (Villegas *et al.*, 2001). In the equation of the curve, y was LAI and x was thermal time from sowing, expressed in growing degree-days. Four variables were derived and used to characterise each curve: the maximum LAI (LAI_{max}); the thermal time from sowing to LAI_{max} (D); the maximum rate of growth (R); and the time from sowing to R (T). The MANOVA command (SAS Inc., 1996) was used to analyze a set of all four variables and any subset thereof applying the methods described by Keuls and Garretsen (1982) and Rao (1973). Wilk's lambda were calculated and converted into *F*-values and the statistical significance was determined.

Results

The logistic curve used in this study provided a good fit to the LAI data obtained in the experiments. The results of the MANOVA for the variables derived from the curves are shown in Table 1. The curves of irrigated and rainfed sites differed significantly only for LAI_{max}, while genotypes did not differ in their patterns of LAI development. Given the lack of significance for the genotype effect,

Effect	Conditional set	Wilks' λ	df n1, n2	*F*	Probability	Final set
Site	LAI_{max}	0.1810	1,7	31.66	0.0008	
	D	0.9737	1,7	0.19	0.6766	
	T	0.9769	1,7	0.17	0.6965	
	R	0.8565	1,7	1.17	0.3147	
	D/LAI_{max}	0.8365	1,6	1.17	0.3204	
	T/LAI_{max}	0.9958	1,6	0.03	0.8793	
	R/LAI_{max}	0.9909	1,6	0.06	0.8221	LAI_{max}
Genotype	LAI_{max}	0.3764	7,7	1.66	0.2606	
	D	0.6461	7,7	0.55	0.7773	
	T	0.6044	7,7	0.65	0.7052	
	R	0.5304	7,7	0.89	0.5618	-

Table 1. Summary of MANOVA results

curves were re-adjusted for irrigated and rainfed sites separately by pooling together the data of all genotypes (Table 2 and Fig. 1).

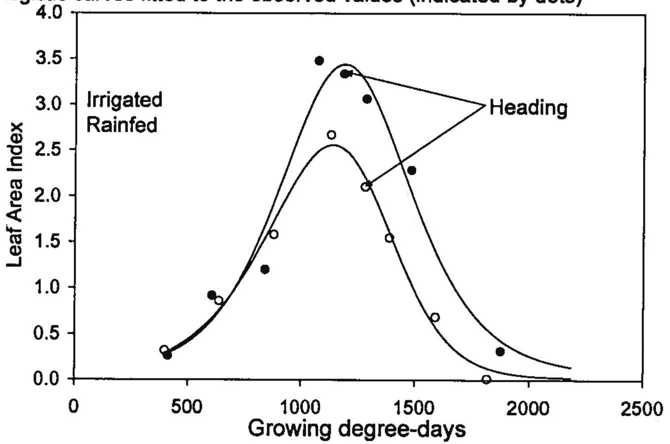
Discussion

Drought reduced $\mathrm{LAI}_{\max}$ a 26%, while T, R and D variations were not significant. The observed decrease in the photosynthetic capacity of the plant is an acclimation mechanism for surviving moisture stress by reducing transpiration (Simane *et al.*, 1993). In fact, at the beginning of the cycle, the curves of LAI were similar at both sites, the differences being evident by springtime, coinciding with the beginning of irrigation and stem elongation. $\mathrm{LAI}_{\max}$ took place at heading time under irrigation, while in the rainfed site, the LAI curve was already declining by heading time (Fig. 1). Blum *et al.* (1990) indicated that before anthesis, the reduction in LAI under stress is a consequence of impaired leaf expansion, whereas after anthesis this reduction is mainly due to the progressive leaf senescence. In our study, the early senescence of leaves under rainfed conditions seems to be a key factor explaining differences in $\mathrm{LAI}_{\max}$ between irrigated and rainfed environments.

Site	$\mathrm{LAI}_{\max}$	D (GDD)	R (GDD^{-1})	T (GDD)
Irrigated	3.45	1189	0.025	935
Rainfed	2.56	1138	0.030	885

Table 2. Estimates of the LAI curve characteristics for the two environments.

Fig. 1 - Patterns of changes in LAI during crop cycle. Lines represent logistic curves fitted to the observed values (indicated by dots)



In this study, variability induced by growing conditions was by far more important than genetic variation between genotypes.

References

Blum, A., Ramaiah, S.; Kanemasu, E.T.; Paulsen, G.M., 1990, *Field Crops Res.* 24, 67-85.
Keuls, M.; Garretsen, F., 1982, *Euphytica* 31, 51-64.
Ludlow, M.M.; Muchow, R.C., 1990, Advan. Agron. 43, 107-153.
Rao, C.R., 1973, In: Linear statistical inference and its applications, John Wiley, NY.
SAS Institute Inc., 1996, SAS/STAT™ Guide for personal computers, Cary, NC.
Simane, B.; Peacock, J.M.; Struik, P.C., 1993, *Plant Soil* 157,155-166.
Van Oosterom, E.J.; Acevedo, E., 1993, *Plant Soil* 148, 223-237.
Villegas, D.; Aparicio, N.; Blanco, R.; Royo, C., 2001, *Ann. Bot.* 617-627.
Zadocks, J.C.; Chang, T.T.; Konzak, C.F., 1974, *Weed Res.* 14, 415-421.

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CHANGES INDUCED BY A MODERNIZATION PROJECT IN AN IRRIGATION DISTRICT

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Introduction

The increasing social awareness about the scarcity of water resources demands a response from Irrigation Districts, since they are the main water users in semi arid areas. State and regional government policies have promoted irrigation modernization through specific subsidies. This work analyzes the changes on water use in a surface irrigation district that has been recently modernized maintaining the on-farm irrigation system. The modernization process has involved land tenure concentration, generalized laser leveling and the upgrading of the structures. The Bayunga Irrigation District is located in a terrace of the Aragón river (NE Spain). Water is diverted directly from the river to the conveyance system, and unused water flows back to the river. The total district area is 1,152 ha. Prior to the modernization project the area was divided in 3,411 plots. The number of plots was reduced to 985 after modernization. The discharge diverted from the river was reduced by 30 %. The current process for water delivery is based on an arranged demand scheme. The district is divided in service areas, in which only one farmer irrigates at a time, using the service discharge. In order to obtain a water allocation, the farmer must state the irrigation date, the irrigation time and the irrigated crop. The objective of this work is to analyze the hanged induced by the modernization project in terms of irrigation performance indexes: Application Efficiency (EA) and Irrigation Time (IT).

Methods

A total of 17 border and furrow irrigation evaluations (Merriam and Keller, 1978) were performed in order to characterize irrigation performance and to provide data for surface irrigation simulation (Playán et al., 2000). The observed flow depths and the advance diagrams were used in conjunction with a surface irrigation model (Strelkoff and Clemmens, 2000) to estimate infiltration parameters (Playan et al., 2000). The plots were grouped in design units. A design unit is characterized by the infiltration parameters, the supply ditch, the slope and the on-farm irrigation system (border *vs.* furrows). Data about the irrigation time, the number of seasonal irrigations an the interval between irrigations were obtained from district records. The irrigation performance before the modernization process was determined by analysis of a previous inventory report. The irrigation model SRFR 4.06 (Strelkoff and Clemmens, 2000) was applied to simulate all the design units before and after the modernization project. The GIS Geomedia Professional was used to for spatial data representation.

Results

Table 1 presents for each crop the percent acreage, the irrigation time, the number of irrigations and the interval between irrigations, for the situations before and after the modernization. The data show an increment in the acreage devoted to intensive crops (such as asparagus tomato and pepper), a decrease in the acreage devoted to corn and an increase in the alfalfa acreage. The crop distribution has therefore changed to a more economically productive one, which also implies a higher water consumption (from 5,424 m^3/ha to 5,721 m^3/ha). The number of irrigations was reduced all cases. A relevant decrease in irrigation time was observed in all crops, with an average reduction of 120 min ha^{-1} and irrigation. This is due to the increment in the irrigation discharge and to an improvement in land leveling.

Table 1. Acreage (%), irrigation time (IT), seasonal number of irrigations and interval between irrigations for the main crops and for the situations before and after the modernization project.

Crops	Before Modernization				After Modernization			
	Acreage (%)	IT (min*ha^{-1})	Nº of Irrigation	Interval (days)	Acreage (%)	IT (min*ha^{-1})	Nº of Irrigation	Interval (days)
Alfalfa					12	134	10	17
Asparagus	2				7	268	3	24
Corn	70	236	12	9	58	153	11	12
Pepper	2	273	14	8	6	151	11	8.5
Tomato	2	330	12	7	5	163	13	6
Cereals	20	309	4	22	2			

The application efficiencies (EA) obtained from the simulation of the design units for both the situations before and after the modernization project are presented in Figure 1. The left figure presents EA previous to the modernization and right side figure presents EA after modernization. In general an important improvement on the EA has been produced. The average EA passed from 57 % to 75 %. The northwest side of the District presented a slight decrease in EA due to the intensive land movement in this area.

Fig. 1. Map of Application Efficiency (EA, %) for the situations before (left) and after (right) the modernization process.

Conclusions

The modernization of the Bayunga Irrigation District involved a change in the crop distribution, with a shift to more economically profitable productions. This has resulted in a more water consumptive alternative. The performance irrigation indexes were improved: the average Irrigation Time decreased by 120 min ha^{-1} and irrigation, and the Application Efficiency of an individual irrigation improved on the average 18 points.

References

Merriam JL and Keller J (1978). Farm irrigation system evaluation: a guide for management. Logan, Utah. Utah State University, USA, 271 pp.

Playán E., Slatni A., Castillo R., Faci J.M.(2000). A case study for irrigation modernization: II Scenario analysis. Agricultural Water Management 42(3): 335-354.

Strelkoff, T. S. (2000). SRFR 4.06 a computer program for simulating flow in surface irrigation. Furrows-basins-borders. Phoenix, AZ, U.S. Water Conservation Laboratory, USDA/ARS.

Crop physiology, production and Management

EFFECTS OF SOWING DATE ON GROWTH AND YIELD OF CHICKPEA *CICER ARIETINUM* L. UNDER MEDITERRANEAN CLIMATIC CONDITIONS.

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Introduction

Tradicional sowing of chickpea (*Cicer arietinum, L.)* in the mediterrean area is carried out in spring due to the sensitivity to Ascochyta blight (Ascochyta rabiei) of the local available cultivars. However, mild winters and autumn-spring rainfalls are more suitable for the development of crops sown in winter. The availability of chickpea cultivars from ICARDA (Syria) resistant to cold and to Ascochyta blight opens the possibility of a winter crop. For that, it is necessary to evaluate new cultivars, and the optimum sowing date and to adapt cropping techniques to this new production system. The influence of sowing date on growth and yield of two chickpeas cultivars resistant to Acochyta blight obtained by Koipesol company were estudied in the south of Spain.

Materials and methods

During two years 1998/99 and 1999/00, 2 cultivars (Athenas and Krema) from Koipesol, both resistant to *Ascochyta blight*, were tested on 2 different sowing dates (December and March). The design was a split-plot with four replications, the sowing date being the main plot and the cultivar the sub-plot. The elemental plot consisted of 12 rows of 12 m length with a separation of 30 cm between lines. During the cropping period, 0,5 m^2 plant samples were taken every two weeks to determine dry matter accumulation and distribution (g m^{-2} of leaves, branches, flowers and pods), and the number of leaves, branches, pods per plant and the number of seeds per pod. The leaf area was also measured in orden to calculate leaf area index (LAI) and leaf area duration (LAD). In addition, during harvesting, yield components and the harvest index (HI) were determined. The first year had a cold winter, with frecuent and small rainfall events, with a total of 350 mm. The winter was milder and rainfall more abundant (more than 600 mm) during the second year.

Results

Date of sowing has a profound influence on the crop performance because it determines the environmental conditions to which the various phenological stages of the crop will be exposed. Frost during emergence and the vegetation phase of the crop sown in December neither damaged nor caused plant loss in either of the two cultivars. Indeed, winter sowing produced higher plant densities than the spring ones given the better water regime of the soil during germination. The duration of both cultivars cycle, especially the vegetacion and flowering periods was shorter for the later sowing date (fig.1). LAI and LAD indexes and total dry matter were higher for the earlier sowing date. This indicates that the winter sowing has a higher yield potencial. The Athenas cultivar flowered 1 or 2 days before the Krema one, with no other significant difference in its cycle. Krema had higher acumulation of dry matter than Athenas in winter sowings without significant differences. From this, it is possible to deduce that Krema is more adapted to winter sowings than to spring sowings (Table 1). In the two years surveyed, there were significant differences between yield in December and March (536 vs 14 and 2892 vs 1460 kg ha^{-1} for the first and second year, respectively. Similar results have been found by Kamal (1988) in Morroco. The relative advantage of winter sowings becomes increasingly more important in low yielding enviroments and as the amount of rainfall declines. There were significant differences in harvest index (HI) of the different sowing dates, with values between 57,75 and 30,87) for winter and spring sowings, respectively.

Conclusions

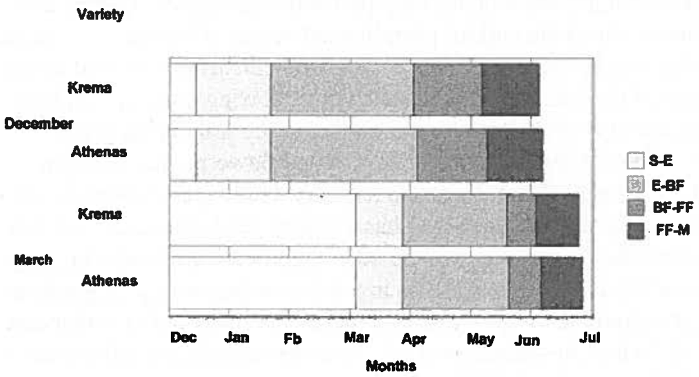
It is possible to conclude that in the south of Spain, the advance of sowing date to winter from tradicional spring sowing is possible because of the availability of Ascochyta blight resistant and cold tolerant cultivars. This promises almost a 100% yield increase, higher water use efficiency and permits the growing of chickpeas in areas where rainfall is insufficient for a spring sowing crop. Similar results have been found by Saxena (1987, 1990) in Syria, R. Khanna.Chopra and S.K.Singh (1987) in the India and K.B. Singh and M.V. Saxena (1996) in Syria.

Table 1. Grain Yield, Harvest Index (HI) and the number of pods per plant in two chickpea cultivars according to sowing dates during 1990/00

Sowing Date	Cultivar	Yield kg ha^{-1}	HI	Pods/plant
December	Athenas	2768,6	54,25	31,39
	Krema	3017	61,25	35,27
	Mean	2892,8	57,75	33,33
March	Athenas	1417,7	33,25	24,60
	Krema	1252,8	28,50	20,45
	Mean	1335,2	30,87	22,52
Mean		2114,1	44,30	27,93

Signification			
S. Date	*	*	NS
LSD (0,05)	92,91	11,70	
Variety	NS	NS	NS
LSD (0,05)			
Interaction	NS	NS	NS
LSD (0,05)			
	C. V. %		
Sowing Date	27,62	16,59	40,48
Variety	33,90	15,23	60,48

Fig. Physiological stage of development in relation on sowing date of chickpea



References

Kamal M. 1988 Potencial for winter chickpea in Morocco. 175-180 in summerfield (ed). World Crops: Cool season food legumes.

Khanna-Chopra and S.k. Sinha. 1987. Chickpea: physiological aspect of growth and yield. 163-87. in M.C.Saxena and K.B. Singh (ed). The Chickpea.

Saxena M.C. 1990. Option Mediterraneennes. Seriea:N° 9. 17-24

Singh K.B. and M.C. Saxena 1996. Winter chickpea in mediterranean Type Environments. ICARDA. pp 39.

FIELD RESPONSE OF YOUNG OLIVE TREES (CV. ARBEQUINA) TO SOIL SALINITY: GROWTH, LEAF ION CONCENTRATIONS AND OIL QUALITY

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Introduction

Irrigated olive orchards are rapidly increasing in Spain and, in particular, in the middle Ebro river basin. Although the potential yields achievable in these intensive plantations are high, they could be impaired by the typical existence of salt-affected soils in a significant proportion of these arid and semiarid areas. However, the real impact of salinity on olive yield and oil quality is uncertain, since their salinity tolerance parameters have not been quantitatively defined under field conditions. Thus, FAO classifies olive qualitatively as a "moderately tolerant crop" (i.e., threshold saturation extract electrical conductivity, ECe_{thr} = 4-6 dS m^{-1}), and various authors have indicated that the long-term effects of salinity on field-growing olives are yet unknown. This work analyzes the 3-years response to soil salinity of growth, leaf ion concentrations and oil quality of young olive trees (*Olea europaea* L. cv. Arbequina) grown in a salt-affected field.

Methods

The experimental plot is located in the middle Ebro river basin (Aragón, NE Spain) and pertains to the Monegros-Flumen irrigation district. The 1-ha field is 250 × 40 m and was selected because of the existence of a soil salinity gradient along it. The one-year old olive trees were planted in spring-1997 with a planting distance of 4 x 1.8 m (i.e., 1400 trees ha^{-1}). Seventy control trees were selected in spring-1999 on the basis of their different heights and root-zone soil salinity values (i.e., apparent ECa) measured with an EM38 sensor.

The trunk diameter and the root-zone ECa were measured five times during may-november 1999. The ECa readings at 25 °C were converted into ECe (0-30 cm soil depth) with the appropriate calibration equations. Twenty apical leaves were sampled in august in each of 54 control trees, dried for 48 h at 65 °C, finely ground and analyzed for Cl^- (coulombic tritation), and Na^+ and K^+ (atomic absorption spectroscopy). A similar sampling strategy was performed in 2000 and 2001 (i.e., four samplings per year for trunk diameter and ECa readings, various soil samplings for ECa-ECe (0-50 cm soil depth) calibrations, and one sampling in summer for leaf ion concentrations). Since some plants died during the study period, only 59 and 42 olive trees were controlled in 2000 and 2001, respectively. The average root-zone ECe and the coefficient of variation (in parenthesis) of the control trees were 6.9 dS m^{-1} (53%) in 1999, 5.2 dS m^{-1} (54%) in 2000, and 4.5 dS m^{-1} (42%) in 2001.

The fruits of each control tree were sampled and weighted at the end of each year. The olive oil was extracted by the Abencor method from composite fruits taken in trees exposed to low, medium and high soil salinity values. Twenty seven chemical parameters were determined following EU regulations Nº 2568/91 and Nº 183/93.

Results

In addition to salinity, the trees were exposed to other stresses such as sodicity, waterlogging and shallow watertables. In consequence, the observations taken for the establishment of the salinity response functions were rather scatter. For this reason, we fitted them to the "threshold-slope" Maas and Hoffman model using the upper-envelope eye-fitting approach. Figure 1, where the observations have been deleted for simplicity, shows the response functions of the annual trunk diameter growth (TDG, given in percent of the annual maximum), leaf Cl^- and leaf Na^+ concentrations against soil salinity (soil saturation extract, ECe) for years 1999 to 2001.

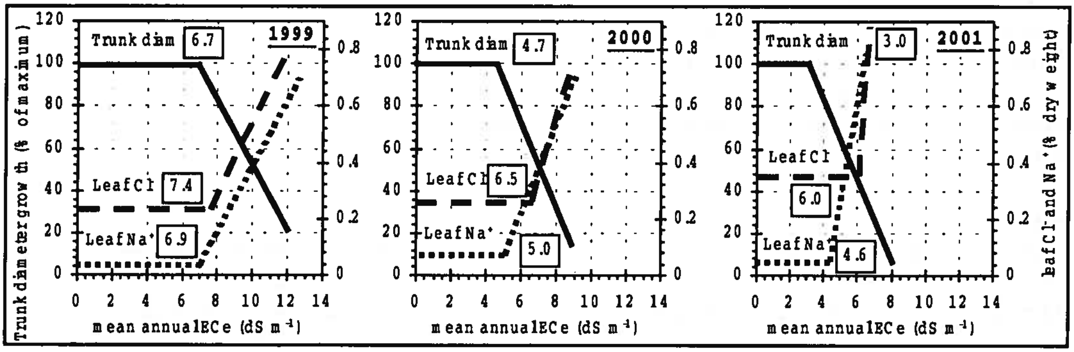

Figure 1. "Threshold-slope" fitting of the annual growth in trunk diameter and leaf Cl^- and Na^+ concentrations against mean annual soil salinity (ECe) measured in years 1999-2001. Numbers within squares are the eye-fitted estimated ECe threshold (ECe_{thr}) values.

The ECe_{thr} of the TDG was high in 1999 ($ECe_{thr} = 6.7$ dS m^{-1}), but decreased with time to a low value of 3 dS m^{-1} in 2001. A similar trend was observed in the ECe_{thr} of leaf Cl^- and Na^+. The ECe_{thr} of TDG were closer to the ECe_{thr} of leaf Na^+ than to the ECe_{thr} of leaf Cl^- (Fig. 1). Leaf Cl^- was much higher than leaf Na^+ at low salinity (i.e., average leaf Cl^- = 0.28% against average leaf Na^+ = 0.06% for ECe < 3 dS m^{-1}), but they were similar at high salinity (ECe > 5.5 dS m^{-1}) (i.e., average values of 0.44% and 0.50% for Cl^- and Na^+). Average leaf K^+ were 1.2% (low ECe) and 1.0% (high ECe), and the K^+/Na^+ ratios were 25 (low ECe) and 4 (high ECe).

Table 2 shows the values of some relevant chemical parameters measured in the extracted oils of olive trees subject to low (Lo), medium (Me) and high (Hi) soil salinity values. None of this and the remaining 20 chemical parameters analyzed were significantly affected by salinity.

Experimental year	1999			2000			2001		
Soil salinity (ECe, dS m^{-1})	Lo (1.7)	Me (6.3)	Hi (7.5)	Lo (2.2)	Me (4.9)	Hi (6.1)	Lo (1.4)	Me (3.7)	Hi (6.4)
Parameter									
Oil content (% dry matter)	44.0	46.1	50.5	42.9	49.4	45.6	46.5	42	45.7
Acidity degree (% oleic)	0.10	0.12	0.12	0.60	0.40	0.20	0.08	0.07	0.10
Polyphenols (mg Kg^{-1})	312	352	303	93	127	121	198	275	431
Oleic, $C_{18:1}$ (%)	73.1	72.5	71.9	71.5	70.9	71.5	73.8	72.8	70.9
Linoleic, $C_{18:2}$ (%)	9.2	9.2	9.7	9.0	10.1	9.5	7.4	8.4	10.1
Linolenic, $C_{18:3}$ (%)	0.6	0.6	0.6	0.6	0.6	0.7	0.5	0.6	0.6
Total sterols (mg Kg^{-1})	1399	1563	1338	1359	1530	1627	1497	1314	1589

Table 2. Chemical parameters measured in oils extracted from olive trees exposed to low (Lo), medium (Me) and high (Hi) soil salinity values in years 1999, 2000 and 2001.

Conclusions

The salinity tolerance of young olive trees decreased by more than 50% in the 1999-2001 studied years, indicating a decline in tolerance with age and time of exposure to salts. Leaf Na^+ was much lower than leaf Cl^- at low salinity values, but increased more with increases in soil salinity. Leaf Na^+ ECe_{thr} were closer to trunk growth ECe_{thr} than leaf Cl^- ECe_{thr}, suggesting that the salinity tolerance of the Arbequina olives and its decline with time were primarily determined by the accumulation of Na^+ in the leaves. The oil chemical parameters were not affected by soil salinity, and all the extracted oils were classified as "extra virgin oils" independently of salinity.

RELIABLE CHARACTERISATION OF PEST POPULATIONS IS REQUIRED TO DEVELOP INTEGRATED PEST MANAGEMENT STRATEGIES. CASE STUDY OF BLACKLEG DISEASE IN OILSEED RAPE CROPS.

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Introduction

Making the transition to sustainable agriculture requires the development of Integrated Pest Management (IPM) strategies. Research programs aimed at analysing the effects of cultural practices on pest development require reliable assessments of pest populations. Prior to any research program, methodological studies should be carried out to provide useful guidelines for pest characterisation. An example of this principle is given in this paper on blackleg, one of the most serious diseases affecting oilseed rape world-wide (West, 2001). First, transmissibility and repeatability of the visual method of observation were assessed. Due to uncertainty related to the effects of aerial dispersion of the disease on the spatial structure of the symptoms in a field, a geostatistical study was then carried out to provide guidelines for plant sampling. Lastly, a mathematical study was carried out to facilitate the definition of sample size adapted to the precision required for disease assessment.

Methods

In France, crown cankers caused by *Leptosphaeria maculans* are generally assessed at crop maturity, by grading plants according to six severity classes after sectioning the plants at crown level. The classes considered are: 1, healthy plant, no visible lesion; 2, 0-5% of the cross-section infected (discolored); 3, 5-50% of the cross-section infected (discolored); 4, 50-75% of the cross-section infected (discolored); 5, 75-100% of the section infected (discolored); 6, section without any living tissue, plant lodged or broken at crown level during sampling (Aubertot et al., 2002). A disease index summarises the observed severity class distribution. It is calculated as follows: $DI = \sum_{i=2}^{6}\left[2(i-2)+1\right]n_i \Big/ \sum_{i=1}^{6} n_i$ where n_i is the number of plants in category i. DI increases with crown canker severity, starting from 0 for healthy plants to 9 for completely lodged plants.

An experiment was carried out in 1999/2000 at the INRA Experimental Centre of Grignon (France) to test whether the method used to assess *L. maculans* crown canker is transmissible and repeatable, and to characterise the spatial distribution of the disease in a field. Samples of 120 plants were collected according to a square grid with a 3.3 m lag in nine plots (51 x 30 m) at crop maturity. Each sampled plant was labeled individually. Two observers rated the plants independently twice at intervals ranging from a half day to two days. Between two observations, plants were stored at 4°C in order to prevent the symptom from progressing. The variable analysed was the difference between two crown canker classes of the same plant (pairwise comparison). Spatial distribution of the disease was analyzed by mapping and by a geostatistical algorithm (Aubertot et al., 2002). The principle of the method consisted in comparing an observed statistic which describes aggregation for each possible distance and direction to expected values computed for 1000 simulated plots containing the same plants distributed spatially under the assumption of randomness.

At last, a relationship between the sample size and the margin of error E on DI at confidence level p was formulated and a sensitivity analysis of the relationship was performed.

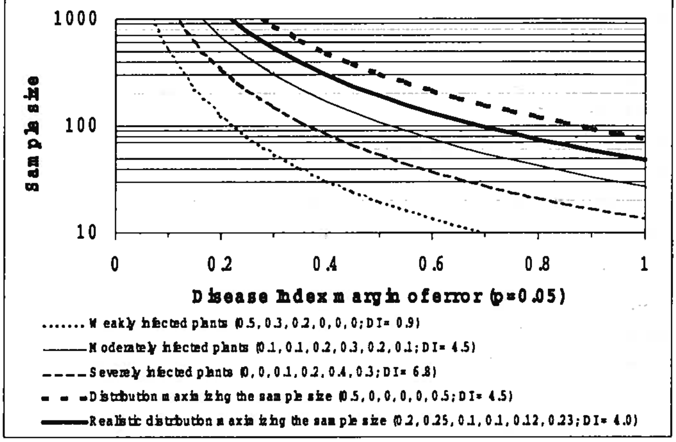
Results

The classes given by the two observers for the same plants were the same or differed by only one class in 96% of cases (plants were graded with exactly the same score in 54% of cases). The method was considered transmissible, though a slight "observer effect" was apparent. The classes assigned by an observer to the same plants at different moments were the same or differed only by one class in 95% of cases (plants were graded with the same score in 57% of cases). The crown canker assessment was repeatable for each observer.

Examination of spatial data maps did not provide strong evidence for departure from randomness. This was confirmed by the geostatistical analysis. Nevertheless, one plot appeared to be slightly structured according to a lateral gradient. For this plot, typical distances for correlation lower than expected under the assumption of randomness ranged from 18 to 43 m.

Figure 1 presents the determination of sample size as a function of the level of precision required defined by the margin of error on *DI,* for several distributions. The first six numbers in the parenthesis are the proportions associated to each crown canker severity class defined above. Sample size is inversely proportional to the squared disease index margin of error. It can be seen that disease distribution greatly influences the sample size required. This implies that sample size cannot be determined beforehand in order to attain a given precision. Conversely, for a given sample size, the precision on DI will depend on the severity of the disease.

Fig.1 Sample size as a function of DI margin of error



Discussion

The method of observation is transmissible and repeatable. The spatial analysis provided guidelines for sampling. First, the field analysed should be divided into non-overlapping 10 x 10 m sections to prevent any sampling bias due to the possible spatial structure of the disease within the field. Then, the total number of plants to be sampled should be allocated among these sections. The relationship between sample size and margin of error *E* on the disease index did not result in the recommendation of a "universal" sample size. Indeed, the precision required may differ as a function of the objectives of the experiment considered. Moreover, it is strongly affected by the distribution of the disease.

Each experimental approach may require the adaptation of pest assessment procedures as a function of its specific objectives, pest characteristics, the precision required and available resources. This is true not only for research programs, but also for formulating Integrated Pest Management strategies that require periodic observations of the crop and related pests. The tools presented may contribute to this end.

References

Aubertot JN, Schott JJ, Penaud A, Brun H, Doré T. 2002. How can crown canker caused by *Leptosphaeria maculans* be assessed in an oilseed rape field? Submitted to Plant Disease.

West JS, Kharbanda PD, Barbetti MJ, Fitt BDL. 2001. Epidemiology and management of *Leptosphaeria maculans* (phoma stem canker) on oilseed rape in Australia, Canada and Europe. Plant Pathol. 50: 10-27.

RESPONSE OF SUGAR SNAP PEA TO SEED DENSITY IN THE EBRO VALLEY

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Introduction

Sugar snap pea (*Pisum sativum* var. *macrocarpon* Ser.) is a legume whose tender pods are used for human consumption. These edible pods are a highly regarded vegetable because of their sweet flavour and their dietetic fibre content (Ron, 2001). The main production centres of this crop have traditionally been the United States, Guatemala, and Zimbabwe. However, in the last few years, the introduction of this crop in the midlands of the Ebro valley, in which the sugar snap pea has not been traditionally cultivated, is being evaluated with great interest. This is with the aim of supplying agro-food companies of the area with vegetable raw material.

Moreover, this short-cycle spring crop is of great interest for the diversification of the typically irrigated land rotations, as well as for offering variety in semi-elaborated agro-food products. At an industrial level, its production needs to be highly mechanised with good methodical grouping as per maturity of pods.

In peas, just as in other crops such as tomato and green beans, the density of sowing can affect different parameters of the crop, such as yield and production homogeneity. However, Meadley and Milbourn (1970) found no yield differences in crops of Dark Skinned Perfection green-shell peas sown at 43, 97 or 172 seeds m^{-2}.

In this study different sowing densities of the sugar snap pea crop, were evaluated for their subsequent industrial processing, in the midlands of the Ebro valley.

Methods

Sugar snap pea seeds of the commercial variety "Sugar Boys" were used. Three field trials were carried out on irrigated land plots situated in the municipal district of Villafranca (Navarra, Spain) for three consecutive years (1998, 1999 and 2000). The sowing was performed with a pneumatic precision drill. The crop management was identical for all trials. The sowing doses tested were 75, 105, and 125 seeds m^{-2} in the first year, 75, 105, and 125 seeds m^{-2} in 1999 and 105, 125, and 150 seeds m^{-2} in the year 2000. Four replicates of each treatment were carried out for each trial.

Continuous follow-up of the crop was performed throughout the crop duration. A thermal integral model was applied. This was calculated as a basic thermal integral, in which the minimal biological temperature of the crop is subtracted from the average daily temperature. In order to be able to calculate the average temperature, in the days in which the maximum daily temperature exceeded the maximum biological temperature, the maximum daily temperature was substituted by the following expression: $\left[t_{Mbiol} - \left(t_{max} - t_{Mbiol}\right)\right]$.

At the time of harvesting, 1 m^2 of each of the four replicates of each treatment was harvested by hand and yield components were determined.

Results

The results of the evaluated crop parameters are shown in Table 1. The biomass yield was significantly higher in the 1999 trial (seed density: 125 seeds m^{-2}). Pod yield did not show significant variations when using different sowing doses in the respective years. With respect to the number of plants present in each surface unit, there were significant differences in the three years under study. The number of pods per square meter was different only in 1999, being higher after using the highest densities. The pod maturity index was not affected by the seed densities tested, in any of the years studied.

Table 1 - Mean data of yield components.

Year	Seeds m^{-2}	Biomass ($g\ m^{-2}$)	Pods ($g\ m^{-2}$)	Number of plants m^{-2}	Number of pods m^{-2}	Maturity index
1998	75	2.067 NS	1.027 NS	73 b	-	1.29
	105	2.002 NS	1.003 NS	96 a	-	1.26
	125	1.998 NS	987 NS	110 a	-	1.20
1999	75	3.999 b†	1.948 NS	69 c	499 b	1.47
	105	3.906 b	1.896 NS	89 b	501 a	1.44
	125	4.752 a	2.323 NS	111 a	593 a	1.40
2000	105	4.011 NS	1.585 NS	94 b	438 NS	1.43
	125	3.978 NS	1.507 NS	104 b	409 NS	1.44
	150	4.109 NS	1.570 NS	129 a	478 NS	1.51

† Means followed by a common letter within a column do not differ significantly at the 0.05 probability level according to Student-Newman-Keuls Test.
NS: Non-significance.

Regarding production, it should be stressed that pod yield was distributed in a higher number of pod-bearing nodes at the lowest densities, and in a lower number of pod-bearing nodes at the highest densities. This had been detected in field observations, in particular during flowering, since after using the highest densities, flowering finished earlier than when sowing at lower densities.

As regards to determination of the quality of the harvested product, the homogeneity of the pod size was evaluated. More homogeneity was observed after treatments with the highest densities. Table 2 shows general data on the cultivation cycle for the three trials performed.

Table 2 - Time interval between the sowing date and the flowering and harvesting date. Values of thermal integral.

Year	Sowing date	Number of days sowing-flowering	Number of days flowering-harvesting	Crop duration (days)	Thermal integral (heat units)
1998	30 March	64	18	82	861
1999	1 April	56	20	76	843
2000	27 March	61	19	80	826

Conclusions

The sowing density of the sugar snap pea, between 75 and 150 seeds m^{-2} did not affect either the crop yield nor the pod maturity index. However, it did affect crop homogeneity and the number of pod-bearing nodes in which the production was distributed. The less dense the sowing, the longer the flowering period.

References

Meadley J.T. and Milbourn G.M., 1970. The growth of vining peas II. The effect of density of planting. *Journal Agricultural Science*. Cambridge 74, 273-278.

Ron A.M., 2001. In *La Horticultura Española*. Ed. Sociedad Española de Ciencias Hortícolas. Reus, 491 pp.

RESPONSE OF DIFFERENT CULTIVARS OF SUGAR SNAP PEA GROWN IN THE EBRO VALLEY

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Introduction

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In this study, different commercial cultivars of the sugar snap pea crop are evaluated with the aim of identifying yield components, crop duration and thermal integral of each cultivar in the midlands of the Ebro Valley, for their subsequent industrial processing.

Methods

Different sugar snap pea cultivars were tested. Two field trials were carried out on irrigated land plots located in the municipal district of Villafranca (Navarra, Spain) for two consecutive years (1999 and 2000). The sowing was performed with a pneumatic precision drill at a dose of 125 seeds m^{-2}. The crop management was identical for both trials. The commercial cultivars used were "Sugar Print", "Sugar Sweet", "Sugar Boys", "Sugar Luv", "Sugar Lady" and "Sugar King". Four replicates of each treatment were carried out in test.

At maturity, 1 m^2 of each of the four replicates of each treatment was harvested by hand. Yield components studies were determined and the characteristics of the crop duration of each cultivar were studied. A thermal integral model was applied. This was calculated as a basic thermal integral, in which the minimal biological temperature of the crop is subtracted from the average daily temperature. In order to be able to calculate the average temperature, on the days in which the maximum daily temperature exceeded the maximum biological temperature, the maximum daily temperature was substituted by the following expression: $\left[t_{Mbiol} - \left(t_{max} - t_{Mbiol}\right)\right]$.

Results

Results of the evaluated production parameters are shown in Table 1. "Sugar Boys" was one of the most productive cultivars in both trials, and "Sugar Sweet" was the less productive cultivar in both years. As for the number of plants present per square meter, the results of both years were different, probably due to the different germination capacities of the seeds in each year. "Sugar Boys" and "Sugar Luv" produced the highest number of pods per square meter in both years. Table 2 shows general data on the crop duration of each cultivar and thermal integral for the two trials carried out.

Table 1 - Mean data of yield components.

Year	Cultivar	Biomass (g m^{-2})	Pods (g m^{-2})	Number of plants m^{-2}	Number of pods m^{-2}	Maturity index
1999	Sugar Sprint	2.176 ab[†]	968 ab	92 b	326 a	1.31
	Sugar Sweet	1.801 b	709 c	80 c	217 c	1.25
	Sugar Boys	2.925 a	1.201 a	94 b	346 a	1.28
	Sugar Luv	2.138 ab	901 bc	95 b	299 a	1.23
	Sugar Lady	2.427 ab	1.035 ab	90 b	281 ab	1.20
	Sugar King	2.644 a	1.072 ab	101 a	307 a	1.17
2000	Sugar Sprint	3.240 NS	796 c	102 ab	249 c	1.04
	Sugar Sweet	3.328 NS	865 c	97 ab	284 bc	1.05
	Sugar Boys	3.704 NS	1.325 a	105 ab	419 a	1.28
	Sugar Luv	3.678 NS	1.288 a	111 a	430 a	1.13
	Sugar Lady	3.783 NS	1.237 a	93 b	311 bc	1.32
	Sugar King	3.454 NS	1.059 b	95 ab	355 b	1.11

[†] Means followed by a common letter within a column do not differ significantly at the 0.05 probability level according to Student-Newman-Keuls Test.
NS: Non-significance.

Table 2 - Time interval between the sowing date and the flowering and harvesting date. Values of thermal integral.

Year	Cultivar	Sowing date	Number of days sowing-flowering	Number of days flowering-harvesting	Crop duration (days)	Thermal integral (heat units)
1999	Sugar Sprint	6 May	42	15	57	793
	Sugar Sweet		44	15	59	822
	Sugar Boys		45	16	61	854
	Sugar Luv		39	14	64	903
	Sugar Lady		39	14	64	903
	Sugar King		39	14	67	936
2000	Sugar Sprint	15 April	42	23	65	787
	Sugar Sweet		44	21	65	787
	Sugar Boys		50	19	69	849
	Sugar Luv		52	19	71	876
	Sugar Lady		52	17	69	849
	Sugar King		53	18	71	876

"Sugar Sprint" and "Sugar Sweet" cultivars presented the earliest characteristics in the two years of the tests. They had the shortest crop duration of all cultivars. In late sowings, the period between flowering and harvesting was shorter than in earlier sowings. The cumulative heat units in each year were similar for cultivars "Sugar Sprint", "Sugar Sweet" and "Sugar Boys". The "Sugar Lady" cultivar tested in the year 2000 was harvested before its optimum time of harvesting, which may explain the slight deviation in the data shown above.

Conclusions

The results obtained could be used as a tool for programming the sowing of different cultivars based on the production programme established for an agro-food company.

References

Ron A.M., 2001. In *La Horticultura Española*. Ed. Sociedad Española de Ciencias Hortícolas. Reus, 491 pp.

Summerfield R.J., Ellis R.H., Roberts E.H., Qi A., 1992. *1st European Conference on Grain Legumes*, Angers, France.

LEAF AREA INDEX RELATIONSHIPS IN WINTER WHEAT CULTIVARS I. EFFECTS OF SOWING DENSITY

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Introduction

Many studies investigated winter wheat canopy (Fotyma et al., 1997; Bindraban, 1999; Heidmann et al., 2000) and associated plant physiology, but canopy - in our case leaf area as main photosynthesis acceptor may be changed by new genotypes and changeable production system. Due to past difficulties of measurements of numerous small leaves of wheat, in literature exists a lack of data about LAI as affected by different sowing densities. With cultivars spread in Slovenia, the effect of sowing densities on LAI changes and yield formation and correlations were studied, specially because increasing LAI may decrease net assimilation rate depending on plant morphology and decrease light interception (Karimi and Siddique, 1991; Sharma et al., 1994).

Methods

A field experiment was conducted on sandy loam in Maribor, Slovenia (43° 34'N, 15° 38'E) the Podravje area (north-east of Slovenia with 40-year long term rainfall 1045 mm) in 1997/98. In our experiment climatic circumstances did not vary in comparison with long term period, except a small shortage of water in May and warmer July (20.7° C) than long term average (20.3° C).

The experimental design was a randomised complete block with treatments arranged as split plot design (Latin rectangle) with four replications. 7 winter wheat cultivars spread in Slovenia and four sowing rates (Table 1) were performed. Investigated cultivars differed in chlorophyll content in the leaves, grain yield and percentage of crude protein in the kernels (Bavec and Bavec, 2001). The dimension of each subplot was 5 x 2 m. Seeds were drilled using an eight-row plot seeder with 12-cm row spacing. Sowing took place in mid October (optimal for this area). Common agriculture practices were used. Yield was harvested with a plot harvester in the mid of July.

10 plants per plot were collected from the middle of each plot at stages EC 70 and EC 80. The individual green leaf areas were measured using a personal computer and a scanner, which enabled counting the number of black dots on the screening picture of leaves and determing leaf area (Bavec and Bavec, 2002). In EC 80 stage 10 plants and their parts per plot were oven-dried for 3 days at 70° C. Total plant dry matter and dry matter of spikes, stems, and leaves were calculated. Grain yield was calculated on 14% of moisture in kernels.

Analysis of variance (ANOVA) for LAI, plant dry matter and grain yield were conducted using SPSSX 7.5, where the significance of factor effects was determined and the significance of treatments means was tested by Tukey's test at $P \leq 0.05$ (*). Pearson's correlation coefficients between LAI and grain yield and grain yield and plant dry matter were calculated and determined at $P \leq 0.01$ (**).

Results

All investigated parameters significantly differed among cultivars. In spite of intensive productive tillering in low sowing density (to 2.7), increasing sowing density from 350 to 800 seeds m^{-2} significantly increased LAI at EC 70 stage from 2.9 to 5.5. Significant differences among LAIs were noted by genotype x sowing density interaction (Table 1). At EC 80 stage the LAI was not significantly different among sowing densities and amounted from 1.9 to 2.5 (data not shown). Dry matter of ears decreased by increasing sowing density from 1.6 to 1,2 g per ear, and dry matter of stems decreased from 3.3 to 2.8 g per plant. Dry matter of leaves formed by 250 to 500 seeds m^{-2} and 650-800 seeds m^{-2} was 0.5 and 0.4, respectively. Dry matter plant weight was significantly higher at low sowing density of 350 and 500 seeds m^{-2} than at higher sowing density, but interaction genotype x sowing density did not affect plant weights, such as grain yield. Increased sowing density from 350 to 800 seeds m^{-2} resulted in an increase of grain yield of 0.8 Mg/ha. Correlations between LAI at EC 70 stage and grain yield were strong (r = 0.50 to 0.57**), except cultivars Mihelca and Soissons (r = 0.3 to 0.27). At EC 80 stage correlations between LAI and grain yield were stronger (r = 0.63 to 0.74**) than at EC 70, except cultivars Marija, Mihelca and Justus (r = 0.5 to 0.41). However, correlation between plant dry matter and grain yield was strong (r = 0.59 to 0.66**) only with cultivars Ana, Justus and Mihelca.

Table 1: The effect of sowing different number of germinated seeds per area on LAI at milk maturity stage (EC 70), plant dry matter (PDM = g $plant^{-1}$) and grain yield (GY = Mg/ha).

Sowing density:	350 seeds m^{-2}			500 seeds m^{-2}			650 seeds m^{-2}			800 seeds m^{-2}		
Cultivar	LAI	PDM	GY	LAI	PDM	GY	LAI	PDM	GY	LAI	PDM	GY
Ana	3.6c	5.9	6.4	4.6b	5.4	6.8	5.2ab	4.7	6.6	6.3a	4.7	7.6
Justus	3.1b	5.5	6.3	4.0b	4.8	6.3	5.3	5.0	6.2	6.6a	4.6	6.3
Krona	3.8b	5.4	5.3	6.5a	6.5	5.0	7.4a	5.4	5.1	7.2a	4.5	6.4
Marija	2.9	6.0	6.8	4.1	5.8	7.2	3.9	4.7	7.3	4.0	3.8	7.2
Mihelca	1.8b	4.2	6.5	2.6ab	4.6	6.9	2.9ab	3.6	7.1	3.7a	3.6	6.9
Profit	3.5b	5.9	4.6	4.5b	5.8	5.9	6.4a	5.5	5.8	8.0a	5.6	6.4
Soissons	1.9b	3.6	6.6	2.5b	3.3	7.2	3.5a	3.5	7.5	2.9a	3.0	6.7
Average	2.9b	5.2a	6.0	4.1ab	5.2a	6.5	4.9a	4.6b	6.5	5.5a	4.3b	6.8

Means within a row followed by different letters for each investigated parameter are significantly different at the 95% confidence level (Tukey's test)

Conclusions

On the basis of investigated winter wheat cultivars spread in Slovenia it is concluded that increased sowing density from 350 to 800 seeds increased average LAI at EC 70 from 2.9 to 5.5, but it differed depending on cultivar. Sowing density did not significantly influence LAI at EC 80 stage in spite of plant dry matter changes, but morphological changes may influence compensation of grain yield. Strong correlations between LAI and grain yield should not be generalised, because the relationships depend on cultivars.

Bavec, F. and Bavec, M. 2001. Commun. Soil Sci. Plant Anal., 32, 2709-2719.
Bavec, F. and Bavec, M. 2002. Eur. J. Agron., 16, 151-159.
Bindraban, P. S., 1999. Field Crop Research, 63, 63-77.
Fotyma, M., Faber, A., Czaykowski, M., Kubsik, K., Stafford, J., 1997. Sci. Publishers Ltd., Oxford,111-118.
Heidmann, T., Thomsen, A., Schelde, K., 2000. Ecol. Moddeling. 129, 229-243.
Karimi, M. M., Siddique K. H. M. 1991. Aust. J. Agric. Res., 42, 13-20.
Sharma, K., Dhingra, K.K., Dhillon, M. S., 1994. Envir. And Ecol., 12, 717-719.
Frederick, J. R. and Camberato, J.J., 1995. Agron. J., 87, 527-533.

FUNGAL PATHOGEN DEVELOPMENT IN CONVENTIONAL AND WEEDY WINTER WHEAT

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Introduction

Basic changes to crop husbandry, such as crop density or alterations in weed management, can affect the epidemiology of disease in various ways. Many studies have documented the effects that weeds can have on the wheat crop growth in terms of competition and yield loss; few have looked at how a weed understorey may affect disease development. In low-input cereal systems, the crop microclimate may be radically different compared to conventional high-input homogeneous systems. The objective of this investigation was to determine the influence of a weed understorey on the development of three diseases of winter wheat; stem-base diseases: eyespot and brown foot rot (BFR), foliar disease: septoria tritici blotch (STB).

Methods

The experimental design was factorial with weeds (2 treatments) and disease (3 pathogens and 3 controls) as main factors. Plots were sown with winter wheat cv. Riband. Broad-leaved arable weed species were sown in designated weedy plots; weed-free plots were maintained by the use of herbicides. Plots were inoculated with one of the pathogens, *Pseudocercosporella herpotrichoides, Microdochium nivale* or *Septoria tritici;* control plots were sprayed with water.

Results

The time from stem elongation (GS 30, April) onwards is crucial in relation to disease development of eyespot, when weather determines whether or not lesions become severe (Higgins et al., 1985). Profiles from *in situ* temperature and RH sensors in weedy and weed-free plots showed that the greatest differences in microclimate between treatment plots occurred during the months of April and May, coinciding with the time of maximum weed density. During this period relatively low temperatures (~10°C) accompanied by high RH (>85%) would have favoured infection by eyespot. Consequently the effect of weeds on disease development was significant ($P<0.05$) with disease severity being significantly greater in weedy plots inoculated with *P. herpotrichoides* compared to weed-free plots (Figure 1). While the presence of an understorey of weeds would have been expected to provide a conducive environment for the development of BFR, there was little evidence from our results to suggest that weeds contributed to significantly greater levels of disease on nodes or internodes. The severity of BFR caused by *M. nivale* was significantly greater on nodes ($P<0.001$) and internodes ($P<0.001$) in inoculated plots compared to control plots, but the main treatment effect of weeds was not significant. It is possible that the residual levels of fungi causing foot rot symptoms may have influenced these results. This may help to explain why the treatment effect of weeds was not significant and is consistent with the fact that control plots also had relatively high levels of disease. Analysis of severity data for STB showed that inoculated plots had significantly greater disease than control plots early in the season but by GS 83 this effect was no longer significant due to similar disease levels in both control and inoculated plots (Figure 2). The main treatment effect of weeds on STB severity was not significant on any of the sample dates (Figure 2). Results demonstrated that weed competition affected the growth strategy of wheat in weedy plots leading to etiolated wheat plants with increased separation of leaves in the upper canopy. This may have influenced disease development, especially with regard to STB, as inoculum transfer from lower infected leaves might have been less effective on etiolated plants. This would have been aided by the presence of the weed understorey which may have physically impeded spore movement in weedy plots. The determined effects on yield by the different pathogens proved to be insignificant but the influence of weeds as a factor reduced yield plot^{-1} ($P<0.05$) and number of ear-bearing tillers plot^{-1} ($P<0.05$); these were significantly lower in weedy plots infected with *P. herpotrichoides* compared to weed-free plots.

Figure 1. Disease severity of eyespot caused by *P. herpotrichoides* at different growth stages (GS). Error bars represent the standard error of the mean of 4 values.

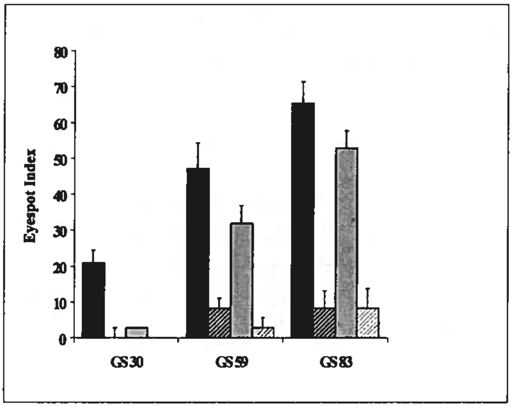
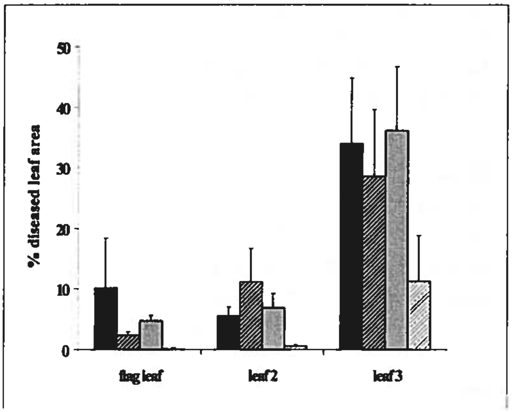


Figure 2. Percentage diseased leaf area with septoria tritici blotch at growth stage 83. Error bars represent the standard error of the mean of 12 values.



Black: inoculated weedy plots; black hatch: control weedy plots;
Grey: inoculated weed-free plots; grey hatch: control weed-free plots.

Conclusions

It is apparent that a low-herbicide cereal cropping system may have markedly different effects on disease development compared to a conventional cropping system, largely as a result of the modified environmental and physical parameters of the cereal crop. Environmental factors such as air movement (Scott et al., 1985) and penetration of light and surface temperatures (Legg et al., 1978) may prove significant in their influence on disease development, particularly of stem-base pathogens. Manipulations of the physical architecture of the crop may severely affect splash-dispersed pathogens, such as *S. tritici* by influencing raindrop penetration. Further detailed investigations are required in the light of these findings but it is evident that weed threshold levels could be critical in determining disease development by certain cereal pathogens.

References

Higgins, S. et al., 1985. Annals of Applied Biology 107: 1-9.
Legg, B.J. et al., 1978. In Plant Disease Epidemiology, Scott et al. (Eds). Blackwell Scientific Publishers, Oxford. Pp. 103-110.
Scott, P.R. et al., 1985. Plant Pathology 34: 578-593.

INFLUENCE OF ABIOTIC STRESSES ON THE YIELD, SEED AND ROOT TRAITS.

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Introduction

Stress abiotic factors /drought, high temperature, low level of nutrients, low pH.../ affect seed quality, seed morphological, physiological and biochemical traits, chemical composition of seeds and vigour of seedlings (Torres 1982, Welch 1977), activity of enzymes and performance of progeny generations, i.e water uptake, plant development, yield formation and especially basic root traits of sprouting plants: length, surface, weight, nutrient uptake, number of root tips, number of lateral roots and root density.

Methods

The 8 winter wheat cultivars - Astella, Estica, Ilona, Samanta, Olga, Patria, Plodna, Šárka - different from morphological, physiological and anatomical point of view were used in a pot greenhouse experiments (15 seeds per pot). The responses of wheat cultivars to different abiotic stresses and their combinations were analysed in pot experiments using a mixture of soil (50% of soil, 50% of sand). The basic conditions are summarized below:

Type of stress	Type of soil	Temperature/night	Temperature/day	Water/ soil capacity	pH of soil
Standard conditions	clay loam	15 °C	20 °C	70%	6. 5
Low level of nutrients	clay loam	15 °C	20 °C	70 %	6. 5
Drought	clay loam	15 °C	20 °C	40 %	6. 5
Drough+Low pH	clay loam	15 °C	20 °C	40 %	4. 5
Drought+High temperature	clay loam	20 °C	35 °C	40 %	6. 5
Drought+High temperature+low pH	clay loam	20 °C	35 °C	40 %	4. 5

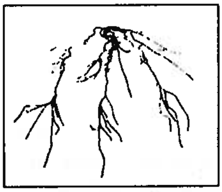
After harvest of the basic experiments with stress conditions the analysis of main yield traits was provided. The next step was the analysis of development of the root system in the following generation (=after the influence of abiotic stresses). For this purpose plants were cultivated under standard conditions in a standard growth chamber. The images of the root system 800 x 600 pixels were analysed by the image analyser LUCIA-(Laboratory Imaging Czech Republic). We recounted acquired values per 1g of dry matter ($kJ \cdot g^{-1}$ of dry matter) by □SN ISO 1928.The chemical composition of seeds was determined by "Megazyme methods" (starch, protein and oil content)

Results

For each type of stress a different type of change of measured traits was obtained. It was concluded, on the basis of statistical analysis, that significant differences for measured influence of abiotic stresses (and their combinations) on the plant traits exist.

Statistically significant differences (5%) among analysed plant traits (i.e.35 morphological, anatomical and yielding traits) of analysed cultivars were only at four traits: harvest index, number of spikelets per spike, lenght of spike and weight of one thousand grains. The very low influence of measured physical stresses was obtained for weight of one thousand grains (=reproductive effort) and for length of the spike. For every type of stress factor or for combination of stress factors a typical reactions of analysed cultivars exist.The cultivars Patria, Olga and Samanta are best tolerant cultivars to abiotic stresses. Plodna and Estica are two cultivars with low tolerance to the abiotic stresses. On the basis of presented results there is also a possibility to conclude, that the influence of abiotic stresses has very important influence on the root system development (length, branching, number of root tips). The importance of individual traits of seeds and especially of roots for plant production is based on the genotype and at the same time the level of manifestation in this group of characters is highly dependent on environmental conditions. The development of root length from the seeds originated from standard and stress conditions are given in the next example for three week old plants:1)Standard conditions (100% - total length of root system), 2)Low level of nutrients (total length of root system was 95% of standard), 3)Drought conditions (total length of root system was 83% of standard), 4)High temperature (total length of root system was 59% of standard), 5) Combination: drought, low pH and high temperature (total length of root system was 43% of standard). The obtained results were statistically different (5%) The example of the root of sprouting plants from seed from standard (1) an stress(5) conditions are in the following figure:

1



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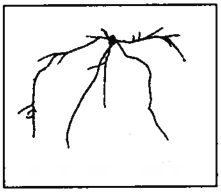

The length of the root, i.e. very important traits in plant production depends on the genotype and especially on the environmental conditions (type of stress). Seed vigour and especially traits of roots of sprouting plants is one of the key issue for crop production.The improved response of cultivars to stress conditions is accessible via plant breeding.

Discussion

From the agronomic point of view, the influence of seed provenance has an impact on the seed traits, chemical composition of seeds, traits of sprouting plants and development of plant in next generation(especially development of the root system). There is probably significant influence of gibberelin and abscisic acid content on the development of sprouting plants.The change of chemical compositon of seeds isn't large in starch content but in the oil and protein content The example of chemical composition of seeds of measured cultivars from three different localities (different soil and climatic conditions) is shown below:

Provenance	Starch content (g/100g of dry matter)	Starch damage (g/100 g of dry matter)	Protein content (g/100 g of dry matter)	Oil content (g/100 g of dry matter)
1.locality	59,7	1,6	14,5	0,97
2.locality	58,6	1,5	15,3	1,06
3.locality	59,1	1,5	14,6	1,21

References

TORRES, J.,L.et al: Increasing seed protein content enhances seedling emergence and vigour of seeds. Journal of plant nutrition, 5, 1982:11233-1140.

WELCH, R.W.: Seedling vigour and grain yield of cereals grown from seeds of varying protein contents. Journal of Agricultural Science, Cambridge, 88, 1977:119-125.

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PHYTOPATHOGENIC *FUSARIUM* FUNGI: EFFECT OF TEMPERATURE ON GROWTH AND *IN VITRO* PATHOGENICITY OF EUROPEAN *FUSARIUM* SPECIES CAUSING HEAD BLIGHT DISEASE OF WHEAT

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Introduction

Fusarium head blight (FHB), Fusarium seedling blight and Fusarium root rot of wheat are commonly caused by *Fusarium culmorum, F. avenaceum, F. poae, F. graminearum and Microdochium nivale* (*Fusarium nivale*) (Parry et al., 1995). FHB has been recorded in most cereal-growing areas of the world and has received significant attention in recent years. Environmental factors such as temperature, rainfall and humidity can affect both the incidence of *Fusarium* species and disease severity (Vieger et al., 1997), and can also play an important role in the production and dispersal of inoculum, and in the infection of wheat heads (Sutton, 1982). Temperature also plays a critical role in the development of Fusarium root rot (Sutton, 1982) and in mycotoxicosis epidemiology (Jimenez et al., 1996).

Methods

The 110 *Fusarium* isolates were stored in 10 % (v/v) glycerol at –70 °C and prior to use were subcultured onto potato dextrose agar (PDA) (Scharlau, Spain) and incubated at 20 °C. Temperature sensitivity was assessed by analysing the growth rate (mm day^{-1}) 3 and 4 days post-incubation of the *Fusarium* isolates at 10, 15, 20, 25 & 30 °C. *In vitro* pathogenicity towards wheat (cv. Falstaff) was assessed using a modified method of Mesterhazy (1983). Coleoptile growth was measured after 2, 3 and 4 days and used to determine the growth rate (mm day^{-1}). Both experiments were conducted twice.

Results

Irrespective of geographic origin, the optimum temperature for the growth of *F. culmorum, F. graminearum* and *F. poae* was 25°C (Fig. 1A) (mean growth rates = 8.2, 6.8 & 5.5 mm day^{-1}, respectively), while that for both *F. avenaceum* and *M. nivale* was 20 °C (Fig. 1A) (mean growth rates = 3.0 & 7.4 mm day^{-1}, respectively). There were significant differences in the growth rates of isolates of any given species from different countries. Depending on the incubation temperature, GLIM analysis showed that species explained > 51.3% and country of origin explained >22.6 % of the variation in the growth rate of the isolates. *F. avenaceum, F. culmorum* and *F. graminearum* were most pathogenic at 25 °C, *F. poae* at 15 °C and *M. nivale* at 10 °C (Fig. 1B). At 25 °C, *F. avenaceum, F. culmorum* and *F. graminearum* caused a 93, 93 & 96 % retardation in coleoptile growth rate, whilst *F. poae and M. nivale* caused a 58 & 55% retardation at 15 & 10 °C, respectively, relative to uninoculated control seedlings ($P < 0.05$) (Fig. 1B). There were significant differences in the pathogenicity of isolates of any given species from different countries. GLIM analysis showed that species accounted for >19.5% of the relative coleoptile growth rate variation while country of origin explained from > 0.7 % of the variation in the relative coleoptile growth rate. There was a significant positive correlation between the *in vitro* growth rates of *F. avenaceum* and the relative coleoptile growth rate retardation by this pathogen at 15 °C ($r = 0.76$; $P < 0.05$). *F. culmorum* also showed a strong positive correlation ($r = 0.64$; $P < 0.05$) at 25 °C; however this pathogen and *M. nivale* showed strong inverse correlations between the *in vitro* growth rates and pathogenicity at 30 °C & 15 °C, respectively ($r = -0.602$; $P < 0.05$ and $r = -0.803$; $P < 0.01$).

Conclusions

This research has highlighted the importance of temperature in the *in vitro* growth and pathogenicity of five *Fusarium* species. Analysis showed that the factors *Fusarium* species and country of origin contributed significantly to the variation in the growth rate and pathogenicity of the isolates. A significant positive correlation was obtained between isolate *in vitro* growth rates and relative coleoptile growth rate retardation by the pathogens *F. avenaceum* and *F. culmorum* at 15 and 25 °C, respectively.

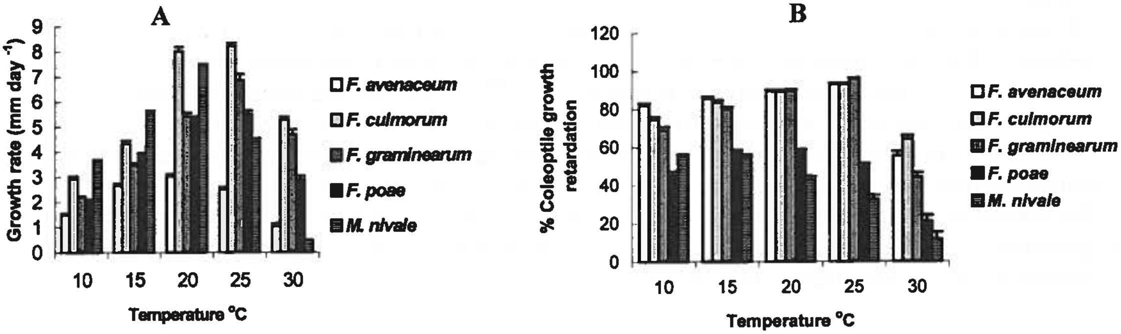

Fig. 1 Influence of temperature on *in vitro* isolate growth rate (A) and seedling pathogenicity (B) of the five *Fusarium* species. Bars indicate SEM.

References

Jimenez, M. et al., 1996. International Journal of Food Microbiology 29: 417-421.
Mesterhazy, A., 1983. Z. Pflanzenzuchtg 91: 295-311.
Parry, D. W. et al., 1995. Plant Pathology 44: 207-238.
Sutton, J. C. 1982., Epidemiology of wheat head blight and maize ear rot caused by *Fusarium graminearum*. Canadian Journal of Plant Pathology, 4: 195-209.
Vieger, B. et al., 1997. Canadian Journal of Plant Pathology 19: 60-65.

PRELIMINARY STUDY ON PROPANIL-RESISTANT *ECHINOCHLOA CRUS-GALLI* IN NORTH-WEST ITALY RICE FIELDS

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Introduction

The genus *Echinochloa* represents one of the most important groups of weeds affecting rice crop worldwide. The control of *Echinochloa* species in rice is increasingly difficult because of the development of herbicide-resistant weed biotypes which are not controlled by herbicides that were once effective. Several cases of resistance to molinate, thiobencarb, fenoxaprop-ethyl, and propanil herbicides have been reported for *Echinochloa* spp. in different temperate areas (Fischer *et al.*, 1993; Fischer *et al.*, 2000; Garro *et al.*, 1991). In Italy the genus *Echinochloa* is mainly represented by *E. crus-galli*, which shows high variability of morphological traits and sensitivity to propanil and other herbicides. The aim of this study was to screen the sensitivity to propanil in greenhouse conditions of eight *E. crus-galli* accessions collected in rice fields in which propanil application resulted inconstant in time.

Methods

The study was carried out in 2002 by performing series of whole-plant bioassays in which seedlings of different *E. crus-galli* accessions were sprayed at different rates of propanil. The seedlings were obtained starting from seeds of eight accessions (accession 1 to 8) collected in paddy fields of north-west Italy in summer 2001. In order to promote the germination, the seed coat was partially cut using a scalpel. The seeds were then placed to germinate in water constantly oxygenated with an air diffuser. The germinated seeds were arranged in pots containing peaty loam maintained at water saturation conditions. When the plants reached the stage of 3-4 leaves, and about 24 h before the herbicide treatment, seedlings were thinned to 4 equidistantly-spaced plants.

A preliminary screening between the accessions was conducted considering four rates of propanil (0, 2160, 4320, and 8640 g a.i. ha^{-1}) correspondent to untreated, 50%, 100%, and 200% of the recommended field rate. In a second experiment, the accession 8, which showed a relatively high tolerance, and the accessions 1 and 7, which showed low tolerance to the herbicide, were sprayed with seven rates of the herbicide (0, 540, 1080, 2160, 4320, 8640, and 17280 g a.i. ha^{-1}).

All the applications of propanil were foliar and carried out using a cabinet track sprayer delivering a spray volume of 400 L ha^{-1} at 203 kPa with a single Teejeet DG8002-VS nozzle. Aboveground fresh weight per pot was assessed seven days after treatment.

All the treatments were arranged in a completely randomised design, with three replicates. All the experiment was replicated three times.

The fresh weight data of the second experiment were expressed as percent of the untreated control and fitted to a log-logistic regression model. The rate of herbicide at which plant growth was inhibited by 50% (GR_{50}) was calculated and the level of tolerance to propanil was determined by comparing the different GR_{50}s.

Results

In the preliminary screening, the eight accessions showed a different sensitivity to propanil (Fig. 1). For the accessions 1, 4, 5 and 8 (group R) a fresh weight reduction of about 50% at 2160 g

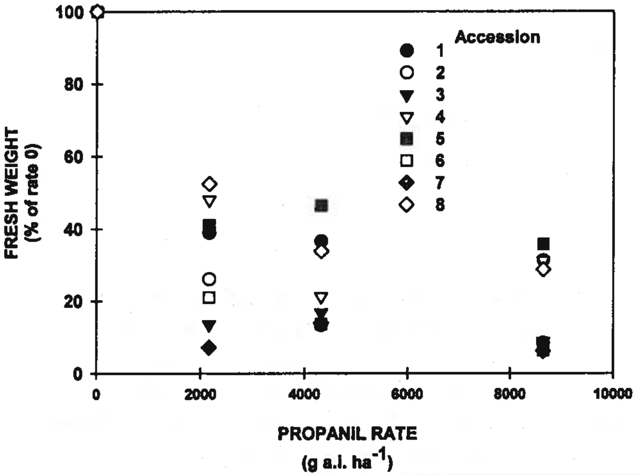
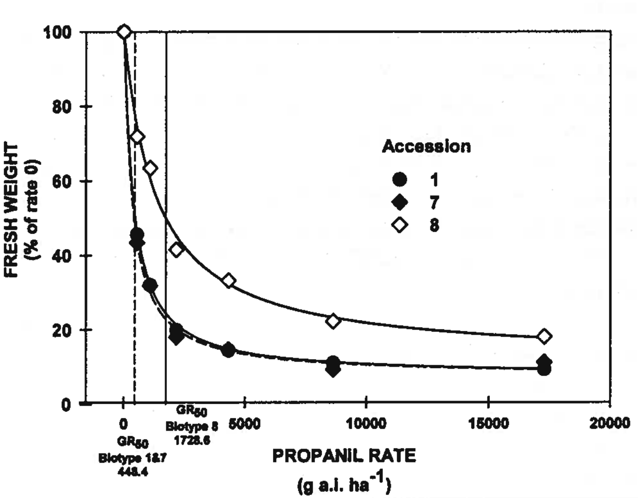


Fig. 1 - Susceptibility to propanil of eight *E. crus-galli* accessions

a.i. ha^{-1} was recorded, while, at the same rate, the fresh weight reduction of the accessions 2, 3, 6 and 7 (group S) was on average 82%. The different sensitivity of these two groups was found also at 100% (4320 g a.i. ha^{-1}) and 200% of the field rate. The greatest difference of susceptibility between the two groups was recorded at the highest rate. In these conditions, the fresh weight reduction of the group R was still less than 70%, while in the group S was always higher than 90%.

The study conducted on the accessions 1, 7 and 8 pointed out that all the dose-response data significantly followed a log-logistic regression model (Fig. 2). The accessions 1 and 7 showed a very similar behaviour, and their estimated regressions were not significantly different. The susceptibility to propanil was always lower in the accession 8, even at the highest rate (17280 g a.i. ha^{-1}), when a average biomass reduction of less than 80% was recorded. The average GR_{50} of the accessions 1 and 7 was 448.8 g a.i. ha^{-1}, while GR_{50} of the accession 8 was 1728.6 g a.i. ha^{-1}. The ratio between resistant and susceptible accessions (R/S ratio) was 4.14.

Fig. 2 - Dose-response of accessions 1, 7 and 8 to propanil



Discussion

This preliminary study pointed out that different accessions of *Echinochloa crus-galli* were not completely controlled with propanil applied at the field rate. For one of the accessions, the calculated R/S ratio was 4.14, indicating a high probability of presence of resistance.

References

Fischer, A. J. *et al.*, 1993, *Weed Science*, 41, 201-206
Fischer, A. J. *et al.*, 2000, *Weed Science*, 48, 225-230
Garro, J. E. *et al.*, 1991, *Proc. Brighton Crop Protection Conference-Weeds*, 1079-1083

EFFECTS OF PLANT DENSITY ON CHERRY TOMATO CULTIVATION

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Introduction

Tomato represents one of the most important vegetable crops in Italy and particularly in Sicily (Di Candilo et al. 1995). In this region, tomato production under protected cultivation accounts for 68% of the national production and is mostly concentrated in the provinces of Ragusa, Siracusa and Trapani. Among different tomato fruit types cultivated, cherry tomato had the greater diffusion in the last 10 years. The great demand and high selling prices of cherry tomato urged many farmers to cultivate this tomato type (Branca et al., 1991; D'Anna 1996). Nevertheless, agronomic knowledge of cherry tomato is still inadequate to optimize yield and quality of cherry tomato grown in greenhouse . The aim of this research was to study the effects of plant density on cherry tomato grown in unheated greenhouses.

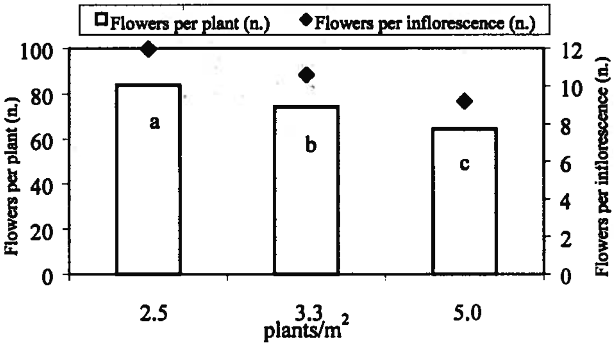
Methods

The trial was conducted in the experimental farm of the Horticultural and Floricultural Branch of the Department ACEP of the University of Palermo (Sicily), from September 1995 till June 1996, in an unheated greenhouse with metallic structure covered with PPMA. On 9/9/1995 plug plants of cultivar "Naomi" were planted on plastic mulched soil and grown with a single stem plant architecture. Three plant densities (2.5 – 3.3 – 5.0 plants m^{-2}) were compared. Different densities were obtained with distances between rows of 1,0 m and 0,4 – 0.3 – 0.2 m between plants. Before transplanting, soil was amended with 100 t ha^{-1} of manure and fertilized with 65 kg ha^{-1} N, 132 kg ha^{-1} P_2O_5 and 95 kg ha^{-1} K_2O. During plants growth fertigation provided 260 kg ha^{-1} N, 140 kg ha^{-1} P_2O_5 and 250 kg ha^{-1} K_2O. Plants were trimmed above 7th cluster. Plants received the cultural practices normally applied to the crop. Data on crop physiology and productivity were recorded measuring different parameters in order to evaluate the effect of plant density on cherry tomato. Single plots of 5.2 m^2 each were replicated 3 times adopting an experimental randomised block design. Statistical analyses of variance were performed, and Duncan's multiple range test was used to separate means (in all graphs reported, bars with the same letters were not significantly different at $P \leq 0,05$).

Results

Plant density had no significantly influence on plant growth rate however plants grown at highest density (5.0 plants m^{-2}) had the longest internodes and the first inflorescence was a bit more higher than in plants grown at lower densities. The highest average number of flowers per plant (83.8) were noticed in plants grown with the density of 2.5 plants m^{-2} (fig. 1). The average number of flowers per inflorescence got lower from 4th to 7th inflorescence. Harvestings started on March and continued till the end of June. Plant density influenced significantly the trend of yield.

Fig. 1 - Effect of plant density on flowers number.



Growing plants with the density of 5.0 plants m^{-2} resulted in a higher production in every harvest period (fig. 2) and also in the highest total marketable yield (62.5 t ha^{-1}) (fig. 3). Not marketable production was not significantly affected by the plant density.

Fig. 2 - Marketable fruit production by harvest period.

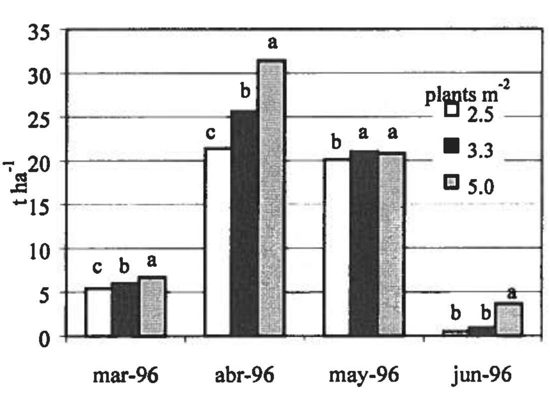
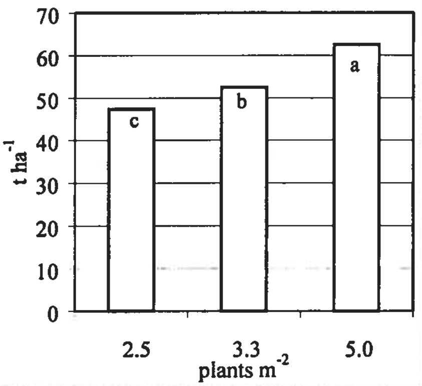
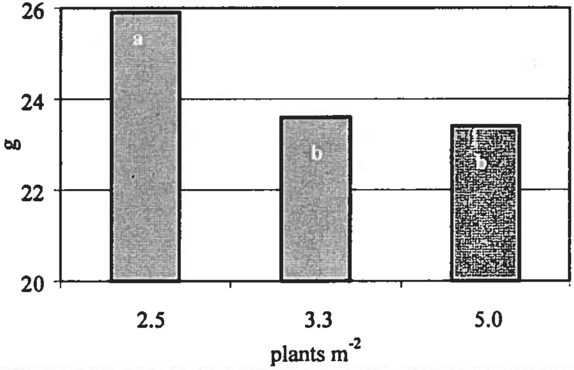


Fig. 3 - Total marketable fruit yield.



Plant density influenced significantly fruit size. The greatest fruits (25.9 g on average) were produced by plants with density of 2.5 plants m^{-2}. Increasing plant density resulted in a similar lower average fruit weight both at 3.3 and 5.0 plants m^{-2} (fig. 4). Differences in the average fruit weight were noticed among the different cluster of the plant. Fruit size increased from first to third cluster then slightly decreased from fourth to seventh. The greatest fruits (30.4 g) were those of the third cluster of the plants grown with a density of 2.5 plants m^{-2}. Sixth and seventh cluster of the plants grown with densities of 3.3 or 5.0 plants m^{-2} had the smallest fruits (about 20 g).

Fig. 4 - Effect of plant density on average fruit weight.



Conclusions

Plant density had a small influence on plants growth rate of cherry tomato cv. "Naomi". Increasing plant density resulted in a lower number of flower per inflorescence. Nevertheless, the reduction in the number of flowers per plant didn't affect cherry tomato production that reached higher quantitative and qualitative values when increasing plant density.

References

Branca F., Leonardi C., 1991. Prime acquisizioni sul comportamento di tipi di pomodo "cherry" coltivati in serra fredda. Coltura Protette 20 (6): 85-88

D'Anna F., 1996. Effetti della densità di piante su tipi diversi di pomodori da mensa coltivati in serra fredda. III Giornate Scientifiche S.O.I., Erice 10-14 Marzo

Di Candilo M., Marino A., Dal Rio P., 1995. Comportamento di cultivar di pomodoro da industria nel nord Italia. L'Informatore Agrario 51 (11): 35-39

(Authors have contributed in equal parts to this research)

EVALUATION OF THE PROTECTION STRATEGY IMPACT ON THE PRODUCTION COSTS IN PROTECTED VEGETABLE CROPS

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Introduction

Protected vegetable crops are important in the Oeste region of Portugal (≈ 90 km in the North of Lisbon). Traditionally, chemical control is, in general, the strategy adopted for crop protection. In the last years, implementation of IPM practices has been seen as a priority objective in face of the consumers demands, environmental safety policies and sustainable agriculture principles. This study was supported by the national research project PAMAF nº 2034 and by Agro-environmental measures from CAP.

Methods

This study was conducted in the IPM Demonstrative Field for Protected Crops of Quinta de S. João, at Caldas da Rainha, during three years (1996-1998), in two similar greenhouses of "capela" type. In one of these, the protection strategy adopted was the chemical control traditionally practised (TCC greenhouse) and in the other one IPM practices were conducted following the programmes defined by Marques *et al.* (1999) for risk assessment and decision tools (IPM greenhouse). The observations were conducted on three lettuce, one small melon, two tomato and two green beans crop cycles. Weekly visual observations were made on 30 plants (10 casually distributed along the two rows next to the lateral windows and 10 in the central row of the greenhouse), in order to evaluate populations of spider mites, aphids, caterpillars, leafminers, thrips, whiteflies and for some of the beneficials (leafminers ectoparasitoids, whitefly parasitoids, mirids, cecidomids, coccinelids and chrysopids). Chemical control treatments were adopted according to regional tradition practices (TCC greenhouse) or according to the economic thresholds proposed by Marques *et al.* (1999) (IPM greenhouse). In each case, pesticides used were chosen, respectively, from a list of the more frequently used in the region or between the ones registered for IPM by the official agricultural services (Lopes, 1997). In the IPM greenhouse, natural control was followed, a net was put in the lateral windows and biological releases were performed only when natural beneficials were too low.

Results

The key pests reported in the Oeste region in protected vegetable crops are spider mites (mainly *Tetranychus* spp.), aphids (several species), whiteflies (*Trialeurodes vaporariorum* West.), leafminers (mainly *Liriomyza huidobrensis* (Blanch.), *Chromatomyia horticola* (Gour)), caterpillars (mainly, *Helicoverpa armigera* (Hbn.), *Chrysodeixis chalcites* (Esper.)), cutworms (*Agrotis* spp.), thrips (*Frankliniella occidentalis* Perg. is the most important one) and snails (Marques *et al.*, 1999). The pests and diseases observed on this study are listed per crop on Table 1. Between them, some (signed by a ⁎) motivated treatments, at least, in one of the two greenhouses. The treatments number performed in each greenhouse is listed in Table 2. In Table 3 cost figures and production level for each crop are presented.

Conclusion

In general, the IPM programmes proposed by Marques *et al.* (1999) and followed in this study lead to a reduction in the treatments number (and to more selective ones), to important decreases in the production costs and to slightly higher production levels. The unique exception, during this three years period, is related with production costs. It was observed an higher phytosanitary cost, in 1998, in the green beans, because of an inundative release of *Orius laevigatus* Fieber. Although, it is important to notice that the labour cost associated with the risk assessment was not taken into account in this study.

Table 1 - Pests and diseases observed or preventively treated in IPM and TCC greenhouses.

Crop	Crop cycle	Pests and diseases
lettuce	1996	snails*, leafminers, botrytis*
small melon	1996	cutworms*, aphids*, leafminers, thrips, whiteflies, nematodes, spider mites (only in the IPM greenhouse), *Fusarium* wilt, anthracnose *
tomato	1996/7	leafminers, whiteflies*, caterpillars*, spider mites, aphids, downy mildew*, botrytis*, nematodes*, *Pseudomonas corrugata*
green beans	1997	aphids*, leafminers*, caterpillars*, thrips, spider mites*, botrytis*, snails*, *Fusarium* wilt*, anthracnose*
lettuce	1997	caterpillars*, leafminers, spider mites, thrips, botrytis*, downy mildew*
lettuce	1997/8	leafminers, caterpillars*, aphids (only in TCC greenhouse)
tomato	1998	whiteflies*, aphids, downy mildew*, botrytis*, and leafminers and caterpillars* (only in IPM greenhouse)
green beans	1998	leafminers, spider mites, thrips, caterpillars*, botrytis*, anthracnose*, rust*

*a treatment was performed

Table 2 – Number of treatments performed in IPM and Traditional Chemical Control greenhouses (molluscicide treatments were counted in insecticide treatments).

crop	traditional chemical control greenhouse				IPM greenhouse		
	fungicide	insecticide	nematodicide	total	fungicide	insecticide	total
lettuce 1996	10	2		12	10	2	12
small melon 1996	1	1		2	0	2	2
tomato 1996/7	13	4	2	19	15	1	16
green beans 1997	7	7		14	5	8	13
lettuce 1997	7	2		9	4	3	7
lettuce 1997/8	11	6		17	8	2	10
tomato 1998	3	1		4	3	4	7
green beans 1998	3	0		3	4	2	6
total (3 years)				80			73

Table 3 – Production and phytosanitary costs.

crop	Production (t ha^{-1})		Phytosanitary costs (in % of total costs)		Phytosanitary costs (euro t^{-1})	
	TCC	IPM	TCC	IPM	TCC	IPM
lettuce 1996	23.5	37.0	20.1	19.2	2.74	0.96
small melon 1996	7.9	17.0	11.2	5.7	3.98	1.85
tomato 1996/7	43.0	51.0	24.0	22.2	3.10	2.22
green beans 1997	21.9	30.7	28.9	27.6	6.17	3.49
lettuce 1997	40.5	47.0	15.7	16.2	1.68	1.28
lettuce 1997/8	28.8	28.3	17.3	12.3	2.70	1.40
tomato 1998	79.0	108.0	23.2	8.9	0.83	0.21
green beans 1998	7.3	8.6	11.4	25.0	5.94	14.90

References

Lopes, A. 1997. *Protecção integrada de horticolas. Lista dos produtos fitofarmacêuticos, níveis económicos de ataque*. DGPC, Oeiras.

Marques, C. *et al.* 1999. *Manual de protecção integrada em culturas protegidas. Principais pragas e auxiliares na região Oeste*, ISA Press, Lisboa, 61 pp.

FIELD EVALUATON OF CRAMBE CULTIVARS IN NORTHERN ITALY

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Introduction

Crambe (*Crambe abyssinica* Hochst. Ex. R. E. Fries) is an oil crop from the mustard family, whose major attraction is the high erucic acid content, which makes up 55 to 60% of the seed oil (Lessman et al., 1981). Erucic acid and its by-products are used to manufacture a multitude of industrial items such as lubricants, coatings, slip-agents, plasticizers, polymers and nylon precursors (Van Dyne et al., 1990). The crop can easily be inserted in rotations in a variety of environments, it is highly resistant to pests and can be mechanized with the ordinary equipment used for wheat and rape. Breeding in crambe has a very recent history. The yields are rather unstable and still too low to compete with high erucic acid rape. Current research is focused on either improving yields or ameliorating crop adaptability to unfavourable conditions. The present work illustrates the results of a three-year variety trial, aiming at establishing crambe as a commercial crop to broaden the horizons of Italian agriculture.

Methods

Twelve accessions of different origin (Table 1) were tested from 1999 to 2001 in a field trial at Bologna (Northern Italy; 44.53 N, 11.48 E., 29 m a.s.l.), adopting a randomised block design with three repetitions. Sowing was executed within the first two weeks of March after nitrogen fertilisation (80 kg N ha^{-1}, as ammonium nitrate). Neither watering nor pest control treatments were necessary, while weeds were controlled manually. During growth biometric and phenological observations were carried out weekly. To avoid pod scattering, all cultivars were harvested simultaneously at the end of June– beginning of July, before complete ripening of the seed.

Results

Cycle duration and phenology. On the average, cycle duration varied from 110 in 1999 to 115 days in 2001. The relative water content of the seed (Table 1), which is an indicator of earliness, was same for all cultivars, except for "2722-2", which showed a late ripening. Flowering lasted 20-22 days, with little difference among the years.

Plant growth and yield. Plant height at harvest was about 1.2 m, with almost no differences among years and varieties. Seed weight and yield varied significantly across the years: poor the first year, good the second and very good the third year. A strong year x cultivar interaction was evident, and it made the three-year average yield not different among the cultivars.

Table 1 – Principal production parameters recorded at harvest. Means of three years (Standard Error in brackets)

Accession	Releasing Institution	Plant height (m)	Seed RWC (%)	TSW (g)	Yield (t ha^{-1})
CPRO 104-71	CPRO-DLO (NL)	1.28 *(0.03)*	6.2 *(0.80)*	7.55 *(0.558)*	3.7 *(0.85)*
CPRO 2709-2	CPRO-DLO (NL)	1.25 *(0.03)*	6.4 *(0.33)*	6.96 (0.587)	3.8 *(0.59)*
CPRO 2722-1	CPRO-DLO (NL)	1.23 *(0.02)*	7.7 *(0.82)*	6.99 *(0.421)*	3.6 *(0.95)*
CPRO 2722-2	CPRO-DLO (NL)	1.25 *(0.10)*	14.0 *(2.01)*	6.75 *(0.637)*	3.2 *(0.86)*
Bel Ann	CPRO-DLO (NL)	1.28 *(0.01)*	6.2 *(0.69)*	6.98 *(0.646)*	3.8 *(0.77)*
Carmen	CEBECO (NL)	1.25 *(0.04)*	5.9 *(0.78)*	7.08 *(0.458)*	3.8 *(0.92)*
Charlotte	CEBECO (NL)	1.26 *(0.06)*	6.6 *(0.76)*	7.13 *(0.434)*	3.8 *(0.95)*
Galactica	CPRO-DLO (NL)	1.18 *(0.06)*	5.9 *(1.28)*	6.69 *(0.701)*	3.7 *(0.54)*
Mario	ISCI (I)	1.24 *(0.02)*	5.8 *(0.85)*	6.87 *(0.448)*	4.1 *(0.82)*
Nebula	CPRO-DLO (NL)	1.16 *(0.03)*	5.7 *(0.72)*	6.68 *(0.630)*	3.4 *(1.08)*
Prophet	ISCI (I)	1.23 *(0.04)*	6.6 *(0.66)*	7.12 *(0.537)*	3.9 *(0.55)*
Ukraina	ISCI (I)	1.24 (0.02)	7.0 *(0.95)*	6.86 *(0.428)*	3.8 *(0.54)*

Figure 1 - Cumulated rainfall (Autumn-Winter, Spring and total rainfall)

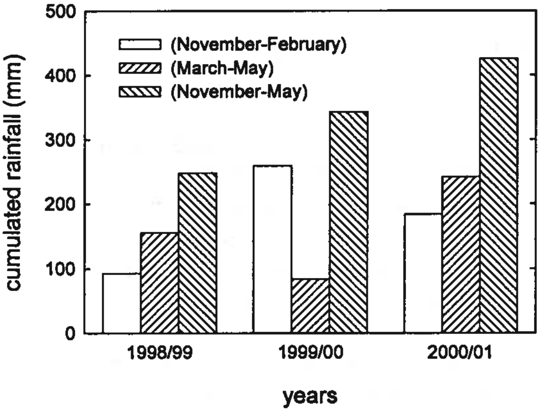
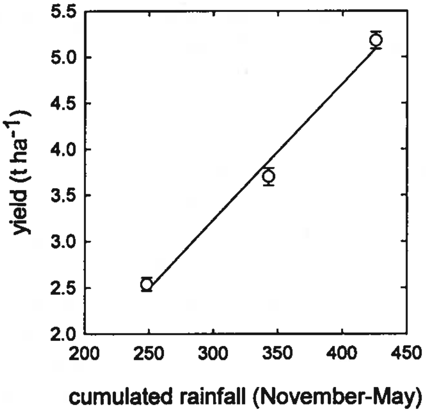


Figure 2 - Relationship between yield and total rainfall



Conclusions

Crambe productivity varied highly through the years in all cultivars, showing high sensitivity to climatic conditions. The temperatures recorded during cultivations were not very different among the years, while a considerable difference was recorded in rainfall (Figure 1). A correlation between yield and rainfall was obtained including the rain recorded in the autumn-winter months preceding sowing (Figure 2). This rainfall provided a useful water reserve for spring growth. In the winter 1998/99, 93 mm were recorded, while they were 259 in 1999/00 and 184 in 2000/01. Spring rainfall appeared less important on yield; it was 155 in spring 1999, 84 mm in 2000 and 242 in 2001. The rather dry weather recorded in the year 2000 had the effect of enhancing temperature stress, thus anticipating ripening and harvest. From the analysis of data, it was evident a rather high correlation between the seed weight and the yield ($r = 0.76$). The yield is therefore closely dependent on the seed development, which in turn is highly sensitive to water constraints.

Some concluding remarks may be drawn from these results.

- the growth cycle of crambe was rather short, between 110 and 115 days; harvest may start just before the end of June;
- the cultivars currently available do not show relevant differences, and their behaviour interacts strongly with the year;
- yield depends on the seed weight, which is the production component most sensitive to climatic conditions;
- the cultivation of crambe is a promising one for this environment, provided it encounters favourable conditions in autumn and winter.

References

Lessman, K.J. et al. (1981). In: Pryde, E.H. et al. (eds.), New sources of fats and oils. AOCS Monograph #9. American Oil Chemists' Society. Champaign, IL.; pp. 223-246.

Van Dyne, D.L. et al. (1990). Printing Services, University of Missouri-Columbia. MO.

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CLOVER BIOTYPES BEHAVIOUR IN 3 LOCALITIES OF CAMPANIA REGION

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Introduction

Secondary pollutants like ozone originate by chemical transformations of primary pollutants and are more mobile and widespread than primary pollutants (Heggestad e Heck, 1971). Therefore, a primary pollutant can be present in agricultural areas located close to industrialized centers, whereas a secondary pollutant can reach critical concentrations even in rural areas (Schenone et al., 1992; Sormani et al., 1995). The present study was performed in three localities of Southern Italy characterized by different pollution levels.

Methods

The experiment was performed from June to October 2001 at Portici (flat urban site), S. Angelo (hilly rural site), and Bellizzi (flat rural site). Two biotypes of *Trifolium repens* L. cv. "Regal", one resistant (NC-R) and one sensitive (NC-S) to ozone were used in the present study. Plants were grown in pots provided with a water reservoir, according to the experimental protocol defined by the ICP-Vegetation (UN/ECE, 1998). Water use was measured twice a week, when the water reservoir was refilled. Intensity of the evapo-transpiration flux was estimated computing the daily water use per unit leaf area. ET_0 was estimated with the Hargreaves method (Hargreaves et al., 1985).

Ozone pattern was measured with a spectra-photometric cell analyzer; data are shown as the average of the maximum daily value and AOT_{40}. AOT_{40} (ppb x h) was calculated as the sum of the hourly differences between the ozone concentration (when higher than 40 ppm) and 40 ppb.

Four harvests were performed at 28-day intervals and total plant biomass, number and weight of leaves and flowers, and leaf area were measured.

Results

The highest average maximum temperature was recorded at Bellizzi, whereas the highest rainfall was recorded at Portici (Table 1). The highest mean values of daily maximum ozone and AOT_{40} occurred during the second growth period at all the experimental sites. In particular, the highest and the lowest values of these parameters were recorded at Portici and Bellizzi, respectively. The NC-R showed higher dry matter yield than the NC-S (Table 2), whereas the highest dry matter production occurred at the Bellizzi experimental site. In addition, the NC-R had the highest water use, but this difference did not occur in the hilly site. The NC-S had the highest average specific water use at Bellizzi, whereas no significant differences between biotypes were found at Portici and S. Angelo.

Conclusions

The three sites were characterized by different environmental conditions. Nighttime ozone degradation did not occur at the hill rural site, therefore ozone concentration was always higher than 40 ppb at this site. In addition, under non-limiting-water conditions, dry matter production appeared to be correlated to water use (R^2= 0.50 for NC-S; R^2= 0.44 for NC-R; $P \leq 0.05$), which was correlated to ET_0 (R^2= 0.50 for NC-S; R^2= 0.54 for NC-R; $P \leq 0.05$). Therefore, the lowest dry matter production occurred at the Bellizzi site, which was characterized by the lowest ET_0. Production loss, estimated as the yield ratio of sensitive-biotype to resistant-biotype (S/R ratio), was 16%. In addition, ozone damage (estimated by the S/R ratio) was not correlated to ozone values. Therefore in territorial studies climatic effects on stomatal conductance and so on ozone uptake must be considered to identify spatial variability of ozone injuries.

	Growth period	T max (°C)	T min (°C)	Rainfall (mm)	ET_0 (mm d^{-1})	O_3 Max (ppb)	AOT_{40} (ppb x h)
Portici	1	28.5	20.5	2.6	4.6	67.7	4595
	2	30.1	20.8	0.8	4.8	74.3	5985
	3	27.0	18.7	167.2	3.4	57.0	2303
	4	26.0	16.4	7.4	3.0	58.4	1974
	Trial	27.9	19.1	178.0	4.0	64.4	14857
S.Angelo dei Lombardi	1	26.0	18.0	0.5	4.5	52.8	1460
	2	29.0	18.0	32.4	4.9	64.1	4575
	3	22.0	13.0	36.2	3.2	51.3	1640
	4	23.0	13.0	58.4	2.7	46.3	1052
	Trial	25.0	15.5	127.5	3.8	53.6	8727
Bellizzi	1	31.4	19.7	1.0	5.8	48.3	1524
	2	32.2	20.5	9.2	5.5	50.9	2165
	3	28.6	18.3	30.2	4.1	39.9	628
	4	28.0	16.0	9.6	3.4	38.8	165
	Trial	30.1	18.6	50.0	4.7	44.5	4482

Table 1. Environmental conditions.

		Yield (g pt^{-1})	Water Use (Kg water pt^{-1})	Leaf Area (m^2 pt^{-1})	S. W. U. (Kg m^{-2} LA)
Locality	Portici	34.1 AB	25.3 A	0.53 C	2.6 B
	S.Angelo	30.7 B	21.7 B	0.60 B	2.0 C
	Bellizzi	35.1 A	24.9 A	0.64 A	3.1 A
Harvest	1	39.9 A	26.4 B	0.35 D	4.0 A
	2	34.6 B	28.3 A	0.46 C	3.3 B
	3	31.7 B	21.2 C	0.65 B	1.8 C
	4	26.9 C	19.8 D	0.88 A	1.3 D
Biotype	R	36.7 A	24.6 A	0.62 A	2.4 B
	S	29.9 B	23.3 B	0.56 B	2.7 A

Table 2. Average principal factor . ($P \leq 0.01$)

References

Hargreaves G.L. et al., 1985. *J. of Irr. and Drain. Engen,* ASCE, 111, 113-124.

Heggestad H.E. et al., 1971. *Advances in Agronomy* Vol 23:111-143.

Schenone G. et al., 1992. *New Phytologist.* 122: 689-697.

Sormani L. et al., 1995. *L'informatore agrario,* 39:44-47.

UN/ECE, ICP-Crops Experimental Protocol, 1998. The ICP- Crops Coordination Center, Institute of terrestrial Ecology, Bangor, UK

THE INFLUENCE OF CUT AND PHYSIOLOGICAL AGE OF SEED TUBER IN YIELD POTATO (*SOLANUM TUBEROSUM*, L.)

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Introduction

The seed tuber is an expensive production factor and usually it accounts for more than a half of the production costs of the potato crop. Usually, portuguese farmers tend to cut seed tubers, as to increase the number of propagules and therefore plant a larger area. As the yield of the crop is related with the physiological age of the seed tuber (O'Brien *et al.*, 1986), we studied the effect of different sprouting periods and the effect of the cut in the seed tuber, considering the conditions of Viseu, Portugal.

Methods

The trial was set in the center region of Portugal (Viseu), in 2001. Seed tuber of cv. Désirée was used, with size grade 35 mm x 55 mm and 70-120 g of weight, produced in Holland. The experiment was established in a randomised complete block design, with 3 replications, having accomplished 9 treatments, indicated in Table 1, matching the physiological age and the type of propagule. The physiological age varied with sprouting period and the temperature of storage. The number of day-degrees > 4°C (Σt) were determined using the following formula: $\Sigma t = (T-4°C)$, in which T represents the daily average temperature during the storage period. The tubers were stored at 3-4 °C and the sprouting occured at a temperature of 15-20 °C. The seed tuber was used uncut or cutted before the plantation. In this case, each tuber was cut longitudinally (LC), getting 2 propagules, or traditionally (TC) as local farmers do, getting more than 3 propagules.

Table 1 – Treatment details.

Treat.	Sprouting period	Sprouting beginning	Seed tuber	Number of day-degrees > 4 °C
T1	No sprouting	-	Uncut	0
T2	No sprouting	-	Longitudinal cut (LC)	0
T3	No sprouting	-	Traditional cut (TC)	0
T4	2 weeks	20 April	Uncut	242
T5	2 weeks	20 April	Longitudinal cut	242
T6	2 weeks	20 April	Traditional cut	242
T7	4 weeks	6 April	Uncut	434
T8	4 weeks	6 April	Longitudinal cut	434
T9	4 weeks	6 April	Traditional cut	434

Results and Discussion

In the present work, the best yield, 43 t/ha (total) and 38 t/ha (commercial), was produced by uncutted seed tubers, with a sprouting period of four weeks, related to the highest number of day-degrees > 4 °C (T7) (Fig. 1). The effect of propagule showed to be statistically significant in the total ($P<0.01$) and commercial ($P<0.01$) yield. The uncut potato seed provided the best results, except T3, followed by LC and finally the TC, independently of the physiological age. However, when compared with uncut tuber seed, the seed investment was about an half, in the treatments where CL was done, and about 1/3 with TC. Moreover, treatment 3, with TC, provided one of the best productions, right after T7. In a previous work, the LC of the seed tuber did not have a significant effect in the total and commercial production relatively to the use of uncut potato. Therefore, probably the option of the farmers in cutting the seed tubers, at least in some cases, allows them to get little lesser yield of that when they use uncut potato, with a minor cost, and, so, it's important to continue these studies. The physiological age did not provide significant differences in the total and commercial production, but the interaction between the type of propagule and the physiological age was significant ($P<0.05$). As the number of day-degrees > 4°C increased, high differences were verified in the productions between the 3 types of propagules. The commercial yield increased with the physiological age, independently of the type of propagule (Fig. 2). However, when the seed tuber was younger physiologically the result with uncut propagule or with LC was identical. When the seed tuber was older, the yield achieved with LC and TC proved to be close.

Only the physiological age had a significant effect ($P<0.05$) in the tuber production with size grade < 33 mm. In fact, the lesser number of day-degrees > 4°C increased no saleable yield (Fig. 3). The uncut seed tuber use also leads to a higher no saleable yield (Fig. 3). The highest yield in tubers with 33-57 mm was obtained in T3 (CT) and in the treatments with uncut potato seed (T1, T4 and T7). The potato production with size grade > 57 mm was higher in the T7 and T8, treatments in which potato seed was older physiologically

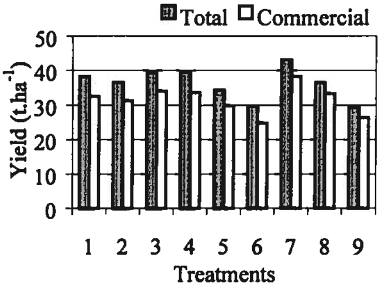

Figure 1- Effect of physiological age of seed tubers and the propagule type on total and commercial (> 33 mm) yield.

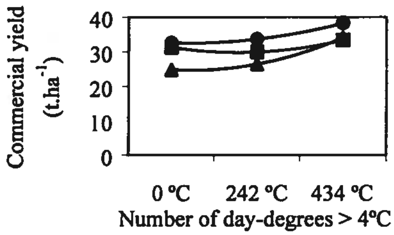

Figure 2- Relationships between commercial yields and number of day-degrees > 4°C, according to uncut propagule (●, $y = 1.7731x^2 - 4.2176x + 35.019$, $R^2 = 1$), with LC (■, $y = 2.4306x^2 - 8.662x + 37.528$, $R^2 = 1$) and TC (▲, $y = 3.0407x^2 - 7.5019x + 29.267$, $R^2 = 1$).

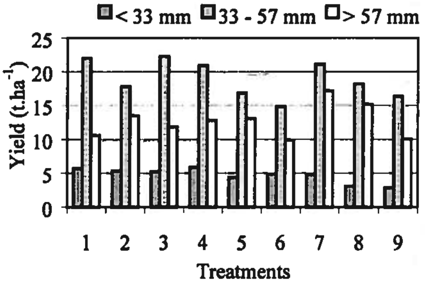

Figure 3- Effect of physiological age of seed tubers and the propagule type on distribution in size grades.

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O'Brien, P. J., Allen, E. J., Bean, J. N., Griffith, R. L., Jones, S. A. e J. L. Jones, 1986. Accumulated day-degrees as a measure of physiological age and the relationships with growth and yield in early potato varieties. *Journal of Agricultural Science*, Cambridge, 101:613-631.

CORRELATION ANALYSIS IN GRAIN AMARANTH (*AMARANTHUS CRUENTUS* L.) CV. 'G6'

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Introduction

On the basis of correlation studies Agong and Ayiecho (1992) identified the best seed-yield predictors in grain amaranth (*Amaranthus hypochondriacus* L. and *A. cruentus* L.) as. plant height, inflorescence lenght, sun-dried inflorescence weight, seed yield per plant, days to flower and days to maturity. According to investigations of field crops, the one sufficient predictor is leaf area index (Bindraban, 1999). Due to the lack of data on amaranths, the objective of this study is to determine yield performance of amaranths.

Methods

Two field experiments were conducted on a loamy sand in Prigorica (continental climate; 45° 43' N, 14° 45' E) and Vrtojba (submediterranean climate; 45° 55' N, 13° 38' E) in a randomised block design with four replicates in 2000. According to our investigation climatic differences may influence emergence (Bavec and Grobelnik Mlakar, 2002) and plant growth. The grain amaranth (*Amaranthus cruentus* L.) cultivar 'G6' was investigated in plots of 6 m^2 (3 x 2 m) with row spacings of 70 cm. Seeds were sown at 1.5 cm in the first decade of May. Influence of cattle manure fertilisation on fresh matter and grain yield was tested and some plant characteristics were recorded on 10 random plants from each plot. Precipitation and air temperature averages in the growing season (V-IX) were 76 mm and 16 °C in Prigorica and 111 mm and 20 °C, in Vrtojba, respectively.

Yield-related characteristics: plant height, inflorescence lenght, leaf area index (LAI), fresh inflorescence weight, seed yield per plant, fresh matter per plant and in Vrtojba air-dried inflorescence weight were recorded. LAI was measured using a personal computer and a scanner, which enabled counting the number of black dots on the screening picture of leaves and determine green leaf area (Bavec and Bavec, 2002). In Prigorica and Vrtojba all characteristics were measured at harvest (8. IX and 18. VIII, respectively), except LAI (at flowering). ANOVA and Tukey test at 0.05 probability level were carried out using procedures of the SPSS statistical package. The data obtained were used for estimation of phenotypic Pearson correlation coefficients among characteristics (*P* □ 0.05).

Results

Fresh matter and grain yield were 38969 kg ha^{-1} and 1948 kg ha^{-1} in Prigorica and 67033 kg ha^{-1} and 4895 kg ha^{-1}, in Vrtojba, respectively. Investigated characteristics according to ANOVA and Tukey tests, were significantly different between locations.

Among many plant characteristics significant relationships existed (Table 1). Fresh inflorescence weight has the strongest correlation with fresh matter and grain yield. LAI indicated strong correlation between plant height and fresh matter per plant. Correlation between LAI and grain yield was not significant in Prigorica. Contradictory to Agong and Ayiecho (1992), the inflorescence length was not correlated with seed yield per plant.

Table 1: Correlations among *A. cruentus* yield-related characteristics.

Characteristic	Location	Air-dried inflorescence weight	Inflorescence lenght	LAI	Fresh inflorescence weight	Plant height	Grain yield per plant	Fresh matter per plant
Air-dried inflor. weight	A							
	B		0.67	0.55	0.46	0.62	0.38^{NS}	0.92
Inflor. lenght	A			0.45	0.12^{NS}	0.63	0.13^{NS}	0.27^{NS}
	B	0.67		0.5	0.24^{NS}	0.62	0.25^{NS}	0.29^{NS}
LAI	A		0.45		0.38^{NS}	0.67	0.37^{NS}	0.52
	B	0.55	0.5		0.55	0.62	0.5	0.55
Fresh inflor. weight	A		0.12^{NS}	0.38^{NS}		0.37^{NS}	0.86	0.81
	B	0.46	0.24^{NS}	0.55		0.46	0.87	0.92
Plant height	A		0.63	0.67	0.37^{NS}		0.52	0.75
	B	0.62	0.62	0.62	0.46		0.2^{NS}	0.65
Grain yield per plant	A		0.13^{NS}	0.37^{NS}	0.86	0.52		0.86
	B	0.38^{NS}	0.25^{NS}	0.5	0.87	0.2^{NS}		0.69
Fresh matter per plant	A		$0,.7^{NS}$	0.52	0.81	0.75	0.86	
	B	0.92	0.29^{NS}	0.55	0.92	0.65	0.69	

A, Pearson correlation coefficient in Prigorica; B, correlation coefficient in Vrtojba (P □ 0.05).

Conclusions

On the basis of the investigation the correlation analysis indicated the strong correlation between fresh inflorescence weight and yield; grain yield and yield of fresh matter per plant, in both locations. LAI and plant height were in strong correlation with fresh matter per plant. Correlation between LAI and grain yield per plant was influenced by location i.e. climatic condition. The relationship between inflorescence weight and grain yield per plant indicates that heavier inflorescences would result in higher grain yield.

References

Agong S. G. and Ayiecho P.O., 1992. Ind. J. of Agric. Science, 62, 822 – 826.
Bavec and Bavec, 2002. Eur. J. Agron, 16, 151 – 159.
Bavec, F.and Grobelnik Mlakar, S. 2002. Eur. J. Agron, In press (accepted 16/1/02).
Bindraban, P.S., 1999. Field crop research, 63, 63 - 77.

VARIATION OF SECONDARY DORMANCY IN GENETICALLY MODIFIED AND CONVENTIONALLY BRED OILSEED RAPE

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Introduction

Oilseed rape (*Brassica napus* L.) seeds from harvest losses can develop secondary dormancy under particular field conditions. These seeds are able to persist several years in the soil and possibly result in volunteer plants in the following crops. When growing genetically modified plants, this phenomenon can lead to a gene flow in time by mixing genetically modified individuals into following conventional oilseed rape crops even years after the first cultivation of the transgenic plants.

In this study a laboratory experiment was carried out to investigate the disposition for persistence among an assortment of transgenic, herbicide-tolerant oilseed rape cultivars and their near-isogenic pendants. The following questions were subject of the study:

- Is there any variation in secondary dormancy within the tested variety assortment?
- What is the level of secondary dormancy in currently available transgenic, herbicide-tolerant cultivars?

Materials and Methods

Seed lots of the hybrid cultivar Artus (F_2 harvest material, site 2) and the transgenic (herbicide-tolerant)/near-isogenic pairs Lilly^{LL}/Liberator (OPs), Modul^{LL}/Falcon (OPs) and Avalon^{LL}/Artus (hybrids; F_1 seeds as well as F_2 seeds) were used for the experiment. Only Avalon^{LL}/Artus (F_2) were grown in the same year at the same site (site 1). The cultivar Artus (F_2, site 2) and the F_2 seeds of Avalon^{LL}/Artus (site 1) were harvested in 2001 and were less than one month old at the beginning of the test. All other cultivars were harvested in different years before 2001.

Samples of one hundred seeds of each cultivar were tested in four replications at three dates within three weeks (i.e. 12 samples per seed lot).

Secondary dormancy was induced according to Pekrun *et al.* (1997) by water stress which was generated under high osmotic pressure of the surrounding medium (polyethylene glycol 6000 solution, - 15 bar) and verified afterwards by a germination test. Seeds were exposed to 20 °C in darkness during both periods. All manipulations with the seed were performed under a green safety light (500 – 600 nm). To assess dormancy all non-germinated seeds were exposed to alternating temperature and light conditions (30 °C/30 °C; light/darkness; 12 hrs/12 hrs) after the germination test. For statistical analysis a general linear model (GLM) and a mixed model procedure were applied, followed by a Satterthwaite's test.

Results

Clear differences were observed within the tested assortment (Fig. 1). The range was between 0.7 % (Modul^{LL}) and 57 % (Liberator) dormant seeds per viable seeds. Among all transgenic cultivars Modul^{LL} showed the lowest level of secondary dormancy, close to Avalon^{LL} F_1. Lilly^{LL} produced about 15 % dormant seeds and Avalon F_2 with 31 % the largest proportion of dormant seeds among the transgenic lines.

No significant differences were found between the transgenic/near-isogenic cultivars Avalon^{LL} F_1/Artus F_1, nor between Avalon^{LL} F_2 /Artus F_2 (site 1).

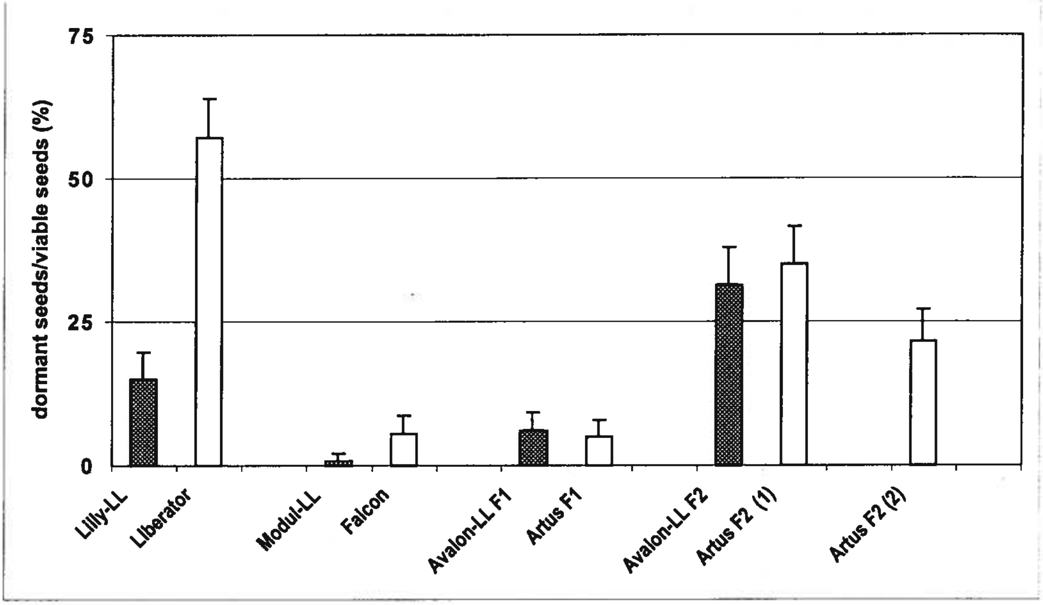

Fig 1: Secondary dormancy in seed lots of several transgenic oilseed rape cultivars and their near- isogenic counterpart (% dormant seeds/viable seeds); checkered columns: genetically modified cultivars; bars: standard error of mean

However, significant differences were found between $Modul^{LL}$ and its near-isogenic pendant Falcon ($p < 0.05$) as well as between $Lilly^{LL}$ and Liberator ($p < 0.01$). Comparing Artus F_2 grown at the two sites 1 and 2 (significant difference, $p < 0.01$) showed that there is not only a genetic effect but also an impact of the environment (growing, harvest and storage conditions).

Conclusion

The examined seed lots of transgenic cultivars can be classified into more dormant or less dormant types. Genetic as well as environmental effects can be responsible for this variation. The difference between F_1 and F_2 seeds may be caused by (genetic) segregation of hybrid seeds in the following F_2 generation, or may be affected by the different sites and years of harvest. Varying expression of seed dormancy in Artus seeds grown at two sites indicates that the conditions during seed ripening may also be involved in the dormancy pre-disposition of the seeds and that the site may be an important factor for the development of secondary dormancy. A plausible explanation for differing dormancy levels within some transgenic/near-isogenic cultivar pairs may also be the effect of site and year since seed lots differed in this respect. In addition, oilseed rape cultivars are not completely homogeneous and the selection of one single plant for a genetic modification may have led to genetic drift. Further experiments should include material harvested from the same site and in the same year to allow an adequate comparison between cultivars, and should evaluate the effects of genotype and environment.

References

Pekrun, C., et al.1997. European Journal of Agronomy, 6:245-255.

The study is financed by the German Federal Ministry for Education and Research. Support by Aventis CropScience is gratefully acknowledged.

HARDENING, GROWTH RHYTHM AND CARBOHYDRATE METABOLISM OF WINTER RYE (*SECALE CEREALE* L.) VARIETIES OF DIFFERENT ORIGIN

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Introduction

Rye is a traditional winter cereal grown mainly for bread making in Finland. The varieties cultivated at present are of domestic origin with good overwintering capacity but with rather modest yield and with a very long straw (Mukula and Rantanen 1989). New varieties with shorter straw, better yield and good winter hardiness and quality properties are being continuously searched. Besides domestic plant breeding efforts, foreign varieties are being tested in Finland. In good conditions, they can produce very good yields, but little is known about their overwintering properties. To promote cultivation of rye, Finnish government launched a multidiscipline research program in 1998. Within this program the domestic varieties are tested together with new Finnish breeding lines, foreign population varieties and hybrid varieties (Hovinen, see below). Different cultivation and plant protection practises are tested to find the best ones for each variety. Data of overwintering, pests and pathogens, yield and quality are collected to eventually improve the production potential of rye. The present report deals with the physiological basis of overwintering of the varieties tested in the rye research program.

Methods

Four types of rye varieties were chosen for the experiments: 1) tall domestic varieties with good crop certainty (Riihi and Anna); 2) a variety with good yield quality and short straw from Polish origin (Amilo); 3) a Finnish breeding line with very short stature (Bor 7068); 4) hybrid varieties with excellent yielding capacity (Esprit and Picasso, Germany). In 1999, varieties Anna, Amilo, Bor 7068 and Esprit were sown in Jokioinen (60°49'N, 23°30'E) in weeks 32, 34 and 36. Week 34 is the usual sowing time in southern Finland. The seed was coated with fungicide Beret 050 FS (fenpiklonil). After melting of soil in the following spring (11 April 2000), plant samples comprising 15 shoots (an approximate total of 1.5 g of dry weight) were taken from three replicate plots of varieties Anna, Amilo and Bor 7068. The samples were freeze-dried and the soluble sugars were measured spectrophotometrically. The winter damages of the plots were observed after beginning of growth, on 2 May. To study the effects of hardening conditions on growth rhythm and carbohydrate accumulation, varieties Riihi, Amilo, Bor 7068 and Picasso were sown in pots and grown in a growth chamber, first in simulated autumn conditions (average temperatures from Jokioinen in 1961-1990, simulated sowing date 23 August) for 6 weeks, and then in hardening conditions (5/2°C day/night, 8 h day) for 5 weeks. The growth was observed weekly, and biomass weight and soluble sugars of the tissue in the crown area (2 cm of shoot tissue above roots, and 1 cm of roots) were determined after the end of the hardening period.

Results

Field-sown rye varieties contained the more soluble sugars in their shoots the later they were sown (Table 1). Soluble sugar content in variety Amilo was very small except in the third sowing. Amilo was the poorest winter survivor as well, with 80-90% of its coverage destroyed during the winter in the plots with the two earlier sowings. The hybrid variety Esprit also lost 93% of coverage in the first sowing and 43% in the second. The latest sowing survived much better, with only 34% of growth lost for Amilo and 7% for Esprit. The main reason for the damage seemed to be snow mould. As the soluble sugar content of Amilo coincided well with the winter survival, it seemed possible that Amilo, and maybe Esprit as well, had poor capacity of collecting reserve carbohydrates, maybe because of too late growth cessation in the autumn.

Variety	Sown week 32	Sown week 34	Sown week 36
Anna	15.7 ± 1.4	22.4 ± 3.4	32.4 ± 2.2
Bor 7068	18.5 ± 2.2	31.9 ± 0.5	34.3 ± 1.5
Amilo	11.0 ± 1.0	10.0 ± 0.8	37.7 ± 0.7

Table 1. Soluble carbohydrates (% of dry weight) in shoots of rye varieties on 11 April 2000

In the growth chamber experiment with simulated autumn and hardening conditions, all rye varieties stopped increasing in length when the temperatures decreased (Fig. 1). However, the number of lateral shoots continued to increase throughout the experiment, even in hardening conditions (Fig. 2). Of the varieties tested, Riihi was the tallest and Bor 7068 the shortest. Amilo and Bor 7068 had the highest number of shoots. At the end of hardening, shoots and crowns of all varieties except Picasso weighted about the same (Table 2). All varieties had high concentration of soluble sugars in their crown, with Bor 7068 having the highest (nearly 40%) and Amilo the lowest (less than 34%) value (Table 2).

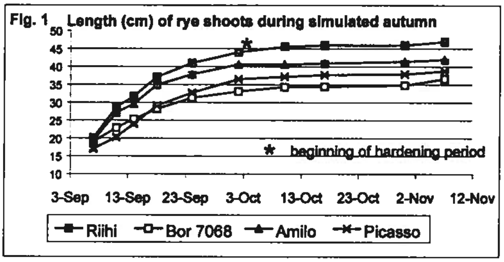
Fig. 1 Length (cm) of rye shoots during simulated autumn

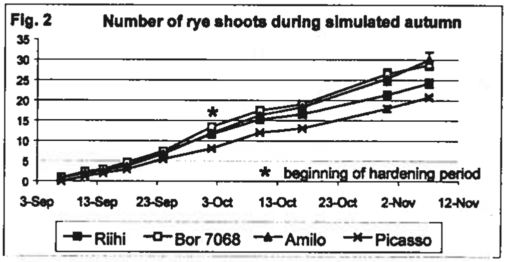
Fig. 2 Number of rye shoots during simulated autumn

	Riihi	Bor 7068	Amilo	Picasso
crown, g DW	1.07 ± 0.17	1.13 ± 0.07	1.20 ± 0.19	0.88 ± 0.08
shoot, g DW	4.89 ± 0.56	4.98 ± 0.20	5.04 ± 0.69	4.28 ± 0.46
sugar content % of DW	37.3 ± 0.8	39.4 ± 1.4	34.2 ± 1.1	37.0 ± 0.7

Table 2. Dry weight (DW, g) and soluble sugar content (% of DW) of rye crown and shoots at the end of simulated autumn growth and a 5 week hardening period.

Conclusions

Rye varieties differed in their overwintering capacity in the field. Successful overwintering seemed to be connected with retaining sufficient amounts of reserve sugars. The experiment in a simulated "average" autumn showed that all varieties were capable of growth cessation and accumulation of reserve carbohydrates. Also in the field, Amilo retained a high amount of carbohydrates when sown late. Foreign varieties may not be as sensitive to changes in day length as the domestic ones, and may lose their reserve carbohydrates during spells of high autumn temperatures. Given "normal" hardening conditions, they may thrive as well as the Finnish ones.

References

Dr. Simo Hovinen, Co-ordinator in the national research project "Increasing the efficiency of rye breeding and cultivation in the North", Boreal Plant Breeding Ltd, Myllytie 10 FIN-31600 Jokioinen Finland, email: simo.hovinen@borealpb.com.

Mukula, J. and Rantanen, O. 1989. Climatic risks to the yield and quality of field crops in Finland. III. Winter rye 1969-1986. Annales Agriculturae Fenniae 28:3-11.

EVOLUTION OF FLOWERING AND RIPENING WITHIN INFLORESCENCES OF BUCKWHEAT PLANTS, EFFECT OF DEFOLIATION, FLOWERS RESTRICTION AND SEED RATE.

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Introduction

Buckwheat plants produce inflorescences at the axils of leaves situated at different levels on the plants. These inflorescences are formed at different moments, they bear numerous flowers which continue to appear through long periods of time. Development stages (of flowers and kernels), within and between different node levels on the same stem, overlap considerably (Halbrecq and Ledent, 2001).

In spite of this continuous flowering, seed set is globally very low, around 20-30%, in our conditions of Belgium.

In this work, our objective was to provide information which could confirm whether or not the availability of photosynthates is an important factor in the evolution of flowers and kernels through time and thus in the regulation of buckwheat seed setting.

We modified the availability of photosynthates available per kernel increasing light available through reduced seed rate, decreasing the number of leaves (thus reducing the source) and reducing the number of inflorescences per plant (to reduce competition per kernel).

Methods

Sowing of cultivar La Harpe took place, in the field, near Louvain-La-Neuve (Belgium), on June 6, 2001 at two rates of 20 and 40 kg/ha. No fertilizers and pesticides were applied and the preceding crop was maize.

The experimental design was a split plot with four replications. Main plot treatment was seed rate, whereas subplot treatment was defoliation (0%, 50%, 100%) or removal of inflorescences of the main stem (50%). In 50% treatments, only inflorescences or leaves at even numbered nodes were removed. We applied the treatments 49 days after sowing, at the beginning of flowering.

Development stages were respectively defined as open young flower, closed flower (flower with senescing wilted corolla), green kernel and brown kernel. Aborted kernels were also counted. Counts of flowers corresponding to different stages were made each week after treatment on nodes 5 and 10 on the main stem of three randomly selected plants within each treatment. This counting is difficult and requires careful observation from the base of the inflorescence towards its tip following a spiral line around its axis.

At harvest time (27 and 28 September, 2001), we determined the number of brown, green, and aborted kernels of inflorescences 5 and 10 and the rest of the whole plant (main stem and others ramifications).

Results

The proportion of flowers that reached kernel stage does not differ significantly between control (treatment 1) and treatment 4 and is in the range of 20% - 30% (Table 1). Reduction of inflorescences number had no effects compared to the control.

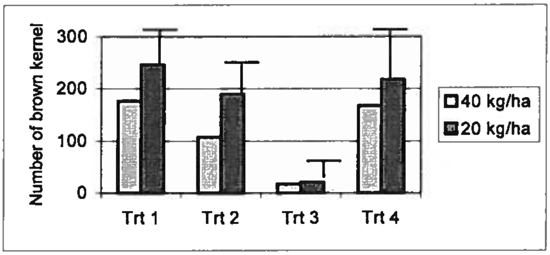
The defoliation treatments reduce the number of flowers that reached kernel stage by increasing early abortion, particularly in treatment 3.

Table 1

Seed rate: 20 kg/ha Node: 10	Early abortion	Later abortion	Flowers that reached kernel stage
Treatment 1 (control)	66.6%	5.5%	27.7%
Treatment 2 (50% leaf)	70%	9.4%	20.5%
Treatment 3 (0% leaf)	87%	0%	13%
Treatment 4 (50% inflo)	63.4%	6%	30.5%

In all cases, the low number of grains was due to early cessation of flower development occurring mainly just after flower opening and complete display of the corolla.
Late abortions or shattering played a minor role in the determination of kernel numbers.

Fig 1: Final mean yield per whole plant



Standard error: ⊤

The effect on grain yield of the removal of 50% inflorescences in treatment 4 was almost completely compensated by the remaining inflorescences; there was no significant difference with the control (treatment 1) (Figure 1). This was achieved by a slight reduction (2 or 3%) of abortion in the remaining inflorescences of the main stem and more probably in a better kernel yield in inflorescences of lateral ramifications (branches) of the main stem.
The defoliation treatments reduced final mean yield per whole plant, especially in treatment 3.

Decrease of grain yield per plant due to the higher seed rate was not statistically significant.

Conclusions

Seeds setting remains low in all treatments and is relatively little affected by partial defoliation. The reduction of grain number related to the number of flowers formed through time is mainly due to early abortion that happens just after flowering whatever the time of appearance of the flower. Relation to environmental stress occurring at a single moment is therefore unlikely.
On the other hand, a drastic reduction of potential competition between inflorescences (treatment 4) has only a negligible effect on kernel yield per plant. Thus, the plant compensates and this compensation seems not to be due to an increase in the number of flowers or a higher percentage of seed set in the remaining inflorescences.
Higher grain production in branches, and higher weight per kernel may be responsible for the compensation observed.

References

Halbrecq B., Ledent J.F. 2001. Evolution of flowering and ripening within inflorescences of buckwheat plants, effect of defoliation and sowing date, p143-152. Edited by Seung Shi Ham, Yong Soon Choi, Nam Soo Kim, and Cheol ho Park. Advances in Buckwheat Research (I). Proceedings of the 8th International Symposium on Buckwheat, Chunchon, Korea.

LEAF AREA ESTABLISHMENT OF FIELD-GROWN MAIZE (*ZEA MAYS L.)* UNDER POTASSIUM DEFICIENCY

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Introduction

Potassium is the second major plant nutrient after N. A common value of its concentration in maize is 0.02 gg^{-1} in plant dry matter and 200 mM as expressed by the ionic concentration of K^+ in plant water tissues where it is the most concentrated ion. K plays many roles in plant physiology, that are usually classified into biophysical and biochemical functions (maintenance of turgor, stomatal control and regulation of plant water content on the one hand, energetic processes, efficiency of photosynthesis, nutrient and assimilates transport on the other hand). If the roles of K in plant physiology appear to be well documented for single processes, they fail in predicting the effect of a K deficiency at the field scale. This study uses the field scale approach developed by Monteith (1977), in which the interception by leaves of incoming photosynthetically active radiation represents the basement of the biomass production. The objectives were to quantify the effect of a K deficiency on the Leaf Area Index (LAI) establishment of a field grown maize crop and to identify the underlying processes such as leaf appearance, leaf elongation rate and final leaf size. At the light of water and carbon status of leaves, the relative importance of biophysical functions of K on leaf growth is discussed towards its biochemical roles. This work belongs to a wider program of plant growth modelling under mineral stresses for improving fertiliser management knowledge.

Methods

The study was carried out in 2000 and 2001 on a K fertilisation experiment cultivated with irrigated maize (*Zea mays L.*) and located at Pierroton in the Southwest of France (lat. 44°48' long. –0°46' alt. 20 m). The same experimental design was applied to the two years of survey. The soil is a podzol. Three K fertilisation regimes have been applied since 1995 : 0 kg K ha^{-1} y^{-1}(K0), 40 kg K ha^{-1} y^{-1} (K1, 1 time the amount of K exported) and 160 kg K ha^{-1} y^{-1} (K4, 4 times the amount of K exported). The amount of soil exchangeable K measured in 2001 before sowing was on average 14, 23, and 44 ppm respectively for the three treatments. The experimental design was a randomised complete block with each experimental treatment replicated three times. Cropping techniques were chosen so as to avoid other limiting factors than K availability. A meteorological station was recording hourly temperature next to the field experiment.

In each plot, ten contiguous plants were monitored for leaf appearance and leaf area measurement, twice a week from seeding until the end of leaves appearance (1100 degree days). On the same period, ten other contiguous plants were weekly randomly sampled in each plot to determine plant fresh and dry weight, plant water content and mineral composition. Additionally, soluble sugars concentrations were measured in fresh growing zones of leaves.

Thermal time was calculated with a base temperature of 6°C. Leaf surfaces were calculated from a geometric formula using actual length, final length and width (Plénet et al., 2000). By considering the successive values of length measured on the same leaves, it was possible to approximate the leaf growth rate (LGR) as the slope of the relationship between length and time, during the quasi-linear elongation period of the leaf.

Results

The concentrations of K in shoots decreased from 45 to 20 mM in K0 plants, which can be considered as very low. By comparison, the range of concentration on the K4 treatment was [80

– 130 mM]. The LAI was strongly reduced between 300 and 600 °Cdays (-55%), corresponding approximately to the 5 to 10 visible leaf stage (Fig. 1).

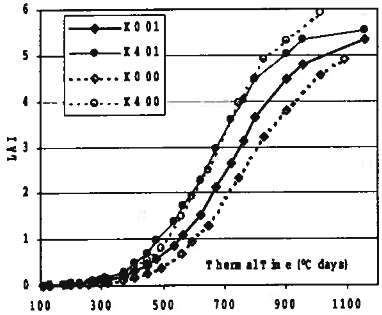

Fig. 1. Establishment of the Leaf Area Index for K0 and K4 treatments in 2000 and 2001

Then, this effect gradually decreased over time. The lower LAI in the K0 treatment was due to a slower rate of leaf appearance (the calculated phyllochrons were 47 and 44 °C days in the K0 and K4 treatments, respectively) and also to a reduction of final leaf sizes. The relative contributions of both effects to the total LAI reduction when the relative difference between treatment was maximal were 27% for the slower leaf appearance and 73% for the reduced leaf sizes. Leaf senescence was not different between treatments. Both final length and width of individual leaves were reduced in the K0 treatment (Fig. 2). The reduction of the final length was strongly related to the reduction of the leaf elongation rate during the quasi-linear elongation period (Fig. 3).
The duration of visible leaf elongation was not significantly affected. Several results suggest that a lower osmotic pressure is likely to explain the reduced leaf elongation rates, rather than a deficit in carbohydrates supply. Soluble sugar concentrations in leaf growing zones were higher on K0 plants (average 122 % for the two years, representing 10 sampling dates). The lower K concentrations in shoots of K0 plants was not totally compensated by an increase in other cations uptake, so that the osmotic potential was probably lower. A lower water content in shoots (up to -2.1%) was observed in K0 plants during the most critical period towards reduction in leaf size, which strengthens this interpretation.

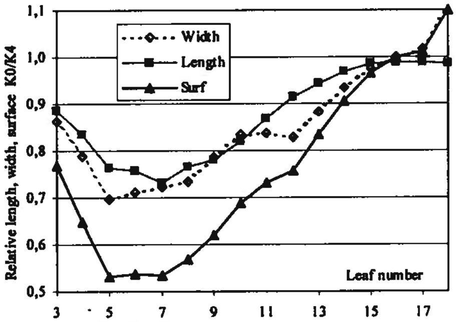

Fig. 2. Relative values of leaf length, width and area between K0 and K4 (year 2000)

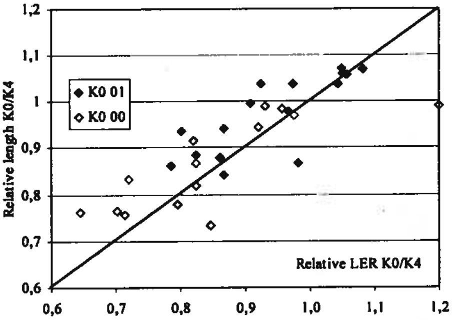

Fig. 3. Relationship between relative values of final leaf lengths and leaf elongation rates

Conclusions

K-deprived plants showed a severe and early reduction in their leaf area index. This can be related to a strong decrease in leaf elongation rate and hence in leaf final length. Leaf appearance was also modified. All the results together suggest that the strong reduction of LAI (up to –55%) was due to osmotic deficit rather that carbohydrate availability. This confirms the conceptual model of Leigh and Jones (1986) stressing that the biochemical functions of K are maintained to the detriment of biophysical functions.

References

Leigh R.A. et al. 1986.. *Plant, Cell and Environment* 9 : 595-604
Monteith J. L. 1977. Phil. Trans. R. Soc. Lond. B. 281, 277-294
Plénet D et al. 2000 Growth analysis of maize field crops under phosphorus deficiency. Plant and Soil 223, 117-130

SOWING DATE AND CROP DENSITY EFFECTS ON GRAIN AMARANTH AND QUINOA IN SOUTH-WEST GERMANY

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Introduction

Pseudocereal crops are of increasing interest as sources of healthy foodstuff in Europe. The production of amaranth (*Amaranthus spp.*) and quinoa (*Chenopodium quinoa*) grain crops on marginal locations is restricted by an uncertain field emergence due to small seeds and their high sensitivity against soil crusting and by long vegetation periods which are additionally delayed by high minimum germination temperatures. The proper choice of sowing date has always to consider early ripening and speedy, high field emergence. Similarly the optimum crop densities for high grain production are uncertain. The range of worldwide published recommendations is large. Earlier experiments in south-west Germany suggest that 30-40 plants m^{-2} of amaranth and quinoa are sufficient for maximum grain yield (Aufhammer *et al.* 1995, Kaul *et al.* 2000). The present study shall contribute to optimize both factors, i.e. sowing date and crop density on a marginal location in south-west Germany for both crops.

Methods

During two vegetation periods (1996; 1997) field experiments with four genotypes each of amaranth and quinoa were conducted in an experimental farm in south-west Germany (500 m a.s.l., 8 °C, 690 mm precipitation, loamy soil with high silt content). The experiments were in a split-plot design with three replicates. Two sowing dates were performed on main plots (April 26, 1996 and May 5, 1997; May 22, 1996 and May 24, 1997). Subplots were sown at three levels of crop density (D1-D3). Actually obtained crop densities are shown in the results section (Table 1, 2). For more experimental details see Kübler *et al.* (2002).

The investigations included the counting of plants at ripeness, the sampling of shoot dry matter, and the separation of grain and residual plant biomass by a lab threshing device. This allowed to calculate the harvest index. The results were statistically analyzed using the GLM procedure of SAS separately for species and years, and least significant differences were calculated.

Results

The present short communication starts from the crop densities which were really observed in the field. The establishment of amaranth and quinoa crops at defined plant densities is difficult to achieve due to the small and very sensitive seed. Field emergence percentages were sometimes very low during the experiments and they never exceeded 40 %. The dependence of field emergence from environmental conditions is discussed in detail in a full paper (Kübler *et al.* 2002).

Results with regard to sowing date effects are shown in Table 1. Due to the comparatively weak test of this experimental factor on main plots of a split-plot, the effects were not significant in most cases. With amaranth, we found no consistent effects of sowing date at all. For quinoa, however, later sowings resulted in lower crop densities. Subsequently in 1997 dry matter production was also impaired.

Table 1: Crop density and dry matter (DM) production of amaranth and quinoa in 1996 and 1997 as influenced by sowing date.

	1996			1997		
	April 26	May 22	$LSD_{0.05}$	May 5	May 24	$LSD_{0.05}$
Amaranth						
Plants m^{-2}	28.1	41.9	n.s.	27.8	36.1	n.s.
Shoot DM [t ha^{-1}]	8.64	8.98	n.s.	8.67	8.00	n.s.
Grain DM [t ha^{-1}]	2.01	2.26	n.s.	2.65	2.08	n.s.
Harvest index	0.23	0.25	n.s.	0.30	0.26	n.s.
Quinoa						
Plants m^{-2}	90.7	52.6	5.8	168.4	77.2	13.0
Shoot DM [t ha^{-1}]	10.08	10.36	n.s.	10.17	8.41	1.18
Grain DM [t ha^{-1}]	3.88	4.03	n.s.	3.73	3.04	0.48
Harvest index	0.39	0.40	n.s.	0.37	0.37	n.s.

Effects of crop density are shown in Table 2. During each experiment, the variation of sowing rates resulted in significant differences in crop density at ripeness. On average, the amaranth crops were less dense than those of quinoa. The increase in amaranth crop density went along with increasing shoot and grain yields. The harvest index was not affected. Quinoa showed a similar reaction, but less pronounced. In 1997, the harvest index of quinoa even decreased with increasing crop density and in consequence grain yields were not affected at all.

Table 2: Crop density and dry matter (DM) production of amaranth and quinoa in 1996 and 1997 as influenced by sowing density (D1 - D3).

	1996				1997			
	D1	D2	D3	$LSD_{0.05}$	D1	D2	D3	$LSD_{0.05}$
Amaranth								
Plants m^{-2}	18.7	32.2	54.1	9.6	9.0	21.5	64.5	11.8
Shoot DM [t ha^{-1}]	8.26	8.71	9.46	0.49	6.53	7.80	10.68	1.11
Grain DM [t ha^{-1}]	1.96	2.11	2.33	0.18	1.88	2.31	2.90	0.43
Harvest index	0.23	0.24	0.25	n.s.	0.27	0.29	0.27	n.s.
Quinoa								
Plants m^{-2}	36.1	68.0	110.9	7.4	50.0	83.9	234.5	18.3
Shoot DM [t ha^{-1}]	9.76	10.52	10.38	n.s.	8.93	9.27	9.66	0.51
Grain DM [t ha^{-1}]	3.80	4.15	3.91	0.28	3.38	3.32	3.46	n.s.
Harvest index	0.40	0.40	0.38	n.s.	0.39	0.36	0.37	0.2

Conclusions

Crops of the pseudocereals amaranth and quinoa are very difficult to establish at defined plant densities due to an uncertain field emergence. A delayed sowing did not significantly improve crop density and the grain yield of quinoa was even reduced. A substantial variation in crop density was achieved, ranging from 9 to 65 amaranth plants m^{-2} and from 36 to 235 quinoa plants m^{-2}. Within these ranges, the effects on dry matter production, grain yield and harvest index were only small. However, the present results indicate yield advantages with crops above 40 plants m^{-2} of amaranth and above 50 plants m^{-2} of quinoa.

References

Aufhammer *et al.* 1995. Eur. J. Agron. 4 (3), 379-386.
Kaul *et al.* 2000. Pflanzenbauwiss. 4 (1), 9-14.
Kübler *et al.* 2002. Bodenkultur 53 (in press).

GRAIN FILLING PATTERNS FOR DIRECT WATER-SEEDED INDICA AND JAPONICA RICE

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Introduction

Grain filling and yield of rice (*Oryza sativa* L.) depend largely on pre- and post-flowering accumulation of carbohydrates that in turns is affected by the cultivar, level of N fertilization, method of cultivation and environmental conditions (Yoshida, 1983). Genetic differences among rice cultivars have been detected for both rate and duration of grain filling and in most cases, duration was more closely related to yield than filling rate (Jones *et al.*, 1979). The objective of this study was to determine if differences in grain filling parameters exist among direct water-seeded Indica and Japonica rice cultivars and to identify possible associations with yield components.

Methods

The experiments were carried out at the farm of the Cereal Institute of Thessaloniki (40°33 lat, 23□00 E long, 0 m alt), Greece, during 1999 and 2000. Five rice cultivars, Olympiada and L-202 (Indica type) and Ispaniki A, Melas and Dion (Japonica type) were used. All cultivars are widely cultivated in Greece and were chosen because of their contrasting agronomic characteristics. Olympiada, L-202 and Ispaniki A are short, late maturing cultivars, Melas is a tall, early maturing cultivar and Dion is a tall, mid-season cultivar. The experimental design was a randomized complete block with four replications. Plots were 6 m long and consisted of 12 rows 20 cm apart.

The field was flooded one day before sowing and the water was maintained at a height between 5 and 10 cm until 15 days before harvest. Sowing was done directly in the field on 24 May 1999 and 27 May 2000 by hand broadcasting. The mean over years final plant density achieved was 162, 153, 125, 137 and 152 plants m^{-2} for Olympiada, L-202, Ispaniki A, Melas and Dion respectively. The field was fertilized with 150 kg N ha^{-1}, 33 kg P ha^{-1} and 62 kg K ha^{-1}, applied by hand broadcasting.

Twenty panicles from main stems were taken weekly from each plot during the period between anthesis and maturity. Panicle growth curves were calculated by fitting data of panicle weight in a cubic polynomial model.

Results

The time course of panicle weight for each rice cultivar between anthesis and maturity in 1999 and 2000 is shown in Table 1. The final panicle weight was generally greater for Japonica type cultivars compared to Indica type cultivars in both years. Since the samples were taken at fixed days after anthesis, the exact time of reaching maximum panicle weight may not be observed. Therefore, a panicle growth model is needed for estimating the maximum panicle weight from samplings that fall short of or beyond the limited set of sampling dates. When the panicle weight data for all of the cultivars were fitted by the cubic polynomial model, the smallest r^2 was found equal to 0.976 (L-202) in 1999 and 0.983 (Ispaniki A) in 2000, indicating a good fitting of the data in this model (Table 2). Additionally, when data of both years were included in the analysis, actual panicle weight was significantly correlated with predicted panicle weight (r=0.916**). Cultivars differed in both grain filling duration and filling rate. Based on polynomial equations, time to maximum panicle weight ranged from 31 (Melas and Dion) to 38 (Ispaniki A) days after anthesis in 1999 and from 30 (Dion) to 37 (Ispaniki A) days in 2000.

Table 1. Time course of panicle weight for five rice cultivars grown in 1999 and 2000

	Days after anthesis						
	0	7	14	21	28	35	42
Cultivar	Panicle weight (mg)						
			1999				
Olympiada	482	595	986	1600	1813	1856	1848
L-202	413	621	968	1638	1750	1787	1672
Ispaniki A	520	730	1100	2200	2650	2960	3059
Melas	494	825	1200	1968	2213	2195	-
Dion	400	650	1150	1980	2254	2250	-
			2000				
Olympiada	445	635	963	1513	1725	1738	1728
L-202	415	581	856	1413	1781	1925	1750
Ispaniki A	475	663	900	2100	2720	2930	2990
Melas	425	650	980	1700	2150	2294	-
Dion	430	628	1050	1688	1950	1800	-

Maximum panicle weight was significantly correlated with maximum filling rate ($r=0.92^{**}$) and mean filling rate ($r=0.90^{**}$), but not with filling duration ($r=0.50$). Japonica type cultivars had generally greater filling rates compared to Indica type cultivars in both years. Ispaniki A had the highest maximum filling rate (104.9 mg day^{-1} in 1999 and 115.2 mg day^{-1} in 2000) and mean filling rate (82.1 mg day^{-1} in 1999 and 83.8 mg day^{-1} in 2000).

Table 2. Equations showing the panicle weight (Y, mg) as related to the time after anthesis (X, days) for five rice cultivars grown in 1999 and 2000

Cultivar	Polynomial equation	R^2
	1999	
Olympiada	$Y=-0.06X^3+2.9X^2+12.9X+446$	0.982
L-202	$Y=-0.06X^3+2.5X^2+24.2X+385$	0.976
Ispaniki A	$Y=-0.10X^3+5.8X^2-7.0X+507$	0.988
Melas	$Y=-0.12X^3+5.2X^2+6.2X+507$	0.991
Dion	$Y=-0.14X^3+6.7X^2+7.5X+401$	0.994
	2000	
Olympiada	$Y=-0.05X^3+2.2X^2+21.8X+422$	0.985
L-202	$Y=-0.08X^3+4.1X^2-7.3X+422$	0.997
Ispaniki A	$Y=-0.13X^3+7.6X^2-34.1X+483$	0.983
Melas	$Y=-0.11X^3+5.7X^2-14.6X+443$	0.996
Dion	$Y=-0.13X^3+6.2X^2-12.8X+435$	0.998

Conclusions

Japonica type cultivars had generally greater panicle weight and filling rates compared to Indica type cultivars. Additionally, between grain filling and duration characteristics contributing to panicle weight of these cultivars the filling rate seems to be more important.

References

Yoshida S. 1983. Rice. *In*: Symposium Potential productivity of field crops under different environments. International Rice Research Institute, Manila, Philippines, pp. 103-127.

Jones D.B. et al. 1979. Association between grain filling and duration and yield components in rice. Crop Science 19: 641-644.

DISTRIBUTION OF ^{35}S IN FIELD-GROWN OILSEED RAPE VEGETATIVE COMPARTMENTS UNDER DIFFERENT SULPHUR-FERTILIZER INPUTS

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Introduction

As soil sulphur is mainly in organic form, it is worth studying conditions favouring its availability for plants. Sulphur determines gliadine and glutenine formation in wheat grains, and so quality of dough. Rapeseed, and *Brassica* in general, needs high amounts of sulphur fertilizer, in complement of N. N metabolism can be disrupted in oilseed rape if S is not sufficiently compensated for, but an excess of S leads also to the increase of glucosinolate production, that is undesirable for seed quality (Mc Grath and Zhao, 1996; Fismes et al., 1999). This study examined the influence of increasing fertilizing levels of S (0, 11 and 32 kg. ha^{-1}) on the distribution of ^{35}S within vegetative parts of oilseed rape sampled at five representative growth stages, and on yield and seed quality parameters (oil and glucosinolate content).

Methods

Three levels of sulphur (0, 11 and 32 kg.ha^{-1}) fertilizer were tested with oilseed rape (cultivar Pollen) grown on a Lorraine calcareous soil. Sulphur was in keserite form (SO_4Mg 50%) and was added at the second input of nitrogen (100 kg N.ha^{-1} at each of both inputs). Every three weeks from 5-leaf stage to late stage of pod filling, four representative field-grown oilseed rape plants were sampled without roots. At laboratory, basis of stems were soaked in a solution containing a constant volume of ^{35}S (10 ml of $Na_2{}^{35}SO_4$, carrier-free at 250 kBq.ml^{-1}) and a volume of $CaCl_2$ 0.05 M (pH=6), varying with plant height (from 10 ml to 30 ml at the end of the experiment). These plants with labelled solution were then installed in a labelling-chamber, 6 hour-day at 15°C, 80% humidity, 410 µmol.cm^{-2}.s^{-1}-light, and then, the plants were left in the dark all the night (12 hour-night), in order to favour sulphur fluxes equilibrium within plants. Leaves, stems, pods and seeds were, then, separated, frieze-dried, and weighed after a 48h-drying period at 80°C. Total ^{35}S was measured in each vegetative compartment after digesting with HNO_3 and $HClO_4$ at 105°C, with a liquid scintillation counter (Packard Tri-carb 2100 TR). Radioactivity measured per gram of dried matter was multiplied with the dry matter of each vegetative part, and expressed in percentage of total radioactivity in the whole plant. At harvest, yield was measured in field plots, with oil and glucosinolate content in seeds (two samples per plot).

Results

^{35}S distribution in the different vegetative compartments was dependent on sulphur input amount, but only from the 4th sampling. At this date, percentage of ^{35}S in stems was significantly lower with 32 S kg.ha^{-1} ($p<0.036$), comparing with 11 kg S.ha^{-1} and the control situations. With the highest S initial input (32 kg S.ha^{-1}), percentage of ^{35}S was the highest in pods, indicating a transfer of this element to reproductive organs. But such a transfer was not so important with lower S fertilizing inputs. Parallel observations on control stems revealed necrosis and sporadic lack of internal tissues, which could explain a blockage of S transfer towards pods. At the 5th sampling, the highest S fertilizer input induced a higher amount of ^{35}S in pods, and a lower in stems. All ^{35}S was in soluble form: labelling time was very short (6 hours) and, thus, little incorporation of ^{35}S in organic compounds was observed in this period. This was confirmed by no difference of ^{35}S percentage in seeds between the three sulphur input situations (Figure 1).

For all S fertilizer situations, percentage values of ^{35}S progressively decreased in leaves. This observation suggests the active transfer of ^{35}S towards the reproductive organs. In addition, rape leaves began to fall down at the beginning of flowering stage, to disappear almost completely at the fourth sampling. Determinations of yield and oil content of seed did not show any significant differences between the levels of S fertilizer inputs. In case of glucosinolate content, it was slightly higher in the intermediate sulphur input, with 11 µmol.g^{-1} of dry matter (DM), but there was only a little difference with the control (10.75 µmol.g^{-1} of DM) and the highest sulphur input, with 10.50 µmol.g^{-1} of DM (results not shown). As yield and seed quality were not greatly affected by sulphur deficiency, this also suggests that soil sulphur mineralisation was sufficient to supply available sulphur for plants.

<u>Conclusions</u> This experiment confirmed that ^{35}S was a powerful tool to highlight the transfers of S within different organs of plant according to S fertilizer inputs. The data showed that a supply of 200 kg N ha^{-1} jointly with 32 kg S ha^{-1} input, was the optimum dose of N and S for rape.

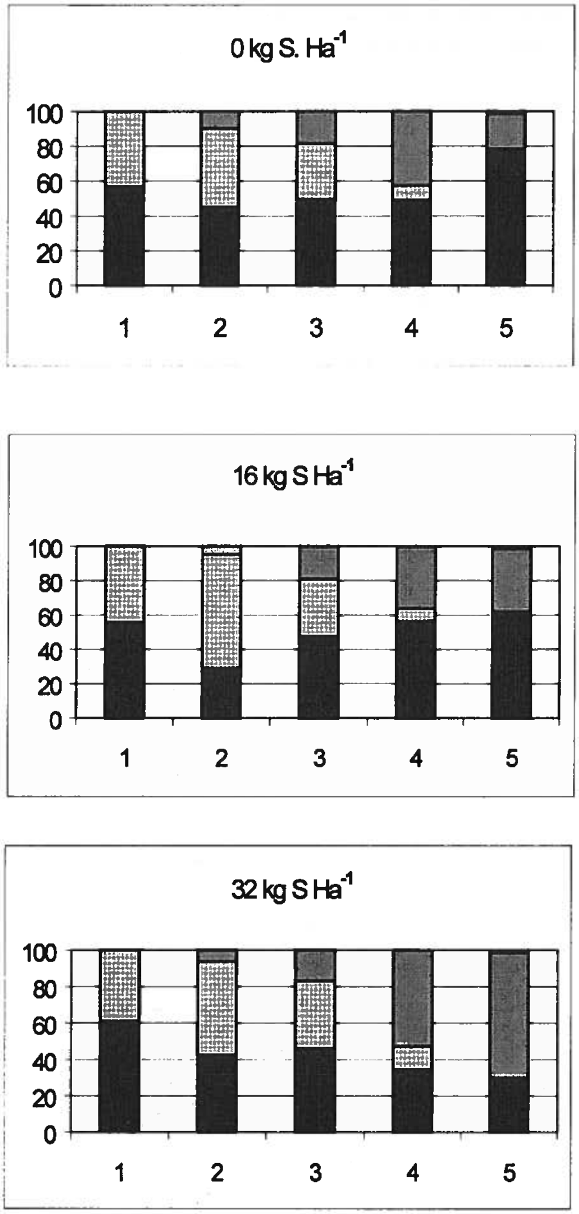

Figure 1: Distribution of ^{35}S in stems (▦), leaves (▩)
flowers+pods (▧), pods (▨), and seeds (■) at the five sampling dates.

References

Fismes J. et al. 1999 Commun. Soil Sci Plant Anal, 30:221-234
Mc Grath S P and Zhao F J 1996 J. Agric Sci 126, 53-62
Schnug E S et al 1993 Sulphur Agric 17, 8-12

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THE ROLE OF ALLELOPATHY IN ECOLOGICAL MIXTURES CROPS

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Introduction

Mixture crops, as opposed to pure sowing crops, are characterised by more stable output, reduced expenditure on pesticides as well as smaller environment pollution thanks to the biological diversification of species. It seems mixture crops have good prospects while the pro-ecology movements are growing in popularity.

The growth and development of plants, both in natural and formed ecosystems, are often modified by physical and chemical processes taking place in neighbouring plants (Putnam, 1986, Rice, 1985). The most typical example of physical process of this type is competition for environmental growth factors such as water, nutrients and light. The phenomenon takes place mostly when such resources are limited. In agricultural ecosystems competition can be controlled by means of agricultural practices and pesticides which eliminate the competitors of crop plants or making up for the shortage of nutritive growth elements, e.g. fertilisation and irrigation. In natural ecosystems the phenomenon of competition leads to one species dominance over others. Apart from this purely physical phenomenon there are chemical interactions observed among plants. The gist of allelopathic interaction is in effect the exudation of chemical substances to the environment by plants, so called donors, and the modification these substances introduce in the growth and development processes of other plants, so called acceptors. Allelopathic compounds are mainly produced in secondary metabolism but also some result from the basal metabolism, too. This kind of modification can either inhibit or stimulate processes. It must be noted that allelopathy is an important theory as well as may have huge practical application (Oleszek, 1999). Vegetal chemical substances may alter both coordinate and subsequent crop outputs and affect the quality of plant material obtained (Narwal, 1994). The influence of vegetal chemical substances may change with time requiring consideration of such issues as "soil sickness" or crop rotation. The possibility of using allelopathic interactions to biological weed control and the compounds themselves as natural pesticides seems to be a very important issue.

Allelopathy may keep on growing if there is a constant stress on the development of research techniques which would allow for a crucial shift from observation and description methods to actual and thorough identification of allelopathic compounds (Waller, 1989).

This experiment aimed at describing the allelopathic interspecies interactions in mixture crops. It is assumed that dominance of a certain crop species in a mixture field may be explained by the allelopathic properties of the species for one reason. Once the allelopathic interactions of crops are determined it will be easier to explain the changes of species composition in mixtures fields.

Methods

A series of tests were conducted on Petri dishes. Experiment required 12-hour artificial light. High pressure SON T Agro lamp with individually designed fitting to insure appropriate and even light distribution was used as a source of light. The established tests concentrated on the allelopathic influence of studied crop species (wheat, barley, oat and triticale) on the energy and ability to germinate of seeds as well as length of rootlets and height of seedlings used for spring mixture crops. The research process was conducted according to the methodology and widely applied rules. Commonly used ratio of corn species were used on the dishes (50 + 50%, 75 + 25%). Pots with so called pure species served for the control purposes.

The vegetation tests were carried out in the Vegetation Experiment Station at Institute of Soil Science and Plant Cultivation in Pu□awy. There were established pot tests with four species of corn (barley, oat, wheat, triticale) in various combinations of two-element mixtures. Tests were laid down by a completely randomised method in three replications.
Pots with so called pure species served as control objects. Pots were filled up with quartz sand. During vegetation plants were nourished with Hoagland 2 nutrient. Germination and initial development of researched species were evaluated. Chemical and biochemical analysis of the subsoil followed. Dried soil (50 g from each pot) was extracted with 70 ml of methanol (MeOH) in room temperature and periodically shaken during 16 hours. Extract was drained and the obtained filtrate underwent complete vaporisation in a vacuum pan. Obtained sediment was dissolved in 1 ml MeOH and the phenol compounds were determined by means of a High-Pressure Liquid Chromatograph (HPLC) equipped with Photodiode Array Detector on RP-18 column (Eurospher, Saulentechnik, 4.6 x 250 nm, 5 mm grain) with linear gradient 20-100% of acetonitrile in 1% H_3PO_4. Reading from the chromatograph was done at wave length of y = 280 nm.

Results
Results of the experiment show that selection of species in a mixture crop affect the energy and ability to germinate. Allelopathic interaction between barley and oat was noticed in the mixture. The percentage of germinated seeds depended on the selection of species used in the mixture. The sprouts growth rate, measured by its weight, depended on the kind of mixture and, to some degree, on the selection of species.
Vegetation tests showed that mixtures with oat had lower green matter crop after harvest.

Once the phenol compounds were determined, it became clear that the dominant compound in most of the tests is the phenol of 272,3 nm spectrum and an unidentified structure. Results of the laboratory analysis connected with this experiment are currently under evaluation and shall be presented in detail on a poster.

Conclusions
Interspecific interactions of various crops result from the allelopathic properties of substances released by germinating seeds and roots of growing seedlings. Detailed identification of allelopathic compounds shall make the question of allelopathy in general more clear.

References
Narwal S.S.: Allelopathy in Crop Production. Scientific Publishers, Jodhpur., 1994
Oleszek W.: Allelopathic significance of plant saponins. In. Recent Advances in Allelopathy. Vol. I. A Science for the Future. Servicio Publiccationes Universidad de Cadiz/I.A.S. 1999. pp. 159-170
Putnam A.R., Tang C.S.: The Science of Allelopathy. Wiley, New York, 1986.
Rice E. L.: Allelopathy – an overview. In: Chemically mediated interactions between plants and other organisms. Plenum, New York, 1985, pp. 81-105.
Waller G.R.: Biochemical frontiers of allelopathy. Biologia-Plantarum. 1989, 31(6), 418-447.

HIGH TEMPERATURE EFFECTS ON COTTON YIELD AND YIELD RELATED TRAITS

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Introduction.

Air temperature is a main factor controlling the growth rate and reproductive events of cotton plants. Simulation models used for predicting cotton yield sometimes are not accurate enough for cotton grown in Andalusia (Gutiérrez et al., 2000). Cumulative heat units in Andalusia reach 1320 DD (180 days season growth from April to September) and higher yield should be expected in the absence of other limiting factors.
Cotton is relatively heat tolerant in comparison with other C3 crops but high temperature may increase square and boll shedding and decrease yield (Guinn, 1974). Leaf temperatures higher than 28°C (cotton thermal kinetic window) (Hatfield and Burke, 1991) might affect metabolic processes. Increase in leaf temperature by a decrease in transpiration has been related to reduction in yield in drought-stressed cotton (López et al., 1995). However, when water is not limiting, high temperature can similarly reduce cotton yield (Reddy et al., 1992). Low stability of seed cotton yield in Andalusia might be related to yearly variation of climatic conditions. In this report, we studied the relationship between cotton yield and temperature (air temperature, cumulative heat units) to detect crop critical stages and limitations to productivity.

Methods

This study was performed for a serial of 7 years of field trials (1991-1997) at Alcalá del Río (Sevilla), a representative area of cotton cropping in SW Spain. A variable number of American and Spanish Upland commercial cultivars (from 14 to 22) was included. Cultivation was optimized for reaching top yields. Maximum and minimum temperatures were recorded in an automated weather station (Sainco, Teletransa). Heat units were computed in °C units and the equation $DD_{15.5}= 0.25(T_{max} + T_{min}-2T)$, where T represents the threshold temperature for growth and development (15.5°C) and T_{max} and T_{min} are daily maximum and minimum air temperatures (°C) recorded in the weather station.

Results

When no management limitations to cotton production are imposed (optimizing irrigation, fertilization and pest control), a decrease in productivity was observed during hot years. The accumulation of heat units (AHU) during the crop season in seven different years showed a negative relationship with cotton yield ($r=-0.731$, $P<0.10$) (Figure 1). When considering the AHU month by month, the AHU values in August were the ones with the strongest negative effects on productivity ($r=-0.86$, $P<0.01$). Seed index (weight of 100 seeds) was more affected those years with great AHU before flowering (April-June) ($r=-0.906$, $P<0.01$). Fiber yield was strongly affected those years with high AHU during August ($r=-0.735$, $P<0.10$). Some fiber traits like fiber length and uniformity were negatively correlated with AHU from April to June ($r=-0.689$ and $r=-0.768$, $P<0.10$ respectively), whereas fiber resistance, lengthening and micronaire were not affected.

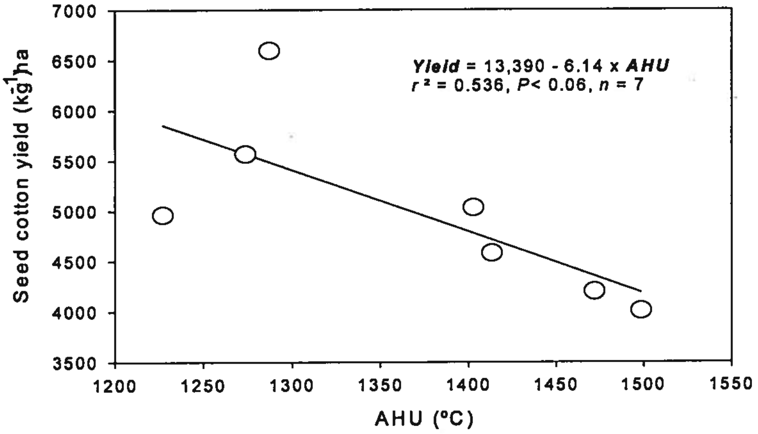

Figure 1. Relationship between seed cotton yield and accumulation of heat units (AHU).

The number of days with minimum temperatures above a threshold of 17°C was negatively correlated with yield ($r=-0.859$, $P<0.01$). The number of days with maximum temperatures above 37°C were similarly negatively correlated with yield ($r=-0.805$, $P<0.05$). The negative effect of high temperature on cotton yield has been related to reduction in boll retention (Reddy et al., 1992) and photosynthetic inhibition (Guinn, 1998). In Pima cotton, selection for higher heat resistance has led to cultivars with higher stomatal conductance and reduced leaf area (Lu et al., 1994). Research now should be focussed on studying the main yield components affected by heat stress and finding out tolerant genotypes for improving yield potential and stability.

Conclusion

High summer temperatures in the Guadalquivir River Valley have been associated to reductions in cotton productivity and fiber quality. Heat seems to be a main limitation to reach yield potential of available cultivars. At present, research is being carried out to identify germplasm with differential sensitivity to heat stress.

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References

Guinn G. (1974) Crop Sci. 14:291-293.
Guinn G. (1998) Proc. Beltwide Cotton Conference 2: 1355-1364.
Gutiérrez J.C. et al. (2000) In: New Frontiers in Cotton Research, WCRC-II, Athens, Greece.
Hatfield J.L., Burke J.J. (1991) Environ. Exp. Bot. 31: 295-302.
López M. et al. (1995) Eur. J. Agron. 4: 119-126.
Lu Z. et al. (1994) Physiol. Plant. 92: 266-272.
Reddy K.R. et al. (1992) Agron. J. 84: 26-30.

RESPONSE OF FOUR LUCERNE CULTIVARS TO TWO CUTTING FREQUENCIES

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Introduction

In relation to the productive characteristics to obtain: qualitative or quantitative, the Lucerne (*Medicago sativa* L.) meadow must be mowed in a different growth stage (Parrini, 1989). It is so necessary to choose a specific harvest schedule that entails a different number of cuts in the year. When considering the results to reach, the Lucerne plants must be submitted to a different cutting frequency. A field trial plots was established with the aim to increase the knowledge about the effects of two cutting frequencies (25 or 35 days between cuts) on the herbage yield parameters of four cultivars of Lucerne. Some of the results obtained during the first two years of study are following reported.

Materials and methods

The experiment was conducted, in rainfed conditions, on the Experimental Farm of Padova University in Legnaro (Padova: NE Italy) in a loam flat soil (pH 7.8). The zone is characterised by 12.2 °C and 824 mm yearly mean temperatures and rainfalls respectively. The plot trial was established on 13th September 1994 (sowing rate 30 kg ha^{-1}), on a soil surface that was adequately prepared and fertilised with 200 kg/ha of P_2O_5 and 250 kg/ha of K_2O_2 and conducted for two year, from 1995 to 1996. An eight replicated randomised block design was laid out, plots size (m 2 x m 10), four of the eight blocks being used as destructive. Eight treatments were compared, deriving from the factorial combination of four cultivars (Agata, Boreal, Delta and Equipe) and two harvest schedules: 25 or 35 days between cuts. Two of the four cultivars (Delta and Equipe) arise from a local genotype and the remaining (Boreal and Agata) from a foreign genotype.

Herbage was harvested leaving a 5 cm stubble, yields were determined by weighting the herbage obtained from a test area of 10 m^2 (m 1 x m 10). A 500 g sample of each plot, at each harvest, was dried at 65 °C to determine the dry matter percentage and the yields. A plant samplings (cm 20 x 50 x 15), consisting of tap roots and aerial portion remaining of plants, were removed from the plots immediately after each harvest and also in correspondence to the last cut of plots treated at 25 d in the plots treated at 35 d. All the survival plants were counted and the diameter of each tap root was measured, at 3 cm from the crown, using a calibre; lastly, only in 1995, all the roots samples (from the crown base to 15 cm deep) were dried at 105 ° C to determine the dry weight.

Results and discussion

In the mean of the two years of trial and of the eight treatments compared, the annual yield was of 11.66 t h^{-1} of DM. This value depended however in part on the different behaviour of the four cultivars compared and in part on the different effects of the two cutting frequency used (Table 1). Instead, the interaction "cultivars x cut frequency" was no statistically significant. The yield trend of the two years trial is reported in the Figure 1a. Each one of the three characteristics observed allow to understand the response of the cultivars compared to the two harvesting schedules. In both the harvesting

Table 1. annual yield (t ha^{-1} of DM). Sig. different at $P \leq 0.01$ the effects: year, *cv* and cutting frequency and also the interactions: year x *cv* and year x cutting frequency. In the last column the values with different letters are sig. different at $P \leq 0.05$ (Duncan test).

Factor	1995	1996	mean
Agata	8.86	12.19	10.53 c
Boreal	10.39	12.41	11.40 bc
Delta	8.88	14.95	11.92 b
Equipe	10.40	15.23	12.82 a
25 d	8.16	9.87	9.02
35 d	11.11	17.52	14.31
mean	9.63	13.69	11.66

schedules the diameter of the tap root (Figure 1c) increased over time, on the other hand, the plants growth was clearly higher in a low cutting frequency (35 d) condition compared to the high cutting frequency (25 d). Thus at the last harvest of 1995 the mean value, of the four cultivars, was of 4.45 mm for the high cutting frequency versus 5.35 mm for the low cutting frequency. In the following year the values was respectively of 5.40 mm and 6.52 mm. The tap root weight, measured only at each harvest of the first year, (unitary weight of the four cultivars: 1st cut 0.44 g; 6th cut of 25 d frequency 0.99 g; 4th cut of 35 d frequency 1.58 g) was higher correlated with the same tap root diameter (treat. 25 d: r = 0.97**; treat. 35 d: r = 0.99**). Thus, the values are not reported, but they support the theory that 35 days between two consecutive harvests allow the plants to restore the root reserves necessary to support the regrowth. Referring to the number of plants per square meter (Figure 1b), in both years the data show that in low cutting frequency condition (35 d) this value decrease as consequence of the high competition producing a rapid and permanent selection among plants. At the last harvest of 1995 and at the first harvest of 1996, the number of plants per unit of area was similar, this probably was the consequence of the major plants vigour due to the high amount of root reserves stored that allowed to support the winter hardiness.
Under frequent harvesting schedule (25 d), instead, the number of plants did not decrease markedly in the first year as a consequence of a low competition among plants. The plants population density of the plots subjected to high cutting frequency, decreased drastically at the and of the winter for all the cutivars, with the exception of the cultivar Delta (local genotype), and also between the 2nd and the 3rd cut of the 1996 for the cultivars Agata and Boreal and between the 4th and the 5th for "Delta". These results are the logical consequence of cutting frequency effects on plant physiology, in fact, too defoliation frequency reduce the reserves and consequently the regrowth and the harvest yield; moreover it may be responsible for the decline of the plant persistence.

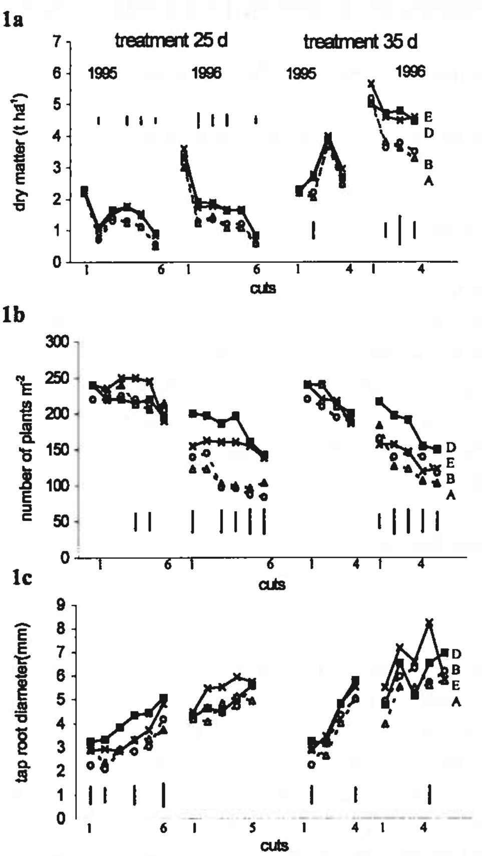

Figure 1 . Yield (1a), number of plants m^{-2} (1b) and tap root diameter (1c) at harvest time. The vertical bars indicate LSD. A = Agata; B = Boreal; D = Delta; E = Equipe.

Conclusions

During the two years trial, no one of the four cultivars compared appeared to be particularly suitable to the frequent or infrequent harvesting schedule. In fact, for all of the cultivars the highest yield had been under low cutting frequency (35 days between cuts), in consequence, essentially, of the possibility to completely restore the organic reserves necessary to support a rapid and vigorous regrowth.

References

Parrini P., 1989. Erba medica (*Medicago sativa*). In Baldoni R., Giardini L., Coltivazioni erbacee. Pàtron editore. 859-892.

EFFECTS OF FREE-AIR CO_2 ENRICHMENT (FACE) AND SOIL NITROGEN FERTILIZER ON RADIATION ABSORPTION, RADIATION USE EFFICIENCY AND YIELD OF WINTER BARLEY

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Introduction

Plant growth depends on the atmospheric CO_2 concentration, which has dramatically changed in the past and will continue to increase in the future. The objective of the present study was to analyse the effect of future atmospheric CO_2 concentrations and variable nitrogen (N) supply on growth and yield of winter barley by using the FACE (Free Air CO_2 Enrichment)-technique. Previous FACE-studies on wheat have shown that CO_2 enrichment increased crop growth by affecting radiation use efficiency of biomass production, while green leaf area index and radiation absorption was not influenced (Pinter et al., 1996, Jamieson et al., 2000). The resulting effect on grain yield amounted to 16% and 9% for the high and low N treatment, respectively (Hunsaker et al., 2000).

Methods

A FACE system consisting of 4 rings (20 m diameter each) engineered by Brokhaven National Laboratory NY/USA is operated at a 22 ha field site in a local crop rotation (Weigel and Dämmgen, 2000). The experiment includes 2 CO_2 concentrations and 2 levels of N supply as a split plot. The CO_2 concentration of the air of 2 rings was enriched to 550 ppm during the daytime (FACE-rings) and 2 control rings received ambient air (370 ppm CO_2). N supply was restricted to 50% of adequate N in half of each ring. The total ring area was divided into 4 sections resulting in 4 replicates per treatment. In autumn 1999 winter barley (cv. „Theresa") was sown and fertilized during the season with 150 and 75 kg ha^{-1} mineral N, respectively. In 2000, crop growth was followed by measuring above ground biomass production of 0.2 m^2 sampling areas in each replicate and by recording the percentage of PAR absorption of the green canopy with a line quantum sensor (%APAR). At maturity sampling area was increased to 2 m^2. Seasonal PAR absorption of the green canopy (APAR) was calculated from the percentage of PAR absorption and the data of incident PAR recorded at the field site. Radiation use efficiency of biomass production (RUE) of each replicate plot was estimated from destructive biomass data and the radiation absorption. Significant treatment effects were evaluated using analysis of variance (ANOVA).

Table 1: Effect of FACE and N supply on seasonal PAR absorption (APAR) and radiation use efficiency of above ground biomass production (RUE). Treatment means (± standard deviation (n=4)) and P-values of the ANOVA are shown (n.s.: p>0.10).

N level	CO_2 level	APAR (mol m^{-2})	RUE (g mol^{-1})
75 kg N ha^{-1}	370 ppm	1779 ± 21	0.732 ± 0.047
	550 ppm	1883 ± 10	0.795 ± 0.023
	CO_2 effect	+5.8 %	+8.6%
150 kg N ha^{-1}	370 ppm	2353 ± 61	0.694 ± 0.032
	550 ppm	2319 ± 19	0.751 ± 0.052
	CO_2 effect	-1.4%	+8.2%
Results of ANOVA			
P_N		<0.001	0.06
P_{CO2}		0.06	0.01
P_N x P_{CO2}		0.002	n.s.

Results

Three way ANOVA of all %APAR data yielded significant effects ($p<0.001$) of date, N and CO_2 and an interaction of N x CO_2, which demonstrated a higher CO_2 effect under low N. This was also detectable for APAR, which was influenced by FACE in the low but not in the high N treatment (Table 1). RUE was significantly increased under FACE (Table 1). At grain maturity, reduction in N fertilization decreased plant growth by ca. 20%, while FACE stimulated biomass and grain yield (Table 2). There was a significant N x CO_2 interaction on stem biomass, which was more affected by CO_2 under low than high N. CO_2 related increase in total biomass was highest under low N but the response of grain yield was similar for both N levels, since harvest index was decreased under FACE and low N.

Tab. 2: Effect of CO_2 enrichment and N supply on biomass and grain yield of winter barley at maturity. Treatment means (± standard deviation (n=4)) and p-values of the ANOVA are shown.

N level	CO_2 level	stem biomass ($g\ m^{-2}$)	total biomass ($g\ m^{-2}$)	grain yield ($g\ m^{-2}$)	harvest index
75 kg N ha^{-1}	370 ppm	394± 23	1360± 88	784 ± 64	0.509 ± 0.016
	550 ppm	499± 23	1546± 52	850 ± 28	0.487 ± 0.002
	CO_2 effect	+26.6	+13.7 %	+8.4 %	-4.3
150 kg N ha^{-1}	370 ppm	522± 26	1679± 37	952 ± 17	0.502 ± 0.002
	550 ppm	564± 26	1815± 6	1023 ± 28	0.499 ± 0.013
	CO_2 effect	+8.0	+8.1 %	+7.5 %	-0.6
Results of ANOVA					
P_N		<0.001	<0.001	<0.001	n.s.
P_{CO2}		<0.001	<0.001	0.004	0.03
P_N x P_{CO2}		0.03	n.s.	n.s.	0.09

Discussion

The present study yielded a positive growth response of winter barley to CO_2 enrichment which was based on an increase of RUE and under low N also of APAR. This could explain the greater biomass response under low than high N. However, such a greater response could not be observed for grain yield, since harvest index was negatively affected. Overall, the size of the CO_2 effect was similar to the findings for wheat (Hunsasker et al., 2000). However, the stimulation of APAR by high CO_2 and low N observed for barley contrasts with the findings for wheat (Jamieson et al., 2000). The CO_2 related increase in APAR of winter barley seems to be due to the strong increase in stem growth which in turn influenced stem area.

References

Hunsaker, D.J., Kimball, B.A., Pinter, P.J., Wall,G.W., Lamorte, R.L., Adamsen, F.J., Leavitt, S.W., Thompson, T.L., Matthias, A.D., Brooks, T.J., 2000. Agr. Forest Meteorol. 104, 85-105.

Jamieson, P.D., Berntsen, J., Ewert, F., Kimball, B.A., Olesen, J.E., Pinter, P.J., Porter, J.R., Semenov, M.A., 2000. Agr. Ecosyst. Environ. 82, 27-37.

Pinter, P.J., Kimball, B.A., Garcia, R.L., Wall, G.W., Hunsaker, D.J., Lamorte, R.L., 1996. In: Carbon dioxide and terrestrial ecosystems, ed. by G.W. Koch and H.A. Mooney, Academic Press, p. 215-249.

Weigel, H.J., Dämmgen, U., 2000. J. Appl. Bot. 74, 55-60.

DETERMINATION OF ^{10}B AND ^{11}B IN TOMATO LEAVES BY INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY

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Introduction

In central part of Brazil, boron is the most important micronutrient for vegetable production (Filgueira, 1972). Boron sufficiency in crop plants is reported to be in the range of 20 – 100 mg kg^{-1} (Fageria, 1992). A deficiency of B can cause reductions in vegetables yields or quality which may contribute to a final depreciation of the product . Hence, B determination in plants and soils is essential to prevent deleterious effects on vegetable yields. However, there is no information in the literature regarding ^{10}B and ^{11}B content in vegetable crops cultivated in Brazilian cerrado soils. Recently, with the development of inductively coupled plasma mass spectroscopy (ICP-MS), these determinations became possible. This powerful equipment efficiently ionizes in most elements introduced to single charged positive ions (M^+) so that the plasma can be used as ion source for the mass spectrometer. This paper reports the results of ^{10}B and ^{11}B determination in leaves of tomatoes (*Lycopersicon esculentum* Mill) cv. Santa Clara cultivated in a cerrado soil of Brasilia Federal District, Brazil, using ICP-MS.

Material and methods

For this study, ryegrass (*Lolium multiflorum* Lam.) CRM 281 leaves (certified value) were included for calibration of the instrument, verification of the method and validation of results. Standard concentration is shown in Table 1. Tomatoes (*Lycopersicon esculentum* Mill) leaves cv. Santa Clara cultivated on a Clayey Yellow-Red Latosol of Brasilia, Federal Disctrict-Brazil, were collected at the flowering stage. Ten grams of finely dried (65°C) tomato leaves were weighed in four replicates, accurately in a Pt dish and heated at 550°C for 5 hours for incineration. The residue was allowed to cool. Two milliliters of 6 mol L^{-1} HCl was added. The mixture was heated for 30 minutes. After, the solution was cooled, filtered through Whatman filter paper and diluted to exactly 5 ml with ultra pure-water into a polyetilene bottle made from metal-free raw materials, from which 0.1 ml was taken and diluted 100 times by adition of 1ml 10.0 µg kg^{-1} beryllium (Be) (used as internal standard element) and 8.9 mL of 1% HNO_3. Serie of standard used were 0.0; 1.0; 5.0 and 10 µg g^{-1} B. Then, the solution was nebulized into ICP-MS (VG Plasma –Quad PQ-1, VG Elemental Ltd) and determination of ^{10}B and ^{11}B were done. A recovery test was done by the addition (1.000 g dry matter) of known amounts of boron.

Results and Discussion

Table 1 shows the quantitative determinations for the standard reference material using ICP-MS. Values obtained were compared to the certified values of standard reference material (ryegrass CRM 281 leaves). Low coefficient determination were observed in the determination of ^{10}B and ^{11}B. The contents of ^{10}B and ^{11}B in tomatoes leaves cv. Santa Clara were 100.5 and 104.3 µg g^{-1} respectively (average of four replicates). Good recoveries of ^{10}B and ^{11}B from the sample were obtained 99 and 97% respectively. Therefore, this method was found suitable for ^{10}B and ^{11}B determination in tomatoes leaves by ICP-MS. Evaluation of digestion methods for multi-elemental analysis of various metals and semimetals in organic fertilizers by ICP-MS is described by Kawasaki et al. (1995). However no reference was done to ^{10}B and ^{11}B determination. Therefore, it is essential to develop analytical methods to examine the influence of ^{10}B and ^{11}B on the environment, crops and human health.

Table 1. Boron content in standard reference material.

Constituents	^{10}B	^{11}B
	($\mu g\ g^{-1}$)	
Ryegrass CRM 281 leaves		
Certified value	6.01 ± (0.22)	6.8 ± (0.028)
Value obtained	6.19	6.20
CV (%)	4.90	8.53

Conclusions

The contents of ^{10}B and ^{11}B in tomatoes leaves cv. Santa Clara were 100.5 and 104.3 $\mu g\ g^{-1}$ respectively (average of four replicates).
The method was found suitable for ^{10}B and ^{11}B determination in tomatoes leaves by ICP-MS.

References

Filgueira, F.A.R. Manual de olericultura. São Paulo: Agronômica Ceres, 1972. 451p.
Fageria, N.K. Maximizing crop yields. Marcel Dekker, New York: M. Dekker, 1992. 274p.
Kawasaki, S.; Arai, S. Evaluation of digestion methods for multi-elemental analysis of organic wastes by Inductively Coupled Plasma Spectrometry. Soil Science Plant Nutrition, Tsukuba, v.42, n.2, 1995. p.251-260.

EFFECT OF TIME OF DESICCATION ON 1000 SEED WEIGHT IN SUNFLOWER

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INTRODUCTION

Introduction of chemical desiccation had solved many problems associated with mechanized sunflower harvest. Advantages of this cultural practice were noted by numerous authors *(Shadden et al., 1970; Degtyarenko, 1976.)*. If chemical desiccation is performed in early stages of plant maturation, it may impair seed yield and quality. Late treatment brings in question the economic effects of the practice. Recommendations for desiccation time vary from 25% seed moisture (*Palmer and Sanderson, 1976.)*, 30-35% seed moisture (*Degtyarenko, 1976, Kosovac and Sudimac, 1980*), 40% seed moisture (*Morozov, 1976, Gumanuiuc et al., 1980; Maširevic and Glušac, 1999)*, to 45% seed moisture *(Gubbels and Dedio, 1985)*.

Maximum 1000 seed weights were achieved at seed moistures of 18-41% *(Chervet and Vear, 1989),* 33-41% *(Farizo et al., 1980)* depending of hybrid. If crop have been treated with high doses of desiccant, 1000 seed weight have been decreased, but not the yield (*Gumanuiuc et al., 1980).* Max 1000 seed weight have been achieved after the yield.

The objective of this study was to determine the optimum time of chemical desiccation in commercial seed production of sunflower hybrids, in order to maximize the economic effects of the production from the point of 1000 seed weight.

METHODS

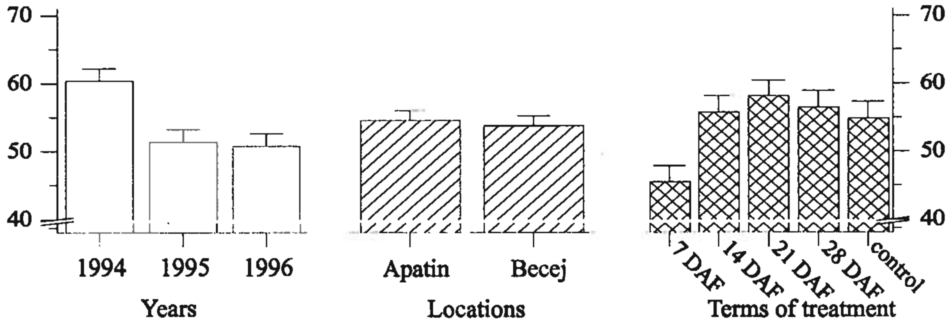
Field trials were conducted in sunflower seed production fields in the course of 1994, 1995 and 1996. Each trial was established in three replicates, with the basic plot size of 17.5 m^2 (one row 25 m x 70 cm, one empty row between the treatments, to avoid drift effect).

Treatments were conducted at 7-day intervals starting from the end of pollination, i.e., from the end of flowering. Reglone forte was used in the concentration of 1%, i.e., the dose of 2 l/ha of the preparation was added to 200 liters of water/ha, as recommended by *Maširevi□ and Glušac (1999)*. Treating was done with a portable sprayer.The experimental material was female component of hybrid NS-H-45 grown on two locations The end of pollination was defined as the end of pollination in the centre of the head. Since the experiment was conducted in large seed production plots, average seed samples from entire heads were taken in order to make the results comparable. Seed moisture was determined by the classical method of drying at 105°C till constant weight. At full maturity, seed samples were taken in all treatments and the control for 1000 seed weight determination.The obtained results were statistically processed using the analysis of variance for two-factorial and three-factorial trials and the regression analysis.

RESULTS

The highest average 1000 seed weight (60.4 g) was registered in 1994, the lowest (50.8 g) in 1996. The differences among the years were significant (Graph. 1). There were no significant differences between locations.

Graph. 1. 1000 seed weight



The lowest 1000 seed weight was registered in the first treatment 7 days after flowering (DAF) (45.5 g, seed moisture at the moment of treatment was 70.68%), the highest 21 DAF (58.1 g, seed moisture 44.9%). There were no significant differences in 1000 seed weight among 14 DAF (seed moisture at the moment of treatment 56.6%), 21 DAF, and 28 DAF, but 7 DAF, 14 DAF and the control had significantly lower weights. Therefore, there was no significant increases of 1000 seed weight after seed had been reached moisture of 56.6%.

It was established that seed moisture at the time of desiccation had a high effect on 1000 seed weight. Coefficients of determination were high and significant at the location Apatin ($r^2 = 0.58^{**}$), but no significant on location Becej ($r^2 = 0.33$). Maximum 1000 seed weights were reached at seed moistures of 29.9%, and 35.7, on locations Apatin and Becej respectively. Evidently, the results of our study are in agreement with the results of *Chervet and Vear, (1989).* There was decrease of 1000 seed weight in the control compared with the optimum treatments. *Hill et al. (1974)* and *Kosovac and Sudimac (1980)* obtained similar results. *Rodrigues Pereira (1978)* attributes this decrease to oil transfer from the kernel to the husk and to the dissimilation, after a steady supply of assimilates coming from the mother plant has been disrupted.

CONCLUSIONS

Following conclusion may be drawn on the effect of time of chemical desiccation on 1000 seed weight.

Annual variations in 1000 seed weight were significant, but not variations between locations. The highest average 1000 seed weight was found in the treatment 21 DAF (seed moisture at the time of treatment was 44,9%). There were no large differences among treatments 14 DAF, 21 DAF and 28 DAF. It means that there was no large increment in 1000 seed weight in the period after the average seed moisture reached 56.6% till maturity.

Desiccation of female component of hybrid NS-H-45 with no significant negative influence on 1000 seed weight, can be done very early, when seed moisture reach 45%.

REFERENCES

Degtyarenko, V.A. (1976): Preharvest dessication of sunflower, Proc. of 7th Inter. Sunflower Conf., pp 174-178

Gubbels, G.H., Dedio, W. (1985): Desiccation of sunflower with Diquat, Can. J. Plant. Sci. 65, pp 841-847

Farizo, C., Pereyra, V. R., Cardinali, F., Orioli, G. A. (1982): Determination of physiological and harvest maturity in sunflower. Proc. of 10th Inter. Sunflower Conf., 42-44

Gumaniuc, N., Nicolae, H., Filipescu, H., Cseresnyes, Z., Ghinea, L., Sin, G., Bondarev, I. (1980): L'application du dessicant Reglone au tournesol et ses implications, Proc. of 9th Inter. Sunflower Conf., pp 380-388

Hill J., Knight, B.A.G., Ogilvy, J.M.E. (1974): The significance of a new harvest technology in the intensive production of sunflower, Proc. of 6th Inter. Sunflower Conf., pp 589-596

Kosovac, Z., Sudimac, V., (1980): Testing the ground for regular desiccation of sunflower before harvesting, Proc. 9th Inter. Sunflower Conf., Tomo II, pp 357-361

Maširevic, S., Glušac, D. (1999): Desikacija i njen znacaj u suzbijanju prouzrokovala bolesti semenskog suncokreta, Zbornik naucnih radova sa 13. savetovanja agronoma, veterinara i tehnologa, Arandelovac, Vol 5. Br. 1., pp 175-181

Palmer, J.R., Sanderson, J.F. (1976): Canadian experience with the pre-harvest desiccation of sunflower with Reglone, Proc. of 7th Inter. Sunflower Conf., pp 167-173

Rodrigues Pereira A. S. (1978): Influence of temperature on seed growth and seed ripening in sunflower, Proc. of 8th Inter. Sunflower Conf., pp 199-211

Shadden, R.C., Mulluns, J.A., McCutchen, T. (1970): Mechanical harvesting of sunflowers in Tennessee, Proc. of 4th Inter. Sunflower Conf., pp 265-270

Chervet, B., Vear, F. (1989): Evolution des caracteristiques de la graine et du capitule chez le tournesol au cours de la maturation, Agronomie, 9, pp 305-313

RELATIONSHIP BETWEEN GRAIN YIELD AND YIELD COMPONENTS IN BARLEY (*HORDEUM VULGARE* L.) GROWN UNDER IRRIGATED CONDITIONS

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Introduction

As in the case of cereals in general, it is common to break down the economical harvest of barley into the product of three components: number of ears per square meter (EM2), number of kernels per ear (KPE) and mean kernel weight, usually expressed through 1000-kernel weight (KW). These yield components are formed over successive stages of the cereal development process. Therefore, an anomalous component may be compensated for by the elevation of those formed next, if environmental conditions are adequate, allowing yield to be more or less stable. Thus, the compensation mechanisms imply that at least one component tends to be negatively correlated with one that develops later.

The relationships between yield and its components are complex, especially due to these compensatory interactions. They limit the value of a simple correlation analysis because it does not specify the characteristics of each variable, although it gives information concerning the magnitude of the influence of each one.

A path coefficient analysis, like that described by García del Moral et al. (1991a, 1991b), was carried out to try to furnish an adequate representation of the relative magnitude of each yield component, separating the direct from the indirect effects exercised through the compensations induced by the others.

The aim of this work is to analyze the contribution that each component makes to the crop and the causes for variations in yield, data which is fundamental in order to correctly orient guidelines for improvement.

Material and methods

A field study was conducted during three years (1997 to 1999) in Ciudad Real (Spain). The Beka variety was used as it is well-established and highly-considered among cereal farmers in Castilla-La Mancha. The crop was irrigated using a sprinkler irrigation system, and the fertilization consisted of 100 kg P_2O_5 ha^{-1} applied at pre-sowing and 100 kg N ha^{-1} fractioned in 50% at sowing and 50% top-dressing at tillering stage. The high levels of assimilated potassium in the soil (415 ppm) made potassium fertilization unnecessary.

Each growing season, prior to harvest, 20 samples of 0.20 m^2 were randomly taken to carry out counts, referring mean kernel weight to 12% humidity. Considering that the interrelationships between the measured parameters can vary each year depending on the particular agroclimatic conditions, a joint analysis over a 3-year period (1997 to 1999) was used. The programs SPSS 8.0 for Windows and Nuevo3.exe, on loan from the cereal physiology research team from the University of Granada, were used for the statistical study.

Results

The correlation coefficients (Table 1) indicate that the grain yield in barley is especially conditioned by EM2. Both KPE and KW have proportionally less effect, the effect of KW even being negative.

The results of the path coefficient analysis (Table 2) differ from those reached in the simple correlation analysis. Therefore, although EM2 remains the most important component in the determination of yield, the effect of KPE increases and a new perspective of the contribution of KW is shown.

Table 1.- Correlation coefficients between grain yield and yield components in barley for three years of experiments in Ciudad Real (Spain)

	EM2	KPE	KW
Grain yield	0.83***	0.32*	-0.62***
Ears per m^2 (EM2)		-0.11	-0.84***
Kernels per ear (KPE)			-0.14
1000-Kernel weight (KW)			

*, ***:Significant at 0.05 and 0.001, respectively

Table 2.- Path coefficient analysis of grain yield in barley for three years of experiments in Ciudad Real (Spain)

Multiple correlation coefficient	R	0.996***
Ears per m^2 *vs.* grain yield:		
Direct effect	P_{14}	1.504***
Indirect effect via:		
Kernels per ear	$r_{12} P_{24}$	-0.065
Kernel weight	$r_{13} P_{34}$	-0.610
Correlation	r_{14}	0.830***
Kernels per ear *vs.* grain yield:		
Direct effect	P_{24}	0.587***
Indirect effect via:		
Ears per m^2	$r_{12} P_{14}$	-0.165
Kernel weight	$r_{23} P_{34}$	-0.102
Correlation	r_{24}	0.320*
Kernel weight *vs.* grain yield:		
Direct effect	P_{34}	0.726***
Indirect effect via:		
Ears per m^2	$r_{13} P_{14}$	-1.263
Kernels per ear	$r_{23} P_{24}$	-0.082
Correlation	r_{34}	-0.620***
Residual	P_{U4}	0.117

*, ***:Significant at 0.05 and 0.001, respectively

Since the direct effect of a factor proportionally expresses its quantitative influence on yield in barley crops, it can be confirmed that in this study EM2 had approximately two times the effect of KW and 2.5 times more than KPE.

The study of indirect effects shows that the correlation coefficient between yield and KW (r_{34}=-0.62***) was affected by the strong indirect effect that this component exerts through EM2 (r_{13} P_{14}=-1.263), since the direct effect of KW on yield is really positive (P_{34}=0.726***). This fact is a consequence of the important inverse relationship existing between EM2 and KW (r=-0.84***), principal determinant factors of grain yield in this study, due to the compensation mechanisms. Thus, a lower KW arises from a higher EM2, so yield appears to increase when KW decreases.

Conclusions

The data presented here suggest that Beka barley is highly capable of compensating the yield by means of the suitable modification of its components, which would explain its acceptable yield under marginal conditions, and that the grain yield depends mainly on the number of ears per square meter.

References

García del Moral L.F., Ramos J.M., García del Moral M.B. 1991a. Investigación Agraria: Producción y Protección Vegetales, 6 (3), 305-317.

García del Moral L.F., Ramos J.M., García del Moral M.B., Jiménez-Tejada M.P. 1991b. Crop Science, 31 (5): 1179-1185.

THE INFLUENCE OF SEEDING RATE ON BARLEY (*HORDEUM VULGARE* L.) YIELD

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Introduction

Cereal production is one of the basis of the agrarian economy of Castilla-La Mancha, together with vineyards and olive groves. At present, barley is the most widely cultivated and economically important cereal in this zone, which justifies the need to find improved cultivation techniques. Farmers often use more inputs than necessary to obtain a given yield, resulting in some cases in environmental damage, such as the overuse of nitrogen fertilizer or water waste. The end result always implies higher investments which lead to lower incomes.

In this study we aim to determine the productive response of 'Beka' barley, cultivated in irrigated conditions, at different seeding rates.

Material and methods

A field study was conducted during three years (1997 to 1999) in Ciudad Real (Spain). The Beka variety was used as it is well-established and highly-considered among cereal farmers in Castilla-La Mancha. The crop was irrigated using a sprinkler irrigation system. The irrigation period varied depending on climatic conditions and development of the crop, from full tillering stage to the pastry grain stage. The irrigation program was established so that the plants received a total of water (rainfall + irrigation) similar to 80% of crop evapotranspiration (ETc). It appears to have been sufficiently demonstrated that this reduction in watering does not significantly affect barley yield (Martín de Santa Olalla et al., 1992; Moreno et al., 2000) and it can imply an important saving of water during dry seasons. The ETc was calculated by means of the water balance using a neutron probe in a nearby plot with similar soil characteristics and subjected to the same farming practices.

The sowing time varied according to climatic conditions (25/II/1997, 20/I/1998 and 16/XII/1998). The fertilization consisted of 100 kg P_2O_5 ha^{-1} applied at pre-sowing and 100 kg N ha^{-1} fractioned in 50% at sowing and 50% top-dressing at tillering stage. The high levels of assimilated potassium in the soil (415 ppm) made potassium fertilization unnecessary.

A randomized complete block design was adopted with five seeding rates treatments and four replications. The seeding rates were 100, 125, 150, 175 and 200 kg ha^{-1}, meaning an average of 260, 330, 395, 460 and 525 seeds per m^2 and 240, 300, 370, 425 and 480 plants per m^2, respectively, resulting in a total of 20 plots of 2.4x17 m (42 m^2).

Each growing season and prior to harvesting, a sample of 1 m row segment (0.20 m^2) was randomly collected to carry out counts in each plot. Both yield and 1000-kernel weight were referred to 12% humidity.

Results

No differences in yield were found between the treatments tested, which means that yield is similar using seeding rates between 100 and 200 kg ha^{-1}. The yield components were not affected either, showing the ability of barley crops to compensate the different seeding densities (Table 1). In particular, the similarity between the number of shoots per m^2 component means that during the tillering stage, a compensating effect for the different populations took place, shoot production increasing in the treatments having fewer plants per square meter. Logically, for this compensating process to occur, enough water and nutrients must be available during the tillering stage. Moreno et al. (2000) show that a serious water deficit during the tillering stage leads to a smaller shoot population.

The analysis of variance (Table 2) indicates that all of the parameters measured differ at $P \leq 0.01$ between growing seasons, which shows the yield variability between years in function of the climate, even when the crop is irrigated. No interactive effect was found between seeding rate and Year, confirming that the absence of differences between treatments occurred over the three-year experimental period. Thus, the particular characteristics of each growing season did not favor one treatment more than another.

Table 1. Mean values of grain yield and yield components in barley for each seeding rate in Ciudad Real (Spain). Years 1997 to 1999.

Seeding rate (kg ha^{-1})	Grain yield (kg ha^{-1})	Ear per m^2	Kernels per ear	1000-Kernel weight (g)
100	4773 a	637 a	18.2 a	41.7 a
125	4920 a	666 a	17.9 a	41.8 a
150	4691 a	654 a	17.3 a	41.6 a
175	4793 a	667 a	17.6 a	41.3 a
200	4541 a	678 a	17.3 a	40.7 a
Mean	4780	661	17.7	41.4

For each parameter, treatments with different letters differ at $P \leq 0.05$.

Table 2.- Summary of analysis of variance (F calculated) of grain yield and yield components in barley according to seeding rate in Ciudad Real (Spain). Years 1997 to 1999.

Source	Degrees of freedom	F Calculated			
		Grain yield	Ears per m^2	Kernels per ear	1000-Kernel weight
Seeding dose (SD)	4	0.99	1.41	2.40	1.62
Year (Y)	2	40.42**	103.55**	15.32**	122.41**
SD x Y	8	0.36	0.84	0.55	0.26
Experimental error	36				

**: Significant at $P \leq 0.01$.

The analysis of regression, considering the yield components as yield predictor variables (Table 3), shows that the ears per m^2 explain 69% of the yield variability, and 87% when considered together with the number of kernels per ear.

Table 3.- Analysis of regression of grain yield on yield components in barley according to seeding rate in Ciudad Real (Spain). Years 1997 to 1999.

Model	Predicting variables	Coefficients	Typical error	R^2
1	(Constant)	2149.34	233.92	0.69***
	Ears per m^2	3.98	0.35	
2	(Constant)	-1212.03	416.25	0.87***
	Ears per m^2	4.22	0.23	
	Kernels per ear	181.86	20.91	
3	(Constant)	-9388.15	281.71	0.99***
	Ears per m^2	7.22	0.112	
	Kernels per ear	255.28	5.49	
	1000-kernel weight	118.11	3.81	

R^2 = Pearson's determination coefficient. *** Significant at 0.001.

Conclusions

- The specific climatic conditions of each growing season have a very marked effect on barley crops.
- The tillering stage is one of the most important in barley development as it constitutes a compensation process for plant density.
- Barley has the ability to compensate for negative effects derived from low or excess seeding density. Therefore, the use of seeding rates between 100 and 200 kg ha^{-1} has no significant influence on the yield of Beka barley, nor on any of its components.

References

Martín de Santa Olalla F., de Juan J.A., Tarjuelo J.M. 1992. Ed. UCLM–ITAP de Albacete. 146pp.

Moreno A., Cabello M.J., Moreno M.M., Ribas F. 2000. XVIII Congreso Nacional de Riegos (Huelva), 54, 31-32.

RECOVERY OF SUNFLOWER AFTER DEFOLIATION: DOES IT DEPEND ON CHANGES IN DRY MATTER PARTITIONING?

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Introduction

As observed in a previous paper (Moriondo et al., 2001) sunflower is tolerant to defoliation (in terms of final yield) when it happens during vegetative growth, whereas since the onset of flower production plants become less able to compensate leaf area loss. Plants defoliated during vegetative growth showed a final yield not significantly different from control plants and the yield recovery was highly correlated with an increase of area of remaining leaves. The aim of this work was to investigate which is the physiological mechanism that allows remaining leaves to have a larger extension than control ones. Two mechanisms were taken into consideration: an increase in Specific Leaf Area (SLA, $cm^2\ g^{-1}$) (the leaves are greater because they are thinner) or in dry matter partitioning to leaves (the leaves are greater because more biomass is allocated to their growth) .

Method

The experiment was carried out in Florence (latitude 43° 46', longitude 11° 13', 42m asl), Italy in 2001. Plants sown on May 25th were grown at a density of 7 m^{-2}. Two treatments were compared: a) plants 50% defoliated at head visible stage, b) control. The experimental design was a randomized block set with three replicates.

Emergence was recorded the 3 of June. The defoliation was performed at head visible stage (29 Days After Emergence, DAE) by removing even-numbered leaf positions to reach about 50% of leaf area removed. At this stage, the leaves per plant were about 20 and leaf area per plant was decreased from 2400 cm^2 to 1255 cm^2 in the treatment. Plants were well watered (every day) during all the experiment and sunflower specific pest and pathogen treatments were performed during the season. The fertilisation was performed at sowing time (~100 kg ha^{-1}) and at first anthesis stage (~100 kg ha^{-1}).

Destructive measurements were performed at 26, 33, 40, 47, 54, 61, 68, 81, 92, 108 DAE removing two adjacent plants per replication. Plant biomass was divided into leaf lamina, shoot (stem + petioles), root and head (receptacle + achenes), dried in an oven at 75°C for 72 h and then weighted. The area of each leaf was measured using a CID Area Meter (CI-203, CID Electronic).

Leaf Area Index (LAI) was calculated as the product of total leaf area and number of plants per square meter. SLA was calculated as the rate of total leaf area (cm^2) and its weight (g). Biomass partitioning coefficients (PC) for leaves, shoot, root and head were estimated as the slopes of the regression between the organ masses and total plant masses (Trapani et al. 1992). Differences among the slopes were detected using *t* test procedure.

Results

Expansion of individual leaves was strongly affected by the treatments: leaves remaining after defoliation showed a larger final area than the corresponding leaves of the control. Leaf position from 10 to 24 (starting from the ground) showed significant differences among the treatments .

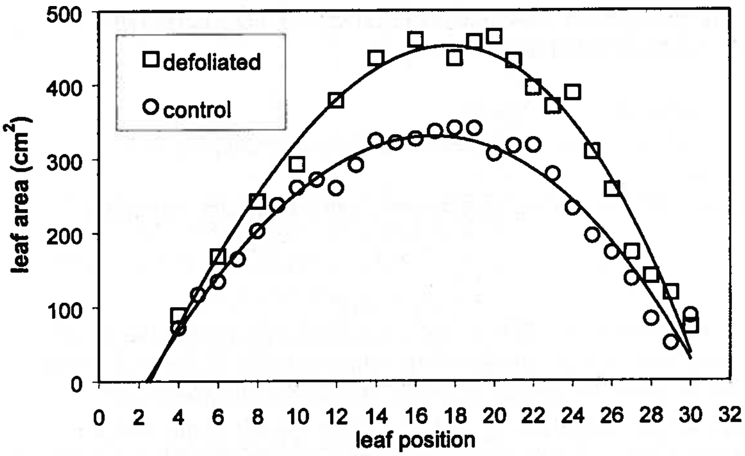

Figure 1. Maximum leaf area for defoliated and control plants

The observed leaf area recovery allowed the treated plants to reach a LAI comparable to control plants and final yield did not show significant differences (data not shown). SLA of control and treatment did not show significant differences during all the season (data not shown). PC for leaves, shoot head and roots calculated for pre-anthesis period is shown in table 1. The PC for the shoot and the head was not statistically affected by the defoliation treatments; whereas the PC's for the root and the leaves were statistically affected, showing however not consistent responses..

PC	leaves	shoot	root	head
Control	0.17 b	0.55 a	0.10 a	0.17 a
Defoliated	0.21 a	0.55 a	0.05 b	0.19 a

Table 1. Partitioning coefficients to leaves, shoot, roots and head

Conclusion

The increase in partitioning to leaves after defoliation supports the hypothesis that remaining leaves are larger because more biomass is allocated in. Moreover the consequent reduction of partitioning to roots suggests that during vegetative growth, assimilates are primarily partitioned to leaf growth. This result has important consequences for modelling purposes, when the effect of leaf area damages (due to fungi, insects or hail) is simulated for determining reliable crop yield.

References

Moriondo et al. 2001. Proc "Modelling cropping systems" 2nd International Symposium, Florence, Italy, 16-18 July, 2001, pp. 73-74.

Trapani et al. 1992. Proc. 13th International Sunflower Conference, Pisa, Italy 8-10 september 1992, pp. 651-657

EXCEPTIONAL RESPONSE OF OAT CULTIVARS WITH Dw6 DWARFING GENE TO ANTIGIBBERELLIC PLANT GROWTH REGULATOR

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Introduction

Plant growth regulator (PGR) effects on growth and yield formation of oat (*Avena sativa* L.) have not been much studied (Rajala *et al*, 2000; Peltonen-Sainio *et al* 2001). As oat is an important cereal crop grown in Finland, this study was arranged to measure the response of conventional, naked and modern dwarf oat cultivars to PGRs at high latitudes.

Methods

Antigibberellic chlormequat chloride (CCC, at ZGS32) was applied to conventional, naked, and dwarf oat cultivars to study its potential to modify yield formation and plant stand structure in northern growing conditions at Viikki Experimental Farm, University of Helsinki, Finland. Numerous traits characterising oat response to PGRs were measured.

Results

No lodging occurred in the years studied. Hence, the recorded alterations in grain yield were not due to associated changes in lodging resistance. CCC increased grain yield of oat by up to 13 %. This was due to more panicles per square meter and thereby greater tiller contribution to grain yield.

Our experiments also included oat cultivars with *Dw6* dwarfing gene. It was interesting to note that stem elongation was rather enhanced than reduced through the use of antigibberellic CCC in contrast to conventional and naked oat. The CCC effect was in general predominant on the uppermost internode, but when treated with CCC, the peduncle of the dwarf cultivars was up to 33 % longer and plants were 3 to 6 % higher at maturity when compared with untreated control plants. This was especially the case when cultivars were grown in the field at high latitudes, i.e. in long day conditions. When further testing them in growth chambers with artificial light conditions in short (14 hours) and long day conditions (18 hours), no such response was detected. In that case stem elongation of the dwarf cultivar showed insensitivity to CCC treatment.

The authors hypothesise that CCC possibly resulted in abundant accumulation of gibberellin biosynthesis precursors, which in addition to that resulting from the expression of the dominant *Dw6* gene, ended up in overdose of gibberellin precursor. This overdose possibly served as an abundant source for gibberellin biosynthesis in CCC treated plants later on. Thus, stem elongation of CCC treated plant was enhanced. This finding, however, contradicts that of Beharav *et al* (1994), who reported that CCC induced significant shortening in stem, which was somewhat greater in tall (*rht1*) than in semi-dwarf (*Rht1*) wheat. Evidently further experiments are needed to test our hypothesis.

References

Beharav A *et al* 1994. Mixed model for estimating the effects of the *Rht1* dwarfing allele, background genes, CCC and their interaction on culm and leaf elongation of *Triticum aestivum* L. spring wheat. Heredity 72: 237-241.

Peltonen-Sainio P *et al* 2001. Chlormequat chloride and ethephon affect growth and yield formation of conventional, naked and dwarf oat. Agricultural and Food Science in Finland 10: 165-174.
Rajala A *et al* 2000. Manipulating yield potential in cereals by plant growth regulators. In Basra, AS (ed) Growth Regulators in Crop Production. Food Products Press, Binghamton, New York, USA p. 27-70.

GROWTH, DEVELOPMENT AND YIELD OF DURUM WHEAT AS AFFECTED BY SEED SIZE

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Introduction

Rapid seedling establishment and early growth have been suggested as useful traits for improving yield under Mediterranean conditions (López-Castañeda *et al.*, 1996). Seed size has been shown to influence early plant development, seedling establishment and even grain yield (see Ceccarelli and Pegiati, 1980). The superiority of large seeds compared with small seeds in producing more vigorous and larger plants is generally more pronounced in case of unfavorable environmental conditions in early growth stages (see Mian and Nafziger, 1994).

In this study, a field experiment was conducted to assess the influence of seed size of durum wheat (*Triticum turgidum* var *durum*) on plant establishment and survival, early vigor, earliness in flowering, grain yield and yield components.

Materials and Methods

A field trial was carried out during 2000-01 growing season at Lleida (Spain). Six commercial durum wheat genotypes (Antón, Boabdil, Camacho, Mexa, Simeto and Vitron) with three seed-size classes each, were sown in a randomized complete bloc design with three replications, at a rate of 500 viable seeds per m^2. The three classes of seeds were: small, medium and large, having respectively a diameter less than 2.2, between 2.2 and 2.5, and more than 2.8 mm, and a 1000-kernel weight of around 20, 40, and 50 grams. Sowing was done on 21 December and harvesting on 4 July. Fertilization was broadcasted as recommended and weeds were chemically controlled at appropriate time. The total amount of water received during the crop cycle was 321 mm.

The measured traits are presented in Table 1. For more detailed information on methodology see Villegas *et al.* (2001). ANOVA, correlation and path analyses were performed.

Results and Discussion

The ANOVA revealed a high significant effect of seed size on all the traits. The superiority of large seeds with regard to all measured traits was clear (Table 1). Large seeds allowed plants to reach anthesis two days earlier than those from small seeds. The differences between classes of seed size with regard to early vigor, is shown by the differences in leaf area per plant (LAP), leaf area index (LAI) and crop dry weight (CDW) at tillering. Large seeds gave plants more vigorous than medium and small seeds. Thus, early flowering resulted presumably from rapid growth that was promoted by large seeds. Accordingly, Wallace and Yan (1998) reported that irrigation and fertilizers might promote early flowering too.

Table 1: Mean values of grain yield and other related traits for each seed-size class, across the six commercial durum wheat cultivars, at Lleida (Spain) during 2000-01. See text for abbreviation.

	At tillering				Days to anthesis	At maturity						
Seed size	Plants/m^2	LAP cm^2	LAI	CDW g/m^2		Plants/m^2	Spikes/m^2	CDW g/m^2	PLHeight cm	HI	TKW g	Yield kg/ha
Large	395 a	7.5 a	0.29 a	28 a	134 c	304 a	413 a	1400a	87.6 a	0.34 a	50.5 a	4855 a
Medium	345 b	6.0 b	0.20 b	20 b	135 b	239 b	388 a	1319ab	85.1 b	0.32 a	46.9 b	4199 b
Small	286 c	4.6 c	0.13 c	14 c	136 a	184 c	334 b	1241 b	84.7 b	0.29 b	45.6 b	3653 c

Means within columns with the same letter are not significantly different at 5% according to Duncan's test.

The advantage effect of large seeds was clearly exhibited by the success of plant establishment at tillering and plant survival. 79% of planted seeds of large size gave plants at tillering and 61% of them reached maturity. In contrast, 57% of planted seeds of small size gave plants at tillering and only 37 % of them reached maturity. The medium seeds gave an intermediate situation. That is, large seeds produce vigorous plants that, according to Evans and Bhatt (1977) are less prone to attack by various microorganisms and that they can better withstand moisture stress, resulting in better stand establishment and yield advantages. The superiority to withstand this stress is confirmed by the production of the tallest plants.

Path analysis (data not shown) revealed that harvest index (HI) exerted a positive direct effect on grain yield for the three classes of seed size. In fact, we assist to a steady increase of this positive effect in parallel with increase in seed size (0.42, 0.47 and 0.69 respectively for small, medium and large seeds). This trend was also true for the correlation coefficient between HI and grain yield (0.46*, 0.64**, and 0.79*** for large, medium and small seeds, respectively). Thus, plants derived from large seeds increased the efficiency of partitioning the available dry matter to grain.

Crop dry weight at maturity exerted a slight direct effect on yield for seeds of medium or large size.

In a sharp contrast however, for small seeds, CDW exerted the strongest negative direct effect on yield. This fact might be due to the production of sterile tillers and/or sterile main-spikes. However, this negative effect was partially counterbalanced by its positive indirect effect via spikes per m^2 and LAI at tillering. This latter trait exerted the strongest positive direct effect on yield followed by CDW. LAI at tillering showed a significant positive correlation with yield ($r = 0.64^{**}$).

Conclusion

This work shed light on the advantage effects of large seeds on plant establishment and survival, early vigor, earliness in flowering, biomass, efficiency in partition of available dry matter to grains (HI), and grain yield. Thus, the use of large seeds might contribute to increase grain yield of durum wheat under Mediterranean conditions.

References:

Ceccarelli, S. and Pegiati, M.T. 1980. Effect of seed weight on coleoptile dimensions in barley. Can. J. Plant Sci. 60:221-225.

Evans, L.E. and Bhatt, G.M. 1977. Influence of seed size, protein content and cultivar on early seedling vigor in wheat. Can J. Plant Sci. 57:929-935.

López-Castañeda, C., Richards, R.A., Farquhar, G.D., and Williamson, R.E. 1996. Seed and seedling characteristics contributing to variation in early vigor among temperate cereals. Crop Sci. 36:1257-1266.

Mian, M.A.R. and Nafziger, E.D. 1994. Seed size and water potential effects on germination and seedling growth of winter wheat. Crop Sci. 34:169-171.

Villegas, D., Aparicio, N., Blanco, R., and Royo, C. 2001. Biomass accumulation and main stem elongation of durum wheat grown under Mediterranean conditions. Annals of Botany 88:617-627.

Wallace, D.H. and Yan, W. (Eds). 1998. Plant breeding and whole-system crop physiology. Improving crop maturity, adaptation and yield. CAB INTERNATIONAL.

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INFLUENCE OF PLANTING DATE ON SEED YIELD AND OIL CONTENT IN EDIBLE-OIL FLAX AS A NEW CROP IN CENTRAL REGION OF IRAN

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Introduction

New genotypes of flax (*Linum usitatissimum* L.) with near-zero linolenic acid concentration (2%) and a linoleic acid concentration of near 70% has been developed by mutation programs (4, 7). The oil of these genotypes is suited to use as edible-oil. Edible-oil flax as a new and alternate oil-crop can be produced in Isfahan province in central region of Iran. To have a successful flax production and introduce this new crop in the region, appropriate sowing date is very important. Previous investigation in abroad showed that delayed sowing in flax caused a reduction in seed yield and its components (2, 5) and oil content (3). Since, there was no investigation on effect of sowing date on seed yield and oil content of this crop in the region, therefore, this study was conducted.

Methods

The experiment was organized as split-plot in a Randomized Complete Block Design with three replications in 2000 at the Research Farm, Isfahan University of Technology. The main factor included six sowing dates (Oct. 17, Mar. 15, Apr. 13, May 14, Jun. 13 and Jul. 15) and the sub factor consisted of four edible-oil genotypes of flax which named in this study as E-18, E-22, E-33 and E-37. Each subplot consisted of four 4m rows spaced 30 cm apart. A specific sowing rate (based upon 40 kg ha^{-1}) for each genotype was used to provide approximately the same number of seeds planted for all genotypes. The number of seedlings m^{-2} for each plot was calculated based upon number of seedlings in a 2m length of two middle rows. Seed yield of each plot was calculated as kg ha^{-1} based upon its seed weight. The oil concentration of a sample of whole seeds from each plot was determined by Soxhlet method. Analysis of variance for each variable was done using the General Linear Model of the SAS Institute, Inc. Program. The least significant difference test was used to determine the statistical differences between those means with significant F-test values.

Results

The results showed that sowing date had a significant effect on all of the traits. The means of emergence, days to maturity, seed yield, yield components and oil content were highest in the first sowing date (Table). Seed yield in the first sowing date was significantly and considerably higher than that of the other dates. Compared to the other sowing dates, significantly higher oil content was obtained in two first sowing dates (Table). In general, all of the traits were reduced due to late sowing, except that the last sowing date considerably led to increase days to maturity and seeds per capsule. The genotypes E-18 and E-22 had significantly lower emergence than two other genotypes (their average of 222 seedlings m^{-2} *vs.* 308 seedlings m^{-2}). The highest seed yield and oil content (939 kg ha^{-1} and 36.98%, respectively) were found in genotype E-18 which was significantly higher than those of the other genotypes. Genotypes E-22, E-33 and E-37 had seed yield of 814, 755 and 727 kg ha^{-1}(with no significant differences) and an oil content of 36.81%, 35.45% and 35.66%, respectively. The differences of oil content between genotype E-22 with each of E-33 and E-37 were significant. Genotype by sowing date interaction showed that in comparison to the other genotypes, genotypes E-22 and E-18 had significantly lower and higher seed yield in the first and second sowing dates, respectively. Reduction of seed yield and yield components due to late sowing in this study was in agreement with others (2, 5). Also, reduction of oil content because of late sowing has been previously reported in flax (3) and it mostly can be related to inverse effect of high temperature during seed development (3, 8).

Table: Means of the traits in different sowing dates.

Trait	Oct.17	Mar.15	Apr.13	May14	Jun.13	Jul.15	LSD(0.05)
No. of seedlings m^{-2}	312	330	289	208	293	158	63
Days to maturity	236	142	112	102	94	146	6.2
Capsule per plant	38	22	27	17	15	21	11.3
Seeds per capsule	6.9	5.2	4.6	4.0	4.4	6.3	0.92
100-seed weight (mg)	510	480	422	401	372	391	27
Yield per plant (g)	1.31	0.54	0.53	0.27	0.26	0.53	0.39
Seed yield (kg ha^{-1})	2118	1210	763	321	190	251	147
Oil content	37.50	37.49	36.02	35.23	35.19	36.14	0.70

A high correlation was found between seed yield and each of yield per plant (r=0.83**), number of capsules per plant (r=0.75**), seeds per capsule(r=0.49*) and 100-seed weight (r=0.76**). Regression analysis revealed that, seed weight as the most important component of seed yield contributed 58% and along with seeds per capsule and number of seedlings m^{-2} 82% in seed yield variation. Most of the variation of yield per plant was contributed by number of capsule per plant (88%) and seeds per capsule (6%). Previously, it has been reported that capsules per plant followed by seed weight (6) and capsules per unit area (1, 9) were the most important component of seed yield in flax.

Conclusions

It seems that there is a good potential for edible-oil flax production in the central region of Iran and autumn sowing is more suitable to maximize the seed and oil yield. However, in autumn sowing, use of cold tolerant genotypes should be considered. If with any reason, spring sowing is favored, it should be done as early as possible.

References

1. Albrechtsen, R.S., *et al.*, 1973. Crop Science 13: 277- 280.
2. Ford, J.H. 1964. Crop Science 4: 52-54.
3. Ford, J.H., *et al.*, 1964. Crop Science 4: 653-656.
4. Green, A. G., 1986. Canadian Journal of Plant Science 66: 499-503.
5. Prasad, B.N., *et al.*, 1975. Indian Journal of Agricultural Research 19 (3): 159-161.
6. Rao, S.K., *et al.*, 1983. Canadian Journal of Genetics and Cytology 25: 495 – 501.
7. Rowland, G.G. *et al.*, 1990. Journal of American Oil Chemists Society 67: 213-214.
8. Sosulski, F.W., *et al.*, 1964. Canadian Journal of Plant Science 44: 381-382.
9. Tadesse, N., *et al.*, 1997. Plant Breeding 116: 561-566.

RELATIVE RESISTANCE TO POWDERY MILDEW IN SAFFLOWER GENOTYPES IN IRAN.

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Introduction

Safflower (*Carthamus tinctorus* L.) is one of the important oilseed crops in the central parts of Iran. Because of its more drought and salinity resistance (8), its cultivation has been expanded in dry region of Isfahan province. A range of diseases has been recorded from safflower in Iran (2), although, a few of them are of economic importance, but some are so damaging and can limit its commercial production. Powdery mildew of safflower, which is caused by the fungus *Leveillula taurica* Arnaud, (1) is one of the important diseases attacking safflower in Isfahan province. Powdery mildew due to *L. taurica* is widespread and can be severe, particularly in dry region (3). The use of resistant varieties is the most effective and eco-friendly mean of powdery mildew control. Major genes are incorporated to host to provide the resistance that is usually associated with hypersensitivity. This investigation was conducted to seek such a type of genetic variation for relative resistance among different genotypes of safflower to find a source of resistance to powdery mildew.

Methods

Field-screening test for powdery mildew resistance was conducted in 2000-2001 at Research Facility of Isfahan University of Technology in Isfahan. Eighty-one genotypes of safflower including breeding lines and varieties were evaluated for agronomic traits and resistance to powdery mildew in a simple lattice design (with two replications). The entries within each replicate were randomized. The "Koose", a susceptible variety was sown as a control and border on all sides of each plot. The sowing was done at15 March 2000. Each plot consisted of a 4m row spaced 50cm apart. Seed yield, days to maturity, plant height, number of heads/plant, number of seeds per head, 1000-seed weight and resistance to powdery mildew was recorded for each plot. Resistance was measured as a scale system of 0 to 10 where 0-1 was considered as highly resistant, 1-3 as resistant, 3-4 as moderately resistant, 4-6 as moderately susceptible, 6-8 as susceptible and 8-10 as highly susceptible. The amount of infection in each row was recorded when the disease symptoms was maximized (approximately 25 days before harvesting). Analysis of variance was conducted using the General Linear Model of the SAS Institute, Inc. program. The least significant difference test was used to determine the statistical differences among the genotypes. The correlation coefficient was calculated among the traits (6).

Results

The results of analysis of variances showed that, the genotypes were significantly different in terms of response to powdery mildew fungus. The adjusted means (for incomplete-block effects) of scale number for resistance was varied between 0.64 to 7.75 with the mean of 3.62 and coefficient of variation of 46%. The LSD $_{(5\%)}$ value of 3.01 indicated that there was significant differences and genetic variation for resistance to powdery mildew among the evaluated genotypes. Three genotypes which were designated as SLT26, SLT31, and SLT62 were highly resistant, 28 genotypes resistant, 22 genotypes moderately resistant, 21 genotypes moderately susceptible, and 7 genotypes were susceptible. In another study, also 6 genotypes of safflower were found moderately resistant (4) and 28 resistant (7) to powdery mildew. In this investigation, no high correlation was found between disease intensity and each of the traits such as plant height, days to maturity and seed yield. It seems that the existing disease intensity under screening condition had no relation with agronomic traits. However, a high disease intensity can affect on agronomic traits of the crops (3).

Conclusions

In this study, the different response of safflower genotypes to infection by powdery mildew indicates that there is genetic control for the disease resistance and a high genetic variation for it implied that there is a good genetic source of resistance which can be used in breeding programs to produce resistant varieties, as a powdery mildew resistant genotype of sunflower has been registered (5).

References

1) Braun, U. 1987. A monograph of the Erysiphales (Powdery mildews). J. Cramer, Berlin.
2) Ershad, D. 1995. Fungi of Iran. Agricultural Research, Education and Extension Organization. Ministry of Agriculture, Publication No. 10. Tehran, Iran.
3) Holiday, P. 1980. Fungus diseases of tropical crops. Cambridge University Press.
4) Jain, V.K., et al. 1978. Indian Journal of Mycology and Plant Pathology 8: 1-13.
5) Jan, C.C. 1988. Crop Science 28: 1040.
6) Mead, R. and Currnow, R.N. 1983. Statistical methods in agriculture and experimental biology. Champman & Hall.
7) Siddaramaiah, A.L., et al. 1981. Current Research 10: 46-47.
8)Weiss. E. 2000. Oilseed Crops, 2nd ed. Blackwell Science Ltd. NY. USA.

THE DEPENDENCE OF MAIZE HYBRIDS ON PLANT DENSITY AND THE CONSEQUENT IMPLICATIONS

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Optimum plant density for grain yield per unit area

The improved grain yield per unit area of modern hybrids has resulted more from the increased optimum plant density rather than from the improved grain yield per plant. Data presented by Duvick (1997) who evaluated 36 hybrids, released consecutively during the years 1934-1991, showed that when hybrids were evaluated at the 1990s' typical density of 7.9 plants m^{-2} they showed the greatest annual gain in grain yield (0.11 Mg ha^{-1}), whereas the annual gain at the 1930s' typical density of 3 plant m^{-2} was 0.039 Mg ha^{-1}, and at the intermediate density of 5.4 plants m^{-2} ,0.088 Mg ha^{-1}. At the very low density of 1 plant m^{-2}, representing the minimum stress condition where the maximum yield per plant is expected, the annual gain was almost zero.

These findings were of paramount importance showing that, in fact, higher grain yield productivity of modern hybrids resulted indirectly by improving a range of traits associated with tolerance to various biotic and abiotic stresses, including high densities, and by improving the efficiency of capture and use of resources. The improved tolerance to high densities in combination with the low potential yield per plant resulted in modern hybrids that have higher optimum density, compared with the older ones. Additionally and more importantly, hybrids present very narrow spectrum of optimum density, as Fig. 1 illustrates. The yield dependence of hybrids on density is acknowledged since seed companies always provide the optimum density for their hybrids.

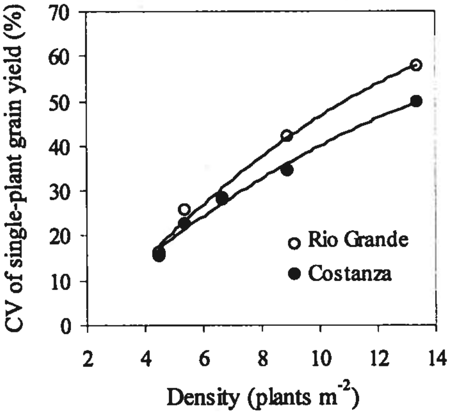
Implications of hybrids' dependence on high plant densities

The very narrow and high optimum density causes a number of adverse effects on hybrids' productivity and stability.

Even if the farmers sow the requirednumber of seeds for optimum density , a percentage of them may fail to germinate due to various factors, such as failure to obtain soil water, clods and cap in too wet soils that the coleoptile cannot go through, insects, diseases, birds, rodents, herbicide residues. Grain yield lost due to missing plants are poorly compensated by the increased yield of the surrounding plants, so grain yield per unit area decreases.

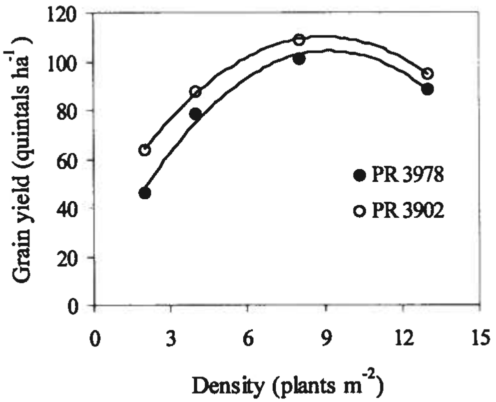
Even if the aforementioned effects are not fatal, the individual plant may survive, but will be late emerging. Also, differences in sowing depth often lead to a variation in the time of emergence. Delays in emergence will give differences in plant height and development during the growing season, resulting in an non uniform stand. The impact is stronger under higher densities. Higher densities are associated with increased plant-to-plant variability for various plant and ear traits (e.g., plant size, days for ear silking, ear length, kernel number per ear), and therefore for individual plant grain yield (Fig. 2). As a final impact of increased plant-to-plant variability, which is associated with decreased resource use efficiency, the grain yield per unit area is influenced adversely, because there is an inverse relationship between them (Fig. 3). At higher densities increase: the grain moisture at harvest, the plant and ear barrenness, the stem lodging, the broken stalks and dropped ears, the required interval for pollen shed and silk emergence, as well as the tassel-silk emergence interval that contribute to increased barrenness. Under higher densities decrease: the chlorophyll content and the photosynthetic rate due to decreased available light throughout of canopy, the grain protein content, the kernel number per row, and the kernel weight. These influences may partly explain the adverse impact of high densities on stability of hybrids.

Fig. 2 - The impact of density on CV



data from Vafias *et al.* (2000)

Fig. 1 - The dependence of grain yield on plant density



adapted from Tollenaar *et al.* (1999)

Conclusions

The requirements of maize farmers for hybrids with more grain yield potential, and greater dependability, imposes the development of hybrids that will be less density dependent. Hybrids that combine density-tolerance and high individual plant yield at lower densities, will have wide range of optimum density (Tokatlidis *et al.*, 2001). Higher yield per plant will ensure better compensation for yield loss due to missing plants, while such hybrids could be planted at lower densities to overcome the adverse effects of high densities. Density-independent hybrids will insure high productivity and stable performance.

References

Duvick, D.N., 1997. p. 332-335, *In* G.O. Edmeades et al. (ed.), Developing Drought and Low N-Tolerant Maize.

Tokatlidis, I.S., *et al.*, 2001. *Maydica*, 46, 21-25.

Tollenaar, M., 1989. *Crop Science*, 29, 1365-1371.

Tollenaar, M., *et al.*, 1999. *Crop Science*, 39, 1597-1604.

Vafias, V.S., *et al.*, 2000. The proceedings of 8th Conference of Hellenic Scientific Society of Genetic Plant Breeding, October 23-25, 2000, Arta, Greece.

PATHOGENIC VARIATION IN POPULATIONS OF *DRECHSLERA TERES* F.SP.*TERES* AND *DRECHSLERA TERES* F.SP.*MACULATA*

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Introduction

Drechslera teres. (teleomorph *Pyrenophora teres*), the causal agent of net blotch disease of barley, is known to have two *formae speciales* based on the symptoms they incite on the host plant, namely the net-form and the spot-form. The disease derives its name from the symptoms caused by the common net-form of the pathogen, *Drechslera teres* f. sp. *teres* which occur as characteristic net-like lesions often surrounded by a chlorotic region (Jordan, 1981). The symptoms induced by the spot-form, *Drechslera teres* f. sp. *maculata*, appear as dark brown elliptical lesions surrounded by a chlorotic zone. Leaf chlorosis appears to play an important role in the disease syndrome and the severity of disease resulting from the spot-form is dependent on the amount of chlorosis, rather than the number or size of the necrotic spots (Smedegaard-Petersen, 1971). Before initiating an effective breeding programme, information on the variation and distribution of virulent isolates of the pathogen and variation in host resistance is desirable. Differences in pathogenicity between the net and spot-forms of the pathogen have been reported.

Methods

Reactions were examined both on whole plants and detached leaves on five cultivars: Botnia, Boreal 94145, CI 5791, CI 2330 and CI 9819. Leaf material was surface-sterilised, plated onto lima bean agar and incubated for 14 days at 20°C ± 2°C under a near-ultraviolet diurnal light cycle. Spore suspensions were made by flooding the plates with sterile distilled water and agitating the conidia with a sterile blade. Single-spores were harvested and transferred to V8 agar plates and incubated for a further 14 days. Conidial suspensions were made as before. Each isolate spore suspension was adjusted to give a final concentration of approximately $2x10^4$ spores ml^{-1}. Plants were inoculated with 1 ml of spore suspension at GS 13 with an ecological sprayer, (Ecospray®) and covered with clear polythene bags for 3 days to enhance spore germination. Seedlings were scored on day 7; symptoms were classified using the numerical scale of Tekauz (1985). Five leaves were placed adaxially on benzimidazole-amended agar plates, with two replicates of each cultivar per isolate treatment; 10µl drops of spore suspension were pipetted onto each leaf and incubated for 7 days under a white diurnal light cycle at 20°C. Length and width of lesions were measured on day 7.

Results

A high level of variation was found among isolates of the net-form and the spot-form in both populations on all cultivars, with most variation in virulence on the susceptible cv. Botnia and the quantitatively resistant cv. Boreal 94145 in glasshouse experiments. No obvious pattern in virulence based on geographical origin was found, with variation occurring between isolates of the same origin. Significant cultivar differences were found between the susceptible (Botnia) and quantitatively resistant (Boreal 94145) cultivars and the three resistant cultivars (CI 5791, CI 2330 & CI 9819) when inoculated with the net-form isolates of the Northern European population (Figure 1). No significant differences were found between Botnia and Boreal 94145 or between CI 2330, CI 5791 or CI 9819. The spot-form isolates, however, caused differing reactions. Cultivars Botnia and Boreal 94145 were not significantly different; however CI 2330 differed from both cvs CI 5791 and CI 9819, but not from Botnia or Boreal 94145 ($P<0.05$). Cultivar CI 2330 therefore showed some resistance to the net-form of the pathogen but less resistance to the spot-form under these experimental conditions.

Figure 1: Overall effect of net-form and spot-form isolates on 5 cultivars in glasshouse experiment.

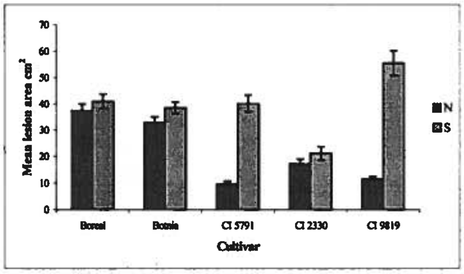
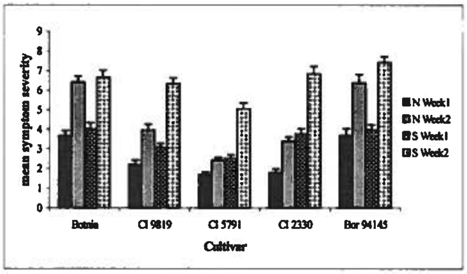


Figure 2: Lesion area of detached leaves inoculated with 10 µl drops of spore suspension.



Results from the glasshouse were compared with assessments made on detached leaves after 7 days (Figure 2). High correlations were found for net-form isolates on the five cultivars inoculated in the glasshouse ($r = 0.965$; $P<0.05$). There was no correlation, however, between the two methods with the spot-form isolates. This may be due to the chlorosis which characteristically accompanies the spot-type lesions and is generally more diffuse throughout the area of the host affected; measurements of the extent of damage by the spot-form may therefore be over-estimated.

Conclusions

This study illustrates the importance of including both the net-form and spot-form isolates in resistance studies of barley net blotch disease as each form produced significantly different virulence spectra.

References

Jordan, V.W.L. 1981. Plant Pathology 30: 77-87.
Smedegaard-Petersen, V. 1971. Royal Veterinary and Agricultural Yearbook 1971, 124-144.

SODIUM-CHLORIDE EFFECTS ON BIOAGRONOMIC RESPONSE OF COTTON CROPS IRRIGATED WITH WATER AT DIFFERENT ELECTRICAL CONDUCTIVITY.

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Introduction

The scarcity of the available water resources and the necessity to reserve waters of good quality for the civil and industrial uses, impose, in many arid and semiarid regions of the world, the use of poor quality waters for irrigation of crops with remarkable risks of environmental degradation and pollution. In Sicily, this problem is particularly serious due to both the presence of clayey soils and to the sub optimal qualitative characteristics of the waters of some reservoirs of the island with high values of SAR associated to high levels of NaCl, exceeding 4 g l^{-1} in some cases. The main objective of this research was to study the effects of the accumulation of NaCl in the soil, due to the use of brackish waters, on the biological and productive behaviour of some cotton varieties.

Materials and methods

The research was carried out at the experimental farm "Orleans" of the Palermo Agricultural University, Italy, during the summer seasons of the years 1995, 1996 and 1997. According to a experimental split-plot design on two cotton varieties (main plot), the effects of irrigation with six different saline waters (sub plot) obtained by dissolving in the water (ECw_0) 2, 4, 8, 12 e 16 g l^{-1} of NaCl were compared. The cotton varieties, grown in the plastic pots (35 x 26 cm) filled with sandy clayey soil, were irrigated every 3 days and with volume equal to the ETc. Electrical conductivities of the irrigation waters were 1.1, 5.2, 8.9, 15.7, 23.2 and 30.4 dS m^{-1} for treatments ECw_0, ECw_1, ECw_2, ECw_3, ECw_4 and ECw_5 respectively. Applied fertilizers included 60, 140 and 80 kg ha^{-1} of nitrogen, phosphorus (P_2O_5) and potassium (K_2O), respectively.

Results

All varieties tested in the three years of the study have shown similar responses to the increase of NaCl concentration of the irrigation water, without significant differences regarding to the salt resistance as indicated by ANOVA.

Electrical conductivity (dS m^{-1})	bolls/plant (n.)	dry weight bolls/plant (g)	height/plant (cm)	total dry matter /plant (g)
1,1	7,6	46,70	51,7	78,06
5,2	5,3	33,79	47,4	60,28
8,9	4,9	33,70	43,8	57,05
15,7	3,5	15,63	37,3	30,52
23,2	3,1	10,74	34,4	27,26
30,4	2,3	7,25	34,0	22,55

Tab.1 - Some bioagronomic cotton traits observed in the trial.
Average of three years

Significant differences in variety x electrical conductivity of irrigation water interaction were observed. During the three years of the trial increasing of the electrical conductivity of irrigation water reduced plant height, number of bolls/plant, dry weight of the bolls and total dry matter accumulation (table1).

Effects of the saline stress was observed going from ECw_0, to ECw_1, where increasing of the electrical conductivity from 1.1 to 5.2 dS m^{-1} determined, in 1995, a reduction of the number of bolls per plant and their dry weight equal to 36.0 and 18.1% respectively. Modest and not statistically different resulted the percentage reductions with treatments ECw_2 and ECw_3. (fig.1).

The effect of the salt stress on the plant height growth, with values of electrical conductivity up to 8.9 dS m^{-1}, was smaller and gradual. For this trait the tallest decrement has been observed with values of electrical conductivity between 8.9 and 15.7 dS m^{-1} (fig.2). A similar pattern has been observed in the second and third year of the trial in which further increases of the electrical conductivity of the irrigation water up to values equal to 30.4 dS m^{-1} has not determined appreciable reductions in the plant height without significant differences among ECw_3, ECw_4 and ECw_5.

Fig. 1 - n. bolls/plant

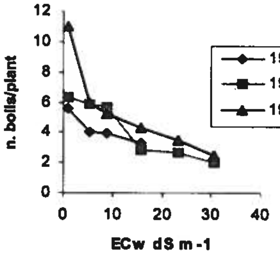


Fig.2 - plant height

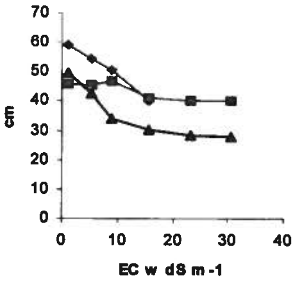
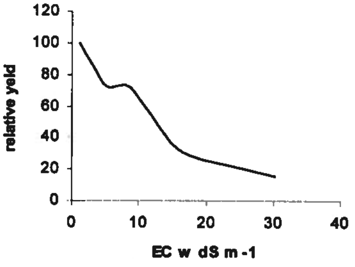


Fig. 3 -Relative yield vs water salinity



Discussion

Salt stress from NaCl, due to the use of irrigation water characterized by increasing levels of electrical conductivity, has had significant inhibitory effects on vegetative development of the crop and on productive behavior. The gradual reduction of plant height values and the most elevated rates of reduction observed in the number of bolls per plant and their dry weight, already manifested with modest values of electrical conductivity of the irrigation water, was determined by severity of salt stress that is established in the soil, due to NaCl accumulation dynamics that is a function of the irrigation frequency. The level of stress, for the conditions in which the trial was developed (plant growth in pot) and without leaching, gradually increases with cotton crop cycle reaching the most high-level of severity in the boll development stage. In this particular phase the build-up of NaCl in the soil, also with treatments Ecw_1 and ECw_2, reached high levels to strongly reduce the potentialities of the crop because of the negative salt effects on the physical-chemical characteristics of the soil. The use of irrigation water with high electrical conductivity gives rise to soil salinity, with increased ESP and SAR (Moreno et al., 2001) and consequently with reduction of the stability of structure and poor aeration. This negative effects was shown also by reduction of the water infiltration rate (data not shown), that is remarkably lower in ECw_5 and by the root development. The dry weight of cotton root decreased with increasing electrical conductivity of irrigation water and showed values of 7.1 g, in ECw_5, with a 32% reduction in comparison to ECw0, that instead showed values equal to 10.3 g. This decline of physical-chemical characteristics of the soil explains the reduction of cotton crop development (Moreno et al., 2001) and the obtained yields, according to results observed by other researchers (Asharaf et al., 2000, Choudhary et al., 2001). In conclusion, the results have underlined that in Mediterranean arid warm environment use of irrigation waters with moderate electrical conductivity doesn't give serious problems for irrigation of cotton crop and identifies also, in the value of 12.5 dS m^{-1} the threshold of electrical conductivity of the irrigation water, that causes a yield reduction of 50% (Fig.3).

References

Asharaf, M., et al., 2000. *Field Crops Research* 66, 115-127.
Choudhary, O.P., et al., 2001. *Agricultural water management* 49, 1-9.
Moreno, F., et al., 2001. *Agricultural Water Management* 48, 133-150.

TURFGRASS IN THE TROPICS REQUIRES NONTRADITIONAL MANAGEMENT

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Introduction

Dynamic development of modern turf industry, in the last three to four decades, has been achieved mainly in the temperate climates of North America, Europe, and Australia. In the last 15 years remarkable growth of the turf industry has occurred also in Asia, especially in Japan where over 2,000 golf courses serve 2.6 million club members and 12 million occasional players (Kuji, 1997). Very expensive golf club memberships pushed Japanese golfers to search for places with year round golfing such as Thailand, Indonesia, the Philippines, Singapore, Malaysia, Guam and other tropical islands of the Western Pacific. Rapid construction of golf courses demands suitable species of turfgrass and adequate management practices. The unavailability of high quality turfgrasses that are fully suited to hot and humid tropical climates forced turf managers to adopt existing species, varieties and hybrids which demonstrate the highest potential for successful establishment and healthy growth. The vast majority of recreational turfs in the tropical countries are hybrids of bermudagrass. (*Cynodon dactylon* (L.) Pers. x *C. transvaalensis*).

Major challenges

Growing bermudagrass in tropical climates is accompanied by several management limitations. Unexpectedly for tropical locations bermudagrass acts as if it was subject to insufficient solar radiation. Throughout the year, but especially during the rainy season, golf course superintendents encounter management problems that are typical for bermudagrass grown in shady conditions. They are mostly manifested by reduced density and increased weed infestation. Bermudagrass in general does not tolerate low light intensity and if grown without adequate light, it thins out, alters its growth habit from horizontal to more vertical, becomes more vulnerable to insects, diseases, and weed infestation, and becomes more susceptible to wear damage resulting from foot and golf-carts traffic (Beard, 1973). On Guam (13°N latitude), just like the other hot and humid Asian countries, temperature is uniform throughout the year and ranges from 23 °C at night to around 30°C in the daytime. Length of the day ranges from 11 hour in December to 13 hour in June and the sky cloud coverage ranges from 50% in the dry season to 85% in the rainy season (NCDC, 2001). Extensive cloud coverage results in detrimental light conditions resembling those found in the shaded places. For example, regular passing clouds reduce solar radiation value from over 1000 W m^{-2} to 100-150 W m^{-2}. Solar radiation under dense tree canopy decreases to as low as 80 W m^{-2} and when tree canopy is transparent, to approximately 200 W m^{-2}. Hybrids of bermudagrass planted under dense trees are unable to survive, and when planted under relatively transparent palm trees show clear symptoms of light deficiency.

A second major management concern is weed control. Weeds invade turf under all climatic conditions but in the tropics weed control strategies appear more challenging than in the temperate regions. There are several reasons which account for these differences. As already pointed under reduced light, the density of bermudagrass declines. During the rainy season, less light and more moisture create favorable conditions for disease development with bermudagrass vigor being additionally reduced, hence being less competitive to weeds. Weeds commonly known as annual are perennial in the tropics, and if allowed to germinate they stay alive for many years. In addition their stems and roots are tougher and more resilient then the same species in temperate climates. Their resistance to post-emergence herbicides is also higher.

Dicots are easier to eliminate with selective herbicides and adequate cultural practices than monocots. Post-emergence elimination of weedy grasses from actively growing turfgrasses often results in non-tolerable injury to the desired species. Highly effective pre-emergence herbicides commonly used in the temperate climates, are of little use in the tropics. Period of massive seed germination in the spring is not present, therefore timing of application that is usually synchronized with the sudden rise of soil temperature is impossible to determine. To some limited extent, the onset of a rainy season results in more germinating seedlings, but generally seeds germinate year round especially when irrigation supplements any deficiencies in rainfall. Since only a portion of weed seeds germinate after pre-emergence herbicide application, pre-emergence herbicides would have to be applied many times a year. This practice however has economic and environmental limitations as well. In the humid tropics, soil longevity of herbicides is substantially lower than in temperate climates because of uniform and high soil temperatures and elevated microbial activity. The higher rate and/or the higher frequency of application are costly and environmentally threatening. Guam and many other Pacific islands follow American pesticide application standards, which often impose strict limits on the amount of an active ingredient that can be applied on a yearly basis. Turf managers often meet these limitations within the first few months of the year and afterwards switch to other, less effective products in order to comply with regulations. In addition to weed control challenges, insects and diseases are also of a great concern. Occurrence of turfgrass diseases and insects continues year round and requires different management and mostly higher usage of pesticides than in the temperate climates.

Conclusions

The economic growth of Europe, Asia, and North America will likely foster construction of tropical golf courses in Western Africa, South-East Asia and Caribbeans. The present dominance of warm season turfgrass species developed mostly for the American golf courses will likely diminish in the next decade or two. New turfgrass species and/or improved varieties of existing turfgrasses are demanded specifically for the tropical golf courses. Breeding programs, tropical turf management research, weed control strategies, insect and disease control strategies will likely be developed to meet these demands. Turf researchers are facing the issue of intensifying their efforts in tropical regions to assure the needed improvements.

References

Beard, J.B., 1973. Turfgrass: Science and culture. Prentice-Hall, Englewood Cliffs, N.J.
Kuji,T., 1997. Golfonomics. Asia in the rough. The Economist. December 20, p.91-93.
National Climatic Data Center, 2001. USCOMM-NOAA, Asheville, N.C.

DEVELOPMENT OF A SALT-RESISTANT MAIZE CULTIVAR

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Introduction

Soil salinity is a major abiotic stress in plant production. Estimates of the total area of saline land world-wide vary between 340 and 950 10^6 ha, which represents between 2.3 and 6.4% of the total land surface (Flowers et al., 1977). NaCl is the predominant salt in most saline environments. Many crop species are sensitive to high concentrations of salt with negative impacts on agricultural production. High concentrations of salts cause ion imbalance and osmotic stress in plants as primary effects, secondary problems such as oxidative damage often occur (Zhu, 2001). Plants have developed a variety of strategies and mechanisms to react to any change of their environment. Anatomical and physiological adaptations allow better growth under unfavorable conditions. The root system is particularly affected by these changes because the root is that part of the plant which is in direct contact to the soil substrate. However, salt resistance may have much wider implications because transgenic salt-resistant plants often also tolerate other stresses including chilling, freezing, heat, and drought (Zhu, 2001).

A key for understanding the physiology of salt resistance in plants is to identify genes and proteins of the pathways for Na^+ transport across the plant cell membranes. Na^+/H^+ antiporters (Fig.1) are integral membrane proteins present in virtually all cell types from bacteria to higher eukaryotes (Dibrov & Fliegel, 1988). The plant *NHX1* gene encodes a tonoplast Na^+/H^+ antiporter and functions in compartmentalizing Na^+ into the vacuole. Overexpression of this gene enhances the salt resistance of plants (Apse et al., 1999). The signal transduction pathway that mediates salt resistance is additionally influenced by the *SOS* genes (*s*alt *o*verlay *s*ensitive, Zhu et al., 1998).

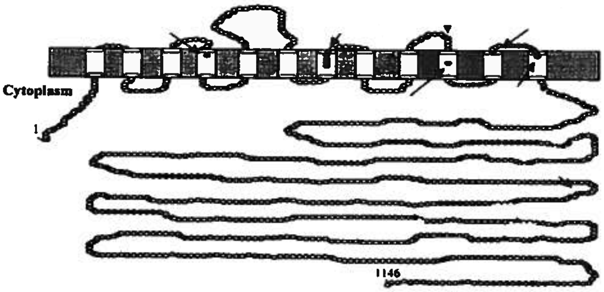


Figure 1.
Diagramatic representation of a plant Na^+/H^+ antiporter. Putative transmembrane helices are shown as cylinders. From: Shi, H. et al., (2000), modified

However, because salt resistance is a multigenic character, only limited success in improving salt resistance of crops has been achieved so far. Since the postulation of a biphasic model of salt stress by Munns (1993) and its partial verification for maize (Fortmeier & Schubert 1985) there is good evidence that maize grown under saline conditions suffers an osmotic problem in a first phase and sodium toxicity in a second phase.

Materials and Methods

Plant material was a sodium-excluding maize (*Zea mays* L.) inbred line which was developed in our lab. Plants were cultivated for 4 weeks in liquid culture under varying NaCl concentrations in a growth chamber (see Fig. 2). Plant roots and shoots were harvested and homogenized in liquid nitrogen. RNA from roots and shoots was isolated and transcribed into cDNA. Single-stranded cDNA was used for running PCR with oligonucleotides enclosing a 320 bp fragment of the Na^+/H^+ antiporter. Primers were designed according to plant *NHX* genes from embl database. PCR-derived fragments were cloned and sequenced. Positive clones were obtained and used for constructing primers for 5′ RACE experiments. Elongated 5′ fragments of the *NHE* homologue of the maize inbred line were cloned and sequenced. We performed northern blot analysis to investigate the expression level of the Na$^+$/H$^+$ antiporter in roots and in shoots. 2-D gels were carried out to monitor the protein pattern in NaCl-treated plants and in controls. Differentially expressed proteins were determined and characterized.

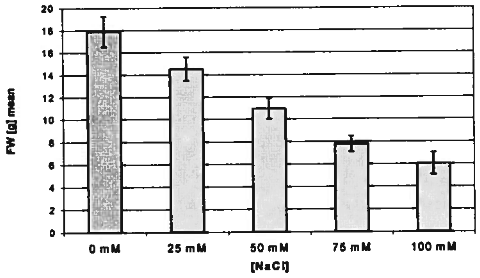
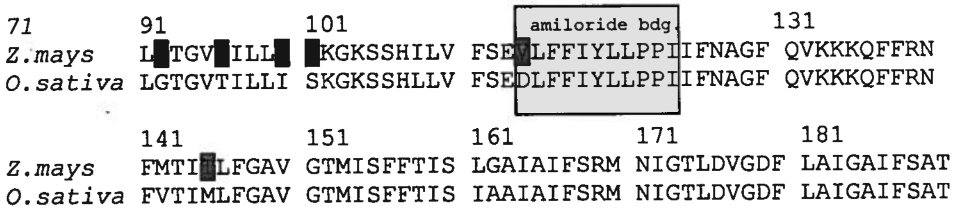


Figure 2. Fresh weight of shoots from a sodium-excluding maize inbred line grown under different NaCl concentrations Data shown are averages. Error bars represents standard errors.

Results and Discussion

Using degenerated primers directed against the conserved motifs of known Na$^+$/H$^+$ antiporters a 320 bp fragment of the putative Na$^+$/H$^+$ antiporter (*ZmNHX1*) was isolated and cloned from root material of Na$^+$-excluding genotypes. The fragment was extended to 460 bp with a 5` RACE system. The sequence was accepted as genebank acc no. AF307944. Amino acid sequence analysis shows high homology (89,8%) to the rice Na$^+$/H$^+$ exchanger (*OsNHX1*). Differences between rice and maize sequences occurred especially at the N-terminus with an insertion of four additional hydrophobic amino acids. Derived amino acid sequence contains the putative amiloride binding site as shown in Fig. 3. A difference in amino acid sequence is expected to change the efficiency of sodium exclusion. In comparison to rice one amino acid exchange was found in the putative amiloride region. Six additional amino acid exchanges were found as shown in Fig. 3. Regulation of the Na$^+$/H$^+$ antiporter gene was checked in a northern blot experiment using the 320 bp fragment as a probe. A single band of 1.6 kb could be detected. The transcript level of maize *NHX* RNA from roots in comparison to shoots is decreased 3.4 fold.



```
71          91          101                   amiloride bdg.       131
Z.mays      L█TGV█ILL█  █KGKSSHILV  FSE█LFFIYLLPPIIFNAGF  QVKKKQFFRN
O.sativa    LGTGVTILLI  SKGKSSHLLV  FSEDLFFIYLLPPIIFNAGF  QVKKKQFFRN

            141         151         161         171         181
Z.mays      FMTI█LFGAV  GTMISFFTIS  LGAIAIFSRM  NIGTLDVGDF  LAIGAIFSAT
O.sativa    FVTIMLFGAV  GTMISFFTIS  IAAIAIFSRM  NIGTLDVGDF  LAIGAIFSAT
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Figure 3. Alignment of a fragment of the deduced amino acid sequences of Na$^+$/H$^+$ antiporter gene (*NHX*) denoted by single letter code. *Z. mays, ZmNHX* from the sodium-excluding genotype. The putative amiloride binding-site is indicated with a frame. Differences in amino acid sequence are marked in gray. Abbreviations: *Zea mays* (acc. no. AF307944), *Oryza sativa*, (acc. no. AB021878)

References

Apse M.P., Aharon G.S., Snedden W.A., Blumwald E. 1999, Science, 285; 1256-1258
Dibrov P., Fliegel L. 1998, FEBS Lett. 424; 1-5
Flowers T.J., Troke P.F., Yeo A.R. 1977, Annu. Rev. Plant Physiol., 28; 89-121
Fortmeier R., Schubert S. 1995, Plant Cell Environ. 18; 1041-1047
Munns R. 1993, Plant Cell Environ.18; 1041-1047
Shi H.Z., Ishitani M., Kim C.S., Zhu J.K. 2000, PNAS, 97; 6896-6901
Zhu J. K., Liu J., Xiong L. 1998, Plant Cell, 10; 1181-1191
Zhu, J. 2001. TIPS 6.2; 66-71

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Agroclimatology an agronomic modelling

A COMPUTER PROGRAM INTEGRATING GIS, SPATIAL WEATHER GENERATOR AND SIMULATION MODELS FOR THE DEVELOPMENT OF AGROMETEOROLOGICAL ADVISES

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Introduction

Nowadays the most part of bulletins of agrometeorological services includes mainly meteorological information. The use of simulation models to provide quantitative information of crop status and crop disease infection levels at regional scale is still not much diffuse.
The objective of this study, carried out within the project SEM 04/204/028 supported by UE, was to develop a computer program that, following other similar systems developed by Engel et al. (1997) and Papajorgji et al. (1996), allows regional simulation of crop development and yield integrating different environments such as databases, spatial weather generators, simulations models (i.e. crops and diseases) and geographic information systems.

Agrometeorological system description

The main components of the system are shown in the figure.

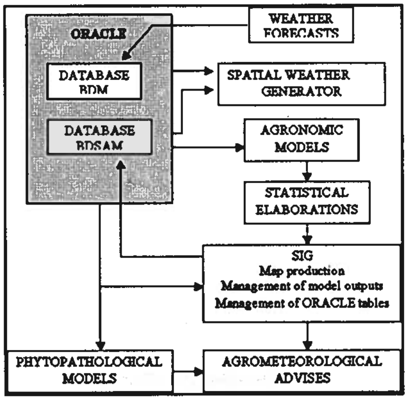
Database BDM (Base de Données Météorologiques). This is an ORACLE database to archive historical meteorological data of all the synoptic and climatic stations located in Morocco. These data can be used by the Spatial Weather Generator to create meteorological reference grids that represent the base for data generation.Database BDSAM (Base de Données du Service AgroMétéorologique). This database was developed in ORACLE 8i during the project. This database includes: geographical, pedological , morphological data of Morocco and species and variety characteristics of the main crops cultivated in the country. All the information are linked to geographical grids with a resolution of 2', 1' and 30''. In this database the SWG and models outputs were also stored.
Spatial Weather Generator. This is a suite of programs developed for the stochastic generation of site-specific synthetic weather series based on grid maps of generator coefficients, as well as for the estimation of these coefficients from meteorological station data and for their topography-guided spatial interpolation (Goebel et al., 1997). In the new version developed during the project, the original software was modified to make use of deterministic forecast maps, as produced by weather forecast models. This program generates one or two years of daily meteorological data (air temperature, rainfall and solar radiation), according to user indications.
Agronomic models. Two models were introduced in the system: Cropsyst model (Stockle et Nelson, Department of Biological Systems, Washington State University) and a modified version of the model, developed by Abdel-Razek (1989), to simulate olive development and production. The model are used to simulate phenological phases and yield of wheat, barley, sugar beet and olive, respectively. The original interface of these models was eliminated and the different options are passed to the model either from main interface or ORACLE database.
Statistical elaborations. This is a module, developed in VisualBasic, to calculate average, minimum, maximum, mode, probability at 75%, and standard deviation of agronomic model outputs.

SIG module. The gridded outputs of statistical analysis can be charged in ArcView GIS 3.2 © of ESRI, to produce final maps to be introduced in agrometeorological bulletins. Several modules developed in Avenue language of ArcView allow the management of ORACLE tables (e.g. selection of a new studies area, modification of work resolution, etc.).

Pest and disease models. Several models were included in the system to monitor and forecast the cycle and attack of pathogens such as vine downy mildew, olive fly, wheat brown rust and sugarbeet cercospora. For these models, the original interface was maintained. These models use hourly values collected by automatic stations located in the studied area (Beni Mellal).

Since the different models included in the system had been developed with different programming languages and their conversion in a same language was impracticable, the different components of the system were connected by some modules developed in VisualBasic that allow the automatic creation of input files with the format demanded by the different models. Also user interfaces and general programs of system management were developed in VisualBasic.

Description of data flux and operative phases to run the system



To run agronomic models, the user has to select work area and work resolution from the main interface, at first. Then, he has to choose the crop and the model to be applied, the repetition number for the SWG and the date of simulation start. Next, the user has to active the generation of meteorological data by choosing the option "Data generation". Automatically, the system creates input files for the SWG extracting data from ORACLE databases (an input file for each area unit), runs the SWG and stores the SWG output files (one file for each row of the working grid) into ORACLE database. Finally, the user has to activate crop simulation by choosing the option "Launch system", that creates, for each grid cell and for all repetitions of SWG, all the inputs files demanded by the selected model (e.g. *.SIL, *.CRP, *.MGT, *.ROT, *.DAT, *.LOC and *.SIM for Cropsystem). The output files (there is one file for each output parameter with one record for each SWG repetitions) are automatically transfer to statistical analysis module and elaborated, e.g. for cereals, phenological phase dates, total biomass and yield. The output files are automatically saved in ORACLE database from which they can be exported to SIG software to further elaborations and/or creation of maps.

To run pest-disease models, the user has to choose the model and to indicate the name of meteorological station from which data have to be extracted, at first. Then, the system automatically creates input file with the format demanded from the model and runs the model, showing its interface. At this point the user has to introduce data demanded from model interface and to active model simulation. Model outputs are used by the user to give indications on disease development and treatment to be applied.

References

Abdel-Razek, M., 1989, Ecol. Modelling, 45, 179-204.
Engel, T., Hoogenboom, G., Jones, J.W., Wilkens, P.W., 1997, Agron.J., 89, 919-928.
Goebel, W., El Ouali, A., Ambri, A. and El Mourid, M., 1997, Proc. of Seminar on "Data Spatial Distribution and Climatology, Volterra (Italy), 28 September – 3 October, 73-95.
Papajorgji, P., Zazueta, F.S., Xin, J.N., 1996, Proc. of Sixth International Conference on Computers in Agriculture. Cancun (Mexico), June 16.

INTEGRATED EVALUATION OF CROPPING SYSTEMS MODELS BY FUZZY-BASED PROCEDURE

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Introduction

Statistical analysis of simulation results is required to evaluate how well the model results correspond to experimental data. The evaluation of a model's performance is often limited to a comparison between a few simulated variables and observed phenomena (Sinclair et al., 2000). Although cropping system models produce several outputs, it is common to evaluate individual outputs separately by means of one or more indices or test statistics (e.g. Martorana et al., 1999). Such simple comparisons may be misleading, because a comprehensive evaluation of the model's performance requires an integrated evaluation of a set of major outputs. An integrated approach for evaluation based on fuzzy theory was proposed by Bellocchi et al. (2002a). An extension of such a methodology is proposed here, accounting for a number of outputs from maize cultivations in the Pisa Valley, Italy.

Methods

Simulations The CropSyst model (Stöckle et al., 2002) was evaluated for its ability to simulate above ground maize biomass and two soil variables at 0-0.60 m depth (i.e., water and NO_3-N) in response to different types of tillage (conventional, no tillage) and nitrogen fertilisation (0, 300 kg N ha^{-1}) on a silty soil at Pisa, Central Italy (lat.: 43.67 North, long.: 10.17 East, elev.: 6 m a.s.l.). Experimental data sampled during the growing seasons 1994 and 1995 were used for this purpose. More details are given in Bellocchi et al. (2002b).

Data processing Model outputs such as soil water content (SWC, $m^3\ m^{-3}$), soil NO_3-N content (SNC, kg ha^{-1}), and above ground biomass (AGB, kg ha^{-1}) were compared against observed values. The agreement between simulations and observations was evaluated through the relative percent root mean squared error (RRMSE). An integrated index (MVPI: multiple variable performance index) was then created aggregating the RRMSE values computed for each output into one index, according to a fuzzy-based procedure. Different expert weights (B_i, i referred to as the i-th output variable) were given to different outputs: $B_{SWC}=1.0$, $B_{SNC}=0.5$, $B_{AGB}=2$. RRMSE was bounded within 20% (favourable) and 40% (unfavourable). The aggregated index ranges from zero (best) to one (worst).

Results

The results of the comparisons between observed and simulated outputs for different management options are summarized in the table below.

Output	RRMSE		MVPI	
	no nitrogen fertilisation	nitrogen fertilisation	no nitrogen fertilisation	nitrogen fertilisation
	conventional tillage			
Soil water content	10.5%	10.0%	0.2165	0.2996
Soil NO_3-N content	26.6%	31.8%		
Above ground biomass	26.6%	27.7%		
	no tillage			
Soil water content	12.6%	8.6%	0.2831	0.2207
Soil NO_3-N content	27.8%	44.1%		
Above ground biomass	28.2%	25.2%		

In general, the NO_3-N dynamics appeared more difficult to simulate when nitrogen fertilisation was applied. However, the satisfactory estimate of other variables tended to compensate the unsatisfactory model response with NO_3-N under no tillage.

Conclusions

This work shows examples of an integrated approach to assess model performance. The methodology was applied to the simulation results of some common variables under contrasting experimental conditions. In particular, the expert system proposed here takes into account three output variables of major interest in cropping systems modelling. We had to decide which attributes have more weight in determining the outcome of the reasoning. Larger importance was given to the model's ability to simulate crop biomass (as it is associated with the yield prediction), whereas possible failure in the simulation of soil variables was considered less stringent. Lower relevance was given to nitrogen balance than to water balance, the latter interacting with the chemical budget (either nitrogen, pesticides, or salinity). These considerations reflect our subjective judgment, and would have been different if the primary goal of our simulation was, for instance, nitrogen dynamics. The results obtained are the consequence of the choices we made regarding the selection of limits and weights, which may significantly change the value of the outcome. The sensitivity of the outcome to weights can be recognized, for instance, with nitrogen fertilisation under no tillage, producing better MVPI (0.2207) than the condition with no fertilisation (0.2831), due to a better response (RRMSE=25.2%) associated with the most influential variable (i.e. crop biomass). A wider examination is therefore required for a general consensus about either weights applied to each output or the limits applied to RRMSE. The fuzzy-based methodology proposed here represents a pragmatic approach towards a satisfactory solution for a comprehensive evaluation of model performance. Analyses of this type may provide some protection against partial conclusions and indicate whether the model as a whole is conceptually consistent and related to experimental evidence. The method is flexible and can be proficiently applied to aggregating more output variables. Provisions for the computation of integrated indices are implemented in the dynamic link library IRENE_DLL (Fila et al., 2002), freely downloadable from the site http://www.isci.it/tools. The installation package includes an example of how use the DLL for aggregating variables within a Microsoft Excel spreadsheet.

References

Bellocchi G. et al., 2002a. Agronomy Journal. (submitted)
Bellocchi G. et al., 2002b. Italian Journal of Agronomy. (in press)
Fila G. et al., 2002. These proceedings.
Martorana F. et al., 1999. Italian Journal of Agronomy 3:19-39.
Sinclair T.R. et al., 2000. Field Crops Research 68:165-172.
Stöckle C.O. et al., 2002. European Journal of Agronomy. (in press)

Acknowledgements Project SIPEAA (http://www.sipeaa.it), paper no. 8.

CALCULATING EVAPOTRANSPIRATION AND CROP BIOMASS USING ESTIMATED RADIATION INPUTS

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Introduction

Crop growth estimation is very sensitive to the calculation of potential evapotranspiration (PET). The Priestley-Taylor (PT) equation is a relatively simple PET estimator that is useful when daily maximum and minimum temperature, and solar radiation are available. Solar radiation is frequently not recorded by weather stations, so when radiation records are incomplete or not available, the PT model cannot be applied unless estimates of solar radiation are done. Estimates of solar radiation are affected by both an overall error and seasonal patterns, that propagate in either PET estimates or derived outputs, e.g. above ground crop biomass (AGB). GSR values were estimated at a variety of sites by alternative radiation models. The purpose of this study was to compare PET and AGB of different crops at maturity calculated using complete daily weather records with recorded solar radiation from a variety of locations against values calculated using estimated GSR values.

Methods

Weather data. Twenty locations with 6 years of complete weather records (rainfall, maximum and minimum temperature, solar radiation) were selected for this study.

Country	Location	Latitude	Longitude	Crop
Australia	Longreach	-23.43	144.27	sunflower
Colombia	Palmira	3.52	-76.32	maize
France	Toulouse	43.32	1.37	maize
Germany	Würzburg	49.77	9.97	wheat
India	Hyderabad	17.45	78.47	wheat
Italy	Perugia	43.08	12.50	sugarbeet
Malawi	Lilongwe	-13.98	33.63	millet
Mexico	Poza Rica	20.53	-97.45	maize
Philippines	Los Baños	14.17	121.25	wheat
Republic of China	Taichung	24.15	120.68	wheat
Spain	Cordoba	37.88	-4.77	sunflower
Syria	Tel Hadya	36.02	36.93	wheat
Tanzania	Morogoro	-6.83	37.65	millet
Thailand	Chiang Mai	19.01	99.01	wheat
The Netherlands	De Bilt	52.10	5.18	wheat
Turkey	Konya	37.87	32.50	wheat
United Kingdom	Blacknell	51.38	51.38	wheat
United States	Gainesville FL	29.63	-82.37	maize
United States	Prosser WA	46.25	-119.70	wheat
Zimbabwe	Kado	-18.32	29.88	millet

Radiation estimate. Three models to estimate GSR from temperature data were applied (BC: Bristow-Campbell; CD: Campbell-Donatelli; DB: Donatelli-Bellocchi) (Donatelli et al., 2002). The measured radiation data were used to parameterize the three models at each location.

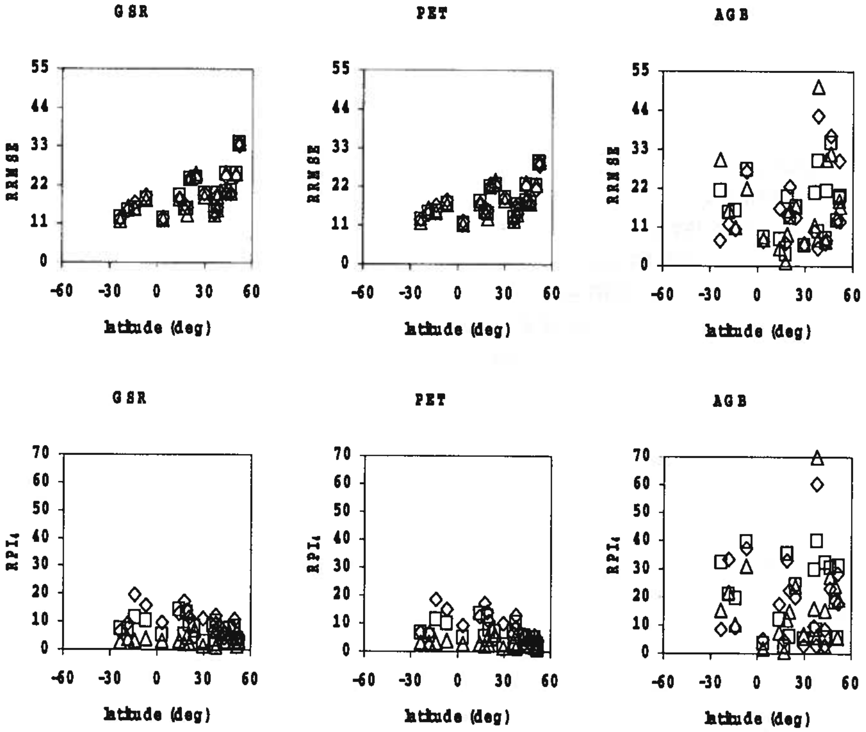
Evapotranspiration estimate. The PT model was used to estimate PET. Average values of both PT constant (PTc=1.26) and aridity factor ($a=0.03$ kPa^{-1}) were used.

Above ground crop biomass simulation. AGR was estimated by the crop growth model CropSyst (Stöckle et al., 2002). One representative crop was selected for each location (table above), and parameterized loading the default crop values provided with CropSyst.

Data processing. The amount of residuals generated by each estimate was quantified by the relative root mean squared error (RRMSE, %). A relative measure of the presence of patterns versus time (calendar days) was also calculated, arranging the residuals in four groups (RPI_4, %).

Results

The results obtained with GSR, PET and AGB are shown in the graphs below (□BC ◇CD △DB).



Conclusions

The three radiation models did not provide appreciable differences in RRMSE for GSR and PET estimates. However, the model DB gave consistently better performance than both BC and CD in preventing GSR and PET estimates from showing patterns over time, with few exceptions in temperate locations. DB gave the lowest value of both RRMSE (1.2%) and PI_4 (0.7%) for AGB, and provided the best performance in 6 cases (both indices). The model CD allowed the best estimates of AGB in 10 cases (both indices). Therefore, better estimates of AGB tend to be associated with the use of GSR models accounting for seasonality, i.e. CD and DB, with a certain preference on the model CD. In general, there was almost no change in RRMSE and RPI_4 when estimating PET, compared to GSR estimates, whereas AGB estimates have noticeable differences: reduction and amplification of RRMSE, and increase of RPI_4. Such an increase indicates that the use of estimated GSR may affect biomass estimates unevenly over the growing season. Further study is required for a better understanding of the distribution of model residuals over specific growing seasons at each location.

References

Donatelli M. et al., 2002. European Journal of Agronomy. (in press)
Stöckle C.O. et al., 2002. European Journal of Agronomy. (in press)

COMPARISON OF MODELS DESCRIBING MAIZE (*ZEA MAYS* L.) YIELD RESPONSE TO FERTILISER IN A LONG-TERM EXPERIMENT

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Introduction

The analysis of crop yield response to fertiliser and the determination of optimum fertiliser rates involves the fitting of various functions to yield data obtained in fertilisation rate experiments. The polynomial functions widely used to describe fertiliser responses may considerably over-estimate the optimum fertiliser rate. In many cases certain environmental or agronomic factors may induce a ceiling effect on the yield, in which case the maximum of the true response surface forms a plateau.

Methods

The research database consisted of a 26-year data series obtained in a long-term mineral fertilisation experiment set up in a random block design with four replications in 1967. The experimental treatments were as follows (NPK doses in kg ha^{-1}): 1. Control (without fertilisation), 2. 100 kg NPK, 3. 200 kg NPK, 4. 300 kg NPK, 5. 400 kg NPK, 6. 600 kg NPK, 7. 800 kg NPK. The maize in the experiment was grown in continuous cropping with conventional cultivation. Four different functions were fitted to the annual yield data: quadratic, square root, inverse exponential (*Overman et al.* 1994) and linear-plus-plateau (*Anderson* and *Nelson* 1975).

Results

The inverse exponential and linear-plus-plateau functions fitted well, predicting smaller yields without fertilisation than the quadratic function and a higher, real yield response up to NPK rates of 200–500 kg (Fig. 1). The quadratic function, on the other hand, indicates an unrealistically high yield increase up to NPK rates of 400–600 kg and considerably over-estimates the optimum fertiliser rates. The square root function fits the data very well. The deviation from regression (measured yield – calculated yield) when fitting the different functions is illustrated in Fig. 2. The deviation values of the quadratic model gave sinusoidal pattern with respect to applied NPK, while the deviation values showed random distribution for the other functions. The difference between the squares of the residuals was greatest between the quadratic and square root functions and between the quadratic and linear-plus-plateau functions. There was no significant difference between the regression deviations of the square root and linear-plateau functions or the square root and inverse exponential functions. In the present experiments the best results were obtained with the linear-plus-plateau function.

Conclusions

When choosing functions the analysis of regression deviations must be considered as a fundamental criterion in addition to the determination coefficient (R^2). If the fertiliser response pattern also contains a depression phase, it is recommended that a square root function should be used instead of a quadratic function. If the maximum of the response surface forms a plateau, rather than a maximum point, the linear-plus-plateau function or the inverse exponential function are recommended. The results show that greater attention should be paid to the choice of function.

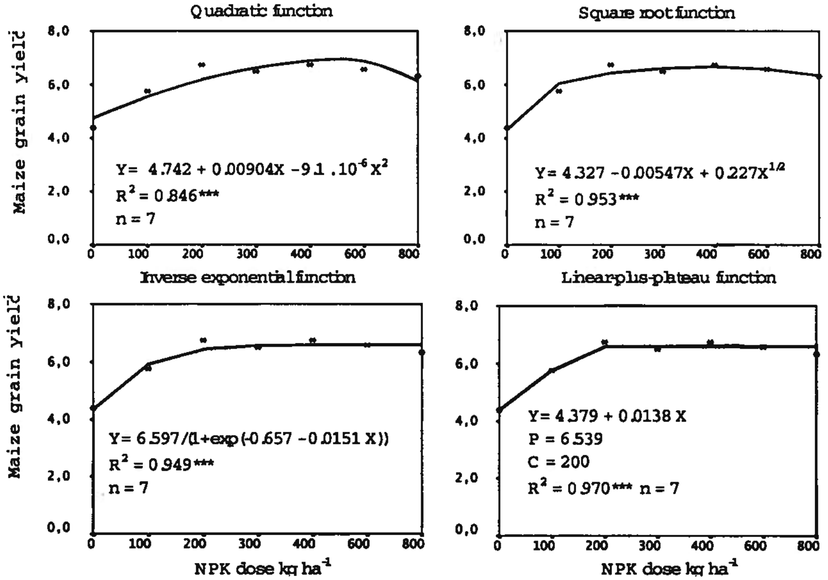

Fig. 1. Prediction of changes in maize grain yield as a function of fertiliser dose by fitting four different functions (mean of 26 years)

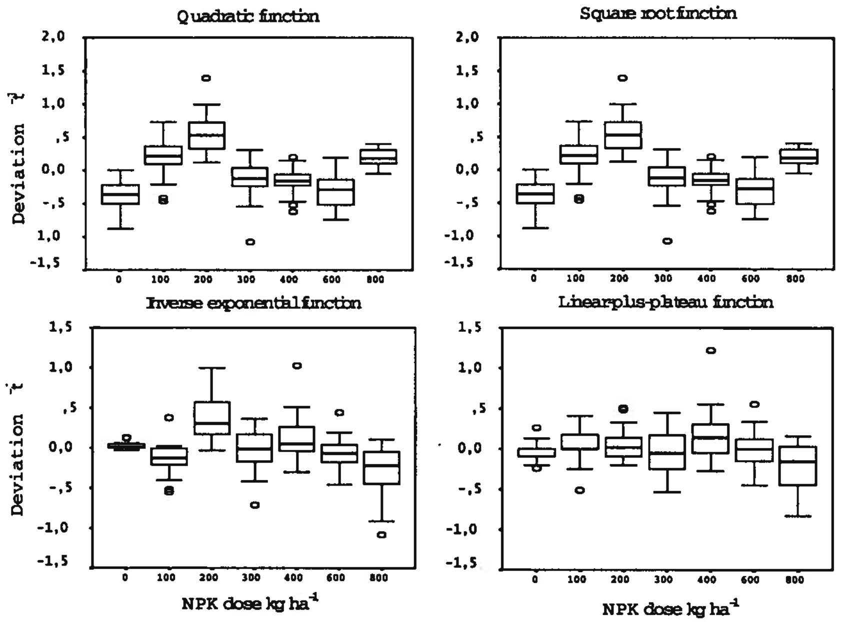

Fig. 2. Deviation from regression (measured yield – calculated yield) when fitting various functions (n=26)

References

Anderson, R.L. – Nelson, L.A.: 1975. A family of models involving intersecting straight lines and concomitant experimental design useful in evaluating response to fertilizer nutrients. Biometrics 31: 303-318.

Overman, A.R. – Wilkinson, S.R. – Wilson, D.M.: 1994. An extended model of forage grass response to applied nitrogen. Agron. J. 86: 617-620.

MODELING DROUGHT-INDUCED ACCELERATION OF REPRODUCTIVE PARTITIONING AND MATURITY IN FABA BEAN

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Introduction

The CROPGRO-faba bean model was recently adapted to predict growth and yield of faba bean (*Vicia faba*) based on literature sources and comparison to irrigated crops grown in two seasons at Cordoba, Spain (Boote et al., 2002). In evaluations of rainfed treatments in both years, the model accurately predicted total biomass accumulation, but failed to predict the more rapid transition to reproductive growth after anthesis, and as a result underestimated grain yields under terminal water deficit. The actual rainfed crop produced reasonably good yields because reproductive growth was accelerated into an earlier phase when crop assimilation was still high (Sau and Mínguez, 2000). The goal of this paper was to hypothesize early stress indicators that could be used to accelerate reproductive progress and partitioning to reproductive.

Methods

The CROPGRO model has features that allow drought to accelerate reproductive maturity after beginning seed stage, but it does not accelerate rate of formation of pods or seeds (Boote et al., 1998). For rainfed crops in this study, CROPGRO's water stress indicators (SWFAC and TURFAC) were observed to be 30-40 days late in providing a signal to accelerate reproductive progress after anthesis and pod addition. Decreases in dry matter accumulation occurred 30-40 days after the signal for shift in partitioning was needed. Both SWFAC and TURFAC are 0 to 1 factors computed from the ratio of potential root water uptake (TRWU) to evapotranspiration demand of the crop (EP1). Potential root water uptake is integrated over total root length density in all soil layers, and considers impact when a majority of the roots may be in drying topsoil layers, despite abundant water in deeper depths where rooting density is low. The SWFAC decreases photosynthetic assimilation when TRWU is less than EP1. On the other hand, TURFAC = (1/1.5) * TRWU / EP1, so that the turgor stress occurs whenever potential root water uptake is less than 1.5 times EP1. TURFAC begins decreasing leaf area expansion and elongation rates while photosynthesis is not yet reduced. For this paper, we evaluated the full range of the ratio of TRWU to EP1, and found that it was typically above 4 to 5 for irrigated crops in mid-season, but fell below 5 soon after anthesis in the rainfed treatment. Thus, we created a new signal (SWDF3 = (1/5.0) * TRWU / EP1), that acts when the ratio falls below 5. Fig. 1 shows the SWDF3 signal occurred much earlier, at 86, 92-100, 112, and 118-160 days after sowing (DAS), whereas the SWFAC did not signal until much later (148 DAS). In other words, SWDF3 can be used as a signal of impending water deficit, even while the crop is continuing to meet evapotranspiration demand and accumulate biomass at normal rates.

The SWDF3 signal was allowed to influence phenology and physiology of the crop in the following ways: 1) accelerate onset of pods and seeds (decreasing photothermal times after anthesis), 2) accelerate maturity (decreasing photothermal time), 3) accelerate addition of pods, 4) increase specific leaf weight, and 5) increase rate of root depth increase. Time course of simulated and observed pod mass and pod harvest index (PHI) were evaluated to determine the degree of improvement in accelerating reproductive growth. Effects on predicted grain yield, final PHI, leaf area index, and days to beginning pod and maturity under rainfed conditions were evaluated to determine improvement attributed to use of the SWDF3 signal.

Results

Fig. 1 SWDF3 and SWFAC indicators for rainfed (RF) and irrigated (IR) faba bean during the 1987-1988 season.

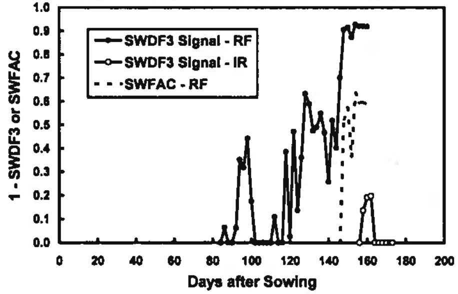
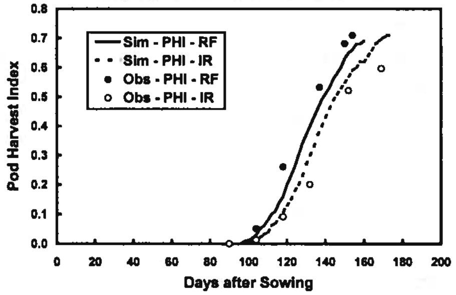


Fig. 2 Pod harvest index of rainfed (RF) and irrigated (IR) faba bean during the 1987-1988 season.



Acceleration of partitioning to reproductive in rainfed faba bean was very clear in the pod mass and PHI (Fig. 2). Acceleration of pod development and maturity were previously reported for faba bean by Grashoff (1990) and Grashoff and Stokker (1992). It is perhaps not surprising that this crop of Mediterranean origin would have evolutionary selection to accelerate reproductive growth under a terminal drought. Grashoff and Stokkers (1992) proposed to accelerate reproductive development and partitioning when the ratio of actual root water uptake to EP1 (same as SWFAC) was less than 1.0. However, that water stress signal (and TURFAC) in CROPGRO occurred much too late to be of value in inducing acceleration. Using the full range of the ratio of potential root water uptake to evapotranspiration demand provided a sensitive early signal that distinguished rainfed from irrigated crops. That ratio fell below 5.0 soon after anthesis, shown as a 0-1 stress indicator (1- SWDF3) in Fig. 1.

When this signal was used to accelerate onset and more rapid addition of reproductive sites, the pod mass and PHI were initiated 4-5 days earlier, value of PHI=0.25 occurred 6 days sooner, and maturity was 10 days earlier (Fig. 2). Because of earlier onset of reproductive growth while assimilation was still high, the crop achieved higher grain yield and final PHI, than without the signal. Earlier onset of reproductive growth resulted in less leaf area growth. In addition, the SWDF3 functioned well to create the early increases observed in specific leaf weight.

Conclusions

We hypothesize that this signal to shift partitioning is the same as abscisic acid known to come from roots in drying or high impedance soil (Davies and Zhang, 1991). The rainfed faba bean situation mimics this, because under terminal drought, the majority of roots were in the upper 0.45 m of soil which dried out first, yet there were some roots and adequate water in the deeper horizons (0.45-1.65 m) to allow water uptake to fully supply photosynthesis. Under this situation, the signal was present nearly 50-60 days prior to the time that biomass accumulation was first reduced, and thus it could not be associated with either lack of turgor or minor temperature-increases induced by lower leaf transpiration. A function like this is needed for accurate simulation of faba bean yield under rainfed conditions.

References

Boote, K. J. et al. 1998. p. 651-692. *In:* Agric. Sys. Modeling and Simulation. Marcel Dekker.
Boote, K. J. et al. 2002. Agron. J. (in press, July-Aug).
Davies, J., Zhang, J. 1991. Ann. Rev. Plant Physiol and Mol. Biol. 42,55-76.
Grashoff, C. 1990. Neth. J. Agr. Sci. 38,21-44.
Grashoff, C., Stokkers, R. 1992. Neth. J. Agr. Sci. 40,447-468.
Sau, F., Mínguez, M. I. 2000. Field Crops Res. 66,81-99.

ESTIMATING SOIL SHRINKAGE CURVE PARAMETERS IN THE SOFTWARE SOILPAR

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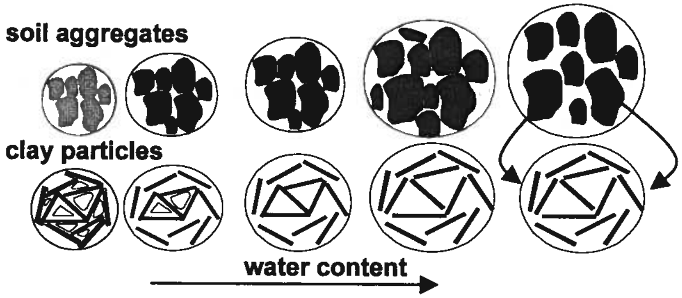
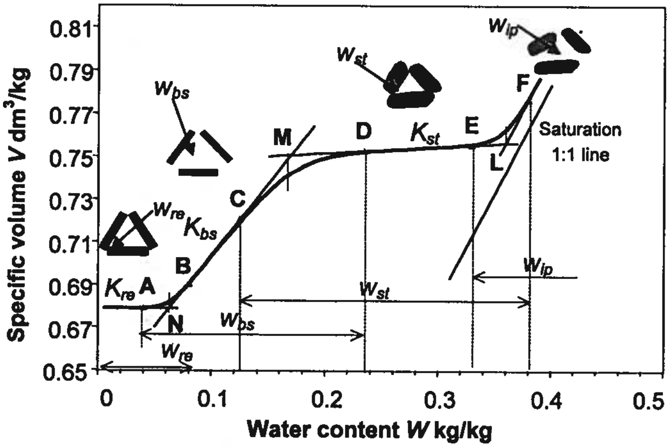
Introduction

The shrinking-swelling properties of soils are the main cause of the variation of preferential flow in the soil pedon. Soil water redistribution is greatly affected by preferential flow, thus influencing several processes modelled in the soil-plant system. Hence, water preferential flow should not be ignored in soil water models.





Water is retained at different tension by soil particles and aggregates. A physical model to describe soil hydro-structural state (see figure above) was proposed by Braudeau et al. (2002). This model enables the estimate of soil apparent volume as a function of water content. The figure on the left shows the characteristic soil shrinkage curve. At any give water content, the variation of soil apparent volume can be estimated as:

$$dV = \Sigma_i dw \;\; = K_{re}dw_{re} + K_{bs}dw_{bs} + K_{st}dw_{st} + K_{ip}dw_{ip}$$

Where w_{re} is water retained by adsorption on particles, w_{bs} is water retained by swelling in micropores (plasmic porosity of primary peds), w_{st} is water retained by adsorption in macropores (interstitial interped pores), and w_{ip} is water retained by swelling in saturated macropores. The curve parameters can be obtained either by continuous measurement, or they can be estimated with good results from commonly available soil parameters (Braudeau and Donatelli; 2001). To facilitate the estimate of such parameters we implemented the methodology in the software *SOIL*PAR (Acutis and Donatelli, 2002).

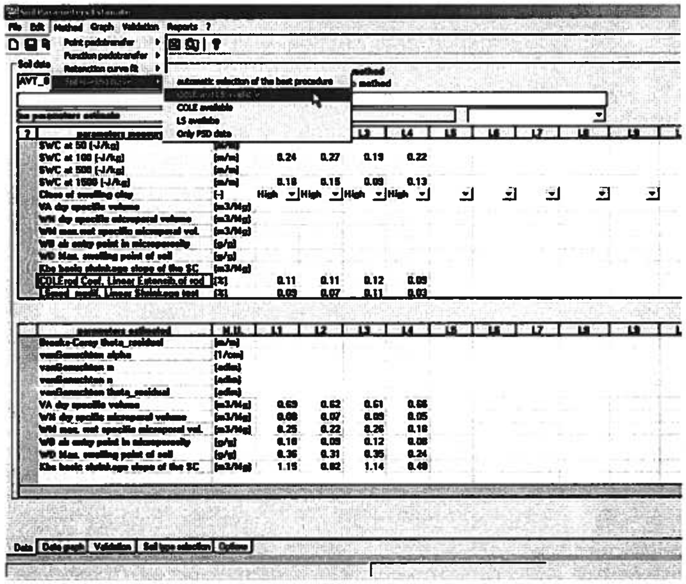
Methods

Some simplifications of the physical model are adopted, that is: $K_{re}=0 \Rightarrow V_A=V_N$, $K_{st}=0 \Rightarrow V_M=V_D=V_L$, $W_{sat}=W_L=V_M-V_S$, where V_S is the volume of the solids, often given as 1/2.65. So that the minimum number of parameters needed to fit the curve is 6, meaning that some different combinations of the numerous (more than 12) parameters of the shrinkage curve can serve to estimate it. The six parameters are (see figure): V_A, W_N, W_M, W_B, W_D, and K_{bs}.

The estimation of the soil shrinkage curve was implemented allowing for different availability of measured data. The first option assumes that the soil volume was measured continuously using the procedure described by Braudeau et al. (1999); curve parameters above are derived from the measured values of soil apparent volume. These values are also used as reference to test parameters estimate using various methods.

A second option uses measured values obtained by simple and standard laboratoty tests. The parameters W_B and W_D are obtained by Richards' pressure plates; V_A, W_M, W_N and K_{bs} can be estimated by standard tests of the soil swelling potential such as the COLE (Coefficient Of Linear Extensibility of non disturbed sample), COLErod (on paste rod), LS (linear shrinkage). They measure the percent shrinkage in one dimension of a soil from a moist state to air dry. The lab procedure is described in the Soil Survey Laboratory Information Manual (Burt, 1995) and in McKenzie et al. (1994). These indicators can also be estimated, but this implies some knowledge of the clay type. As a consequence, the clay swelling class was also added as optional input parameter. Finally, the COLErod and LSstd allow estimating W_M and W_N; COLEstd and LSmod allows estimating V_A and V_D; together, COLErod and LSmod allow estimating W_M, W_N, V_A and K_{bs}.

A third method minimizes the number of measured parameters required, and it relies on pedotransfers to estimate some parameters (Braudeau and Donatelli, 2001). The precision of the curve estimate, in terms of matching between the measured values and estimated curve values via estimated parameters, resulted good even for the third option, and it is variable if the user estimates of the type of clay present in the soil. New soil parameters were added to the *SOIL*PAR database to enable the estimate of soil shrinkage curve parameters, as shown in the figure below:



Conclusions

The soil shrinkage curve is a sound, physically based model to simulate soil swelling-shrinking properties. The implementation in *SOIL*PAR enables estimating the soil shrinkage curve parameters in a convenient and effective way. The basic theory and the procedures implemented in the software are described in the on line help/user manual. *SOIL*PAR version 2.01 can be downloaded at: http://www.isci.it/tools .

References

Acutis and Donatelli 2002. Eur. Agr. J. (in press)
Braudeau et al. 1999. Soil Sci. Soc. Am. J. 63:525-535
Braudeau et al. 2002. Soil Sci. Soc. Am. J. (submitted)
Braudeau and Donatelli 2001. Proc. ESA Symp. Modelling Cropping Systems, 53-54
Burt 1995. Report n° 45. National Soil Survey Center. Lincoln, Nebraska
McKenzie, et al. 1994. Aust. J. Soil Res. 32:931-938.

ABOUT THE CROP TEMPERATURE AS SIMULATED BY THE STICS MODEL

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Introduction

In order to account for the thermal environment of the crop, a daily crop temperature is used in the STICS crop model (Brisson et al., 1998) to drive the response functions of the crop to temperature and plays the role of the upper limit for the soil temperature calculation. In this work, simulations and measurements of crop temperature are compared.

Methods

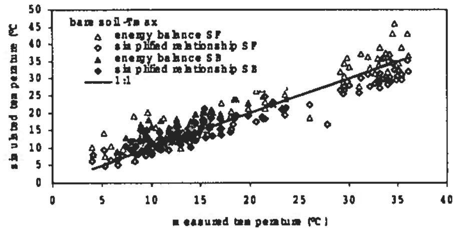
The daily crop temperature is computed as the arithmetic mean of the maximal and the minimal crop temperatures. It is necessary to first calculate net radiation. Atmospheric radiation is calculated from the Brutsaert formula, using temperature and moisture content as input variables. Albedo evolves between the soil value and the vegetation value and soil albedo varies according to the type of soil, the humidity in the surface layer. Soil radiation is a function of crop temperature (a variable that is to be calculated) and is therefore the object of an iterative calculation based on a convergence criterion of 0.5°C.

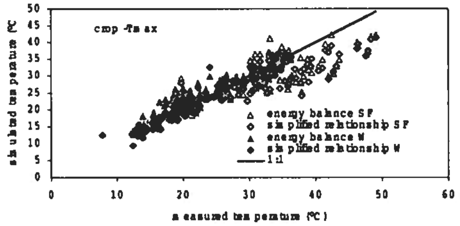
Then two calculation methods are proposed (simplified relationship and energy balance) depending on the availability of climatic data. The first approach is based on a relationship between midday surface temperature and daily evaporation and accounts for the surface roughness (Riou et al., 1988). It is hypothesised that the minimal crop temperature coincides with that of the air. The second approach is based on two instantaneous calculations made at the time of the maximum and minimum temperature. Atmospheric radiation is assumed to be constant throughout the day, whereas soil radiation is calculated with the maximal and minimal temperatures (same iterative processes as above). At the end of the night, evapotranspiration and radiation values are zero and the soil heat flux is calculated as an empirical function of wind under the cover and of minimal net radiation. Total radiation and evaporation in the midday sun are estimated assuming that the fluxes evolve sinusoidally during the day. Night-time wind is assumed to be equal to 0.5 x daily mean wind.

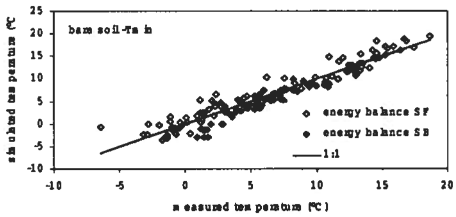
The crop temperature is compared to radiative or soil temperatures, which are the solely measurements that can be faced to the calculated values. Data sets of radiative temperatures (daily minimum and maximum) come from the Alpilles-Reseda experiment in the South of France (Prevot et al., 1998). Values of three fields are used : the "water stressed" sunflower (SF) field which was cropped from May to September and was bare soil in the other periods, the wheat (W) and the alfalfa (AL) pasture fields were instrumented during the crop cycle only. Data sets of soil temperature (sensors in the first 3 cm) come from experiments devoted to the emergence dynamics of sugar beet (SB) in the north of France (Durr et al., 2001).

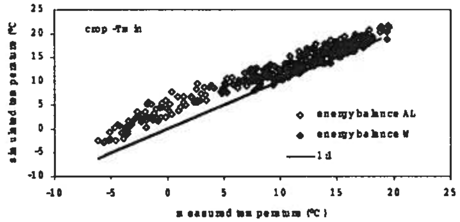
Results

The simplified relationship seems more robust than the energy balance with lower RMSE even if the bias in cases of elevated temperatures is higher. Some questions can arise about the significance of the maximal radiative temperature when the plants are sparse (case of sunflower) because in this case the radiative temperature is different from the aerodynamic temperature within the canopy and hence different from the result of the plant-soil energy balance (Prevot et al., 1994). The energy balance does not succeed in correctely simulating the night temperatures, essentially for planted surfaces because of the limits in correctly describe temperature profiles during the night. The imposed lower threshold for windspeed during the night prevents the model from erratic results but generates a systematic over-estimation.









measurements			radiative temperature				soil temperature
surface			bare soil (winter and summer)	sunflower	alfalfa	wheat	bare soil (spring)
Maximum temperature	simplified relationship	RMSE	2.88 °C	5.05 °C	4.27 °C	1.83 °C	2.19 °C
		bias	-65%	-64%	-34%	4%	23%
	energy balance	RMSE	3.93 °C	5.02 °C	5.82 °C	2.54 °C	3.47 °C
		bias	29%	-46%	48%	30%	65%
Minimum temperature	air temperature	RMSE	1.66 °C	1.33 °C	3.66 °C	1.60 °C	2.37 °C
		bias	17%	51%	92%	39%	-27%
	energy balance	RMSE	1.72 °C	1.32 °C	3.53 °C	1.56 °C	1.71 °C
		bias	8%	50%	90%	36%	-42%

Table 1 : Statistics of the comparison between measured and simulated crop temperature. Bias is estimated following Willmott (1981) recommandations.

Nevertheless, it is important to analyse this precision in view of the use of the crop temperature within the model, which is more or less under a cumulative form, either directly for phasic development, leaf and root elongations, germination and maturation of harvested organs or indirectly by the sum of the simulated mecanisms like net photosynthesis and mineralisation process in the soil. The table 2 shows that the differences with air can be not significant or even negative if we use averages. The results are better for the maximum temperatures but the energy balance exagerates those differences for planted surfaces. The weight of the errors on minimum temperatures is important. As most of the mechanisms concerned are diurnal, it could be worth ponderating the extremes in the calculation of a daily temperature .

crop		sunflower	wheat	alfalfa	sugar beet
period		crop cycle	tillering to harvest	4 growing cycles	emergence
measured	avg	249	-7	-306	-3
	max	743	123	209	-11
simplified relationship	avg	124	68	107	18
	max	289	135	211	42
energy balance	avg	165	128	435	55
	max	354	266	899	112

Table 2 : Differences between experimental or simulated temperature sums and the equivalent air temperature sum for average or maximum values

References

Durr et al, 2001, SSSAJ 35, 414-423.

Prevot et al., 1998. IGARSS Seattle (Wa, USA), 1998.

Prevot et al., 1994. Proc. Workshop thermal remote sensing (Lalonde, FR), 1993

Riou et al., 1988. Int. J. Remote Sensing 9, 1529-1533.

Willmott, 1981. Phys. Geogr. 2 : 184-194

Brisson et al., 1998. Agronomie 18 : 311-346

AN INTEGRATED FORECASTING SYSTEM OF FORAGE QUANTITY AND QUALITY AT FARM AND REGIONAL SCALE THROUGH A WEB-BASED GIS

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Introduction

In order to improve livestock farming system sustainability, from an economical and an environmental point of view, tools necessary to manage nutrient stocks need to be implemented. They must be able to estimate forage availability in quantity and quality to adjust foodstuff complementation and, in this way, to reduce nutrient wastes.

The use of dynamic models seems to be a promising tool to reach these objectives. Such models are widespread and they are based on the biomass formation through the photosynthetic activity of the plant under different environmental conditions (temperature, soil water content...). Nevertheless, grass monitoring is very special to consider at a spatial level due to the very wide heterogeneity of management practices. To by-pass this difficulty, this tool must be an integrated system which exploits different scale data and it must be operational at different spatial levels. By this, the grass monitoring system becomes more complex. To be operational, the challenges are on the one hand to link the model to a geographical information system (GIS) to cross multi-scale data (weather grid, remote sensing...) and on the other hand to implement this integrated system in an accessible and interactive form for farmers.

This paper provides an overview on the development of such an integrated system for the South Eastern part of Belgium, where more than 75 % of agricultural land is covered by grasslands.

Methods

The growth and nutritional value of forage depend on interactions between environment, genetics and both current and previous management practices. Parameter reflecting the genetic factors can be obtained from previously published literature or from experimental fields. They are fixed (constant) during the development of the model. Other parameters, such as date of fertilisation and amount of fertiliser, can more accurately be described as initial conditions (conditional variables) which are specific to the field. They must be introduced in the system by the farmer to be accurate in new situations. Finally, other groups of parameter, as environmental and pedological data, are neither constant in the time and/or space, nor convenient to measure on all the study area (variables). A reliable and economical system for determining the values of these parameters is needed to make the system widely applied.

One component of the Grass Monitoring System is a dynamic model, which predicts the dry matter production and the nutritional value of forage. In the present study, a grass growth model, developed in 1994 by the Agricultural Research Centre for the parcel level, was generalised to a wider geographical area by a spatialisation of the model, the input and the output data to take meteorological, soil and farm practices heterogeneity into account. To be operational on all the South Eastern part of Belgium this system needs multi-scale data which are managed in a GIS. Simulations are performed on georeferenced Elementary Mapping Units (4874 EMUs) characterised by similar soil and meteorological conditions. In the same way, new modules had been added allowing the integration of nitrogen fertilisation and prediction of grass quality which is represented by the amount of protein that could be digested in the intestine DVE (g/kg of Dry Matter) and the metabolisable energy content (VEM/kg of DM).

A GIS is also necessary by the fact that Grass monitoring is very particular and complex due to the multiple farming practices, numerous combinations of exploitation modes (grazing, cutting…) and their evolution during the season. This context forces the system to exploit spatialised information at large scale to obtain local (i.e. farm level) monitoring and to be an integrated system which generates information at multi-scales. Remote sensing data is the other component of this grass monitoring system. The project used VGT-S10 images and after a pre-processing phase, NDVI (Normalised Difference Vegetation Index) and SWVI (Short-Wave Vegetation Index) were calculated. Then we have evaluated the possibilities to use these vegetation indexes to predict grassland biomass in parallel to the agro-meteorological model, to estimate winter stock of forage and to define the dynamics of grassland exploitation, mainly in the definition of cutting periods.

Results

The model was tested on independent data recorded on 27 observed fields located in 9 different locations over the 2000 season under real farming practices.

For the prediction of biomass, the coefficient of determination (R^2) is equal to 0.77 but the model underestimates DM value. This could be linked to an underestimation of nitrogen supplying through the mineralization of soil organic matter. For the quality module, we obtained a R^2 respectively of 0.64 for the DVE and 0.56 for VEM.

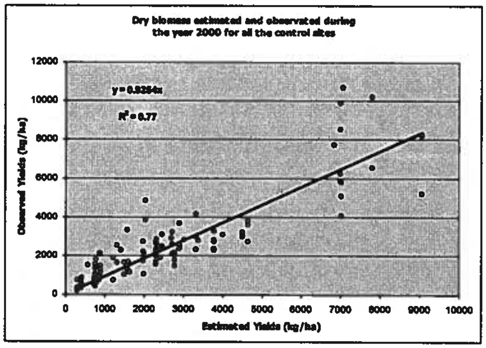

Fig. 1: DM estimated vs observed.

The possibilities to use remote sensing to predict forage stocks formation in animal farming system have also been explored The analyses highlighted a relation between the observed biomass, all sites included, and the NDVI (R^2=0.32) or the SWVI (R^2=0.46).

An NDVI threshold level has been defined. It corresponds to the biomass necessary to feed the herd under grazing. All value higher will underline possibilities to accumulate some forage stocks, while all value lower will underlined a production deficit that will necessitate stocks consumption.

Conclusions

This study allowed the development and the implementation of a grass monitoring system based on an agro-meteorological model (MCP) and remote sensing data. The MCP model takes into account hydrological soil properties, thermic stress and its impact on the delay before regrowth starting or on the speed of this regrowth and nitrogen supply. A quality module had also been developed and integrated. This model was calibrated and validated to be used at regional and farm level through a GIS. At regional scale, estimations of biomass and quality classes are performed and linked with information coming from remote sensing (biomass index, forage stocks…). This first level of information forms a referential system to direct and refine simulation outputs at local scale. For these reasons, this monitoring system can not be locally installed on end-user PC. The only way to return it into an accessible form to end-users is therefore to use a Web-based GIS.

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A GROWING DEGREE-DAY MODEL FOR EVENING PRIMROSE CROPS

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Introduction

Evening primrose (*Oenothera* spp.) is grown for its seed oil, which is used for pharmaceutical and nutritional applications. It is a temperate species that is cultivated both as biennial or annual crop. The biennial crop, in particular, has a long and variable duration. In order to improve crop management and predict crop responses to different and changing environments we need to be able to model development. The aims of this work were to estimate base temperature and growing degree-days for predicting evening primrose phenological stages.

Methods

Evening primrose plants cv. Juno were grown in pots under different air temperatures from four sowing dates (4th April, 18th May, 1st May and 16th May) in three environments ("warm" and "cold" greenhouses and outside) at University of Essex, south-east England. Evening primrose lifecycle was divided into six phenological stages (Table 1), and duration of each was measured by observing the dates when 50% of all plants started and finished them. Air temperature was measured each ten minutes using thermocouples and a logger and daily mean temperature was calculated. Base temperature (Tb) and thermal time (θ) were estimated by linear regressions between rate of development (1/duration) and mean temperature (T) and considering that $1/\text{duration} = b[T - Tb]$, $Tb \leqslant T \leqslant To$, To is optimal temperature, *b* is a constant (Jones, 1996); $\theta = \Sigma[T - Tb]$ (Hall, *et al.*, (1995) and $Tb = -a/b$, $\theta = 1/b$, *a* is the other regression coefficient (Qi, *et al.*, (1999). For comparison and validation of the phenological model, thermal time was calculated for a previous nearby field experiment (Fieldsend, 2001) using general estimated base temperature from the pot experiment.

Results

Pot Experiment: Table 1 shows the regression coefficients between reciprocal duration and mean air temperature for the full lifecycle and the separate phenological stages. Estimated base temperature and thermal time are also shown. Base temperature for stages 0-1 and 1-2 was 1.6°C, which is low compared to some other temperate species. Stem formation (2-3) had a higher base temperature: 3.0°C. Flower formation (3-4) and fruit formation (5-6) had the highest base temperatures 6.4°C and 8.4°C, respectively.

Stage 4-5 (first flower to last flower open) showed positive ***a*** and negative ***b*** indicating a negative relationship. When its ***duration*** was plotted against mean air temperature a positive linear relationship was observed (Figure 1). As mean air temperature increases so duration of this stage, and therefore, the number of flowers produced was increased too. This effect may be a characteristic of undetermined species, which duration of this stage and production of flowers could be stimulated by warm temperatures. This relationship can be used to estimate duration of this stage using a similar procedure.

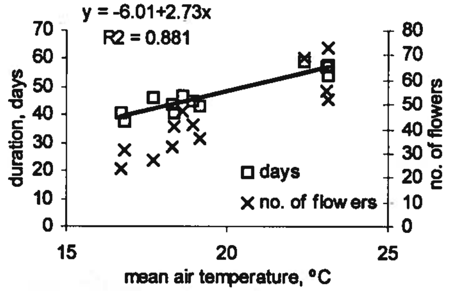

Figure 1. Linear relationship between temperature and duration and temperature effect on number of flowers for flower production stage of evening primrose [duration=b'(T-Tb'). Tb'=2.2°C, θ'=0.122].

Table 1. Linear regression coefficients and calculated base temperature (°C) and thermal time (degree-days) for the lifecycle and phenological stages of evening primrose under four sowing dates and three environments.

Phenological stage*	*a* x 10^{-3}	*b* x 10^{-3}	Tb °C	θ degree-days	R^2
0-1	-12.95	8.222	1.6	122	0.980
1-2	-3.27	2.081	1.6	480	0.911
2-3	-10.68	3.507	3.0	280	0.925
3-4	-24.13	3.784	6.4	264	0.925
4-5	44.15	-1.156	-	-	0.861
5-6	-36.09	4.311	8.4	232	0.967
0-6	-1.24	0.431	2.9	2331	0.907

*0-1: sowing to emergence; 1-2: emergence to stem elongation; 2-3: stem elongation to bud; 3-4: bud to first flower open; 4-5: first flower to last flower open; 5-6: last flower open to plant dead; 0-6: sowing to plant dead.

Field Evaluation: Comparison with a previous experiment (Table 2) showed that for spring-sown crops (1996 and 1997) and winter-sown crops (1995-96 and 1996-97) difference for calculated and observed thermal time for emergence was 35, 30, 1 and 11 degree-days, respectively, which was considered low. For emergence to flowering, respectively, difference was 327, 322, 208 and 394; spring-sows difference was higher for this stage. For flowering to dead difference was 53, 399, 298 and 476, respectively, which was acceptable. From sowing to dead, difference was 309, 47, 507 and 881, respectively, also acceptable. Spring differences were lower than winter differences as it was expected. Only difference for 1996-97-winter (0-6) was considered high.

Table 2. Estimated (e) thermal time (degree-days) from field experiment during spring and winter sows and differences (d) against pot experiment* for three phenological stages and complete life cycle of evening primrose.

Field experiment Cycles	Sown To emergence		Emergence to flowering		Flowering to dead		Sown to dead	
	e	D	e	d	e	d	E	d
	0-1		1-F		F-6		0-6	
1996-spring	132	-35	828	-327	1062	53	2022	309
1997-spring	137	-30	833	-322	1408	399	2378	47
1995-96-winter	168	1	1363	208	1307	298	2838	507
1996-97-winter	178	11	1549	394	1485	476	3212	881

*Thermal time for pot experiment using general Tb=2.9°C: 0-1:167, 1-F: 1155, F-6: 1009 and 0-6: 2331.

Conclusions

The simple thermal model of development using base temperature and thermal time is considered useful for estimating the dates of evening primrose phenological stages.

References

Hall, D.O., J.M.O. Scurlocks, H.R. Holhar-Nordenkampf, R.C. Leegod and S.P. Long. 1995. Photosynthesis and production in a changing environment. 1st ed. Chapman & Hall.

Jones, H.G. 1996. Plants and microclimate. 2nd ed. Cambridge, UK.

Qi, *et al.*, 1999. Modelling the effect of temperature on the rates of seeding, emergence and leaf appearance in legume cover crops. Exp. Agric. 35: 327-340.

Fieldsend, A.F. 2001. Productivity, canopy development and resource use in evening primrose (*Onothera* spp.) crops. PhD Thesis. Department of Biological Sciences, University of Essex. U.K.

SIMULATION OF GROWTH, YIELD AND N, P AND K UPTAKE OF FIELD-GROWN GREEN BEANS

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Introduction

Using appropriate models (Ferreira *et al.*, 2000), the harvest date for green beans can be decided based on thermal time. This can be used to obtain the greatest yield compatible with good pod quality, if nutrients do not limit plant growth. We have now developed a growth model that can be used to simulate plant growth, pod yield, and uptake of N, P and K during the crop growth.

Methods

In 1992 and 1993, two field trials with green beans (*Phaseolus vulgaris* L., cv. Alcade) were conducted in Central Portugal. Three plant populations, two irrigation levels and various harvest dates were studied. In 1997 and 1998, three other cultivars were grown in the same location (cv. Carlo, Cleo and Mutin), without water or nutrient limitations. The three cultivars were sown simultaneously, with six sowing dates the first year and four in the second. Weather data was collected hourly. Dry matter accumulation and the concentrations of N, P and K in the shoots and pods were determined each week. Based on these measurements sub-models that predict N, P and K concentrations were developed (de Varennes *et al.*, 2002).

The present growth model was constructed using the 1992/93 data set, and validated with 1997/98 data. Empirical relations to predict N, P and K shoot concentrations were obtained with the 1997 data and validated with the 1998 data, using the same approach as before (de Varennes *et al.*, 2002). The model was programmed in object-oriented Pascal. The main program controls three objects dealing with weather variables, crop processes, and pod quality and nutritional relations. The program reads from a weather file date, maximum and minimum temperatures, global radiation or sunshine hours, and wind speed, if available. Another input file contains crop parameters.

Results and discussion

The evolution of above-ground dry matter (DM) was simulated satisfactorily, although there was sometimes some underestimation in the beginning of the season and overestimation later on (Fig. 1 A and C; Table 1). Pod production (fresh weight) is very difficult to simulate, because water content of the pods varies with developmental stage and weather conditions. However, reasonable estimates were also obtained (Fig. 1 B and D; Table 1).

Simulation of N, P and K uptake depends both on the sub-models that estimate the nutrient concentration and on the accuracy of the DM estimates. Notice that the slopes of the regression lines of predicted versus observed values of N, P and K uptakes were almost the same than the slope of the corresponding line for DM (Table 1). The proportion of the variance accounted for by the model and the standard errors of the estimates show that the model is generally in good agreement with the measurements (Table 1). It should be pointed out that there was no tuning of the model, and that the same set of parameters were used for all cultivars. In spite of these, developmental stage, DM partitioning and leaf area evolution were predicted closely in most cases, although the parameters were obtained with another cultivar and different crop conditions (data not shown).

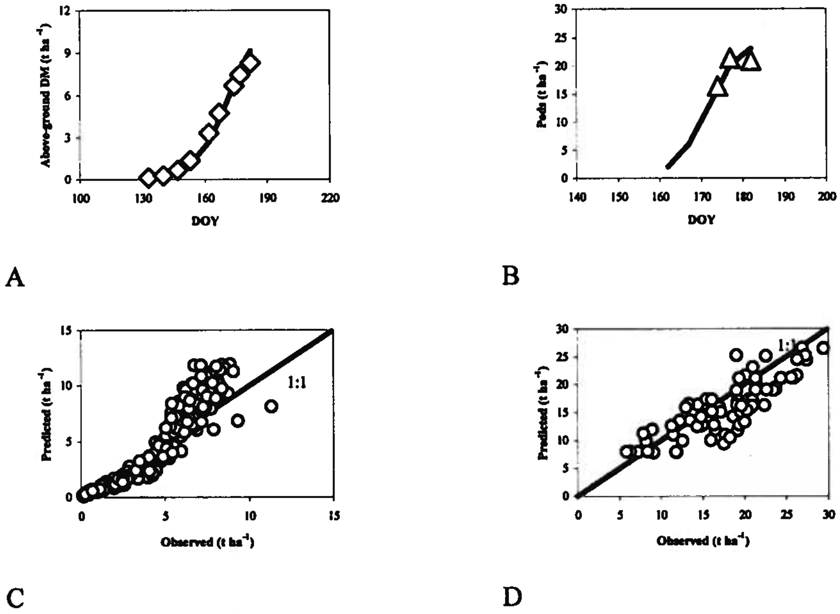

Fig. 1 Example of model output: A) changes of above-ground DM in relation to day of year (DOY) and B) pod fresh weight in relation to DOY; C) Predicted versus observed values of above-ground DM; D) Predicted versus observed values of pod fresh weight.

Table 1. Statistics from linear regression analysis of predicted versus observed values. *N* is the number of observations, $\overline{P}$ and $\overline{O}$ are the average predicted and observed values, S_p and S_o are their standard deviations, *a* and *m* are the intercept and slope of the line, and SE is the standard error.

Simulation	N	$\overline{P}$	$\overline{O}$	S_p	S_o	a, m	SE (r^2 in %)
Above-ground DM (t ha^{-1})	249	4.4	4.2	3.6	2.7	a = -0.73 m = 1.24	1.23 (0.89)
Pod fresh weight (t ha^{-1})	90	15.8	17.7	5.1	5.6	a = 2.19 m = 0.77	2.81 (0.70)
N uptake (kg ha^{-1})	105	137.6	118.9	108.0	75.5	a = -12.85 m = 1.26	48.84 (0.78)
P uptake (kg ha^{-1})	105	17.8	14.7	14.6	9.8	a = -2.35 m = 1.37	5.56 (0.86)
K uptake (kg ha^{-1})	105	128.1	110.2	101.3	68.7	a = -16.93 m = 1.31	45.98 (0.80)

References

Ferreira, M. E., Abreu, J. P. de Melo e, Ferreira, A., Andrada, L. & Bianco, V. V., Monteiro, A. A., 2000. Acta Horticulturae, 533: 489-495.

de Varennes, A., de Melo-Abreu, J. P. and Ferreira, M. E., 2002. European Journal of Agronomy, in press.

A SIMPLE RELATION TO INTERPRET THE OCCURRENCE OF DISEASES IN SUNFLOWER AS A FUNCTION OF CROP MANAGEMENT

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Introduction

Canopy management of sunflower crop has an impact on the occurrence and severity of cryptogamic diseases. Increasing plant population, nitrogen rate or irrigation amount increase the proportion of organs infected by *Alternaria helianthi* (Shaik Mohammad et al., 1983), *Phoma macdonaldii* (Debaeke and Pérès, 2000), *Phomopsis helianthi* (Debaeke et al., 2002) and *Sclerotinia sclerotiorum* (Masirevic and Gulya, 1992). Crop management has consequences (a) on spore splashing (irrigation), (b) on the success of initial infection, by providing a suitable microclimate or increasing plant receptivity (sowing date, nitrogen, density, row width, irrigation), (c) on the severity of symptoms (sowing date). Leaf area index (LAI) and the fraction of photosynthetically active radiation (PAR) intercepted by the canopy may constitute synthetic variables to represent the effect of canopy management and predict the risk of diseases associated to a given crop management strategy.

Methods

Field experiments were conducted at INRA near Toulouse from 1994 to 2000 to study the effects of crop management and genotype on the occurrence and severity of major sunflower diseases including phomopsis stem canker (*Phomopsis/Diaporthe helianthi*). In 1994, a cultivar (Select) was sown on 3/05 on 53 plots differing by plant population (5-7 plants/m^2), N rate (0 to 60 kg/ha) and irrigation amount (0-45 mm). An isolated but strong event of natural infection occurred at the end of June. In 1999, the management differed by genotype (susceptible : Olbaril ; phomopsis-tolerant : Labrador, Santiago), sowing date (2/04 or 3/05), plant density (5 vs 7.5 plants/m^2), nitrogen (0 to 120 kg/ha) and irrigation (0 vs 120 mm). The natural infection occurred in May but was moderate. The fraction of PAR intercepted (fPARi) was measured at early anthesis (early July) and the proportion of stems bearing a phomopsis lesion was scored on 50 plants during the 1st decade of August.

Results

In 1994, the proportion of stems infected by *Phomopsis* (ranging from 0 to 100 %) was exponentially related to the fraction of PAR intercepted at early flowering for a genotype moderately susceptible to phomopsis, grown on a range of unprotected plots differing only by soil fertility and stand density (Fig.1). 84 % of the variation of infection rate was explained by fPARi at flowering, crop density and N fertilisation being the major components of the variation of fPARi. When fPARi > 85 % (or LAI > 2.5), the proportion of infected stems increased rapidly.

This simple relation was used for interpreting the effects of crop management on phomopsis infection in 1999 when varying genotype susceptibility, water supply and sowing date. When comparing the genotypes (early sowing, irrigated), 3 genotypic behaviours were observed (Fig.2): (1) Olbaril, a susceptible genotype (S), had infection rates greater than the 1994 model for a given value of fPARi; (2) Santiago, a tolerant genotype (TPS), had extremely low values of infection rates but LAI was also low; (3) Labrador, classified as tolerant (TPS), had higher infection rates than Santiago in this experiment because of a higher LAI in response to crop density and N fertilisation. In experiments evaluating their disease susceptibility, genotypes should be compared for the same value of fPARi. When comparing the conditions of infection for a susceptible genotype (Olbaril), 3 groups were discerned (Fig.3): (1) early sown and irrigated conditions resulted in the highest rates of infection partly in relation with LAI, (2) early sown but unirrigated conditions did not succeed in the same infection rates, in spite of the same range of LAI than previously, because leaf attacks were hindered in their development by plant water stress and high temperatures, (3) late sown and unirrigated conditions escaped the infection events and LAI was too low for a successful attack on stems.

Conclusions

From these experiments, and from others (Debaeke et al., 2002), a simple model of the effect of crop management on phomopsis occurrence was suggested. For a single genotype, increasing plant density and N fertilisation result in more plants infected by the fungus. The

1994 relation (Fig.1) was built in moderate conditions of infection and was kept as a medium reference. Conditions favouring inoculum pressure (rainy season), plant receptivity (early sowing), extension of leaf symptoms (late irrigation) combined with the use of susceptible genotypes should result in infection rates above the curve. Drought, late sowing, fungicide application and resistant genotypes should result in infection rates lower than the relation for a given value of fPARi at flowering. This generic and simple model, which was applied to other diseases (phoma) (Debaeke and Pérès, 2000), could be used as a diagnostic tool in field survey.

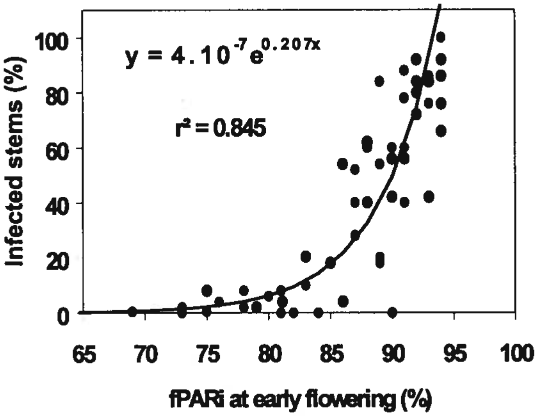


Fig.1 – Relation between the proportion of stems infected by Phomopsis and the fraction of the PAR intercepted (fPARi) at anthesis for unprotected situations (cv.Select, 1994)

Fig.2 – Relation between the proportion of stems infected by Phomopsis and fPARi at anthesis for early-sown, unprotected and irrigated situations (cv.Labrador, Olbaril, Santiago, 1999)

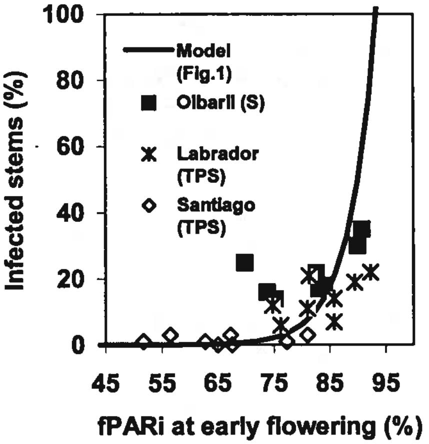
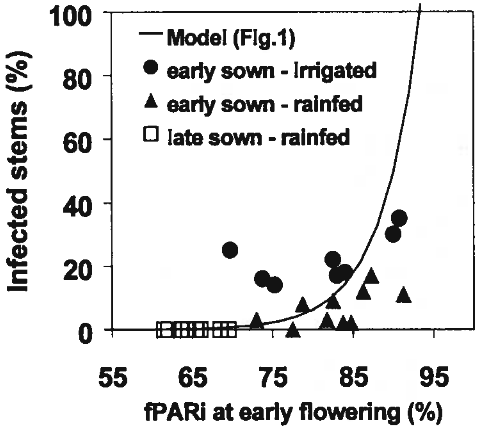


Fig. 3 – Relation between the proportion of stems infected by Phomopsis and fPARi at anthesis for a susceptible unprotected genotype (cv.Olbaril, 1999).



Debaeke P., Pérès A., 2000. Proc.6th Int. Conf. Plant Diseases, Tours (France), 553-560
Debaeke P. et al., 2002. Agronomie (submitted)
Masirevic S., Gulya T.J, 1992. Field Crops Research 30, 271-300.
Shaik Mohammad et al., 1983. Helia, 6, 29-31.

QUESTIONNING THE IMPORTANCE OF CROP GROWTH SIMULATION FOR PREDICTION OF WINTER WHEAT YIELDS IN BELGIUM

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Introduction

The Belgian Crop Growth Monitoring System (B-CGMS), based on the European Commission's CGMS, is intended for the prediction of crop yields and productions at the Belgian regional and agrostatistical circumscription levels (Tychon *et al.*, 2000). It applies the crop growth simulation model WOFOST and trend functions to account for weather influences and long-term increases in yield series respectively. However, the operational usefulness of the crop growth simulation model is in doubt here as in the European CGMS (Supit, 1999). In this study, various winter wheat yield prediction models were evaluated in order to pave the way for an improvement of B-CGMS. Inputs were a trend function, and either a crop growth simulation result or a simple climatic variable.

Methods

The following models were tested to predict winter wheat yields in the 13 agrostatistical circumscriptions belonging to the three most important agricultural regions of Belgium in terms of grain production:

$$\hat{Y} = b_0 + b_1 Y_{trend} \qquad \text{(Model 1)}$$

$$\hat{Y} = b_0 + b_1 Y_{trend} + b_2 Y_{sim} \qquad \text{(Model 2)}$$

$$\hat{Y} = b_0 + b_1 Y_{trend} + b_2 X_i \qquad \text{(Model 3)}$$

where $\hat{Y}$ denotes the predicted yield (kg/ha), Y_{trend} the technological time trend (kg/ha), $b_{0,1,2}$ the regression coefficients, X_i the value of climatic variable X in growth period i and Y_{sim} the B-CGMS simulated yield (kg/ha). In Models 1,2 and 3, linear or quadratic functions of time fitted to yield series from a 17-year reference period (1982-1998) were used to determine Y_{trend}. Table 1 presents the potential explanatory variables X_i retained for Model 3. The choice was inspired by Landau *et al.* (1998). In this approach, the cropping season was divided into four growth periods according to the phenological development of winter wheat in Belgium. The dates of beginning and end of each period, based on an average crop calendar, are specified in Table 2.

Table 1: Potential explanatory variables X_i selected for Model 3

X_i	Meaning
$TSUM_i$	Sum of daily average temperatures above 0°C in growth period *i* (°C day)
$Frost_i$	Number of freezing days ($T_{max} \leq 0°C$) in growth period *i* (day)
$LogRR_i$	Logarithm of the total precipitation amount in growth period *i* (-)
Rg_i	Sum of the daily global radiations in growth period *i* (kJ/m²)
$ET0_i$	Sum of daily potential Penman evapotranspirations in growth period *i* (mm)

Table 2: Start dates and end dates used to define the winter wheat growth periods of Model 3

Growth period *i*	Characteristic development phases	Start date – End date	Duration (month)
1	Germination, emergence	Oct. 1 – Nov. 30	2
2	Vegetative growth, tillering	Dec. 1 – March 31	4
3	Ear growth, anthesis	April 1 – June 15	2 ½
4	Grain filling, maturity	June 16 – July 31	1 ½

The results were evaluated against National Institute for Statistics (NIS) yield data relative to the 1989 – 2000 period. These constituted a set of 156 official yields at circumscription level. B-CGMS furnished crop growth simulation results aggregated at circumscription level, either *POT_STO* (potential grain yield) or *WL_STO* (water limited grain yield). The climatic variables of Table 1 were determined at circumscription level, using daily weather data averages from the B-CGMS database.

Results

The root mean square errors (RMSE) and the adjusted coefficients of determination (R^2) of Model 3 are presented in Table 3. For those climatic variables dependent on temperature (*TSUM, Frost, ET0*), the highest R^2 are reached with growth period $i = 2$. By contrast, R^2 doesn't vary significantly with i for *LogRR* and *Rg*. The overall best result is obtained with $X_i = ET0_2$. In Table 4, the R^2 and RMSE of Models 1 and 2 are compared to those of Model 3 with $X_i = ET0_2$.

Table 3: R^2 and RMSE of Model 3 using explanatory variable X of Table 1 and growth period i of Table 2. For temperature-dependent variables $TSUM_i$, $Frost_i$, $ET0_i$, the highest R^2 are in bold.

	R^2					RMSE (kg/ha)				
Growth period number i	*TSUM*	*Frost*	*LogRR*	*Rg*	*ET0*	*TSUM*	*Frost*	*LogRR*	*Rg*	*ET0*
1	0.58	0.55	0.57	0.55	0.56	639	656	645	660	649
2	0.67	0.68	0.60	0.55	0.69	562	558	618	658	550
3	0.55	0.58	0.60	0.57	0.58	660	639	622	643	639
4	0.58	0.55	0.58	0.56	0.56	637	658	639	651	652

Table 4: R^2, RMSE and regression coefficients of Mod. 1-3. For Mod. 2, two types of simulation results (*POT_STO* and *WL_STO*) were considered. For Mod. 3, the explanatory variable X_i leading to the highest R^2 was retained.

Model		R^2	RMSE (kg/ha)	b_0	b_1	b_2
(1)	$\hat{Y} = b_0 + b_1 Y_{trend}$	0.55	658	-1356	1.1851	-
(2^a)	$\hat{Y} = b_0 + b_1 Y_{trend} + b_2 POT\_STO$	0.55	659	-1711	1.1812	0.0407
(2b)	$\hat{Y} = b_0 + b_1 Y_{trend} + b_2 WL\_STO$	0.57	643	-62	1.2300	-0.1809
(3)	$\hat{Y} = b_0 + b_1 Y_{trend} + b_2 ET0_2$	0.69	550	1508	1.0822	-24.1436

From Table 4, it is clear that the crop growth simulation results do not contribute in a significant way to the explanation of the variance of the NIS data. An unsophisticated model, consisting of the trend plus a climatic variable (Model 3), fits the data best.

Conclusions

The crop growth simulation results of B-CGMS may not account for the variation of the regional winter wheat yield per hectare over the last decade in Belgium. A similar conclusion was reached by Supit (1999) at the European level. This is also consistent with Landau *et al.* (1998), who warned against using such a simulation model as CERES for decision support in the UK. For winter wheat in Belgium, a simple model, based on a trend function and a temperature-dependent variable aggregated over the Dec. 1 – March 31 period, performs best.

References

Landau S., Mitchell R. A. C., Barnett V., Colls J. J. , Craignon J., Moore K. L. , Payne R. W., 1998. Testing winter wheat simulation model's predictions against observed UK yields, *Agricultural and Forest Meteorology 89 pp. 85-99.*

Supit I., 1999. An exploratory study to improve predictive capacity of the Crop Growth Monitoring System as applied by the European Commission, Treemail Publishers, 180 p.

Tychon B., Buffet D., Dehem D., Eerens H., Oger R., Verheijen Y., Veroustraete F., Wouters K., 2000. Adaptation of the European Crop Growth Monitoring System to the Belgian conditions, Fondation Universitaire Luxembourgeoise, 15 p. (available on http://b-cgms.cragx.fgov.be).

ARE WE MANAGING CORRECTLY THE CANOPY OF OUR OLIVE TREES?

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Introduction

The use of physical and physiological based models to predict the functioning of whole canopies is of major importance to improve production in agricultural systems. The model used in the present work is based on (a) a robust model of stomatal conductance and photosynthesis for olive leaves, and (b) a detailed model of radiation interception especially designed for trees in orchards. The model estimates the spatial and temporal distribution of the micrometeorological variables driving the gas exchange in the canopy. The intracanopy distribution of both short and long wave radiation, and the wind speed and surface temperature of the canopy are influenced by crown characteristics such as its dimensions and the distribution of leaf area density. This, in turn, affects the energy balance and the CO_2 assimilation rate of the tree. These characteristics depend on pruning practices and plant density. The aim of this work was to elucidate, with the help of a model, the effect on the olive tree transpiration and photosynthesis of (a) the increase of the leaf area density, and (b) two different crown shapes.

Methods

The experiments were carried out at the experimental farm of the *Instituto de Recursos Naturales y Agrobiología* at Coria del Río near Seville in Spain (37° 17′ N, 6° 3′ W, elevation 30 m). Weather variables were measured with an automatic weather station located near to the experimental tree. Soil water content was measured with a neutron probe calibrated for the experimental soil, and leaf water status was estimated from measurements of leaf water potential and leaf water content. Seventy 2-year-old olive trees grown in pots were used to calculate the parameters related to Jarvis and Leuning's stomatal conductance models and Farquhar's photosynthesis model. We used the RATP model (Sinoquet *et al.*, 2000) for simulating the spatial distribution of transpiration and photosynthesis within complex canopies. Briefly, the model uses a 3D representation of the canopy as an array of 3D cells, each one characterised by its leaf area density (*LAD*). The canopy is treated as a turbid medium where direct and diffuse radiation are considered as directional. In 1999, the spatial distribution of 3D cells in a 31-year-old olive tree was determined by the point quadrats method. The distribution of leaf area density was kept constant when simulating the crown geometry, while the distribution of the foliage was changed to compare a truncate sphere with a crown of cylindrical shape with a central gap.

Results and discussion

Due to the high degree of coupling between isolated trees and the atmosphere, enhanced in the case of the olive tree because of the small leaf size, the correct characterization of the response of stomata to the environment is critical for modeling leaf gas exchange. For this species most of the transpiration is driven by the vapor pressure deficit (*VPD*), responsible for up to 80% of the variation in transpiration (Moreno *et al.*,1996).

After analysing the response of stomatal conductance to *VPD* under controlled conditions, we found a similar sensitivity of stomata to *VPD* in leaves of trees under different water treatments. The only difference between treatments was the value of maximum conductance, which was found to be highly correlated with the total available water in the soil. The response of stomata to *PAR* showed that this variable takes a secondary role in determining transpiration of the olive tree in our climate.

Consequently, transpiration (E_p) should not be markedly affected by an increase in the shaded area due to an increase in leaf area (*AF*) density. Photosynthesis (*A*), however, will be seriously reduced, as well as water use efficiency (*WUE*). This agrees with the model outputs (Fig.1)

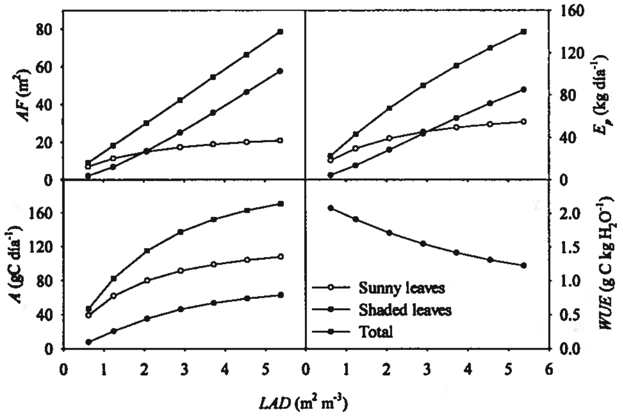
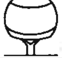


Fig. 1. Effect of leaf area density on tree gas exchange

Apart from the leaf area density, the shape of the crown has a significant influence on the fraction of sunny and shaded leaf area. In Table 1, the model outputs for two types of crowns are compared. The main difference between the two considered crowns is the existence of a central gap in crown F1, while crown F2 is spherical. The leaf area density and total leaf area have been kept identical. The predicted *PAR* interception efficiency was higher in crown F2 than in F1. However, the radiation use efficiency was higher in F1 than in F2, as well as the *WUE*, as a consequence of the greater sunny leaf area. This simulation exercise shows to what extent CO_2 assimilation and *WUE* of an olive tree can be improved by modifying its crown structure.

Table 1. Model outputs for two types of crowns.

	Fraction leaf area		Transpiration		Photosynthesis		PAR interception efficiency	WUE
	Sunny	Shaded	Sunny	Shaded	Sunny	Shaded		
 **F1**	0.42	0.58	30.6	32.05	60.9	38.6	0.22	1.6
 **F2**	0.33	0.67	25.3	34.09	50.0	33.4	0.28	1.4

References

Moreno F *et al.*, 1997. Plant and Soil, 184: 85-96.
Sinoquet *et al.*, 2000. Plant, Cell and Environ, 24: 395-406.

(Work funded by the CICYT of the Spanish Ministry of Education and Science)

USE OF IR THERMOGRAPHY FOR ASSESSING THE CANOPY EXCHANGE PROCESSES IN SUNFLOWERS

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Introduction

During the last two decades, infrared thermography has been successfully used to infer surface temperatures and to provide information on canopy water status. Both canopy transpiration and canopy stomatal conductance can be derived from infrared measurements, but most methods require simultaneous acquisition of environmental variables such as absorbed radiation, air temperature & humidity, and wind speed at the canopy level. Jones (1999), using a simple reformulation of the leaf energy balance involving temperature measurements on reference surfaces of known conductance to water vapour, was able to bypass the need for estimation of intra-canopy environmental variables. The aim of the present work is to validate the use of this technique to predict canopy transpiration and photosynthesis in sunflowers.

Methods

Measurements were made on dwarf sunflowers (*Helianthus annuus* L. cv. Teddy Bear). Plants were grown in a greenhouse in Reading (UK), using a photoperiod of 14 h with supplementary lighting. Temperature was kept at 23 °C ± 2.5 °C. At the time of measurement the plants were two months old and they had started flowering. Simultaneous measurements of surface temperatures of leaves (T_{leaf}) and reference surfaces were obtained with a portable infrared camera (IR Snapshot® model 525, ISI Inc, USA). As the references surface (see Jones, 1999) we used polyethylene-backed absorbent paper, either on its own (for the wet and dry reference, with surface temperatures T_{wet} and T_{dry}) or with the paper side covered with a microporous membrane (to represent the conductance reference surface, with a temperature T_{ref}). The membrane selected was Opsite (Surgical dressings, Smith & Nephew Ltd.) as suggested by Jones (1999). The following formula was used to calculate leaf stomatal conductance, g_s:

$$g_s = G\ \{(T_{dry} - T_{leaf}) / (T_{leaf} - T_{wet})\} \qquad (1)$$

where G is a term that depends only on the resistance of heat and water loss through the leaf boundary layer (see Jones, 1999). G was calculated from

$$G = g_{ref}\ \{(T_{ref} - T_{wet}) / (T_{dry} - T_{ref})\} \qquad (2)$$

where g_{ref} is the conductance of the Opsite. Air temperature and humidity were recorded, as well as the incoming and outgoing shortwave and longwave radiation using a Kipp and Zonen 4-component radiometer. Stomatal conductance and photosynthesis (A) of the leaves were measured with a portable photosynthesis system (LI-6400, LiCor Inc., Lincoln NE, USA) at three different canopy levels. The environmental variables were measured every 10 minutes. Scales (accurate to 0.1 g) monitored the evolution of plant transpiration (E_p); soil evaporation was assumed to be zero as the soil was covered with cling film. Estimated values of E_p were obtained using the Penman-Monteith equation, with estimates of g_s as obtained from Eq. 1. Measured leaf area was used to scale up from leaf to plant transpiration. The specific parameters for the Farquhar (Farquhar *et al.*, 1980) model of photosynthesis were calculated for this sunflower variety. This model was driven using the estimated leaf surface temperatures and g_s, as provided by the IR camera and Eq. 1.

Results

During the experiment the lights of the greenhouse were switched off at 11:30 and 15:30, and switched on at 13:00 to stimulate a dynamic response of g_s and A. Most of the incoming radiation was longwave (up to 80%) and shortwave radiation reached maximum values of only 64 Wm^{-2}. Air humidity fluctuated between 30-40%. Fig. 1a shows the evolution of the five surface temperatures from which g_s, shown in Fig. 1b as the continuous line with black squares, was estimated.

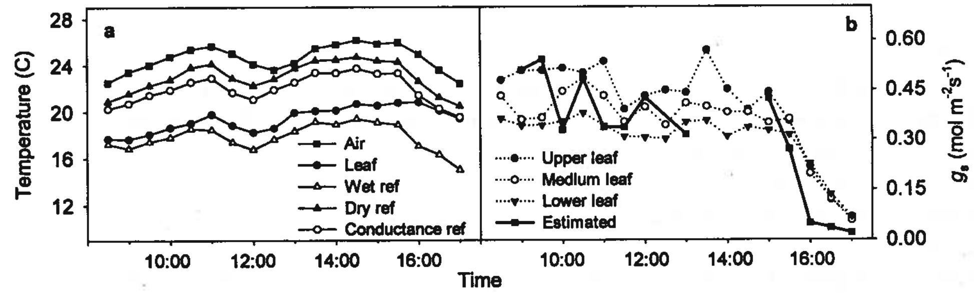

Fig 2. a. Diurnal courseof surface temperatures, as measured with the IR camera, for a leaf at medium canopy level and references surfaces; b. Diurnal course of stomatal conductance as estimated from Eq.1 and as measured with the IRGA at three canopy levels.

Figure 2 represents the evolution of E_p and A. The low values of A are a consequence of the low PAR levels during the experiment. The combination of high g_s values (mainly caused by a high incoming longwave radiation load) and low values of A could cause inaccuracies when using A-g_s based models under these radiative conditions.

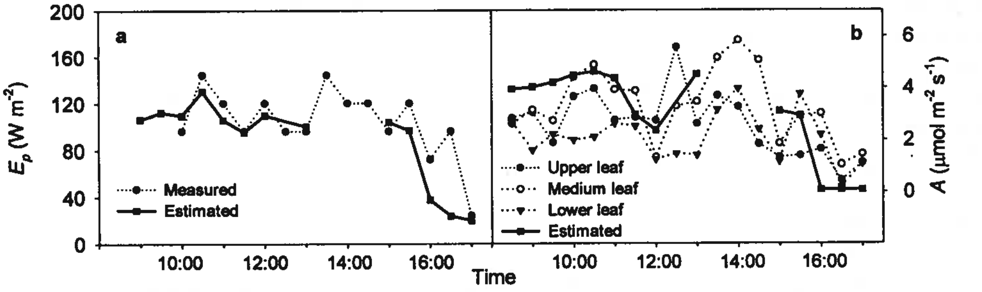

Fig. 2. a. Measured and estimated values of whole-plant transpiration; b. Measured (at 3 canopy levels using the IRGA) and estimated values of photosynthesis.

Discussion

This preliminary analysis shows that the described method seems to be suitable for remote estimation of spatial and temporal variation of canopy stomatal conductance and photosynthesis (if photosynthesis model parameters are available). The disadvantages of the approach are related to the high sensitivity of leaf temperature to stomatal conductance. This means that the method is very sensitive to small errors in the estimated surface temperatures.

References

Farquhar *et al*., 1980. Planta, 149, 78-90.

Jones, H.G., 1999. Plant, Cell & Environment 22, 1043-1055.

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SIMULATING KERNEL LOT SAMPLING: ESTIMATING THE EFFECT OF HETEROGENEITY ON THE DETECTION OF GMO CONTAMINATIONS

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Several guidelines defining kernel sampling strategies for quality and purity analyses are available from both standards authorities and national organisations. EU Member States have provisionally adopted such guidelines for the detection of genetically modified (GM) contamination in kernel lots (Kay, 2001). All these approaches include three important assumptions:

- Statistically, the sampling procedure is considered as a single operational step, even though it may comprise a series of individual, independent actions;
- No consideration is made for the statistical implications of the typical clustered sampling of kernels (increments) applied in practice to the lot;
- The binomial distribution is used to calculate the precision of the estimate (Remund et al., 2001). This assumes that the target material is randomly distributed in the lot and that each sampling unit (i.e., individual kernels) has an equal probability of being selected during the sampling process (but see Kruse and Steiner,1995 for discussion on kernel lot heterogeneity).

By contrast, we contend that these three assumptions present a major case for review. The objective of this paper is to explore the criteria to be followed when choosing sampling procedures for the detection of low levels of kernel traits, such as GM material, in large grain or seed lots. Specifically, we address the problem of non-random distribution by investigating the effectiveness of different sampling strategies without the constraints implicit in the assumption of uniform (random) distribution of impurities.

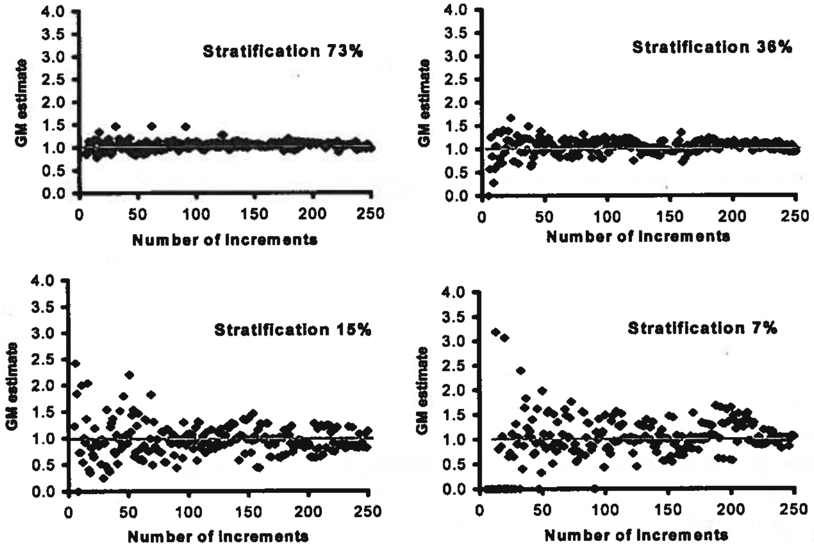
Materials and Methods

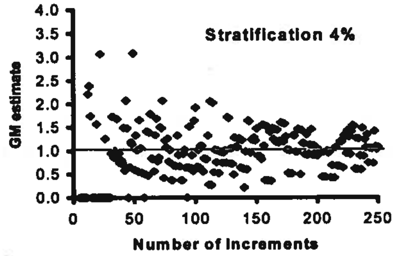
The methodology used in this paper is based on a two-step modelling procedure: first, the kernel lot, from now on named "population" is created and, second the population is sampled. Creating populations permits the evaluation of different degrees of stratification of impurities (i.e. lot heterogeneity), as opposed to full random distribution of single GM kernels. This allows assessing different sampling strategies as a function of specific combinations of population characteristics and sampling parameters. In order to test various population structures and different sampling strategies, we developed a prototype program – *KeSTE*, Kernel Sampling Technique Evaluation. Results presented in this paper are derived from this experimental tool. The populations to be sampled are created through the definition of three parameters: the total number of kernels, the percentage of GM kernels, and the level of stratification of GM kernels (this is a measure of the degree of spatial aggregation of GM kernels. In *KeSTE* the stratification level can range from 100% --uniformity: all N units contain GM kernels, to 1/N% --maximum heterogeneity: all GM kernels are located in a single unit). The data shown refer to populations of 10^7 kernels, 1% GM contamination, and 5 levels of stratification. In order to visualize the population and to impose different degrees of non-random distribution of GM impurities in the lot, we used a cube analogue to spatially define every population.

Results

The simulation of 5 levels of stratification on both the contamination level and the variability of the estimates are shown in fig. 1. Even modest levels of stratification indicate that a large number of increments is needed to correctly estimate the known level of GMO contamination (1% in the data shown). Moreover, false-negatives (GM estimate = 0) become evident.

Figure 1: GM impurity estimates based on different numbers of increments, for 5 levels of stratification. GM impurity level = 1%.





Conclusions

The analysis run allowed an initial screening of sampling techniques in the case of non-uniform distribution of impurities in kernel lots. The simulation results show that current sampling techniques are sensitive to non-uniform distribution of impurities, resulting in high probability of the wrong estimates of impurity levels and the high likelihood of false-negative results. While the simulation of non-uniform distributions can be extended to deal with more complex scenarios of GM impurity (multiple sources, different strata densities, within-stratum GM kernel distribution modelling), these exploratory results issue a clear warning with respect to the unconditional acceptance of standardized sampling procedures in absence of the knowledge of GM material distribution in kernel lots.

References

Kay, S. 2001. European Commission Report, Code EX21167/A, JRC Publications Office
Kruse, M. and Steiner, A.M. 1995. ISTA 24th Cong. Copenhagen, Seed Symposium, Abstract 21
Remund, K. et al.. 2001. Seed Science Research, 11:101-120.

A METHOD TO QUANTIFY TIME MISMATCH OF MODEL ESTIMATES

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Introduction

The evaluation of simulation models is a crucial step in the complex task of model development. Currently available methodology to evaluate model performance does not explore adequately some areas of the dynamical modelling of processes. For example, when simulating energy transfer or mass transformation, a time delay/anticipation frequently occurs if estimated versus measured values are compared. In this case, peak synchronization between estimates and measurements most often will not occur. Consequently, if standard indices based on the synchronous comparison between estimates and measurements are used, models which produce no response with respect to a specific process can yield better index values, compared to models which show a time mismatch in the response. Poor parameterization may produce a time shift of estimates when simulating a process. In such cases, large residuals easily result from few points that may lead one to discount the model especially if an automatic optimization procedure is used. This research is focused on contributing to the development of a suitable methodology to integrate available tools for simulation model evaluation.

Methods

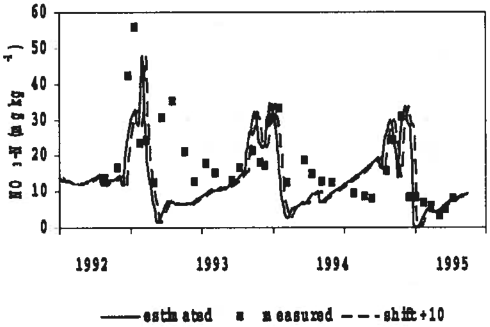
Indices A common index for the quantification of model adequacy is the root mean squared error (RMSE), which ranges from zero (good model) to positive infinitive. A novel index (Donatelli et al., 2002) applied to dynamic models is the pattern index (PI). In this case we used the PI_4 (the 4-group pattern index) versus time, which varies from zero (good model) to positive infinitive. RMSE and PI address different evaluation criteria: RMSE is sensitive to extreme values, whereas PI highlights bias in model residuals versus the independent variable chosen (time in this case). When used together via an aggregated index, the two indices allow optimizing the amount of the model deviation and the presence of systematic bias versus time. Hence, we aggregated both RMSE and PI_4 in one integrated index, i.e. TMI (time mismatch index), according to the fuzzy-based procedure by Bellocchi et al. (2002). TMI ranges from zero (best) to one (worst).
Identification of time mismatch. The procedure starts from an observed model performance as initial condition, then
1) relative weights are attributed to RMSE and PI_4, as required for the computation of TMI according to fuzzy-based procedure (we propose larger weight is attributed to RMSE - i.e. 0.8 - than PI_4 - i.e. 0.2);
2) bounds are set to define the favorable and unfavorable values for RMSE and PI_4, based on the users' expert knowledge; the range of time shift to be investigated (which includes the actual matching in time of estimated and measured data) is bounded;
the simulated points are moved backward in time to the maximum anticipation chosen to evaluate the time mismatch;
4) RMSE, PI_4 and TMI are computed;
5) the simulated points are moved of one selected time step forward;
6) points 4 to 5 are reiterated until the maximum allowed time delayed is reached.
Application. The type of output attainable from this methology was illustrated by using multi-year (1992-1995) simulations of soil NO_3-N (at 0-1 m depth) and NH_4-N (at 0-0.5 m depth) performed in the Po Valley, Italy (Grignani et al., 1996) with the model LEACHN (Hutson et al., 1992). Both RMSE and PI_4 were bounded within 2 (favourable) and 12 (unfavourable). A time interval of 100 days (50 days forward and 50 days backward) was explored by shifting 1 day at a time.

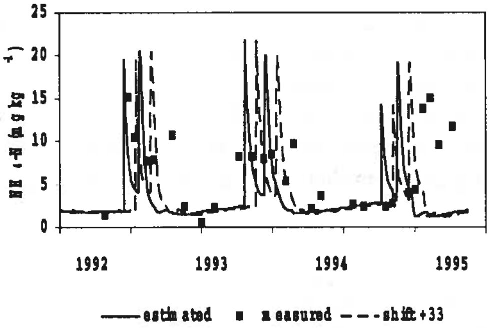
Results

The time mismatch, as identified either by RMSE, PI_4, or TMI for both simulations, is reported in the following table. The index values for no time shift are also reported. Bordered cells indicate the minimum value of each index, and the corresponding time shift.

NO_3-N				NH_4-N			
time shift	RMSE	PI_4	TMI	time shift	RMSE	PI_4	TMI
0	10.8	11.0	0.96	0	5.7	5.2	0.33
+3	10.6	9.8	0.92	+5	5.6	5.5	0.33
+10	11.8	5.7	0.85	+50	6.6	2.0	0.34
				+33	6.0	3.4	0.28

The graphs below represent the time mismatch over the multi-year time course, as identified by TMI for both simulations.





Conclusions

This work is meant to provide an initial approach to develop a technique for making comparisons among time series. The application examples illustrated here represent common scenarios that may happen. A mismatch was observed in both the time histories investigated (more consistent with NH_4-N), according to either validation index computed. Therefore, clues for further model refinement emerged from this application. Provisions for the computation of integrated indices are implemented in the dynamic link library IRENE_DLL (Fila et al., 2002), freely downloadable from the site http://www.isci.it/tools. The installation package includes an example of how use the DLL for calculating time mismatch within a Microsoft Excel spreadsheet. On-going work is addressing: 1) the unevenness in the distribution of mismatch across time, and 2) the drift effect of state variables in long-term time series.

References

Bellocchi G. et al., 2002. Agronomy Journal. (submitted)
Donatelli M. et al., 2002. Agronomy Journal. (submitted)
Fila G. et al., 2002. These proceedings.
Fox D.G., 1981. Bulletin American Meteorological Society 62:599-609.
Grignani C. et al., 1996. Rivista di Agronomia 3 suppl., 339-349.
Hutson J.L. et al., 1992. Version 3. Department of Agronomy, Cornell University, Ithaca, NY.

Acknowledgements Project SIPEAA (http://www.sipeaa.it), paper no. 6.

INTEGRATED PROCEDURES FOR EVALUATING TECHNICAL, ENVIRONMENTAL AND ECONOMICAL ASPECTS IN FARMS: THE SIPEAA PROJECT

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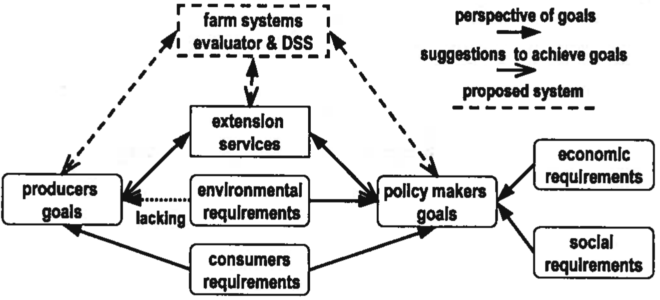
Introduction

The often contrasting and evolving goals between producers and policy makers to satisfy consumer, ecological, economic and social requirements that have increased in recent history, require the evaluation of agricultural systems with an equally adaptable perspective. Producers have long term intimate knowledge about the effect of production factors on yield in their environment, but often lack knowledge about the ecological effects of their systems. Farmers may have mastery of the management options in order to achieve both yield stability and profitability in slow changing systems, but often lack information needed to adapt to fast changing regulations and/or environmental conditions. From the policy makers' perspective, the wide variability of environments, agricultural practices, economic and social constraints have frequently demonstrated that there is no unique package of solutions to achieve the expectation of both producers and consumers. Policy makers would benefit by tools designed to evaluate a broad range of complex scenarios to produce regulations that would define the parameters for production techniques that would effectively satisfy the requirements of their constituency. In many situations, extension services are ready to provide assistance on specific aspects of crop management, but they are not properly equipped to help producers adjust their agricultural systems to accommodate the at times substantial changes needed to cope with new regulations. In recent decades significant advances have been made in the development of computer based tools and particularly computer simulation models for application to agricultural systems (Stöckle, 1999) and may provide an effective way to bring the agricultural policy and production goal perspectives into resolution. Both interdisciplinary integration and the subsequent development of operational tools have several challenges for further progress. Integrating well documented models which refer to different domains of the farming system would provide an approach to evaluate agriculture management strategies accounting for the wide variety of goals and constraints in many countries.

The project SIPEAA

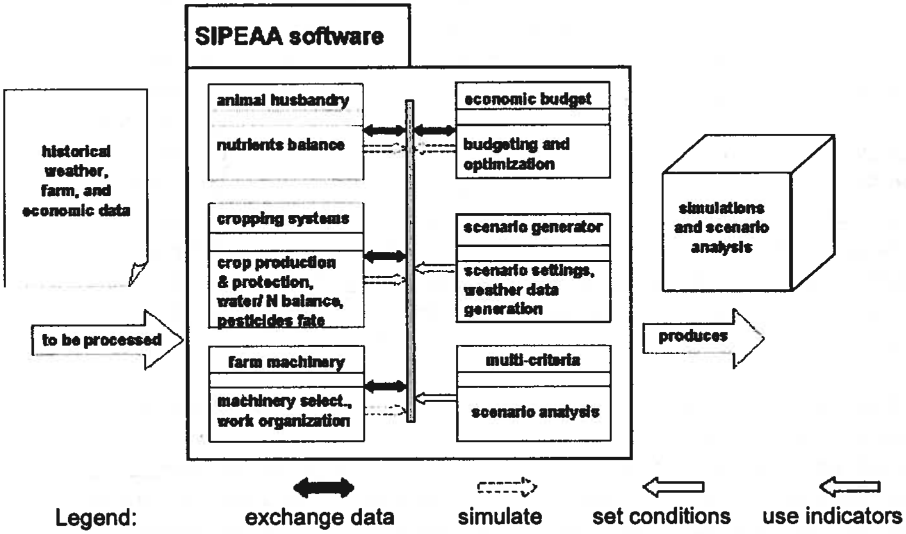
The first term (2002-2004) of the SIPEAA project (Software Tools for Eco-compatible Farm Planning) has commenced. Supported by the Italian Ministry of Agricultural and Forestry Policies (MiPAF), this project aims to quantify and integrate the major components (i.e. technical, economical, environmental) that influence the decision process in overall farm design. The principle goals are: 1) to provide extension services with tools for integrated analysis to help farmers adhere to environmental regulation, 2) to increase the understanding of the and .4) to impact associated with alternative management ensuring sound environmental policy, 3) to identify solutions adaptive to changing conditions that optimize farmers' income while minimizing environmental impacts, and 4) to create an integrated decision support database for policy and regulation enactment at regional or national levels. The ultimate objective is very ambitious, and exceeds the feasibility of the restricted time frame



of the first term of the project, thus the effort in the preliminary phase will then be devoted to the development of a decision support system to be used at farm level.
The following research units are involved in the project:

- Research Institute for Industrial Crops (ISCI), Bologna (leading unit)
- Italian Sugar Beet Growers Association (ANB), Bologna
- Research Institute for Animal Production (ISZ), Cremona
- Dep. of Electronics, Computer Science and System Analysis (DEIS), Bologna
- Dep. for Promotion of Food Resources (DIPROVAL) , Bologna
- Institute of Agricultural Engineering (IIA), Milan
- Dep. of Crop Science (DIPROVE), Milan
- Institute of Agricultural and Environmental Chemistry (ICAA), Piacenza
- Dep.of Crop Science and Agricultural Technology (DPVTA), Udine

The following figure shows the major components of the software to be developed:



The methodological aspects related to model modularity and reusability in this project would benefit of a research activity in the area of model development which will be proposed within the EU 6th research Framework Programme (Van Ittersum, 2002). The technical framework for allowing modular model development will be devised, followed by model selection and implementation. Currently, use cases are being developed and the requisite analysis is being performed. Seven farms of various size and organization will be the case studies used during the preliminary phase of software design. Data will be collected and prepared for use to test the tools being developed. The research units involved are interested in establishing a cooperative effort with other groups working on the development of an integrated farm level decision support system (please contact: agronomy@isci.it).

References

Stöckle C.O., 1999. Proc. 1st Inter. Symp.Modelling Cropping Systems, Lleida, Spain, 19-24.
Van Ittersum et al., 2002. Proc. of the 7th ESA Congress. This volume

Acknowledgements SIPEAA project (http://www.sipeaa.it), paper no. 1.

AN ALTERNATIVE TO THE LOGISTIC EQUATIONS FOR SIMULATING SHOOT ELONGATION.

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Introduction

Growth modelling is a prerequisite for understanding the response of crop functioning to the environment. A widely used equation to simulate growth is the logistic equation, which has only three parameters and allows for the simulation of typical sigmoid growth curves. However, the relative growth rate concept has limitations when applied to the volume growth of an organ, because its growing part is not spread within the whole organ but is localised in growth zones. Also, cell division and cell expansion both respond to environment in different ways, with consequences which cannot be analysed using the logistic equation. As a consequence, lasting effects of environmental conditions on morphogenesis are difficult to simulate using the logistic equation. Gandar (1995) proposed a more flexible model of growth to simulate the lasting effects of temperature on early phases of apple fruits' expansion. This approach was successfully applied to the analysis of the response to temperature of the elongation of a grass leaf (Durand *et al.* 1999). Indeterminate organs exhibit a different dynamics. We present here a similar approach to simulate such a situation, the Lucerne stem elongation in response to temperature.

Methods

Growth results from the production of new cells in the division zone (DZ), their expansion and accumulation in the mature zone. The system considered here is made of the different morphologically active compartments of the stem *i.e.*, DZ where cells expand and divide, the expansion-only zone (EOZ), where cells only expand but do not further divide, and the mature zone (M) where they keep a constant length. The length only will be considered here. Lucerne stems, like in most dicots, are built from a series of intercalary meristems, which function simultaneously. In that case, the different stems' compartments represent the sum of all compartments distributed between the different internodes. The rate at which each of the compartments change is described by the following equations:

$$\begin{cases} \dfrac{dD_Z}{dt} = k_1(1 - at - a_0)D_Z \\ \dfrac{dE_{OZ}}{dt} = k_1(at + a_0)D_Z + k_2(1 - bt - b_0)E_{OZ} \\ \dfrac{dM}{dt} = k_2(bt + b_0)E_{OZ} \end{cases}$$

where D_Z is the length of DZ, E_{OZ} is the length of EOZ, a, a_0, b, b_0, k_1, k_2 are parameters , and t is the thermal time. Minimum and optimal temperature are fixed to 5 and 20°C, respectively.The growth curve is then entirely determined when the initial conditions are set, defining D_Z, E_{OZ}, and M at $t=t_0$. The initial conditions are those when measurements start. The system has a semi-analytical solution. However, the solution including integrals of gaussian functions, it is here integrated numerically.

The maximum length of the organ depends on the initial length of the division zone by contrast to the logistic equation where, only the rate at which the final length is reached is determined by initial length.

An experiment was made for analysing the response of the elongation of lucerne stems to temperature. Seeds of Lucerne (*cv Mercedes)* were sown in 1 litre pots filled with sand and soil. Plants were grown from seeds in two phytotron at 10 and 20 °C under 500 +/- 50 µmol m^{-2} PPFD, 80 % RH. Plants were cut once to 5 cm stubble height and measurements lengths started at the day of cut. The experiment was repeated twice. During the second experiment, in the 10 °C phytotron, the temperature was raised up to 20 °C at 54 days after cutting.
Indeterminate growth was simulated setting up of a growth zone, which would further continue functioning conservatively. To do this, the parameters b_0 and b were fixed to 1 and 0, respectively. Initial conditions were fixed by the initial bud length at t=0. The parameters were adjusted on the 10 °C first experiment data and applied to the other data.

Results

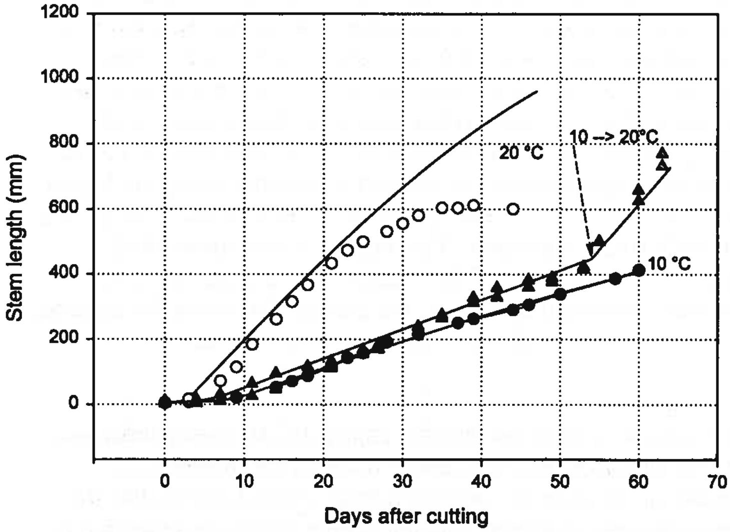

Figure 1. Data (dots) and simulation (lines) of stem length in lucerne grown at controlled temperature. Each point is the mean of 5 plants at least .

Following a phase of increasing elongation rate, the stems elongated almost linearly. At 20 °C, the stems reached the ceiling of the phytotron and their elongation rate declined. At 10°C, following an initial phase of slow elongation, the rate remained almost linear.
The computed maximum length of the growth zone simulated was 30 mm, which was probably too short. The length of the simulated division zone went from a maximum of 5 down to 3 mm.
Using these parameters, adjusted only on first experiment at 10 °C, the transition from 10 to 20 °C was simulated properly by the model (Fig 1). The initial growth of plants at 20°C was also well simulated. However, the gradual decline in elongation rate at 20°C was not simulated. It was likely linked to the canopy expansion in the growth chamber, inducing a strong competition for light between plants not taken into account by the model.

Conclusion

The Gandar equations offers a valuable alternative for simulating plant growth. Measurements of the length of the elongation zone will be required for a complete validation of the model with indeterminate plant organs.

Margarita Ruiz-Ramos had a grant from the Spanish Ministerio de Ciencia y Tecnología

Gandar P, Hall AJ, de Silva HN,1996. In Habib R and Blaise P *eds. Proceedings of the 4^TH^ International Symposium on Computer Modelling in Fruit Research, 103-112.*
Durand JL, Schäufele R, Gastal, F, 1999. Annals of Botany 83; 577-588.

VALIDATION OF "PROCULTURE" MODEL TO PREDICT *SEPTORIA TRITICI* DEVELOPMENT ON WINTER WHEAT IN THE GRAND-DUCHÉ OF LUXEMBOURG IN 2001.

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Introduction

One of the most serious foliar diseases on winter wheat in the G-D of Luxembourg which farmers need to take into account when deciding upon fungicide application during stem elongation is septoria leaf blight caused by *Septoria tritici* Roberge in Desmaz (anamorph of *Mycosphaerella graminicola*) (El Jarroudi *et al.*, 2001).

The disease can result in severe crop damage during summer, leading to substantial yield losses (Hunter *et al.*, 1999). Management of *S. tritici* aims at keeping the top three leaves of the cereal free from infection, as these leaves make the main contribution to grain yield (Shaw & Royle, 1989).

The objective of this work is to validate in G-D of Luxembourg the decision-support for *S. tritici* control "Proculture" developed for Belgium at the Unit of Phytopathology, UCL (Moreau & Maraite, 1999 and 2000). Phenoloy in winter wheat and *S. tritici* development were monitored on the upper leaves in 2001 in trials set up at Everlange and Reuland, in the G-D of Luxembourg.

Material and Methods

The "Proculture" model simultaneously assesses the development of each of the last five leaf layers of the crop and the availability of inoculum on or close to those leaves based on weather conditions favoring infection by *M. graminicola.* The software runs with hourly meteorological data of relative humidity (RH), air temperature and rainfall (fig. 1). In addition to weather data, crop sowing dates and crop phenological stages are necessary to run the model. The combination of the disease module with the phenological module allows the simulation of the diseases development in the canopy (Moreau & Maraite, 2000). The simulation model can be used to predict primary and secondary infection expressed or in incubation if correct information on leaf emergence is provided. The criteria used to determine favorable conditions to infection by the pathogen, the latent period and inoculum dispersion in the canopy, have been described in detail (El Jarroudi *et al.,* 2001).

The progression of the disease is evaluated in a dynamic way. Such monitoring is impossible through regular observations. Therefore, information on the infection status is simulated before symptoms appear, quite on time for en efficient control of the disease by fungicide supplies.

Results

In Everlange during 2001, the emergence of leaf F3 (flag leaf is F1) began around 21 April. This day, the symptoms were already observed on F5. The first symptoms on F4 were observed the 7th of May and on F3, the 14th of May. Thus F3 was infected most probably by the inoculum produced on F5 at the end of April. Leaf F2 was infected at the beginning of its emergence by F4 during the first 10 days of May. Some F1 were infected during their emergence by F3 around the14th of May.

In Reuland, in 2001, leaves F5 and F4 were infected during their emergence. Inoculum had already been produced on F5 when F3 was emerging (26 April) leading to early infection of this leaf level the 27th of April. F2 was infected most probably by F3 and to a lesser extend by F4.

The first symptoms on F1 were detected the 25th of June. The flag leaf was infected by F2.
Good agreement was observed in 2001 between model data output and field observations of the disease (table 1).

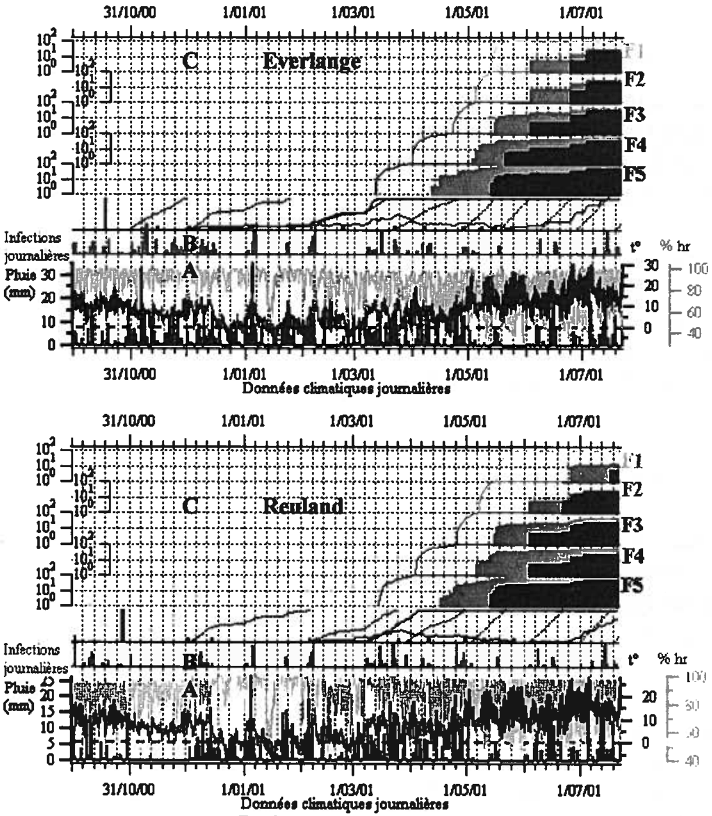

Figure 1 :

Output of the *Septoria* risk simulation model for year 2001 in winter wheat fields at Everlange and Reuland.

A : daily values of air mean temperature (°C) and rainfall (mm) measured at Everlange and Reuland.
B : number of hours per day of high probability of infection at Everlange and Reuland.
C : lines : leaf area development (0-100 %) of leaves F5 to F1.

Table 1 :
Agreement (%) between forecasted and observed leaf blotch development

	a Everlange						*b* Reuland					
Period / leaves	F5	F4	F3	F2	F1	Total	F5	F4	F3	F2	F1	Total
Forecasted and expressed	16	10	7	6	6	45	16	11	8	7	5	47
Forecasted not expressed	1	3	2	0	0	6	1	1	2	0	1	5
Expressed not forecasted	0	0	0	0	1	1	0	0	0	0	0	0
% accurate forecasting	94	77	78	100	86	87	94	92	80	100	83	90

Discussion and conclusion

A validation process on the “Proculture” model in the G-D of Luxembourg was performed during 2000 and 2001. The peculiarity of the simulation model is its ability to analyze interactions between winter wheat development and progression of *M. graminicola* on the already developed wheat leaves, to simulate disease progression in the crop and to allow users to experiment the model through a web interface with their own input data in order to get advice on individual fields. This decision making tool helps to find the optimum time of fungicide spray in fields i.e. when high risk of early F3 infection occur. Fungicide application before GS-32-37 stages (Zadocks *et al.*, 1974) would have provided efficient protection of the upper leaves (F2 and F1). The model will be in validation in several experimental plots in the G-D of Luxembourg for three years.

References

El Jarroudi M., Tychon B., Maraite H. Florence ESA 2001. 63-64.
Hunter T., Coker R.R., Royle D.G. 1999. Plant Pathology. 48 : 51-57.
Moreau J-M., Maraite H. 2000. Bulletin OEPP/EPPO. Bulletin 30 : 161-163.
Moreau J-M., Maraite H. 1999. Aspects of Applied Biology. 55 : 1-6.
Shaw M.W., Royle D.G. 1989. Annals of Applied Biology. 115 : 425-442.
Zadocks J.C., Chang T.T, Konzak C.F. 1974. Weed Research 14 : 415-421.

PREDICTING POTENTIAL DISTRIBUTION OF KARNAL BUNT (*TILLETIA INDICA*) OF WHEAT

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Introduction

Tilletia indica the cause of Karnal bunt of wheat threatens wheat quality, yield and exports. It has been listed as a quarantine pest in several countries world wide including the EU. World Trade Organisation rules require quarantine regulations to be justified by Pest Risk Analysis (PRA). Available models used in these PRAs are based on an approach in which Karnal bunt incidence is calculated depending on climatic factors at a time when wheat is particularly vulnerable to Karnal bunt infection (Jhorar et al., 1992). However, crop development varies depending on seasonal climate, variety and sowing date, which might affect predictions of Karnal bunt distribution. The work described here is part of a larger project (Karnal bunt risks) in which a PRA is performed for *Tilletia indica* on bread and durum wheat across Europe. In the present study we combine a Karnal bunt forecasting model with a wheat phenology model to predict the potential distribution of Karnal bunt on bread wheat in the UK. We use historical weather data recorded at different locations across the UK. We assess the effects of sowing date and variety on predictions of Karnal bunt distribution.

Materials and methods

We use a biometeorological model (Jhorar et al., 1992) which has been applied in several PRAs on wheat (e.g. Murray and Brennan, 1998; Sansford, 1998). Briefly, the model uses a linear relationship between Karnal bunt incidence and the Humid Thermal Index (HTI) calculated from the ratio of afternoon relative humidity and maximum temperature over a period of three weeks at the time of ear emergence. HTIs between 2.2 and 3.3. are particularly favourable for the disease. Wheat phenology was simulated using thermal time totals between stages (Weir et al., 1984). The model was calibrated for bread wheat varieties grown in the UK representing early, mid and late maturity classes and validated with data presented by Kirby et al. (1999). We used twenty years (1970-1990) of daily weather data from 57 stations in England and Wales to simulate phenological development and HTIs for the period between flag leaf emergence and anthesis. Simulations were performed for early, mid and late varieties and for three sowing dates (1 September, 1 October, 1 December).

Results and Discussion

Simulations indicate that dates of flag leaf emergence and anthesis were delayed by up to one month due to late sowing and for late varieties (Table 1). Simulated development stages also varied depending on year and location. The time range of stage occurrence was particularly high for late sowing dates and late varieties (Table 1) which was mainly due to high variation in early development (sowing to double ridge) simulated for these treatments (not shown). Simulations of HTIs suggest that there was a high risk for Karnal bunt in about 50 percent of all seasons with only small differences among sowing dates and varieties (Table 1). This is consistent with calculations of HTI with no direct link to phenological development, i.e. for a fixed period of three weeks in June (not shown). Further analysis indicated that consideration of phenological development in the calculation of HTI had some impact on predicted spatial and temporal distribution of Karnal bunt (not shown). We conclude that consideration of variation in phenological development of wheat for predicting Karnal bunt distribution allows more accurate determination of areas under high risk. An extension of the present analysis for other regions is required together with an analysis to assess the possible impact of errors in weather input data, particularly with respect to relative humidity (Baker et al., 2000). In addition, information about the validity of the HTI approach for European conditions is required.

Table 1. Simulations of flag leaf emergence (DC 37) and anthesis (DC 65) and the risks for Karnal bunt for early (E), mid (M) and late (L) varieties at three sowing dates in England and Wales between 1970-90.

	1 September			1 October			1 December		
	E	M	L	E	M	L	E	M	L
DC 37									
Mean (day of year)	133	142	149	139	148	155	153	160	167
Range (days)	48	43	45	51	51	56	55	65	73
DC 65									
Mean (day of year)	159	165	171	163	170	176	174	180	187
Range (days)	56	61	73	64	77	89	85	105	125
Karnal Bunt (%)[1]	42	48	54	47	53	49	52	53	56

[1] Seasons (percent of all seasons, years x location) with high risk for Karnal bunt (HTI between 2.2 and 3.3)

References

Baker, R.H.A. et al., 2000. *Agriculture, Ecosystems and Environment*, 82, 57-71.

Jhorar, O.P. et al., 1992. *Plant Dis. Rep.*, 7, 204-209.

Kirby, E.J.M. et al., 1999. *Eur. J. Agron.*, 11, 63-82.

Murray, G.M., Brennan, J.P., 1998. *Aust. Plant Pathol.*, 27, 212-225.

Sansford, CE, 1998. In: Malik, VS, Mathre, DE (Eds.), *Bunts and Smuts of Wheat,* NAPPO, Ottawa, pp. 273-302.

Weir, A.H. et al., 1984. *J. Agric. Sci., Camb.*, 102, 371-382.

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MODELLING THE EFFECT OF GENOTYPE ON GENE FLOW BETWEEN RAPESEED VOLUNTEERS AND CROPS

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Introduction

Oilseed rape is among the first crops for which authorisation to grow transgenic varieties was requested. These varieties are herbicide tolerant or have seeds with high contents of fatty acids for industrial uses. The new genes can disperse (a) in time through rapeseed volunteers rising from seeds lost during or after rape harvest; and (b) in space, through pollen and, to a lesser extent, seeds. The apparition of transgenic rape volunteers can be a nuisance. A gene coding for herbicide tolerance would lead to volunteers difficult to eliminate from rape crops or from any other crop where the same herbicide were used. Transgenic volunteers growing in non-transgenic varieties would compromise the quality of the harvests if the transgene coded for a different fatty acid or if the farmer wanted to obtain a "non-GMO" label for his harvest. Because of the spatial and temporal aspects, it is difficult to analyse gene flow and volunteer management solely by field experiments. Consequently, a model (Colbach *et al.*, 2001a, 2001b) was developed to quantify gene dispersal in regional cropping systems. Its aim is to identify cropping systems with high/low gene flow risk and to propose systems limiting this risk. The present work describes the quantification and evaluation of rapeseed genotypic effects on gene flow, in interaction with crop rotation and management.

Presentation of the GENESYS model

The input variables of the first GENESYS model (Colbach *et al.*, 2001a, 2001b) are (a) a field pattern (a few square kilometres), with roads and their borders, that are often colonised by rapeseed; (b) crop rotations for each field; (c) cultivation techniques (stubble breaking, tillage, sowing, herbicide treatment, harvest, border and set-aside cutting). New variables have been added to describe (d) the genotypic composition of the rapeseed varieties. This composition results from the combination of six genes: the transgene, modelled as a dominant allele A associated to a recessive allele a (already present in the previous version of the model); two genes H1/h1 and H2/h2 determining plant height; one gene C/c for flower morphology (closed, semi-open, open); a cytoplasmic gene M/m coding for male sterility and a last nuclear gene R/r restoring male fertility.

The input variables influence the annual life cycle of cultivated and volunteer rape (seed bank, seedlings, adult plants, flowers, pollen and seed production). For instance, tillage moves seeds between layers whereas herbicides both reduce plant densities and change genotypic composition. The life-cycle is simulated for each plot (field and border) of the region. At flowering and during seed shed, the various plots exchange pollen and seeds, depending on flowering dates, distances between plots and plot areas. Model output consists of densities and genotypic composition for adult plants, newly produced seeds and seed bank for each simulated plot and year.

The six genes taken into account in the model influence various parts of the life-cycle. Herbicide tolerance depends on transgene presence. Flower and seed production increase with plant height (relative to neighbour plants). Seed production is larger for male-sterile plants but these produce no pollen. Pollen emission (but not production) and self-pollination rates depend on flower morphology; closed vs. open flowers liberate little pollen and are mostly self-pollinators.

Determination of genotypic parameters

Several field experiments were set up to measure the effect of genotype on life-cycle parameters for different rapeseed types: cleistogamous rapeseed (closed flowers), varietal association (80% male sterile, 20% male fertile), dwarf rapeseed and conventional rapeseed. Experimental results showed cleistogamy to be unstable in time, without effect on self-pollination rate (Table 1). Pollen emission was lower for closed vs. open flowers (Table 2).

Table 1. Effect of flower morphology on self-pollination rate

	Cleistogamous rapeseed	Conventional rapeseed
1999	0.62	0.64
2000	0.72	0.74
2001	0.57	0.49*

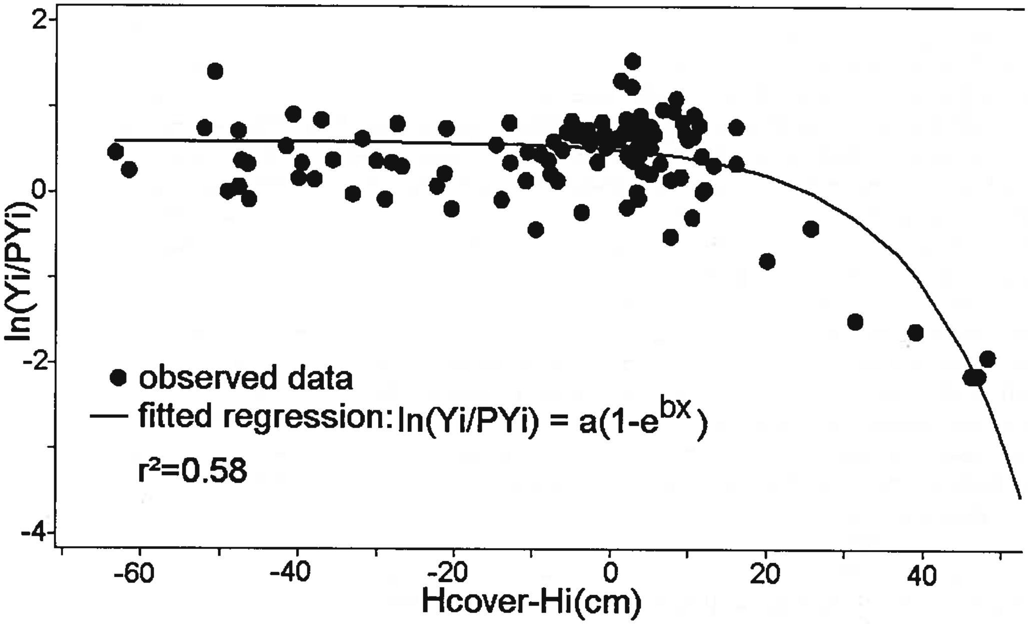
* significant difference

Table 2. Effect of flower morphology on relative pollen emission rate (conventional rapeseed = 1)

	Cleistogamous rapeseed	Conventional rapeseed
2000	0.10*	1
2001	0.37*	1

* significant difference

Another series of experiments studied the effects of competition on seed and flower production of rape volunteers in rape crops of different varieties. First, an equation expressing potential yield PY_i as a function of plant density D was established for each genotype i on pure-stand trials with densities ranging from 4.3 to 128 plants per m²: $PY_i = \frac{k_i}{a+b \cdot D}$ where k_i is the yield per m² of genotype i at 49 plants/m², and a and b are parameters independent of genotype. The other trials had mixed stands where individual plants of genotype i were sown at a density D_i of 5 plants per m², together with D_j =40 plants per m² of genotype j. The yield Y_i of the individual plants decreased with plant height H_i relative to the height of the field cover $H_{cover} = \frac{H_i \cdot D_i + H_j \cdot D_j}{D_i + D_j}$, where H_j is the height of genotype j (Fig.).



References

Colbach N. et *al.* 2001a. *Agriculture, Ecosystems and Environment*, 83, 235-253
Colbach N. et *al.* 2001b. *Agriculture. Ecosystem and Environment*, 83, 255-270

DIURNAL VARIATION OF CANOPY TEMPERATURE IN PLANT ROWS OF GRAPEVINE (*VITIS VINIFERA L.*) ON SOUTH FACING SLOPES OF THE DOURO VALLEY IN RESPONSE TO WATER AND MICROCLIMATE CONDITIONS

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Introduction

In N E Portugal vineyards are grown in slopes along the Douro River which runs from Spain towards the west, to the town of Oporto in the Atlantic coast. Soils on the slopes are mainly made of schist, with a low water holding capacity. During the summer season, from July to September, the soil profile dries significantly, with vines withstanding an increasingly harsh environment characterised by high temperatures, low rainfall and extreme dryness of the atmosphere. From climatological point of view, the south facing slopes benefit from higher solar radiation input and, consequently a higher soil and air temperature than the north facing slopes, which can lead to an earlier onset of soil water deficit. The primary objective of this work was to evaluate the suitability of canopy temperature to be used as crop water stress indicator and a tool for irrigation management in vineyards of the Douro Valley. This paper evaluates the effect of irrigation on variation of canopy temperature in the south and north facing halves of vine rows and the nature of the relationship between the canopy-air temperature differential (T_c-T_a) and the saturation deficit (SD).

2. Materials and methods

The study was conducted between 7-10 September 2001, in a commercial vineyard of 15-year old Tinta Roriz vines grafted onto the rootstock 99R, located at Quinta do Zimbro, in the Portuguese region of the Douro Valley, near 'Foz do Tua' (lat. 41°13' N; long. 7°22' W; alt. 180 m). The experiment consisted of individual plots containing six consecutive vine rows to give a total of 48 plants. The vineyard was planted on a sloping schist soil facing the south and at a spacing of 1.8 m between rows and 1.0 m within row with east-west orientation. The experimental layout was a split block design with the main plots consisting of irrigated and rainfed treatments. The rainfed treatment was taken as the control, representing traditional farming in the area. Each treatment was replicated five times. Water in the irrigated treatment was applied through a trickle system with two drippers (2 litres h^{-1}) per vine, located 0.25 m on either side of the vine's trunk down the row. Irrigation took place from mid June to first week of September, with the vines receiving a total of 540 litres $plant^{-1}$ (300 mm) over this period. Soil water was monitored in the top 0.2 m layer of the soil by gravimetric sampling, and at depths below this, down to 1.0 m, with a neutron probe (Wallingford MK IIL, Didcot Instruments Company, Ltd., U.K.). Field measurements took place just after the last irrigation application when all plants had fruits already set and the upper leaves were still green. Three hourly intensive measurements of environmental variables and canopy temperature was carried out, under cloudless conditions, from 8 am to 8 pm during four consecutive days (7-10 September). Crop canopy temperature readings were taken in the north (N) and south (S) facing sides of the selected plant rows with a hand held infrared thermometer (Everest Interscience, Tustin CA, Model 510 Agritherm IRT) with an acceptance angle of 4°. Therefore, during each measuring session, two readings of air temperature, humidity, saturation deficit, total solar radiation and canopy temperature were taken on the N and S sides of each plant row of the selected plots, at an angle of 45 degrees from the horizontal position and roughly at 0.5 m distance from vines avoiding the gaps in the foliage.

3. Results and discussion

The daily mean air temperature and humidity remained constant at about 25°C and 42% respectively over the measuring period, whilst the mean daily wind speed decreased almost linearly from 1.2 (7/09) to 0.8 (10/09) m s^{-1}. Within a day, saturation deficit of the air above the canopy varied from about 1 kPa in early morning to 5 kPa at the time of maximum temperature. The potential soil water deficit as calculated from the cumulated difference between rainfall and Penman evapotranspiration during the period indicated a value of 125 mm. The mean soil water content measured by the neutron probe counts in the upper 1 m of soil profile, showed a clear difference between irrigated and droughted treatments, starting from mid June. The canopy-air temperature differential (T_c-T_a) in the rainfed plots varied from –06°C (early morning) to almost zero (at maximum temperature). By contrast, this differential on the irrigated crops varied from –12°C to –04° C in the same period.

According to Idso *et al.*(1981), the relationship between (T_c-T_a) and SD in well watered plants is unique and negative, irrespective of the environmental variables, except cloud cover. However, when determined for the irrigated crops this relationship showed different linear functions with the north facing half of the plant row (Fig. 1.(a)) displaying, as expected (Idso *et al.*, 1981), a negative slope ($y= -1.982x-4.259$; $n=16$ $r^2=0.60$), in clear contrast with the south facing side (Fig. 1.(b)) which slope was positive ($y= 1.580x-11.802$; $n=16$ $r^2=0.57$).

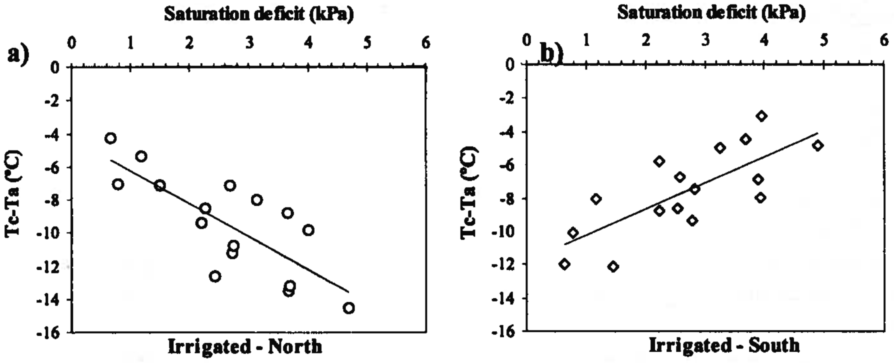

Fig 1. Relationship the relationship between (T_c-T_a) and SD in irrigated grapevine plants rows: (a) in the north facing half and (b) in the south facing half. Measurements taken between 7-10 Sept 2001 in Tua.

Interestingly, this positive slope was similar to that of the south facing side ($y= 1.552x-7.250$; $n=16$ $r^2=0.73$) of stressed plant rows and nearly half of the slope found ($y= 0.692x-6.062$; $n=16$ $r^2=0.52$) for the north facing side of same treatment.

4. Conclusions

The results show the positive effects of irrigation on crop canopy variation, implying a stronger transpiration activity (Jackson, 1982). However the nature of the relationship of (Tc-Ta) vs SD depended on the irrigation treatment and leaf orientation, which needs further investigation.

5. References

Idso, S.B., Jackson, R. D., Pinter, P. J., Jr., Reginato, R. J., Hatfield, J. L. 1981. Normalizing the stress degree day for environmental variability. Agricultural Meteorology, 24:45-55;

Jackson, R. D. 1982. Canopy temperature and crop water stress. pp 43-85. In: Advances in Irrigation, Volume (1). Daniel Hillel (Ed). Academic Press Inc (London) Ltd. 302p.

EVALUATING FROST RESISTANCE IN CRAMBE

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Introduction

Crambe (*Crambe abyssinica* Hochst. Ex. R. E. Fries) is considered to be a promising source of high erucic acid seed oil, which has an established market in the oleochemical industry. During the last ten years this crop was extensively studied in Italy, where it showed a good productive attitude. Due to its sensitivity to high temperature stress, crambe is cultivated in spring in the North, whereas in Centre and South Italy only the autumn-winter cycle appears feasible (Lazzeri et al., 1995). Even in the North however, late spring high temperatures may shorten the flowering period with detrimental effects on yield. This justifies the attempts which are currently being made to extend the growth cycle through winter cultivation or earlier spring sowing in Northern environments. In the course of a three-year research program, twelve accessions from Northern Europe and Italy, including registered varieties and breeding lines, were evaluated for freezing resistance under controlled conditions. The hardening capacity of the most resistant ones was then tested outdoors, to evaluate their potential adaptability to winter cultivation.

Methods

The chosen accessions were supplied by CPRO-DLO (Wageningen UR, NL), CEBECO (NL) and ISCI (Research Institute for Industrial Crops, I). They were preliminarly tested for frost resistance under controlled conditions by following two basic approaches: 1) Survival at whole plant level after a frost stress; 2) *In vitro* determination of the freezing Lethal Temperature 50% (LT_{50}).

1) Plant survival

Crambe seedlings were grown in a greenhouse until the four leaves-stage, then they were transferred to a growth room where they were kept at 8 °C for two weeks. A freezing stress was then induced by gradually lowering air temperature to –3 °C, which was maintained for three hours. Temperature was then gradually raised until 8 °C, and frost damage was visually assessed the day after by a visual subjective score, (0 = no damage, 1 to 3 = injured plant, and 4 = dead plant). The experiment was repeated twice.

2) In vitro LT_{50} determination

LT_{50} was determined on seedlings at the cotiledonary stage acclimatised at 5 °C for two weeks in a growth room. The assay was similar to that described by Griffith et al. (1993). The excised cotyledons were inserted in test tubes in a controlled temperature cooling bath, where they were first stabilized at –1 °C. Ice formation was initiated by adding an ice chip, then temperature was gradually lowered until -12 °C at a rate of 2 °C $hour^{-1}$. Samples were removed at 1 °C intervals and shaken in deionised water overnight. Finally, the ion leakage was determined as the water electrical conductivity. The temperature corresponding to the 50% ion leakage was extrapolated from the resulting curve and taken as a measure of frost tolerance.

Outdoors hardening capacity

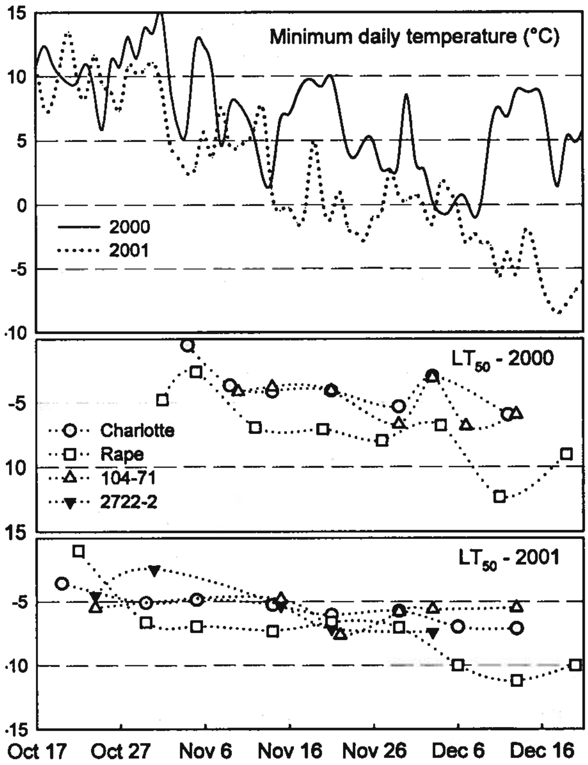
From this first screening, the cultivars contrasting for survival and LT_{50} were chosen, and their hardening capacity was evaluated under outdoors conditions for two years . They were "104/71", (high survival and high *in vitro* resistance) and "Charlotte" (low survival and low *in vitro* resistance). In the first week of October 2000, 200 plants for both genotypes were sown in pots, together with 200 plants of rapeseed. The LT_{50} was measured weekly on leaf-discs as described above. The experiment was repeated in 2001 with the same procedures and timing, including the accession "2722/2" (high survival and high *in vitro* resistance).

Results

Controlled conditions experiments.

The freezing stress applied in a growth room brought about a range of damage scores in the twelve cultivars tested. As it is shown in the table, "104/71" resulted the least damaged, with a visual score of 0.6. The less resistant was "Charlotte", with a score of 3.0. The LT_{50} measured *in vitro* in the separate experiment varied from –1.3 ("Ukraina") to – 5.0 ("2722/2")."104/71" and "Charlotte", chosen for the outdoors experiment, had a LT_{50} of -4.3 and -2.3 respectively.

Cultivar	Releasing Institution	Survival score	LT_{50} (°C)
104-71	CPRO-DLO (NL)	0.6 *(0.16)*	-4.3 *(0.51)*
2722-2	CPRO-DLO (NL)	1.1 *(0.19)*	-5.0 *(0.41)*
Bel Ann	CPRO-DLO (NL)	1.1 *(0.21)*	-4.2 *(1.52)*
Nebula	CPRO-DLO (NL)	1.1 *(0.19)*	-4.1 *(0.66)*
Prophet	ISCI (I)	1.4 *(0.22)*	-2.6 *(0.30)*
Carmen	CEBECO (NL)	1.5 *(0.20)*	-2.8 *(0.32)*
Galactica	CPRO-DLO (NL)	1.6 *(0.21)*	-2.4 *(0.25)*
Ukraina	ISCI (I)	1.6 *(0.21)*	-1.3 *(0.32)*
Mario	ISCI (I)	1.7 *(0.22)*	-1.8 *(0.83)*
2709-2	CPRO-DLO (NL)	1.7 *(0.26)*	-2.7 *(1.02)*
2722-1	CPRO-DLO (NL)	1.9 *(0.23)*	-2.3 (0.53)
Charlotte	CEBECO (NL)	3.0 *(0.22)*	-2.3 *(0.66)*



Outdoors experiments

The figure shows the daily minimum temperatures and the LT_{50} recorded from October 17 to December 24. In both years, starting from the four-leaves stage, the LT_{50} was around – 5/-6 °C in crambe with no differences among cultivars. All crambe cultivars maintained this LT_{50} value almost unchanged until the end of the experiment. A rather different behaviour was observed in rapeseed. During the first 5-6 weeks, LT_{50} was lower than crambe, around –7 °C. After the first mild freezing events (-2/-3 °C at night), a sensible decrease was recorded, towards –10/-12 °C in both years. Towards the end of December, when night temperature fell below –7/-8 °C, all crambe plants were completely destroyed. At this point the experiments were concluded.

Conclusions

Crambe abyssinica showed a low frost resistance, and a narrow variability among cultivars for this trait. From the outdoor experiments, it appears that crambe does not acclimate to freezing. In both years, after a non-lethal sub-zero temperature falling, crambe kept its LT_{50} almost unchanged. Under the North Italy condition, winter cultivation is therefore not possible. Besides, the apparent lack of hardening ability, discourages attempts of genetic improving for this trait. The existing variability among genotypes may be exploited however for early spring sowing.

References

Griffith M. et al., 1993. Physiologia Plantarum, 87, 335-344.

Lazzeri L. et al., 1995. *Agricoltura Mediterranea*, 125, 251-266.

(Research funded by EU project "DiCra – Diversification with Crambe"; FAIR CT98 4333)

DEVELOPING DYNAMIC LINK LIBRARIES FOR AGROMETEOROLOGY AND AGRICULTURAL MODELLING

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Introduction

The task of modelling agricultural like other dynamic systems calls for a proper analysis of the system, for gathering of knowledge from different disciplines, and for the collection of suitable data. But of crucial importance is also an appropriate software development technology for implementing the often quite complex models. A well-recognized method for reaching that goal involves structuring the model as a set of distinct modules (Jones et al., 2001), thus facilitating more systematic model development, documentation, maintenance, and sharing. The concept of modularity gained strong momentum with the wide spread of the object-oriented approach in software development (e.g. Van Evert et al., 1994). Routines for crop, soil, cropping systems calculations have been implemented in several crop growth and hydrologic models by applying the traditional procedural approach, with minor investment on code transparency. The consequence is the re-implementation of the approaches every time an estimate is needed into specific applications. Therefore, we chose to develop public dynamic link libraries (DLL), that incorporate relevant aspects of crop model computations and evaluation, and which can be plugged into existing application softwares running on a Microsoft Windows-based operating system.

Dynamic Link Libraries for Agrometeorology and Agricultural Modelling

ET_CSDLL. It contains routines to estimate reference crop evapotranspiration following the guidelines of the FAO Irrigation and Drainage Paper No. 56 (Allen et al., 1998) for implementing the Penman-Monteith equation. In addition, the Priestley-Taylor equation (implementation by Steiner et al., 1991) is also included for calculating reference crop evapotranspiration for conditions where meteorological data are insufficient to apply the Penman-Monteith equation.

PAR_CSDLL. It consists of routines to load files containing information about driving variables (weather) and input parameters of cropping systems simulation models. It allows loading crop, soil, location/meteo, management, rotation, and simulation files. The file format is the one used in the model CropSyst (Stöckle et al., 2002). This DLL allows model developers to use CropSyst parameter and meteo files when developing their own applications.

CropPheno_CSDLL. It contains routines to estimate variables related to crop phenology according to the approach used in the cropping systems simulation model CropSyst (Stöckle et al., 2002), based on thermal time requirements. Correction factors for vernalization, photoperiod and water stress can also be computed.

IRENE_DLL. It contains routines to provide easy access to model evaluation techniques. An integrated evaluation of model performance is allowed, based on the difference between estimates and measurements, the correlation between estimates and measurements, probability distributions, pattern analysis (Donatelli et al., 2002a), and fuzzy-based aggregation statistics (Bellocchi et al., 2002). Statistical tests are applied when replicates of estimates, measurements or both are available. Options are included for investigating the uncertainty about possible displacements (delay or acceleration) registered in the time series (Donatelli et al., 2002b).

The DLLs mentioned above have been tested on MS Window 98, 2000 and XP operating systems. The libraries are available for downloading from the website http://www.isci.it/tools, as part of a larger software production in the field of agrometeorology and agricultural modelling, distributed by the Crop Science Section of the Research Institute for Industrial Crops (ISCI-TC). The installation packages (including the manuals and sample files) are available free of charge for non profit users. Each DLL is provided with a documented help file that includes examples of how to use the DLL within MS Excel spreadsheet. Sample applications of the DLLs within the visual modelling environment MODCOM (web page at: http://biosys.bre.orst.edu/modcom; Bolte, 2001) are under development.

Conclusions

The DLLs illustrated here are part of a joint effort towards a commonly-agreed architecture for agronomic/agrometeorological modelling. They serve as convenient means to support collaborative model development among a large, distributed network of scientists involved in creating object-oriented models in the agronomy and agrometeorology fields. They can be used as submodels or utilities of any model, written in any language. The documentation provided significantly increases transparency of the underpinning science.

References

Allen et al., 1998. Irrigation & Drainage Paper 56. UN-FAO, Rome, Italy.
Bellocchi et al., 2002. Agronomy Journal. (submitted)
Bolte J., 2001. Specification documentation (draft version). Bioengineering and Computer Science departments, Oregon State University, Corvallis OR, USA.
Donatelli et al., 2002a. Agronomy Journal. (submitted)
Donatelli et al., 2002b. These proceedings.
Jones et al., 2001. Agricultural Systems 70:421-443.
Steiner et al., 1991. Agronomy Journal 83:240-247.
Stöckle et al., 2002. European Journal of Agronomy. (in press)
Van Evert et al., 1994. Agronomy Journal 86:325-331.

Acknowledgements Project SIPEAA (http://www.sipeaa.it), paper no. 7.

DEVELOPMENT OF A TOOL FOR RETROSPECTIVE DIAGNOSIS OF THE WATER SUPPLY HISTORY OF COTTON PLANTS

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Introduction

Knowing the water supply history of a crop is a major key to plot diagnosis. However, in many cases, the data required to establish a water balance are not available. The available literature looks extensively at the effect of water supply on plant growth and development, and particularly on the expansion of organs that were growing at the time of stress. The idea of using length observations as chronological indicators of the water supply history of the plant was suggested for pea plants by Lecoeur (1995). For these plants, leaves are the organs used, whereas in the case of cotton, most leaves have already fallen by the time of harvesting. We therefore set out to use the internode profile of the main stem, measured at the time of harvesting. Based on experiments conducted in glasshouses at the agricultural college ENSA Montpellier, we built an internode development and growth model taking account of the water stress constraint. Assuming that only water supply had an effect during the growth cycle, we tested the prediction capacity of the model on stands in the field. This paper reports on the main results obtained and opens the discussion on the merits of the method.

Material and methods

The field data are from agronomy trials conducted in 1995, 1996, 1997 and 1999 at the Lavalette site (Montpellier) with variety DES119. From December 1999 to May 2000, two trials were conducted in glasshouses at ENSAM in Montpellier to measure accurately the relation between cotton plant transpiration and soil water status on the one hand, and the rate of internode elongation and soil water status on the other. The first trial compared three water supply regimes applied after cotton plant emergence: constant satisfaction of requirements, a daily water supply lower than transpiration, and no water. The second trial compared five soil water status levels, maintained from emergence until the end of the trial, with daily weighing and applications. Both trials were halted once the ninth internode had completed its growth.

Results

- *Construction of the model of internode development and expansion under water stress*

The model identify the following stages : internode morphogenesis, establishment of internode profiles without stress and impact on the internode profile of a reduction in water availability.

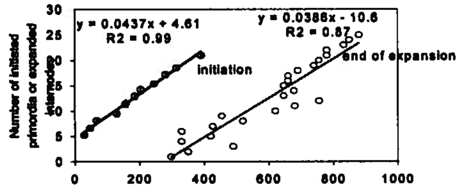

Fig 1: Model of cotton internode development, initiation, and end of expansion as a function of thermal time.

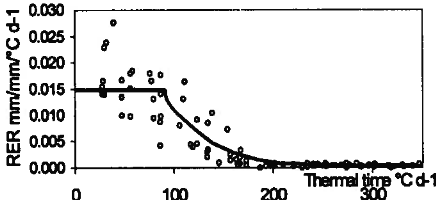

fig 2: Model of coton internode length expansion as a function of thermal time, results are from field experiments with unbranched cotton at Montpellier

- *The internode development and growth model*

Internode morphogenesis comprises two phases: initiation within the apical meristem, followed by organ expansion until its final size is reached. Expressed on a thermal time scale in relation to emergence (basis: 13°C), the dates for the end of initiation and of expansion of the successive internodes are linear (figure 1). Moreover, the rate of organ expansion varies in time. Figure 2 shows this pattern for the relative elongation ratio (RER), calculated from observations of cotton plants from which all secondary branches had been removed. After a short constant phase, the

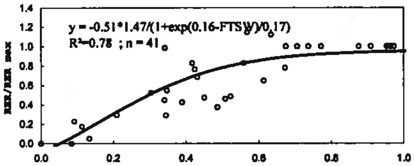

Fig 3: Internode relative elongation rate as a function of fraction of transpirable water, Montpellier glasshouse experiment in 2000

growth rate slowed according to an exponential function of time, for which the equation was established after 150 observations (r^2=0.81): RER = 0,0168*exp((-0,03*(t-110)). These results are similar with those obtained for sunflower leaves by Granier and Tardieu (1998).

- *Effect of water stress on internode expansion rate*

To take account of this effect we applied the relationship described by Lecoeur et *al.* (1995). The equation used for the reduction in RER as a function of soil water status was as follows: relativeRER = -a+b/(1 + exp(c*FTSW-d), where a, b c and d are four parameters characteristic of the variety. The relation was obtained from the greenhouse trials (figure 3). The curve obtained with these values was not significantly different from that obtained by Rosenthal (1987) for leaves.

- *Simulation of an internode profile and comparison with observed data*

We applied the model to a set of internode profiles observed in field trials. The simulations were satisfactory for situations without competition with fruiting sites (figure 4), but there was a difference between the observed and simulated lengths, particularly towards the end of the profile (figure 5), when early stress was applied, showing that compensation phenomena need to be taken into account in order to complete the model.

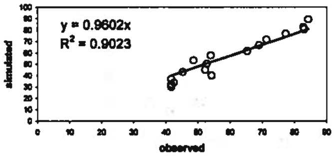

fig4: Simulated and observed internode length for unbranched cotton, Lavalette 1997

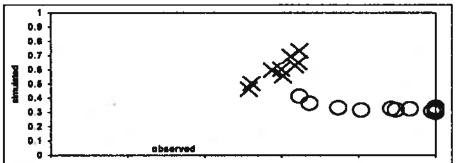

figure 5: comparison between simulated and observed fraction of potential internode length developed during pre-fruiting (X) and fruiting (O) phases, field experiment, Lavalette 1995

Conclusions

The model built produced a satisfactory simulation of internode lengths. The idea of applying a reasoning developed on leaves to internodes proved to be appropriate. This model is another step on the road towards developing a retrospective indicator of the water supply history of cotton crops. However, the interactions with density and the competition from fruiting organs on the internodes need to be studied to complete the model and make it a real plot diagnosis tool.

References

Granier C., and Tradieu F. (1998). Spatial and Temporal Analyses of Expansion and Cell Cycle in Sunflower Leaves. *Plant Physiol.* 116: 991-1001.

Lecoeur J., Wery J., Turc O. and Tardieu F. (1995). Expansion of pea leaves subjected to short water deficit: cell number and cell size are sensitive to stress at different periods of leaf development. *Journal of Experimental Botany* 46: 1093-1101.

Radin J. W., and Boyer J. S. (1982). Control of leaf expansion by nitrogen nutrition in sunflower plants. *Plant Physiol.* 69: 771-775.

Rickman, R. W., and Klepper, B. L. (1995). The phyllochron: where do we go in the future? *Crop Science* 35: 44-49.

Rosenthal W.D., Arkin G.F., Shouse P.J., and Jordan W.R. (1987). Water deficit effects on transpiration and leaf growth. *Agron. J.* 79: 1019-1026.

A CONTRIBUTION TO THE MODELLING OF CROPPING SYSTEMS WITH PERMANENT GROUND COVER AND ZERO TILLAGE

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Introduction

In temperate regions, research has begun to study the possible benefits of a 'permanent ground cover and zero tillage'' crop system (Picard *et al*, 2000). This cropping system may reduce soil erosion and leaching of nitrates and pollutants to the underground water.
A specific study is under way to deal with the first part of the crop rotation, which includes an association of wheat and red fescue (Ghiloufi *et al*, 2001).
This paper presents the modelling of this association and a first evaluation of the model used.

Materials and methods

The experiment was conducted in Grignon (40km from Paris) during the 99/00 season. Fourteen treatments were tested (Tab.1.) : 2 with pure fescue, 4 with pure wheat and 8 associations.

Treatment	I1	I2	S1	S2	I1c	I1su	S1c	S1su	I2c	I2su	S2c	S2su	c	su
Wheat	I	I	S	S	I	I	S	S	I	I	S	S	0	0
Wheat density	1	2	1	2	1	1	1	1	2	2	2	2	0	0
Fescue	0	0	0	0	c	su	c	su	c	su	c	su	c	su

Tab.1. Treatments at Grignon 99/00
I : Isengrain wheat variety; S : Scipion wheat variety
c : Center fescue variety ; su : Sunset fescue variety
1 : low density 150 pl.m^{-2}; 2: high-density 350 pl.m^{-2}

The winter wheat was sown with 0.17 m between rows, on the same day as fescue, which was broadcast.
The trial results were used for the parameterisation of the ''associated plants'' version of the STICS model (''associated crops model'') (Brisson, 1998) derived from the generic crop model STICS (Brisson *et al*, 1998). This model was developed under tropical conditions for a tropical legume shrub and a forage grass association. The two versions differ mainly in the way they deal with light absorption and plant water requirements. The pure crop model version used in this study is performed with these new formalisms; it will be designed as ''improved pure model''.
The modelling work began by parameterising the ''improved pure model'' for pure crops of wheat and fescue; this was followed by modelling the whole association with the ''associated crops model''.
The first evaluation of the model (associated and pure) was based on the RRMSE criterion: Relative RMSE (root mean squared errors) (Irmak *et al*, 2000) where RRMSE= RMSE/average of the simulated variables.

Results

The first results are encouraging for wheat but are unsatisfactory for fescue grown in association.
The experiment begun in 2000/2001 at Grignon aims to complete this work; the analysis of the results is in progress.
The results for wheat grown alone and in association, together with the first test of the model are presented here.
The curves of the observed and simulated dry matter and leaf area index (LAI) development for wheat grown as a sole crop and in a mixture show that these variables are well estimated by the model (Fig.1). For the mixed crop, an overestimate of these variables is apparent at the end of wheat

growth, which can be explained by the under-estimation by the model of the competitive effect of fescue towards wheat maturity.

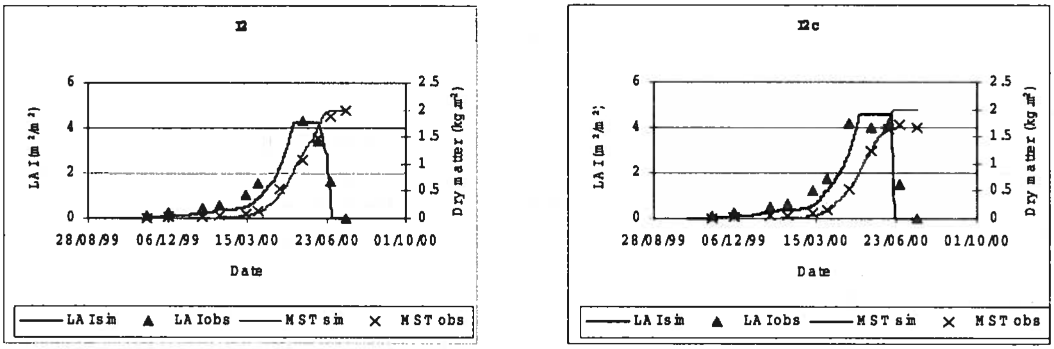

Fig. 1. simulated-observed dry matter and LAI evolution, two examples: pure treatment (I2) and associated treatment (I2c)

The yields are slightly overestimated by the associated and ''improved pure'' model (Fig. 2). The quality of prediction is, however, a little better in the case of the pure crop (lower RRMSE). The model gives a good simulation of the differences between the wheat varieties, which are statistically different for the observed values. The effects of the presence of fescue and its interaction with wheat sowing density, seen in the observed data, are taken into account differently by the model for the Scipion variety.

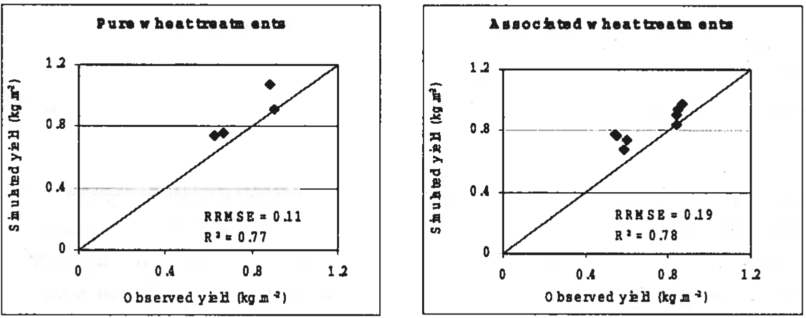

Fig. 2. simulated- observed yield comparison

Future prospects

The work of modelling is still in progress to perfect the ''wheat – fescue'' STICS model. Another objective of the model will be to simulate the intercropping period, when the fescue crop stays in place, to estimate its capacity to limit the nitrogen leaching and to sequestrate the atmospheric carbon. Simulations are envisaged to compare, during this intercropping period, the value of a ''nitrate trap crop'' with that of a permanent ground cover such as fescue.

References

Brisson, N., 1998. STICS-APC. Document INRA -Antilles: 40.
Brisson, N., et al., 1998. Agronomie., 18, 311-346.
Irmak, A., et al., 2000. Agronomy Journal, 92, 1140-1149.
Ghiloufi, M., et al., 2001. I World Congress on Conservation Agriculture, Madrid.Picard, D., et al., 2000. 3rd International Crop Science Congress, Hambourg.

MODELING STUDY OF THE IMPACT ON RUNOFF AND EROSION OF CHANGING SOIL MANAGEMENT IN OLIVE ORCHARDS OF SOUTHERN SPAIN

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Introduction

Spain is the largest olive oil producer in the world. Approximately 75 % of the Spanish olive production is located in the Southern region of Andalusia, where olive orchards cover roughly 14% of the region. Modifications of the soil management in olive orchards may have important effects on surface hydrology and erosion risk, especially in the traditional areas of olive production where olive trees occupy most of the available land. The most extended soil management in Andalusia is mechanical cultivation, CT. Additional methods adopted more recently are: non-tillage combined with herbicide use, NT; reduced tillage consisting of herbicide combined with tillage only in the inter-tree row, RT; minimum tillage consisting in herbicide and a single annual tillage, MT; and cover crop sowed in the autumn and killed with herbicides in early spring CC. Our objective is to show a comparison of the effect on runoff and soil losses of different methods of soil management, using simulation models.

Methods

A physically based model was used to study the effect of management on runoff generation. It is an event-based model that introduces the effect of soil management using different roughness and infiltration parameters. It also incorporates the spatial variability in infiltration between inter-tree and below-tree areas, observed in olive orchards. A full description of the model and its validation appears in Gómez et al$_a$. (2002). A hillslope 180-m long, 5% steep and 8-m wide with a tree spacing of 8x8-m and tree aligned in the maximum slope direction was used to determine the Curve Numbers, CN, (Soil Conservation Service, 1972) for each of the treatments considered. For the simulations we used a set of 26 rainfall events recorded nearby Cordoba. Three different soils; two different trees sizes (covering 5 and 25% of the surface) and two different initial soil moisture content (corresponding to –1500 and –33kPa of matric potential) were included. The estimated CN numbers were used to calculate the average daily runoff coefficient using the daily rainfall measured at Cordoba from 1953 to 1996.
An empirical erosion model, RUSLE (Renard et al. 1997), was used to analyze the effect on soil erosion. RUSLE provides an estimation of the long-term average soil loss, and it was calibrated to the different soil management methods used in the region, Gómez et al.$_b$ (2002) The same 43 year-long rainfall dataset used for the runoff simulations was used for the erosion study. The same plantation and soil characteristics used for the runoff simulations were considered here, although four different slope steepness: 5, 10, 15 and 20% were used.

Results

Figures 1 shows the runoff coefficient for the different soil managements simulated, average of the two different tree sizes. Four different situations were considered for CT, combination of considering a plow layer ~YP, or not ~NP; and assuming the soil freshly tilled FT~, or with the effect of tillage degraded by previous rainfalls DT~. Two different widths of the strip of protective crop: 2 meters, ~2~, or 4 meters ~4~ were considered. Figure 1 shows how runoff is significantly affected by soil management. The average daily runoff coefficient is significantly larger for NT when compare to cover crops or even to degraded tillage. These differences are more dramatic for an initially moist soil, especially those with a low infiltration rate, not shown.

Fig. 1.: Daily runoff coefficient for different managements on a clay-loamy soil with moderate infiltration rate

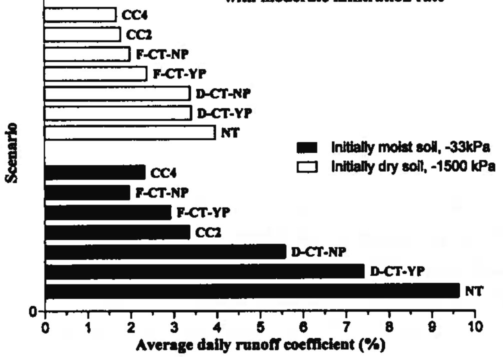
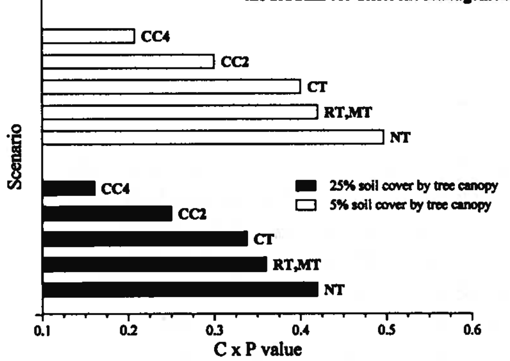


Fig. 2: Product of the C and P values of the RUSLE for different managements



RUSLE predicts soil losses according to the equation A= R K LS C P, where A is the average annual soil loss, R is the rainfall erosivity factor, K is the soil erodibility factor, LS is the slope length and steepness factor, C is the cover-management factor, and P is the support practice factor. For a given location, soil and topography the differences in soil losses will be determined by the product of the C and P factors. Figure 2 shows a comparison of these factors for the different management simulated at Cordoba. According to RUSLE the management method has a significant impact on the C and P factors, and subsequently in the erosion risk. NT showed the highest soil losses while protective cover showed the lowest with tillage in their several combinations ranking second to NT.

Conclusions

The modeling studies predict a significant modification of runoff and erosion risk as results of the change of soil management. These changes in cultivation have happened in the last years and continue nowadays. The predictions agree, qualitatively, with published experiments on runoff and water erosion at plot scale. The simulations provide a way to perform a systematic comparison among a large number of treatments, almost impossible to incorporate simultaneously in field studies. The extrapolation of these results, field and modeling, to larger spatial scales remains an open question. Since most of the information relevant for policy-making is at these larger scales, that should be the focus of further efforts.

References

Gómez, J.A:,et al., E. 2001$_a$. Analysis of the effect of soil management on runoff generation in olive orchards using a physically based model. Soil Use and Management (in press).
Gómez, J.A., et al., 2001$_b$. Evaluation of the impact of different soil management on soil losses in olive orchards in Southern Spain using RUSLE. (In preparation).
Renard, K.G., et al.,1997. Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). U.S. Dep. Agric., Agric. Handb. No. 703. Washington D.CSoil Conservation Service. 1972. National Engineering Handbook. USDA-SCS, U.S. Gov. Print. Office, Washington DC.

SENSITIVITY ANALYSIS OF LISEM MODEL FOR ITS APPLICATION IN DRY FARMING AREAS IN CENTRAL NAVARRE

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Introduction

The Department of Agriculture, Livestock and Feed of the Government of Navarre, decided to establish a network of, up today, three agricultural experimental watersheds, provided with state of the art technology, operational since 1995, and representative of wide Navarrese areas (Casalí et al). Unique data sets from these watersheds will be very useful to: 1) better estimate water resources in the area; 2) characterize the hydrologic response of the study areas; 3) describe the impact of agrarian activities in the environment; 4) evaluate different simulation tools for land management and planning. One of those tools is LISEM (Limburg Soil Erosion Model) (De Roo et al, 1995). In this paper, a sensitivity analysis of LISEM, required step before model validation, applied to one of the agricultural experimental watersheds, named La Tejería, is presented and discussed.

Methods

La Tejería watershed is located around 30 km west from Pamplona, in Central Navarre. It covers 169 ha, and it is completely cultivated with winter grains (wheat and barley). At the watershed outlet there is one automatic meteorological station, recording values of the most important variables in a 10 min basis; and one hydrological station, where water level is recorded every 10 min, and where ten water quality parameters are recorded daily. Discharge is calculated from water level data, which in turn is determined with pressure probes. LISEM is a physically based event-oriented distributed model that simulates direct runoff, erosion and deposition in small watersheds. Watershed surface is divided by LISEM in cells, which are the operational computation unit. LISEM simulates rain interception by Aston's model and infiltration by different optional models like Holtan's, Green and Ampt's, or a finite difference solution of the Richard's equation. Rainfall excess routing from one cell to the next one is determined by a kinematic wave approach. The most important parameters, whose effect on model behavior was analyzed in this study, include: hydraulic conductivity at saturation, K_{sat}; leaf area index, *LAI*; standard deviation of surface heights (roughness), *RR*; initial water content, θ_i; Manning's coefficient in hillslopes, n; Manning's coefficient in channels, n_c; soil cohesion in hillslopes, *Coh*; soil cohesion in channels, Coh_c; aggregates stability, *As*; and average particle size, D_{50}. Sensitivity analysis was made by calculating the sensitivity coefficient defined by Nearing et al (1989):

$$S = \left| \frac{(O_{Max} - O_{Min})/O_{Ave}}{(I_{Max} - I_{Min})/I_{Ave}} \right| \qquad (1)$$

where I_{Max}, I_{Min} and I_{Ave} are, respectively, the maximum, minimum and average values of the model input variables; and O_{Max}, O_{Min} and O_{Ave} are the corresponding model outputs.

Results

For the present study, the simulation of the event occurred on July 9th, 1997, at La Tejería watershed, was selected. Total rainfall depth was 20.5 mm and storm duration was 60 min. The ranges of values for each of the selected parameters, necessary for calculating S, were determined according with average watershed characteristics. Those ranges are, respectively: K_{sat}, 1.1-11.7 mm h^{-1}; *LAI*, 0-3; *RR*, 1-5 cm; θ_i, 0.0-0.51; n, 0.02-0.20; n_c, 0.02-0.20; *Coh*, 9-27 kPa; Coh_c, 9-26 kPa; As, 14-35; D_{50}, 0.15-0.35 mm. Model response was studied by analyzing estimated: a) peak discharge; b)total runoff volume and; c) total sediment yield. On Figure 1, S coefficient value for each of the selected model parameters, calculated from (1), is shown. Provided that the uncertainty in defining the ranges of values for each of the selected parameters is high, variation of S as a function of the selected parameter value interval, was studied. Ranges for each parameter were divided in intervals of the same length, calculating the sensitivity coefficient (1) for each of those intervals, S_i. On Figure 2, the normalized values of the parameters $i_i = I_i / I_{Max}$ are represented *versus* the corresponding S_i for each interval.

Fig1. Model sensitivity (S) for selected parameters and output variables

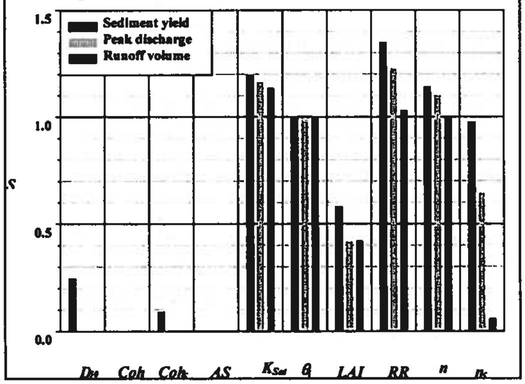
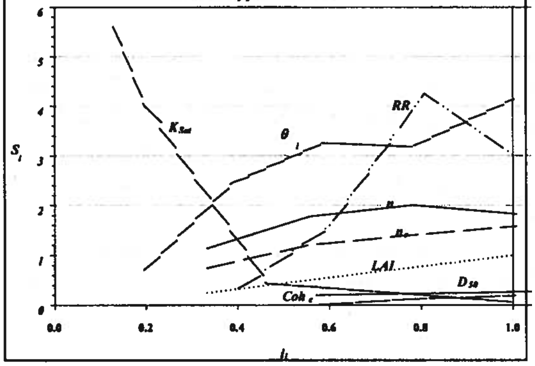


Fig 2. Variation of model sensitivity as a function of the interval of parameter values



From Figures 1 and 2, it can be concluded that Coh, Coh_c, As and D_{50} do not affect model response regarding peak discharge and runoff volume and, among them, only D_{50} and Cho_c affect sediment yield estimations. K_{sat}, LAI, RR, θ_i, n and n_c clearly affect peak discharge, runoff volume and sediment yield. It is remarkable that, although n_c does not affect runoff volume, it significantly affects model behavior regarding peak discharge and sediment yield. RR is the most important parameter regarding peak discharge and sediment yield estimations. From Figure 2, it can be stated that S_i is clearly dependent on the interval of parameter values considered, being K_{sat} and RR the parameters for which S_i shows a greater variation.

Conclusions

LISEM erosion component shows the highest sensitivity to parameters that control peak runoff discharge, which are hydraulic conductivity at saturation (K_{sat}), standard deviation of surface heights (RR), initial water content (θ_i), and Manning's roughness coefficient in hillslopes (n). Sensitivity coefficient S is dependent on the interval of parameter values considered for its determination, being K_{sat} and RR the parameters for which such variation was greater.

References

Casalí, J., J.J. López, U. Agirre and M. Goñi. Runoff and sediment yield from agricultural watersheds in Central Navarre (Spain). CATENA (submitted).

De Roo, A.P.J. and R.J.E. Offermans, 1995. LISEM: a physically based hydrological and soil erosion model for basin-scale water and sediment management. Modelling and Management of Sustainable Basin-scale Water Resource Systems. IAHS Publ. 231, 399-407.

Nearing, M.A., L.D. Ascough and H.M.L. Chaves, 1989. WEPP model sensitivity analysis. WEPP-USDA water erosion prediction project. USDA-ARS-NSERL, 2, 14.1-14.33.

USING THE CROPPING SYSTEMS SIMULATOR APSIM TO INVESTIGATE THE IMPACTS OF SUBSOIL CONSTRAINTS ON WHEAT PRODUCTION

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Introduction

Recent appreciation of the importance of subsoil nitrogen has led to a new practice of chemical analysis of subsoils. This trend has led to the discovery that many soils in the southern Mallee (a grain cropping region in Victoria, Australia) have simultaneously high levels of salt, sodium and boron. There is a keen interest by farmers and researchers to investigate what might be done to manage these soils. The first step is to gain an appreciation of the impact of these factors on crop yields. In this paper we used crop monitoring and simulation to improve our understanding of the impact of these soil factors on the performance of wheat; the most important crop in this region. Experience with the Agricultural Production Systems Simulator APSIM in many locations, in Australia and other countries, has shown that good agreement is usually observed between measured and simulated results provided the simulation is well parameterised with soil, weather and cultural practices (Keating *et al.* 2002). APSIM however does not have any functions dealing directly with salinity, sodicity, or boron toxicity. In 2001 researchers from CSIRO cooperated with the BCG agronomists to obtain input data for simulating crops in the Cropping Systems Trial. We proposed that in the absence of any impacts of subsoil constraints on crop growth APSIM would predict yield and soil water usage within an acceptable error range. On the other hand an over-prediction of yield by APSIM could lead us to investigate further how subsoil limitations prevent wheat from reaching its production potential.

Methods

The experimental work was conducted on a single plot of a farming systems experiment conducted by the Birchip Cropping Group. A key component of the program was the characterisation of the soil for plant available water content (Dalgliesh *et al.* 1998, Hochman *et al.* 2001). In addition, soil water and nitrogen were sampled, at seven depth increments to 115cm, five times during the crop and fallow periods. A climate station to record daily weather data was installed at the site. All agronomic operations, dates and rates were recorded. Plant population, tiller numbers, phenology, above ground dry matter and grain yields were measured. Root depth was estimated four times during the growing season from replicated soil core samples taken for determination of water and nitrogen. Final root depth was confirmed by a 1.5m deep pit excavated with a back hoe after crop maturity. The abovementioned data were used to set up initial conditions for and comparison with predicted results of the APSIM simulation.

Results

Total rainfall for 2001 was 261mm of which 197 mm fell during the April to October growing season. These conditions are well below average and the first sowing opportunity (June 15) was later than optimal. On the positive side we measured 245 kg/ha nitrate N in the soil and 79mm of stored plant available soil moisture prior to the start of the season, cooler than average temperatures during grain filling were also favourable. Ultimate observed rooting depth was 100cm. At 100 cm EC was 1.3 dS/cm, chloride concentration 800 ppm, boron 20 ppm, and ESP 50%. Grain yield was 3.1 t/ha. The grain yield result was matched to within 100kg/ha by the APSIM simulator. However, a comparison of observed and predicted root depth showed that the actual root depth penetration rate was well below that predicted for healthy soils. A simple function for reducing relative root penetration rates in the presence sodium exchange percentages of more than 10% and reduced to zero at 60%, resulted in the closer fit of predicted and observed results as shown in Figure 1. Using this new simulation also produced a close fit of measured and observed soil moisture throughout the simulated period as shown in Figure 2. Interestingly, adding the sodium restricted root function resulted in an insignificant change in predicted grain yield.

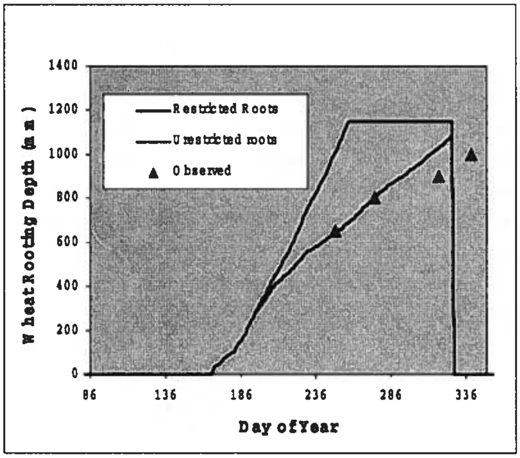

Figure 1. Simulated and observed root depth

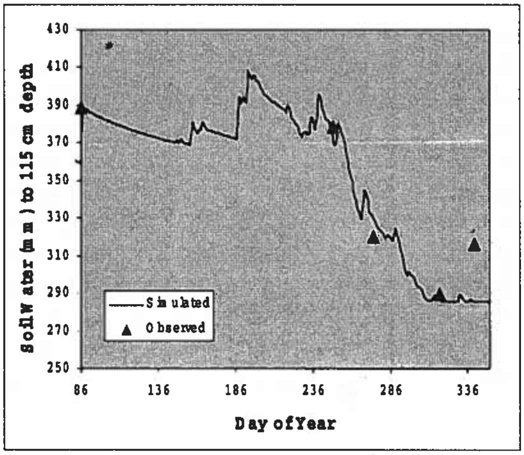

Figure 2. Simulated and observed soil water

Conclusions

Adaptation of APSIM to an environment with high levels of salt, sodium, and boron required a new function to reduce the rate of root front extension. In the water limited environment of the southern Mallee, the observed root restriction appears to have had little impact on final grain yield. Additional impacts of subsoil constraints on wheat may be expressed in the crop lower limit of moisture extraction. However, as simulated grain yield was approximately equal to observed yield while observed soil moisture was well tracked by the simulation, we conclude that there was no evidence to support an affect of these subsoil constraints on either water use efficiency or radiation use efficiency.

References

Dalgliesh, N.P. and Foale, M.A. 1998. Soil Matters – monitoring soil water and nitrogen in dryland farming. Agricultural Production Systems Research Unit, Toowoomba, Australia. 122 pp.

Hochman, Z., Dalgliesh, N.P., Bell, K. 2001. Contributions of soil and crop factors to plant available soil water capacity of annual crops on black and grey vertosols. Aust. J. Agric. Res. 52 p 7-14.

Keating, B.A., Asseng, S., Brown, S.D., Carberry, P.S., Chapman, S., Dimes, J.P., Freebairn, D.M., Hammer, G.L., Hargreaves, J.N.G., Hochman, Z., Holzworth, D., Huth, N.I., Meinke, H., McCown, R.L., Probert, M.E., Robertson, M.J., Silburn, M., Smith, C.J., Snow, V.O., Verburg, K., Wang, E. 2002. The Agricultural Production Systems Simulator (APSIM): its history and current capability. European J. of Agronomy (in press).

CROPSYST APPLICATION TO SIMULATE SOIL WATER DYNAMICS IN A FLUVIAL PARK: COMPARISON BETWEEN CASCADE AND FINITE DIFFERENCE METHODS

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Introduction

A monitoring programme of the Provincial Administration of Mantova with the collaboration of the University of Padova has been underway since 1999 with the aim of reducing agricultural water pollution in the Mincio river park. One of the aims of the project was to evaluate the effect of Best Management Practices (BMPs) in the area. For this reason the CropSyst (ver 3.02.23) model, integrated into a GIS, was applied to the entire park territory (Stöckle, 2002).
A preliminary phase was necessary to evaluate the model's reliability and sensibility in simulating the cropping systems. In CropSyst water movement can be calculated by the simple cascade method (CM) and with the Richards equation solved numerically using the finite differences techniques (FDM). The objectives of this work were to evaluate the model's ability to simulate the soil water dynamic by comparing the two methods.

Methods

Monitoring was carried out on four farms representative of the most interesting landscape units in the park (table 1), between May 1999 and September 2001; these range from morainic hills in the north, characterised by gravelly soil with no water table, to the low-lying plain in the south, with heavy soils and shallow water table.
Various kinds of monitoring devices (ceramic plates, piezometers, etc.) were installed in the fields and water, soil and vegetation samples were collected periodically. Soil moisture was measured weekly using TDR probes in three different layers: 0-30, 30-45 and 45-60 cm.
On all farm, soil chemical and physical characteristics (soil texture, bulk density, soil water retention, surface infiltration) were measured at the start of monitoring. For farm 1, because of the high gravel content, the water retention characteristics have been corrected according to Bechini (1999). Soil moisture data were compared with CropSyst output. A rough calibration was carried out adjusting the saturated hydraulic conductivity, not directly measured in the field.

	Farm 1	Farm 2	Farm 3	Farm 4
Landscape unit	Morainic hills	Fluvial terraces	Medium plane	Alluvial plane
Usda taxonomy	Calcic Haplustalfs	Typic Ustochrepts	Calcic Ustochrepts	Calcic Ustochrepts
Gravel (%)	35	5.4	-	-
Soil texture	SA-L	SA-L, L	L	SI-C
Water table depth	-	150-300 cm	-	50-150 cm
Culture succession	-maize -meadow	-maize -meadow	-maize -ryegrass-maize -alfalfa	-maize -ryegrass-maize

Table 1 – features of the four farms in the Mincio river park.

The following indexes were used to evaluate the model accuracy:

$$E = \frac{100}{n} \cdot \sum_{i=1}^{n} \frac{P_i - O_i}{\overline{O}_i}$$

Relative Error

$$GASD = \sum_{i=1}^{n} \frac{|P_i - O_i|}{\overline{O}_i} \cdot \frac{100}{\overline{O}_i}$$

General Absolute
Standar Deviation

$$r = \frac{\sum_{i=1}^{n} (P_i - \overline{P}) \cdot (O_i - \overline{O})}{\sqrt{\sum_{i=1}^{n} (P_i - \overline{P})^2 \cdot \sum_{i=1}^{n} (O_i - \overline{O})^2}}$$

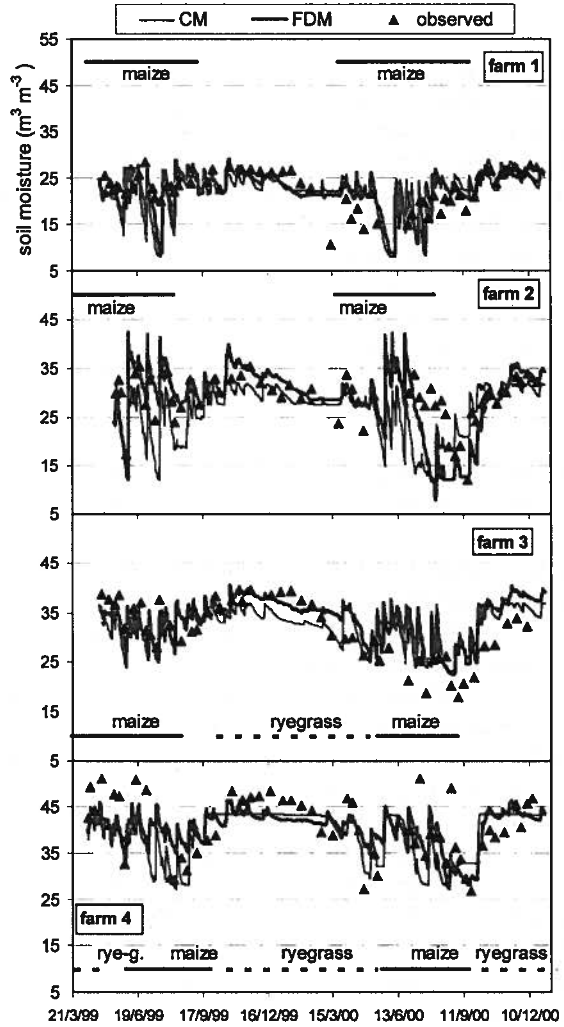
Coefficient of Correlation

P = simulated values
O = observed values

Results

Just the simulation of soil water content is presented (March'99- December'00) in the 0-30 cm layer for the following cultural successions: maize (farm 1 and 2), ryegrass-maize (farm 3 and 4). In farm 1, despite the high gravel content, the model behaviour was satisfactory (fig 1 and tab. 2) throughout the season, with the exception of spring 2000, when there was a clear difference between simulated and observed values. In farm 2 CropSyst fitted the observed values quite well, particularly with FDM (r = 0.66) (tab 2); instead, the CM underestimated (E = -10.11) the soil water content. In the farm 3, until may 2000, the model simulated the soil water dynamic very well, then there was a clear overestimation (fig. 1); however, even with the CM, the coefficient of correlation was still higher than 0.6. In the last farm both methods (CM and FDM) were able to explain most of the observed variation in soil water content, even if CM slightly underestimated the real values (tab 2). In this environment the model performances were improved considering the water table as lower boundary conditions.

Fig 1 – CropSyst daily simulated (FDM e CM) and observed values



Discussion

The FDM generally gave a better response in simulating the water soil dynamic, highlighting higher correlation (r) and less deviation (GASD) compared with observed values. CM, however, provided fair results because it is a simple transport model which only moves water downward as field capacity is exceeded. Taking into account that CM saves computer time and memory and requires few input parameters, it can be considered acceptable for territorial simulations.

Table 2 – statistical indexes of validation.

		n	mean O	var O	E	GASD	r
Farm 1	FDM	60	22.66	15.63	1.79	12.67	0.46
	CM	60	22.66	15.63	0.41	15.24	0.23
Farm 2	FDM	60	28.81	23.32	-4.66	12.93	0.66
	CM	60	28.81	23.32	-10.11	17.10	0.44
Farm 3	FDM	49	31.28	37.06	7.26	11.58	0.75
	CM	49	31.28	37.06	5.03	13.38	0.62
Farm 4	FDM	55	40.57	46.61	-0.33	11.14	0.60
	CM	55	40.57	46.61	-4.64	12.06	0.60

Reference

Stöckle C.O. and Nelson R., 2002. *Cropsyst User's manual*, 119-141.
Bechini L., 1999. *PhD Thesis*.

CALIBRATION AND TESTING OF THE CROPSYST MODEL FOR SIMULATING SOIL WATER DYNAMICS UNDER TOBACCO

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Introduction

CropSyst is a multi-year, multi-crop, daily time step crop growth simulation model which was developed with the objective of serving as an analytical tool to study the effect of cropping-system management on crop productivity and the environment (Stöckle and Nelson, 1996). Within the framework of a European research project, this model was selected for simulating the effect of N fertilisation on tobacco crop growth and soil nitrate leaching risk. Since tobacco was not included in the original model's crop pool, calibration and testing at a local level are preliminary steps to the application of the model for practical purposes.

Methods

Field experiment. It was carried out in 1998 and 1999, at the Experimental Tobacco Institute, Bovolone (Verona, Italy), on flue-cured tobacco, cv K326. Fertilised (4 N levels) and unfertilised plots, with 2 replications (10 plots in all) were compared. Water supply and management practices were kept at technically optimal levels. Time course measurements needed for the evaluation of the crop parameters and of the above-ground plant biomass (AGB) were collected weekly in each plot from individual plants, with 2 replicates. Gravimetric soil water content in 0.2-m layers down to 0.8-m depth was monitored weekly from the crop transplanting date until the last harvest event.

Model calibration and testing. On a economic yield basis, environmental conditions were more suitable to the tobacco crop in 1998 than in 1999. Therefore, for calibration purposes, the 1998 field measurements in the fertilised plots were used. All the crop parameters considered as crucial for the crop simulation were determined from measurements. Selected outputs from simulations with measurement-based crop parameters were compared with those obtained by partial parameter calibration. This calibration was made by substituting 2 measured parameter values (biomass/transpiration ratio= 3.8 kg kPa m^{-3}, and canopy global radiation extinction coefficient = 0.3) with values (6.0 kg kPa m^{-3} and 0.45, respectively) included in the range suggested by the model's user manual. The calibration option producing the best fit of the estimates to the measurements was applied to test the model, using the 1999 dataset (10 plots), and to evaluate the model efficiency in simulating soil water content, which is preliminary to the correct simulation of nitrate leaching. Two model options for simulating water infiltration, that is cascade and finite differences, were compared. Measured hydrological parameter values were used with the cascade option, while they were estimated by the model with the finite difference one. Model efficiency in simulating soil water content was determined using the mean value of the measured and simulated soil water content in the 10 plots at the various sampling dates (24 dates in 1998, 23 in 1999) and soil depths (4 depths).

Results

Model calibration. The table compares the results obtained using the measurement-based set of parameters with that including 2 calibrated parameter values. The partial calibration allowed a remarkable reduction of the estimate error.

Model testing. The model error in simulating AGB, using partly calibrated parameter values and the cascade method, was of the same order, in 1999, as that of 1998, even though the sign of the mean difference between observed and measured values was opposite.

Soil water content simulation. The two infiltration submodels, cascade and finite differences, gave on the whole quite similar results. In 1998, the higher underestimation of the soil water content with the finite difference submodel, which probably brought about the higher AGB estimate error, could be associated with the unsuitability of the model-predicted hydrological parameter values, in these experimental conditions.

The unsuccessful crop calibration results, obtained by using measurement-derived parameter values, may be due to the fact that the functions describing crop growth, originally developed for simulating very common crops, such as maize and sorghum, may not be suitable for describing the tobacco crop growth pattern, which is indeed peculiar. In fact crop coefficients, for the most common crops, have much higher values than those which were experimentally determined for the tobacco crop. The difficulty of generalising the adoption of measurement-based parameter values may also arise from the fact that parameters, such as radiation-use efficiency and specific leaf area, which are expected to have a constant value, sometimes have not (Ceotto and Castelli, 2002).

Model evaluation statistics.

Condition	Year	Crop parameters	Output	MEAN		RMSE	MD	n
				observed	predicted			
Model calibration	1998							
Cascade		measured	AGB	933	55	94.1	+878	8
			LAImax	4.23	0.34	93.1	+3.89	8
Cascade		partly calibrated	AGB	933	863	8.9	+70	8
			LAImax	4.23	4.15	13.6	+0.08	8
Finite differences		partly calibrated	AGB	933	690	27.9	+244	8
			LAImax	4.23	4.08	14.4	+0.14	8
Model testing	1999	partly calibrated						
Cascade			AGB	834	906	10.7	−71	10
			LAImax	4.20	4.01	9.6	+0.19	10
Finite differences			AGB	834	892	9.7	−57	10
			LAImax	4.20	4.15	9.1	+0.05	10
Model testing		partly calibrated						
Cascade	1998		SW	0.234	0.218	13.5	+0.017	96
	1999		SW	0.246	0.268	14.2	−0.022	96
Finite differences	1998		SW	0.234	0.188	23.9	+0.046	92
	1999		SW	0.246	0.227	13.9	+0.019	92

AGB, above-ground biomass (g m^{-2}); LAImax, maximum leaf area index (m^2 m^{-2}); SW, soil water content (m^3 m^{-3}). RMSE, root mean square error (Loague and Green, 1991); MD, mean difference between observed and predicted values; n, number of data pairs.

Conclusions

Even though the empirical calibration of few parameter values allowed the achievement of good model performances, from the crop physiologist's point of view the model clearly needs to be specifically adapted for the simulation of the tobacco crop growth, since measurement-based coefficient values do not allow a good fit of simulated to measured biomass values to be obtained.

References

Ceotto E., Castelli F., 2002. Field Crops Research, 74, 2-3, 117-130

Loague K., Green R.E., 1991. Journal Contaminant Hydrology, 7, 51-73

Stöckle C.O., Nelson R.L., 1996. CropSyst user's manual. Dep. of BSE, WSU, Pullman, WA, USA

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PREDICTION OF SOIL CARBON EVOLUTION IN AGRICULTURAL FIELDS

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Introduction

Predicting the evolution of soil organic carbon (SOC) is an important challenge to evaluate the potential of C sequestration in soils, improve N fertiliser recommendation methods and assess the sustainability of agricultural systems. Long-term field experiments are essential to test the capacity of our models to simulate the dynamics of organic C in soils. This work aims at: i) analysing the data obtained in a 30 year-old field experiment, varying in organic matter returns and soil tillage practices; ii) calibrating and evaluating a simple simulation model on this experiment; iii) evaluating the model in agricultural conditions in Northern France.

Material and Methods

This paper considers two data sets: i) a long term experiment conducted by ITCF since 1970 at Boigneville (France); ii) a data base of soil analyses made in agricultural fields several times during the period 1970-1998 in Picardie (Northern France).

The Boigneville experiment includes 2 main rotations: maize-wheat and continuous wheat. Each rotation has been either 'conventionally tilled' (CT), superficially tilled (ST) or no-tilled (NT). Harvest yields were recorded every year. Soil measurements were realised at several dates between 1970 and 1998. They consist in bulk density, total N, organic C, total C and natural ^{13}C abundance at different depths up to the deepest plough layer. Calculations of C stocks were made up to a soil mass of 3900 t ha^{-1}, corresponding to the maximum ploughing depth.

The Picardie data base came from a soil analysis laboratory (Station Agronomique de l'Aisne, Laon). We selected farmers fields which had been analysed at least 3 times between 1970 and 1998, and whose C contents showed a consistent trend with time. The C stocks were calculated over a constant depth (30 cm) using a bulk density specific of the soil type. A linear regression was made to obtain the mean annual variation in C content.

The data obtained in the two data sets were compared to the outputs of a simple model (called AMG) simulating the evolution of organic C in the long-term. The model considers two fractions of humified organic matter, one of which is active and the other is almost stable (Mary & Guérif, 1994). It has three parameters: the amount of stable fraction (Cs), the humification coefficient (k_1) and the decomposition rate constant of the active fraction (k). It was previously used to predict SOC evolution in the Argentina's pampa. (Andriulo *et al.*, 1999).

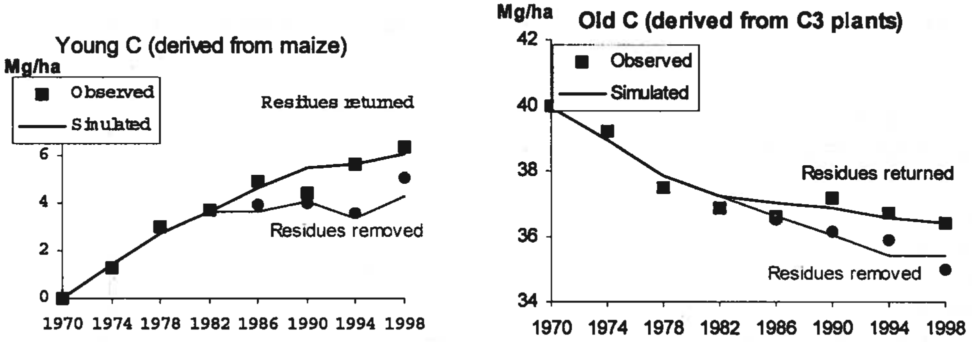
Results and discussion

1. Boigneville experiment. The general trend for both rotations was a slight increase in organic C vs. time and vs. reduced tillage. In the maize-wheat rotation, with a full return of crop residues, the increase in SOC was 2.8, 5.7 and 4.7 t ha^{-1} in the CT, ST and NT treatments respectively (Table 1). Reduced tillage had increased soil C at a rate of 0.09-0.11 t ha^{-1} yr^{-1}.

		CT	ST	NT
1970		39.9 (1.7)	39.9 (0.8)	40.2 (0.9)
1998	Crop residues returned	42.7 (0.6)	45.6 (1.1)	44.9 (2.3)
1998	Crop residues exported*	40.0 (2.1)	43.1 (1.1)	41.7 (2.4)

Table 1: Amounts of organic carbon (t ha^{-1}) in the ploughed layer of the maize-wheat rotation vs tillage practice. Confidence intervals in brackets. *Crop residues exported from 1982 to 1994.

The natural ^{13}C abundance technique was applied to determine independently the incorporation of maize derived C into SOC (humification coefficient k_1) and the decline of 'old' carbon (rate constant k).



The AMG model was calibrated on the maize-wheat rotation, in the treatment with full return of crop residues. The results indicated that the effect of reduced tillage was to lower both the decomposition rate of SOC (k) and the humification rate (k_1) of crop residues. The model was then evaluated on the same rotation in the treatment with crop residues removed during 1982-1994. Satisfactory simulations of the SOC kinetics were obtained (Figure 1), suggesting that the effect of crop residues could be well predicted.

Figure 1. Observed and simulated amounts of 'young' and 'old' SOC fractions (calculated using $\delta^{13}C$ measurements) in the maize-wheat rotation at Boigneville, with or without return of crop residues. Total SOC is the sum of young and old fractions.

2. Picardie data base. The analysis of the data base indicated that among the 391 situations retained, SOC was found stable in 49%, had decreased in 29% and had increased in 22% of the situations (Wylleman *et al.*, 2001). SOC has decreased in fields which either had high initial SOC contents (45-75 t ha^{-1}) or which were cropped with a large proportion of low returns crops (potatoes, sugarbeet). SOC increases were found in fields which had low initial SOC contents (25-35 t ha^{-1}).

The AMG model parameterised on Boigneville experiment was used to simulate the Picardie data base. The model was able to explain 60% of the variance of the changes. It slightly underestimated the observed changes (Figure 2). However it behaved much better than the classically used Hénin-Dupuis' model which explained only 34% of the variance and severely underestimated the actual changes in SOC in these agricultural fields.

The model appears as a valuable tool for predicting SOC changes vs time and as a function of agricultural practices. It is now being implemented in France.

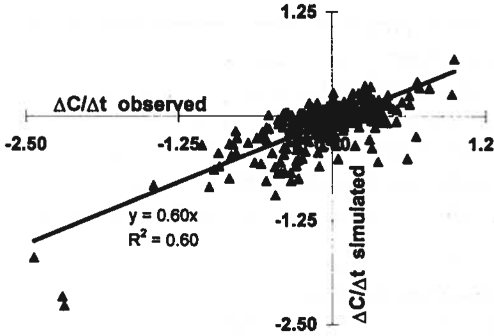


Figure 2. Simulated variation of SOC (t C ha^{-1} yr^{-1}) using AMG model vs. actual variation measured in Picardie fields during 1970-1998 (311 fields).

References

Andriulo A. *et al.*, 1999. *Agronomie*, 19: 365-377.

Mary B. and Guérif J., 1994. Intérêts et limites des modèles de prévision de l'évolution des matières organiques dans le sol. *Cahiers Agricultures* 3: 247-257.

Wylleman R. *et al.*, 2001. Evolution des stocks de matière organique dans les sols de grande culture: analyse et modélisation. *Perspectives Agricoles* juillet-août 2001, 270, 8-14.

ANALYSIS OF THE INFLUENCE OF DIFFERENT ENVIRONMENTAL FACTORS ON CROP GROWTH

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Introduction

Solar radiation, evapotranspiration, temperature and availability of nutrients are the main factors conditioning plant production in the absence of weeds, diseases and other biotic limiting factors. Influence of the environment on crop growth is well described in literature (for example Stanhill, 1986, Sinclair and Muchow, 1999), however each different environmental factor can represent the main aspect that influences crop growth.

Daily crop growth rate in CropSyst is calculated choosing the minimum value between the potential growth limited indipendently by radiation, water and nitrogen. Without considering nutrient availability, establishing correct relationship between Radiation Use Efficiency and Water Use Efficiency is the key to tune the role of the different processes influencing growth.

Material and Methods

Evolution of biomass and LAI were measured in maize, wheat and soybean during the period 1997-2001 in a eight year experiment running in Lombriasco (Northern Italy). Meteorological data were recorded during the same period.

Parameter	Unit	Maize	Soybean	Wheat
Light to biomass conversion	g MJ^{-1}	3.5	2.4	2.9
Extinction coeff. for solar radiation		0.50	0.50	0.45
Biomass - transpiration coefficient	kg kPa m^{-3}	10.0	4.5	4.5
Optimal temperature for growth	°C	25.0	20.0	10.0
Thermal time base temperature	°C	10.0	10.0	0.0

Management was quite constant through the different years in the different crops. Maize and soybean received 2 or 3 irrigations of about 60 mm each, while wheat was not irrigated.

CropSyst (Stockle and Nelson, 1998) was used to simulate the crop growth without considering nutrient cycling. Crop parameters used in the simulation are reported in the table. Parameters were chosen from literature and calibrated only in the case of the biomass-transpiration coefficient.

Results

Figure 1 reports the results in terms of simulated *vs.* measured values of accumulated biomass at

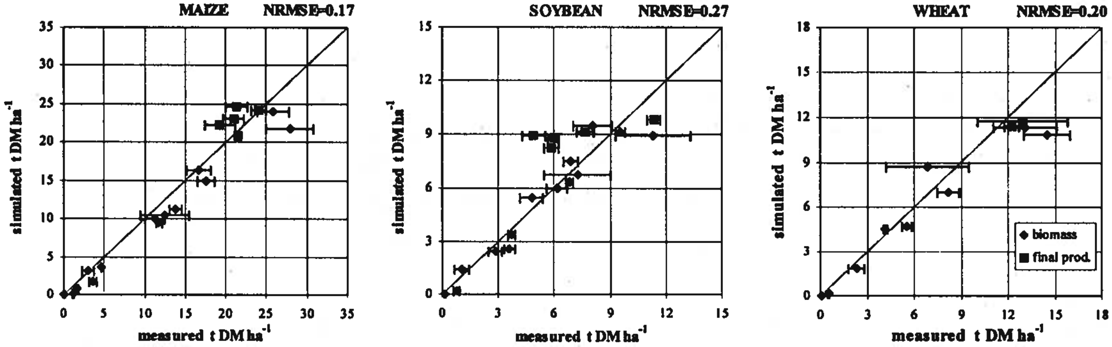

Figure 1: Simulated *vs.* measured values of accumulated biomass and final production in different crops considering date recorded during the entire period (1997-2001 in maize and soybean, 2000-2001 in Wheat).

different growth stages and of final production. Data are referred to the different years. The graph shows a good performance of the model for all crops. NMRSE values range between 17 and 27%. Maize is the crop best predicted by the chosen parameters. Final production tend to be overestimated, above all in soybean. This is due to the frequent loss of biomass at maturity (mainly leaves, but also grains) not simulated by the model.

The good agreement between simulated and measured data shows also a good interpretation of main growth processes dependent on environmental factors through different years and variable climatic conditions.

Figure 2 shows between years variability of potential production of maize due to differences in evapotranspiration and in radiation. Similar data were obtained for the other crops. The effects of temperature are not shown because highly correlated with radiation.

Potential production curves identified with (1) represent the maximum production obtainable each year as limited only by evapotranspiration process (Daily CGR = ETP VPD^{-1} WUE). Production curves identified with (2) represent maximum production as limited by transpiration process therefore by the evolution of LAI and the variation in crop coefficient (kc). Finally, production curves identified with (3) represent evolution of biomass as simulated by the model and limited not only by transpiration, but also by radiation. Crop water stress never occurred.

Graph (1) shows a higher potential production of 1999 in respect to 2001 and 1997. However graph (2) shows that potential production controlled by transpiration in 2001 is very similar to 1997 because of a lower crop canopy development at the beginning of the 2001 growing season. Finally considering also solar radiation (graph 3) the classification of the different years changes: the most productive year is 2001 (as it was in reality) due to higher radiation availability.

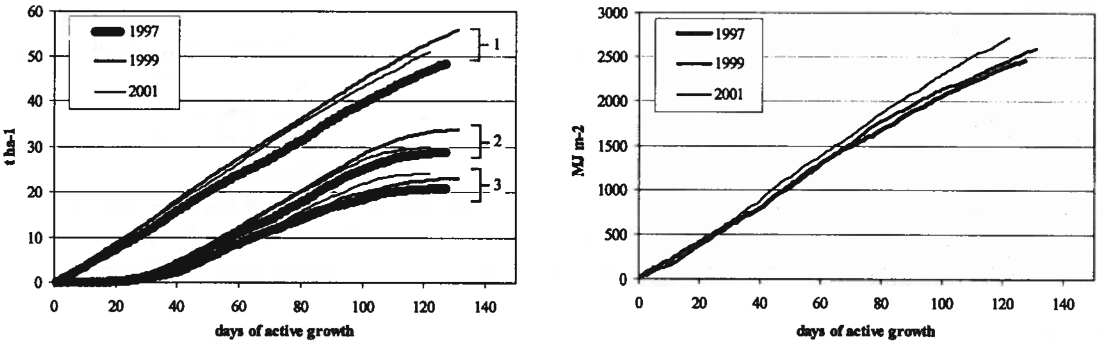

Figure 2: On the left data referred to maize of (1) potential production limited only by ETP, (2) potential production limited also by transpiration process according to developped LAI (as output of model) and (3) actual production as simulated by the model considering also solar radiation. On the right: solar radiation.

Conclusions

Accumulated biomass and final production of maize, soybean and wheat simulated during a period characterised by different potential evapotranspiration and solar radiation show a good agreement with measured data. NMRSE ranges between 17 and 27% in the different crops.

The reported list of parameters used for the simulation leads to a good understanding of the relative importance of each process determining crop evolution and total biomass production.

References

Stanhill, G., 1986. *Water use efficiency*. Adv. Agron. 39, 53 – 85.

Sinclair, T.R., Muchow, R.C., 1999. *Radiation use efficiency*. Adv. Agron. 65, 215-265.

Stockle, C.O., Nelson, R.L., 1998. *CropSyst, cropping system simulation model. User's Manual.* Department of Biological System Engineering, Washington State University, Pullman, Washington.

COTTON CROP COEFFICIENTS UNDER ADVECTIVE CONDITIONS

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Introduction

The horizontal transport of heat and humidity resulting from a heterogeneous surface is very pronounced in arid and semi-arid regions, due to the fact that local irrigating wet patches are surrounded by dry lands. The resulting transport can increase the evaporation rate and distort the energy balance in the wetter regions.

Several studies (i.e. Brakke et al., 1978; Philip, 1987) have suggested, on the one hand, that the evaporation rate is large close to the boundary separating a dry from a wet surface and, on the other hand, that it decreases smoothly downwind from the leading edge. These studies have been made under the assumption of constant surface resistance for the downwind surface.

However, recent studies have suggested a feedback interaction between the saturation deficit and the stomata that keeps the downwind evaporation rate within rather narrow limits (i.e. McAneney et al., 1994; Brunet et al., 1994; Zermeno-Gonzalez et al., 1997).

The aim of this research was to analyze the behavior of the cotton crop coefficient (ratio of evapotranspiration to reference evapotranspiration) in local advection conditions and the influence of stomatal conductance on this coefficient.

Methods

Throughout August 2001, daily means of the maximum values for the crop coefficient (Kc) were obtained from three commercial cotton plots, all of them located in the same irrigation district inside the valley of the Guadalquivir (SW Spain). These plots were selected according to contrasting surrounding conditions: the first one could be considered a representative "non-advective" plot, in contrast with the other two which were typical of advective conditions.

The first was selected, on the one hand, because of its relatively upwind wet surroundings and, on the other hand, because of its large dimensions (18 ha in size). Under these boundary conditions, it was assumed that the "non-advective" conditions were obtained to a very large extent at the inside of the plot to a place sufficiently separated from the edge.

The data obtained from this "non-advective" plot were compared with data from other two plots considered as "advective". These two plots were selected for the growth state of the crop (similar to the "non advective plot"), for their relatively dry surroundings upwind of the plots, and for their size (small enough to analyze the effects of the local advection and large enough to achieve a height of equipment/fetch ratio not lower than 1:100).

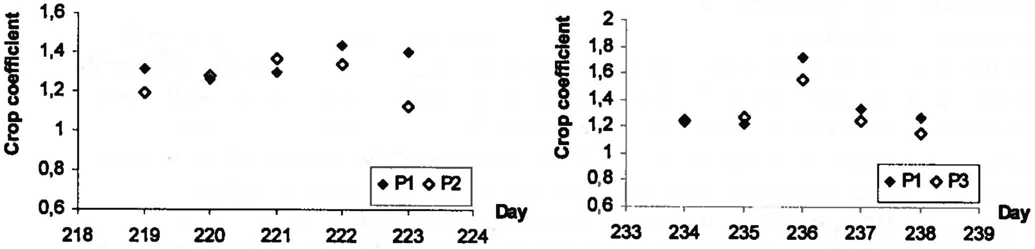
Kc was calculated as the ratio crop evapotranspiration (ET)/ reference evapotranspiration (ETo). All the energy balance components (including ET) were measured as follows: Sensible and latent heat fluxes (H and LE) were measured by the eddy covariance method (Swinebank, 1951), using air temperature, water vapor and vertical wind velocity fluctuations, respectively. Net radiation (R_N) was measured directly with a net radiometer. Soil heat flux (G) was estimated using measured values of heat flux at 0.05 m depth, soil water content (0-5 cm) and soil temperature changes at 2.5 cm. Measurements of leaf area index (LAI) using a LAI2000 sensor and stomatal resistance using a porometer were also performed. Canopy temperature was measured using an infrared thermometer.

ETo was estimated according to the adjusted expression of Penman-Monteith for a grass reference crop (Monteith, 1965), using hourly data measured by an automatic weather station located in the irrigation area.

Results

Hourly crop coefficients were calculated and, when compared for each day of study, similar values for all plots were found. For these reason, hourly fluxes of LE and H were compared, but not significant discrepancies were found either. The following step was to study the canopy resistance for the daytime hours, and the values found for the "advective" plots were higher than those for the "non-advective" plot. Finally, the values of the stomatal resistance measured in each of the plots were compared. The stomatal resistance for the plots considered to be "advective" resulted to be higher than that for the "non advective" plot.

Daily crop coefficients for the "non-advective" plot (P1) compared with the "advective" plots (P2 and P3)



Conclusions

The advection of sensible heat in homogeneous weather areas is divided in regional and local advection. The regional advection causes the same variation in Kc for all the irrigated crops in the area. However, the local advection caused by dry areas surrounding well irrigated crop plots, leads to an ET increase (smaller whichever grater is the distance to the plot edge) and therefore, an increase of the stomatal resistance to make up for this effect.

When the plot is large enough it has been found out that the greater the distance to the edge, the lower the value of the ET until a horizontal homogeneity is established. On the contrary, when the plot is not large enough, a stomatal reaction takes place in order to decrease the ET loss far and wide the plot due to the fact that there is not enough distance to reach the horizontal homogeneity. Therefore, as opposed to Allen et al. (1998) we have found out that given a region characterized by homogeneous weather conditions, the actual crop coefficient for regions surrounded by dry areas is not necessarily greater than that for plots surrounded by wet areas. Before applying any general conclusion, it is necessary to carry out a local study of crop coefficients behavior under local advective conditions.

References

Allen et al., 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper no. 56. FAO, Roma. 300 p.
Brunet et al., 1994. Agric. For. Meteorol., 71: 227-245.
Brakke et al., 1978. J. Appl. Meteorol., 17: 955-963.
McAneney et al., 1994. J. Hydrol., 161: 375-388.
Monteith, J.L., 1965. Evaporation and environment. In: The state and movement of water in living organisms.19th Symp. Soc. Exp. Biol., 205-234. Swansea,Cambridge University Press
Monteith, J.L., 1973. Principles of Environmental Physics. Edward Arnold, London. 241 pp.
Philip, 1987. Irrig. Sci., 8: 101-114.
Swinebank, 1951. J. Meteorol. 8: 135-145.
Zermeno-Gonzalez et al., 1997. J. Hydrol., 192: 189-210.

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COTONS® - SIMBAD: A TOOL FOR ESTABLISHING COTTON BOLLWORM ECONOMIC DAMAGE THRESHOLDS

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Introduction

Defining economic damage thresholds for cotton pests is a complex undertaking, since cotton growth is indeterminate and the plant can compensate for the loss of fruiting organs. A given population of insects can cause varying yield losses, depending on whether or not the crop is able to compensate for damage. The multiple interactions between the environment, the crop management sequence, plant growth and pest population dynamics make it difficult to establish damage thresholds using a conventional experimental approach in the field. The recent progress made on the Cotons® model of cotton development (Jallas *et al.*, 1999) has paved the way for a clearer understanding of the interactions between the plant and pests.

The Simbad (SIMulation of Bollworm Attacks and Damage) model was developed with a view to modelling the demography and feeding behaviour of the main four African species of cotton bollworms (*Helicoverpa armigera, Diparopsis watersi, Earias* spp. and *Spodoptera littoralis*). Coupling the COTONS® and SIMBAD models allows an assessment of yield losses due to bollworm attacks, depending on parameters such as the size and species composition of the pest population, date of the attack, potential yield of the crop, etc. The final aim is to develop decision support tables that can be used to trigger insecticide treatments, depending on the target yield, production potential, climate scenarios, etc. The tables obtained will then be tested on smallholdings.

Simbad is structured around three sub-models:

- a demographic model, which simulates the changes in bollworm numbers depending on temperature and natural mortality;
- a feeding preference model, which determines the type and position of organs likely to be attacked by bollworms;
- a voracity model, which determines the number of organs eaten.

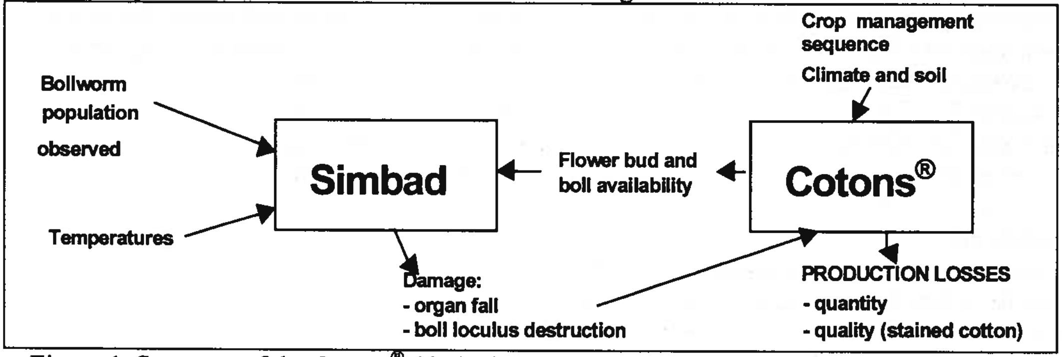

Figure 1. Structure of the Cotons®-Simbad model combination

Methods

The approach adopted to define economic damage thresholds consists in converting the cost ha^{-1} of an insecticide treatment into the weight of cottonseed ha^{-1} corresponding to that value, and determining the number of bollworms capable of causing a yield loss equivalent to the cost of treatment.

Simulations were carried out by steadily increasing the number of bollworms (first-instar *H. armigera* bollworms) per hectare from 1000 to 100000. This sequence of simulations was repeated every seven days, from 48 days after emergence (DAE) to 118 DAE. The fluctuations in threshold values were assessed by drawing contour plot graphs showing bollworm numbers, dates of attack and yields. The graphs were generated using the SAS G3GRID procedure (SAS Institute, 1990).

Two types of treatments were considered: either a pyrethroid + organophosphate (OP) combination or an endosulfan treatment. The costs in cottonseed equivalent for pyrethroid + OP combination and endosulfan are 13 kg ha^{-1} and 40 kg ha^{-1} respectively (insecticide costs and cottonseed purchase price for the 2000 season).

The data sets used for the soils and climate were those for the Maroua-Guiring farm during the 2000 season. The crop management sequence used corresponded to the recommended sequence for the far North of Cameroon (variety, planting density, fertilizer applications...).

Results

Figure 2 gives an example in which the yield / bollworm numbers relation is relatively constant. However, in some situations (see figure 1), this relation is less consistent, with alternate periods with and without yield losses in the event of increased bollworm numbers. A look at the contour plot graphs of the results enables a clearer understanding of some of the fluctuations in threshold values, and possibly also smoothing of the results.

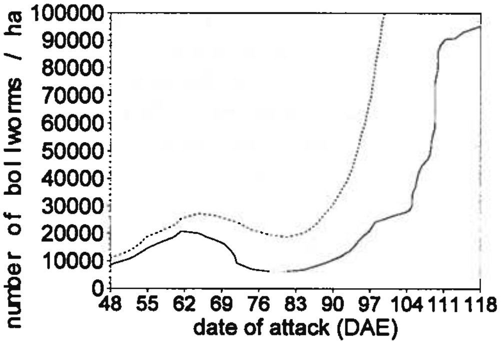

Figure 1. Yield patterns according to the date of attack and number of bollworms, for plants that emerged on 15/06. Solid line: contour plot for 1466 kg ha^{-1} (threshold for treatment with a pyrethroid/OP combination), dotted line: contour plot for 1439 kg ha^{-1} (threshold for treatment with endosulfan)

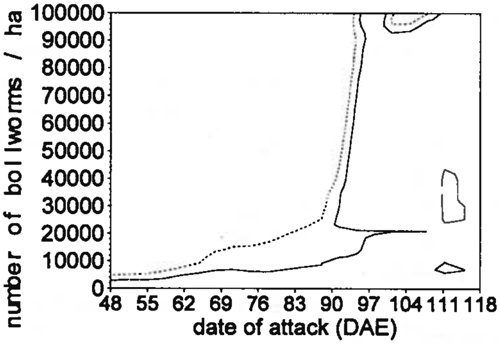

Figure 2. Yield patterns according to the date of attack and number of bollworms, for plants that emerged on 15/07. Solid line: contour plot for 1100 kg ha^{-1} (threshold for treatment with a pyrethroid/OP combination), dotted line: contour plot for 1074 kg ha^{-1} (threshold for treatment with endosulfan)

Conclusions

The results shown here are examples that illustrate the possibilities of using the Cotons® -Simbad combination. There is still a considerable amount of work to be done before establishing tables of recommendations for testing on smallholdings.

References

JALLAS E. et al. 1999. Cotons®, une nouvelle génération de modèles de simulation des cultures. Agriculture et développement, 22: 35-46.

SAS Institute. 1990. *SAS/GRAPH Sofware: Reference, version 6, first edition, volume 2.* SAS Institute Inc., Cary, North Carolina, USA, 664 p.

PHOTOSYNTHESIS AND PRODUCTIVITY OF *ZEA MAYS* ESTABLISHED UNDER PLASTIC

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Introduction

Forage maize can be an important crop for supplementing livestock rations over winter. The first evaluation of maize for this purpose in Ireland took place between 1971 and 1975, with little success, but the development of early maturing varieties that were less susceptible to the lower temperatures prevailing in Northern Europe has resulted in a re-examination of their agronomic potential (Crowley, 1998). Maize production has subsequently increased in significance in Ireland since 1982 and most is grown under photodegradable plastic film, which provides a microenvironment that may enhance establishment and growth and speed up maturity (Keane, 1997). To date, however, there is little information on the physiology of maize, a C_4 species, which has been established in this way. Our objective was to examine photosynthesis and productivity of maize varieties established under plastic in order to improve our understanding of the benefits of this practice with a view towards the selection of the most suitable varieties.

Methods

Field work was carried out on the UCD Lyons research Farm between April and August 2001 using a perforated plastic cover system and four maize varieties, Hudson, bred in the Netherlands, Avenue and Nancis, bred in France and Ethiopian, bred in Ethiopia. In this system the seeds were sown through the perforations in the plastic in April. Six weeks after planting the number of seedlings germinated were counted. Photosynthetic responses to light were measured using an infra-red gas analyser with a Parkinson leaf chamber and an artificial light source (CIRAS-1, PP Systems, Hitchin, UK) three times during the growing season with similar results. Only the results for the first series of measurements made in May are reported here. The third leaf of each variety was sampled using ambient carbon dioxide concentrations, a leaf temperature of 20°C and a VPD of ~0.7kPa. Fluorescence measurements were made using a modulated fluorometer (FMS 2, Hansatech, King's Lynn, UK) on the same leaves as those used for the photosynthesis determinations. Temperature and humidity were measured using miniature dataloggers (Tinytalk/Tinytag). Standing biomass was measured in August on individual plants after drying in a force-draft oven at 85°C.

Results

Microclimate under the plastic

Significant increases in relative humidity and temperature were found below the plastic in comparison to uncovered bare ground. Daily relative humidity beneath the plastic rarely fell below 90% and air temperatures reached a high of ~30°C in June.

Germination

Germination varied from a low of 10% for the Ethiopian variety to a maximum of 50% for the variety Hudson.

Photosynthesis, stomatal conductance and respiration

Maximum photosynthetic rates varied from 10-14 μmol m^{-2} s-^{1}, and stomatal conductances from 60-80 mmol m^{-2} s^{-1}, with little variation between the varieties. Similarly, there was no evidence of any differences in photosynthetic water-use efficiency. There was also no evidence of light saturation of photosynthesis in any of the varieties even at light levels as high as ~2,000 μmol m^{-2} s^{-1}, considerably in excess of the average light levels to which the plants are normally exposed under these conditions. Dark respiration rates varied from 1.25-2.0 μmol m^{-2} s^{-1}.

Fluorescence measurements

Little variation in fluorescence parameters measured in the light was observed, although significantly lower values for the dark-adapted ratio of variable (F_v) to maximum (F_m) fluorescence were found in the variety Nancis.

Biomass production

Total dry biomass production per plant varied from ~130-221 g, with the Ethiopian variety exhibiting the highest values, although this variety did not produce any reproductive structures. The higher shoot mass was associated with an increase in both leaf and stem structures. Little variation was found in root biomass and the Ethiopian variety also had the highest shoot:root ratio.

Conclusions

Clearly a major factor limiting maize production under these conditions is successful establishment, even when grown under plastic. Whilst the Ethiopian variety showed poor germination it out-yielded the other varieties in terms of vegetative production, although it never reached reproductive maturity. One goal, therefore, is to improve seedling germination and establishment, this may, in turn, increase the chances of earlier maturation. Differences in yield were not correlated with photosynthetic rates, measured by gas exchange, or photochemical capacity, as measured using fluorescence. There was, however, some evidence based on dark-adapted measurements of F_v/F_m, that Nancis may be more susceptible to environmentally-induce reductions in photochemical efficiency. Rather surprisingly little variation in carbon assimilation was found, despite the different geographic origins of the experimental material and light saturation of photosynthesis was not observed. Whether this is due to an inherent characteristic of these maize varieties or is associated with establishment under plastic requires further examination. Of the factors that could have lead to the higher yields in the Ethiopian variety are the increased leaf and stem areas. The higher shoot:root ratio of the Ethiopian variety could lead to an increased susceptibility to water deficits under these conditions, where the plastic restricts water penetration, as there was no evidence of a higher water-use efficiency. Comparative experiments, using different coverings, together with fully exposed treatments are required to examine this and other factors relating to the merits of growing maize under plastic in these environments.

References

Crowley, J. G. (1998). Growing maize under photodegradeable polythene film: effect of film type. *Proceedings of the Agricultural Research Forum*, University College Dublin, pp. 285-286.

Keane, G. P. (1995). The influence of plastic on maize yield and quality. *Proceedings of the Agricultural Research Forum*, University College Dublin, pp. 239-240..

FILLING THE GAPS IN TIME SERIES FROM A FARM METEOROLOGICAL STATION

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Introduction

In Quinta da França, (7.26W, 40.16N) a farm located near Serra da Estrela, Portugal, there is a meteorological station active since August 2000. Values of the air temperature, relative humidity, total solar radiation, wind velocity and direction, soil temperature at 1, 5 and 10cm depth are sampled every minute. The half an hour mean values of these variables are stored together with total precipitation and atmospheric pressure. This meteorological data is collected through a modem via mobile phone.

Due to factors like: storms, high relative humidity and excessive heat, among others, meteorological data is lost and studies such as crop growth prediction, accumulated precipitation, etc, become compromised.

Methods

Gaps in meteorological data must be filled before these data can be used for hydrological and meteorological applications. We fill these gaps with the results of the mesoscale model MM5. This model was developed at Pennsylvania State University and National Center for Atmospheric Research (USA) and is used for meteorological prediction and related studies such as pollution and climate. The characteristics of MM5, namely being nonhydrostatic and having a coordinate system that follows the terrain, makes it a good candidate to model meteorological data at the small scale (Dudhia, 1993).

At Instituto Superior Técnico, Lisbon, this model is implemented for Portugal in a 9 km grid and the meteorological predictions are available at an internet site (http://jddomingos.ist.utl.pt/~sae). The model is being validated with observations of Lisbon, Porto and Faro surface stations, made available to us by the National Weather Service (USA), and with observations recorded by the surface station located in Quinta da França.

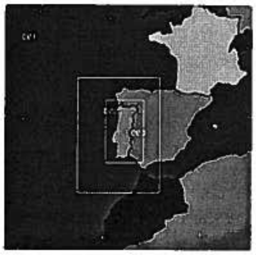
MM5 has been optimized to this farm, namely choosing the correct physical parameterizations for precipitation, sun radiation and boundary layer; improving the topography, ground coverage; initial conditions and refining the grid. Four dimensional data assimilation will also be tested. Results of the optimized MM5 model will be compared with observations at Quinta da França to compute meteorological bias. The filling of gaps in meteorological time series will be made with these predicted results.

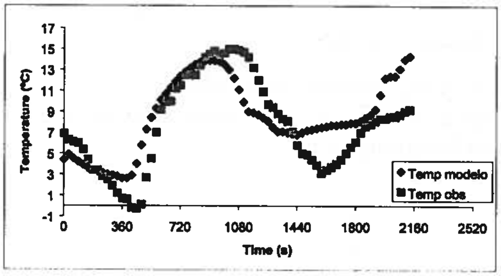
Preliminary Results and Conclusions

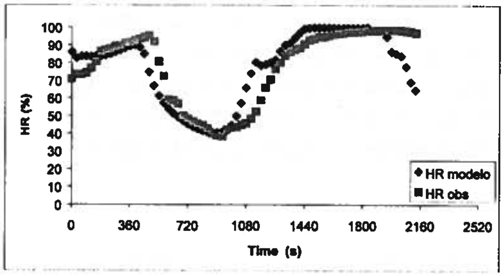
The primary tests done for Quinta da França were made for the 4th and the 5th of April 2002 with several domain sizes and different terrain resolutions. All the simulations were done with three domains running together in a two way nesting. The number of vertical levels is 23, the nest distances are 81 km, 27 km and 9 km and the results report to the smallest domain (9 km). The physical parameterization for each are presented and explained in Dudhia et all (1995 and 2000).

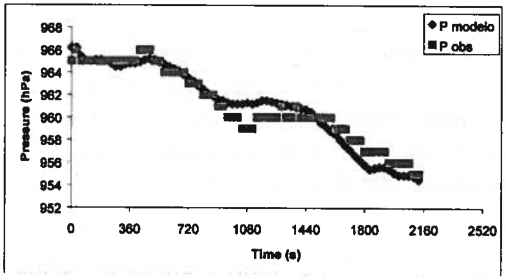
Nest Size (km)	81	27	9
Time step (seconds)	243	81	27
Cumulus Parametrizations	Grell	Grell	Grell
Boundary Layer	MRF	MRF	MRF
Explicit Humidity	Simple Ice	Simple Ice	Graupel
Radiation	Clouds	Clouds	Clouds
Ground Temperature	5 Layers	5 Layers	5 Layers

With the domains shown, the topography and land use resolutions of respectively 19, 9 and 4 km and for the mentioned period the results are presented. The first tests show good results concerning pressure, temperature and relative humidity. The variables, which show the largest difference towards observations, are wind direction and wind velocity, thought they are better simulated with larger wind speed. The likely explanation for this behavior is the strong variation of topography due to the very near mountain of Serra da Estrela. This is supported by the fact that in Lisbon, Porto and Faro the wind (specially the direction) is better simulated by MM5.

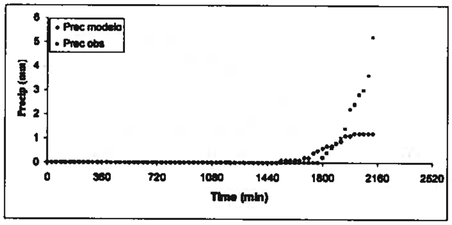








With the results got so far the only variable that shows significant improvements with domain size and terrain resolution is pressure. Precipitation is shown bellow.



References

Dudhia, J., 1993: A Nonhydrostatic Version of the Penn State –NCAR Mesoscale Model: Validation Tests and Simulation of an Atlantic Cyclone and Cold Front. Montlhy Weather Review, 121, 1493-1513.

Dudhia, J.,Grell, G., Stauffer, D., 1995: A description of the Fifth-Generation Penn State/NCAR Mesoscale Model (MM5). NCAR TECHNICAL NOTE.

Dudhia, J., Gill, D., Guo, Y., Manning, K., Wang, W., Chiszar, J., 2000: Mesoscale Modeling System Tutorial Class Notes and User's Guide: MM5 Modeling System Version 3, PSU/NCAR.

A WATER BALANCE MODEL CAN BE USED TO EVALUATE THE WATER STRESS EXPERIENCED BY A CROP IN FARMER'S FIELDS : A CASE STUDY IN VINEYARDS IN SOUTH-EASTERN FRANCE.

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Introduction

Evaluation of the water stress experienced by a crop in farmer's field should provide information on the periods of water deficit and on its intensity in order to diagnose its effect on yield determination and quality. In vineyards, as for many crops, extensive research has been conducted to identify plant measurements (e.g. predawn water potential, Ψb ; stomatal conductance, gs…) that can be used in the field to quantify water stress experienced by the plant (Pellegrino *et al.,* 2001a). Despite their physiological significance for plant water status, these measurements are of limited relevance for field diagnosis because of their high sensitivity to soil water status at the time of measurement and their lack of "memory" (Pellegrino *et al.,* 2001b). The objective of this study was to develop a water balance model that can give at a daily time step and during the whole crop cycle an indicator of the level of water deficit experienced by the crop : the Fraction of Transpirable Soil Water, FTSW (Available Soil Water, ASW/Total Transpirable Soil Water, TTSW). For this purpose, measurements of FTSW in field conditions and in soil columns, using the approach of Lacape *et al.* (1998), were related to plant measurements commonly used to characterise water stress in vineyards (Ψb, gs), and to source of carbon (net assimilation, An). Relationships between FTSW and various parameters of shoot development (sinks in competition with grapes) were also investigated in soil columns following the approach of Belaygue *et al.* (1996).

Methods

Experiments were carried on cultivar Syrah in two vineyards in south-eastern France with contrasted soils (Aspère 2001 and Roujan 2000-2001, respectively white and black symbols in the figures 1, 2 and 3), and in soil columns (2001). Each vineyard was divided in two sub-fields with different water treatments : rainfed/irrigation for Aspère ; rainfed/rainfed plus plant intercropped for Roujan. The intercrop (chickpea in 2000, pea in 2001) was aimed to reduce the amount of water in the soil before significant consumption by the vineyard. Soil water status was measured with neutron probe every fifteen days in the field and with TDR and tensiometers every day in soil columns. Measurements of Ψb, gs and An were performed on the same days in the field and every week in soil column. In soil columns, daily irrigation scheduled with tensiometers measurements allowed to obtain a range of level of soil water status maintained at a constant level during at least 45 days. Main stem of the plant was cut above the 15th node. Leaf appearance rate was measured twice a week on the primary lateral branch witch had the highest level of growth (LAR 1) and on secondary laterals branches growing on it with no tendril carried (LAR 2).

Results

As suggested by Lacape *et al.* (1998) on cotton, FTSW can be related to Ψb across the measurements made at different dates and in two fields (Roujan and Aspère) with contrasted soils (figure 1). These data can be reasonably fitted with the regression curve obtained by Lebon on Gewurztraminer cultivar in Alsace (fitted line Lebon, pers. com.).

FTSW was linked to gs at midday (figure 2) under non limiting conditions of radiation (PPFD>800µmol m^{-2} s^{-1}) and to An (Anmax, figure 3) under the same conditions of radiation plus non limiting conditions of nitrogen and temperature ($25<T<35°C$). Low levels of gs and Anmax were measured in field around flowering (cycled points) in comparison with post-flowering measurements and with the regression curve obtained from pots measurements. Apart from these points around flowering, the relationships between gas exchange (gs, Anmax) and FTSW were similar between Aspère 2000 and Roujan 2000-2001, and between field conditions and soil column.

The parameters of shoot development, LAR1 and LAR2 (respectively black and grey symbols in figure 4), were highly correlated to FTSW in soil columns (r^2=0.92 for LAR 1; and r^2= 0.87 for LAR 2). The sensitivity of these two variables differed markedly, LAR2 being more sensitive to FTSW than LAR1.

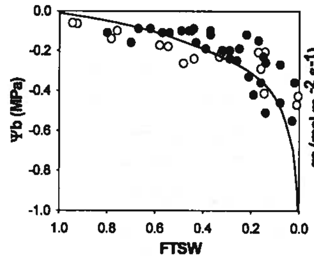

Figure 1

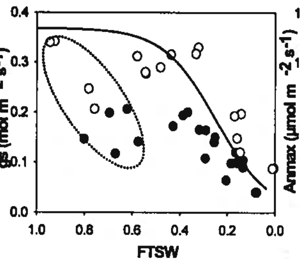

Figure 2

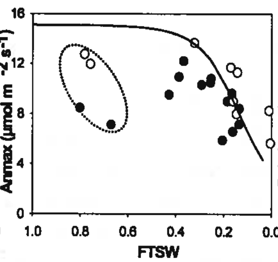

Figure 3

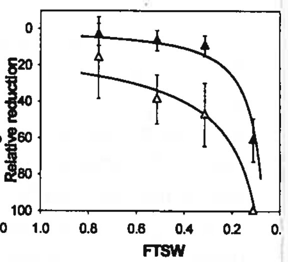

Figure 4

Conclusions

Across a range of soil/water management conditions and two years of experiments in farmer's field we found a reasonably constant relationship between FTSW and Ψb indicating that FTSW can be considered as an indicator of the soil water deficit experienced by the plant. The relationships between FTSW and gas exchanges (gs, Anmax) were also stable, at least after flowering, across this range of conditions, including field and soil column conditions. In soil column, we obtained relationships between FTSW and the rate of leaf emission on primary (LAR 1) and secondary branches (LAR 2). By using Anmax as an indicator of the status of the carbon source on the plant and LAR1 and LAR2 as indicators of the status of the vegetative sinks we can characterise each day of measurement with a source/sink status related to the soil water deficit experienced by the plant (FTSW). The latter can be obtained at a daily time step from a water balance properly parametrized in each soil for TTSW. This parameter could be calculated from few measurements of Ψb during the growing season by optimisation of FTSW on the relationship between Ψb and FTSW shown on figure 1. Each field could therefore be characterised with the pattern of the effect of water deficit on source/sink ratio during the crop cycle and compared to the optimal pattern required to improve grape quality. This approach is under investigation in a network of farmers fields in south-eastern France.

References

Belaygue C., Wery J., Cowan A.A. et Tardieu F. 1996. *Crop Sci.* 36, 1240-1246.

Lacape M.J., Wery J. et Annerose J.M. 1998. *Fied Crop Res.* 57, 29-43.

Pellegrino A., Lebon E., Simonneau T., Riou C. et Wery J. 2001a. 12èmes Journées GESCO, France, 2001 : 37-42.

Pellegrino A., Lebon E., Codis S., Riou C. et Wery J. 2001b. 12èmes Journées GESCO, France, 2001 : 31-35.

RELATIONSHIP AMONG FLOWERING, VIGOUR AND PRODUCTION IN OLIVE TREES: AN APPROACH FOR A YIELD PREDICTION

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Introduction

Several factors, both endogenous and exogenous, influence the annual yield of a tree as are flowering and fruitfulness characteristics, and vigour. They are also affected by environmental conditions. Fruitfulness depends on internal characteristics like variety, and external conditions like the incidence of diseases, crop management, climate and soil features of the grove. The final production of an olive tree is defined by the number of bearing fruits after bloom under the prevailing growing conditions (Rallo *et al*, 2001) and the tree size too (as number of fruiting positions). However, there is a negative relationship between the amount of inflorescences and the number of bearing fruits (Vargas, 1993; Ramírez *et al.*, 2000).

The radiation-use efficiency of intercepted radiation is the main factor in crop productivity (Loomis & Connor, 1992). Tree size and homogeneity in leaf area distribution are the features that have more influence in the amount of intercepted radiation in olive trees (Mariscal, 1998).

The aim of this study is to establish the relationship among flowering levels, vigour and production in olive trees, and to determine how much simple measures with flowering and vigour categories can predict potential crop.

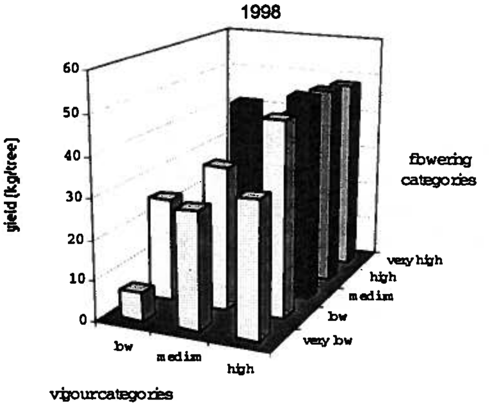
Methods

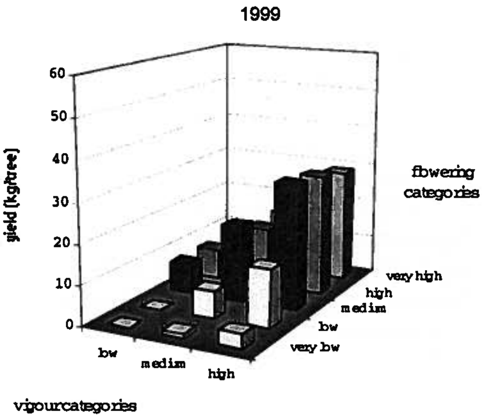
The experimental orchard was carried out in a hillside of 'Picual' cv. in the C.I.F.A. experimental farm in Cabra (Spain), in order to obtain vigour variability. 'Picual' trees were planted in 1982 at 7 m x 7 m and trained in open centre. Records were taken in the same 75 trees in 1998 and 1999. Experimental design was completely randomly and unbalanced, with the tree as experimental unit. Data recorded in each tree were flowering categories in a visual classification from 1 (very low flowering level) to 5 (exceptionally high flowering level), tree vigour, also in a visual classification, from 1 (very weak vigour) to 3 (strong vigour), trunk perimeter at 25-30 cm from the tree base and final production. Canopy volume and canopy surface of each tree were measured as an spheroid (Villalobos *et al.*, 1995).

Statistical ANOVA of final production, trunk perimeter, canopy surface and volume, related with flowering and vigour classes were computed. Also, linear regression analysis between accumulated yield and vigour measures were computed for each flowering category and for the total tree number in the essay.

Results

Production in olive trees is distributed as the proposed model of visual classifications of flowering and tree vigour categories, with $R^2_{1998}= 0.69$ and $R^2_{1999}= 0.58$. Visual classification of tree vigour categories have more consistence in the prediction model than flowering classes, showed higher determination coefficients (vigour categories $R^2_{1998}= 0.43$ and $R^2_{1999}= 0.45$ vs. flowering categories $R^2_{1998}= 0.22$ and $R^2_{1999}= 0.12$). There is no interaction between visual categories of tree vigour and flowering ones.





Linear regression of accumulated crop with trunk perimeter, canopy volume and canopy surface shows a similar fit between yield and the vigour parameters, with R^2 values of 0.55; 0.53 and 0.53, respectively. For flowering categories, the better fit depends on the year. Thus, in 1998 yield had higher R^2 with canopy measures than with trunk perimeter; in 1999, the higher R^2 values were between yield and trunk perimeter. This difference would be a consequence of the alternate bearing behaviour.

Conclusions

This study shows the relationship among flowering levels, vigour and production as flowering classes enclose the flowering intensity and tree size categories integrate the fruiting capability of the tree as well as big canopies have higher number of fruiting shoots for the same flowering level. Also, it could be seen that visual categories of flowering and tree vigour result useful measures to help to predict crop production in olive trees as the R^2 values of the two years shows. Finally, to improve the results of this study, canopy density could influence the proposed prediction model, so visual categories of it, added with flowering and tree vigour ones, would help to a better fit for yield prediction on olive trees.

References

Loomis, R. S., Connor, D. J. 1992. *Crop ecology: productivity and management in agricultural systems.* Cambridge: Cambridge University Press, 514 p.
Mariscal, M. J. 1998. *Intercepción de radiación solar y acumulación de biomasa por cubiertas de olivo.* Tesis Doctoral. Universidad de Córdoba.
Rallo, L., Cuevas, J. 2001. Fructificación y producción. In: Barranco, D. Fernández-Escobar, R., Rallo, L. *El cultivo del olivo.*4ª ed. Madrid: Junta de Andalucía. Ed. Mundi-Prensa, pp. 121-152.
Ramírez, M., Navarro, C., Rallo, L. 2000. *Relationship among flowering, fruitfulness and crop in 'Manzanilla de Sevilla' olives.* 4th International Symposium on Olive Growing. Valenzano (Bari), Italia, (in press).
Vargas, A. 1993. *Relación entre producción y fructificación en olivo en árboles en contraalternancia.* Trabajo Profesional Fin de Carrera. Universidad de Córdoba.
Villalobos, F. J., Orgaz, F., Mateos, L. 1995. Non-destructive measurement of leaf area in olive (*Olea europaea* L.) trees using a gap inversion method. *Agricultural and Forest Meteorology,* vol. 73, pp. 29-42.

TEMPERATURE RESPONSE TO THE ONSET OF WIND MACHINE OPERATION

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Introduction

Wind machines for frost protection mix warm air aloft with cold air near the surface to raise the temperature within an orchard. However, cold air is more dense and hence it is hypothesized that mixing by wind machines may be inhibited if the fans are started after a strong inversion has formed (Snyder, 1993). For example, Turrel (1973) and Gerber (1979) suggested that wind machines are more effective at mixing air if started before a well developed temperature inversion forms. Based on this, growers have a tendency to start fans too early and stop fans too late. In California, it is common to see wind machines operate unnecessarily for 24 hours (Snyder, 1993). Immediately after starting wind machines, air temperature is known to increase near the ground, however, to our knowledge, the immediate temperature response to starting fans under different inversion conditions has never been published. In this paper, the results of a trial in Northern Portugal will be reported along with data on the influence of fan operation on temperature as a function of distance from the wind machine.

Methods

Field trials were conducted in a hedgerow apple orchard (10 ha) located in Carrazeda de Ansiães (41° 48'N, 6° 44'W alt. 690 m) in the Northeast of Portugal, in the spring (1998–2000). The orchard was planted in 1989 with a row spacing of 4.65 m and an azimuth angle of 40° from North. The height of the orchard canopy was approximately 3.5 m. A wind machine was installed in the orchard in the spring of 1998. The wind machine has a 5.4 m long double bladed fan that rotates at 590 rpm and completes a turn around the tower in 4 minutes and 20 seconds. It is mounted on a 10.5 m steel tower and it is powered by an industrial diesel engine that provides 160 horsepower (118 Kw) at 2300 rpm. The axis of the fan was tilted 7 degrees to the horizontal. Air temperature was monitored using 0.2 mm wire copper-constantan thermocouples shaded from radiation with white-painted thin aluminum caps. Two vertical air temperature profiles (0.05, 0.1, 0.3, 0.6, 1, 1.5, 3, 5, 10, 15 and 24 m) were measured, within the influence of the wind machine. Air temperature was additionally measured at a height of 1.5 m at distances of 30, 70 and 110 m from the wind machine in the directions NW, NE, SW and SE. A CR10X datalogger (Campbell Scientific, Inc., Logan, Utah, U.S.A.) recorded data every 10s and the data were averaged every minute.

Results

Table 1 shows the air temperature measured at 1.5 m ($T_{1.5}$) and the inversion strength (T_{24}-$T_{1.5}$), where T_{24} is the temperature measured at 24 m, before operation and the temperature increase after the 1st, 2nd and 3rd rotation of the fan around the tower. The increase of temperature starts immediately after wind machine operation and it is highly related to the inversion strength T_{24}-$T_{1.5}$ (Table 2).

The temperature profiles (Fig. 1) show an increase in temperature near the surface and a decrease in the upper levels as a result of the air movement to the surface. Under these inversion conditions the $T_{1.5}$ increased by 19 % to 40 % of T_{24}-$T_{1.5}$.

The temperature increase diminished with distance from wind machine and the pattern is influenced by natural wind drift (Fig. 2).

Table 1 Air temperature ($T_{1.5}$) and inversion strength (T_{24}-$T_{1.5}$) measured at 30 m from the tower before operation and mean temperature increase (ΔT) after one, two and three rotations of the fan around the tower.

Date	Before wind machine		Air temperature increase (°C)		
	Air temperature (°C)	T_{24}-$T_{1.5}$ (°C)	After 1st rotation	After 2nd rotation	After 3rd rotation
4/14/99	-0.2	2.7	0.9	1.0	0.9
4/18/99	0.0	1.3	0.3	0.2	0.1
4/19/99	-2.2	2.7	1.1	1.1	1.0
4/24/99	-0.1	3.4	1.2	1.1	1.2
3/26/00	-0.3	4.5	1.2	1.2	1.1
3/28/00	-2.2	1.6	0.4	0.6	0.9
3/29/00	-0.9	3.1	0.7	0.8	0.8
3/30/00	-0.3	4.7	1.7	1.7	1.9
4/01/00	-1.8	4.6	1.4	1.3	1.4
4/05/00	0.1	6.1	1.1	1.7	1.8
4/06/00	-0.2	5.5	1.2	1.7	1.8

Table 2 Linear regression statistics for ΔT versus inversion strength (T_{24}-$T_{1.5}$), measured at 30 m from the tower, after two rotations of the fan around the wind machine tower

Regression	Intercept	Slope	S.E. (°C)	R^2	F ratio	N
ΔT *vs* T_{24}-$T_{1.5}$	0.07	0.29	0.18	0.87	69.0[a]	12

[a] $P<0.0001$

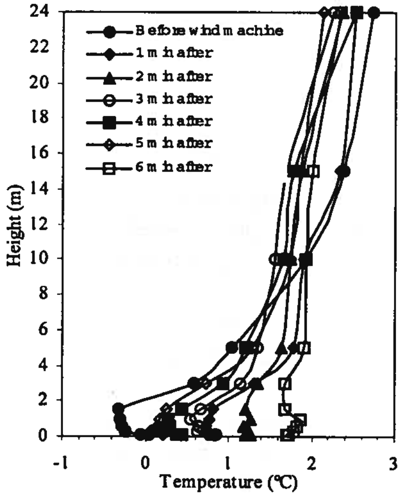

Fig. 1 Temperature profiles (30 m from wind machine) before and after operation on 26 March 2000.

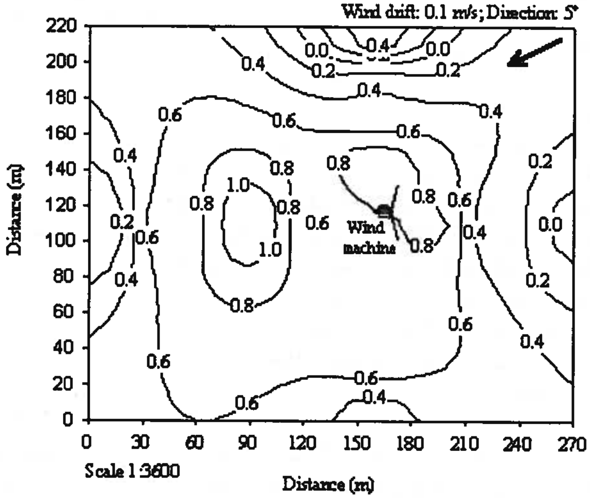

Fig. 2 Temperature response pattern produced by wind machine after 2 complete rotations around the tower on 26 March 2000.

Conclusions

The results confirm the hypothesis that, immediately after starting the wind machine, there is a temperature increase near the surface. This temperature increase is highly correlated with the inversion strength and it drops with distance from the wind machine. Wind drift is important in distorting the circular pattern of the air temperature modification near the surface, which is elongated in the downwind direction.

References

Gerber, J.F., 1979. Mixing the bottom of the atmosphere to modify temperatures on cold nights. *In Modification of the aerial environment of plants*. Barfield, B.J. and J.F. Gerber (eds). Amer. Soc. of Agric. Eng. St. Joseph, Michigan.

Snyder, R.L., 1993. Wind machines for freeze protection of citrus. Final Report. UC, , Davis.

Turrel, F.M., 1973. The science and technology of frost protection. *In The Citrus industry*. W. Reuther (Ed.). Vol. 3. University of California, Berkeley.

MORPHOLOGICAL CHARACTERISATION OF A CANOPY: THE BASIS FOR STRUCTURAL-FUNCTIONAL MODELLING.

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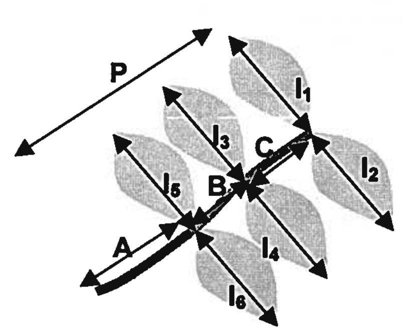
Introduction

ALAMEDA v.2 (Ruiz-Ramos *et al.* 2001) is a model of faba bean (*Vicia faba* L.) based on a Lindenmayer-system (L-system). The mathematic formalism of the L-system recognises different levels of plant organisation (organ, plant, canopy). Geometric and topologic evolution in 3D can be simulated for every organ by ALAMEDA. An accurate description of the evolution of the canopy geometry is needed to construct such a model, and there is currently little information in the literature. Since thermal time (TT) can be used as the driving factor of the simulation, the changes in the geometry can be studied as a function of TT, and referred to each organ within the L-system, to build a virtual plant as described in Hanan and Room, (1997). In this work, allometric relationships and the dynamics of organ elongation were established within the 3D plant structure.

Material and methods

Nineteen faba bean plants were monitored in the field, with an electromagnetic digitizer, during two growing seasons, 1999-2000 and 2000-2001, and with two sowing dates, mid-autumn and mid-winter. Length of leaflets, number of leaflets per leaf and leaf position on the stem, petioles, and internodes of the main stem were derived from these measurements (see Fig. 1) taken every two weeks. Plant organs were numbered from the bottom of the plant upwards, according to the digitalisation protocol. During 2000-2001, internode length and leaf area were also measured by harvesting different plants, every two weeks until crop maturity. Air temperature was monitored above the canopy.



$$TLL = A + B + C + \sum_{i=1}^{i=n} l_i$$

Fig. 1 Detailed measurements in a leaf

Results

Geometric evolution of internode length, total leaf length (TLL, considered here as the sum of leaflets and petiole length (P); Fig. 1) and petiole length were established as functions of TT and organ number, as described in Fournier and Andrieu (2000). In Fig. 2, TLL in relation to leaf number is represented for different TT during 2000-2001. The percentage of TLL corresponding only to P was estimated from the digitalisation data (Fig. 3) for every leaf and for several TT.

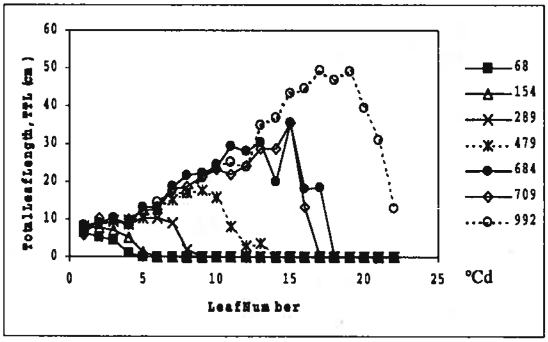


Fig. 2 TLL in relation to leaf number for different TT during 2000-2001

A linear relationship was found between leaf number on the stem and TT until this percentage reached 65% (65.24 ± SD:14.13) of its final value (R^2=0.87).
Within the petiole, the percentage corresponding to part A of the petiole (Fig.1) showed a linear correlation (R^2=0.9) with the leaf number (Fig. 4)

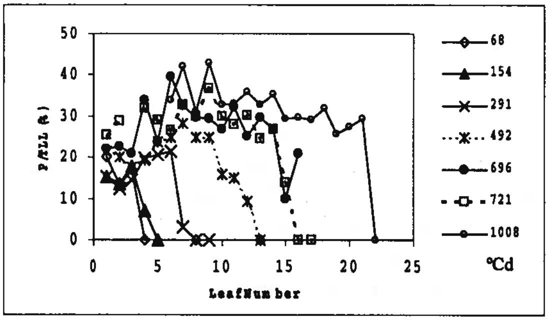


Fig. 3 Percentage of TLL corresponding to P in relation to leaf number for different TT

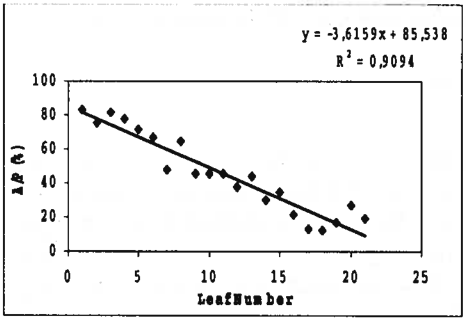


Fig. 4 Percentage of P corresponding to A in relation to leaf number for different TT

The slope of the linear regression in Fig. 5 shows the leaf appearance rate derived from data from both years and sowing dates. Leaf area per leaf, calculated as the average of data from both growing seasons and sowing dates, was related to mean TLL, obtained from digitalisation (Fig. 6).

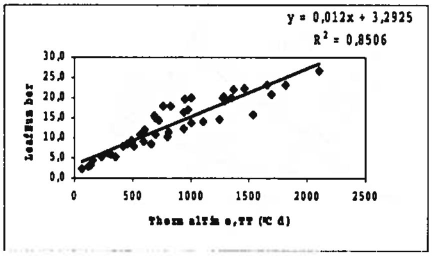


Fig. 5 Leaf number as a function of TT

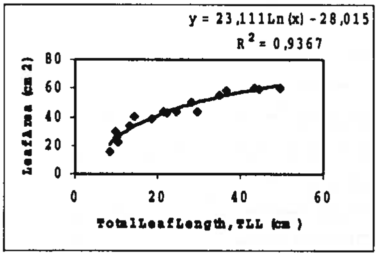


Fig. 6 Leaf area as a function of TLL

Conclusions

A detailed description of plant geometry was obtained by digitalisation and destructive measurements. Allometric relationships and dynamics of organ elongation found in this work, will enable us to calibrate the parameters of the growth functions. By connecting these functions with the 3D L-system model (ALAMEDA v3.1, Fig. 8), the growth of each organ can be simulated independently within the canopy.

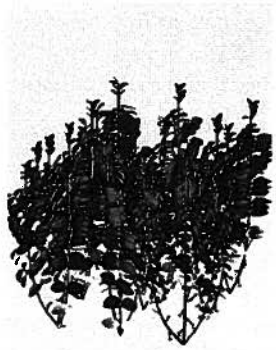


Fig 8. L-system iteration for *ca.* 800°Cd

References

Fournier C, and Andrieu B, 2000. Annals of Botany, 86, 551-563

Hanan J., and Room P., 1997. In M.T. Michalewicz (Ed.). *Plants to ecosystems. Advances in Computational Life Sciences*, CSIRO Pub. pp. 28-44.

Ruiz-Ramos M, Méndez V, Tarquis A, Díaz-Ambrona CH, and Mínguez MI, 2001. In *Proceedings of the 2nd International Symposium of the ESA- Div. 2, Florence pp. 177-178.*

INCORPORATING STEM ELONGATION FUNCTIONS TO A AN L-SYSTEM CANOPY MODEL

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Introduction

A detailed description of the geometry and topology of *Vicia faba* L. plants within a crop canopy was simulated with the 3D Lindenmayer system (L-system) ALAMEDA v.3.1. (Ruiz-Ramos and Mínguez, 2002). The final aim of these type of models, is to build a functional-structural model of a crop, sensitive to environment. We have considered the simulation of stem growth as a first step for a detailed modelling of the leaf area, because internode length will determine the vertical distribution of leaf area. After establishing the allometric relationships and dynamics of organ elongation for faba bean (Ruiz-Ramos and Mínguez, 2002), we have linked a growth model to ALAMEDA v.3.1 to simulate internode elongation.

Methodology

<u>Description of the structural model</u> (Ruiz-Ramos *et al.* 2001):

ALAMEDA is a L-system based-model that considers the plant made of modules or structural units. Every module changes following rules applied in parallel. The model can run with 0.5 h to 24 h. steps, in continuous time simulation. It is a parametric, stochastic (for angles and number of organs), context free, sensitive to environment (T°) L-system. It has 3 sub L-system built in for stems, leaves, and reproductive structures. It can simulate senescence, and the canopy is built by aggregation of individual plants. Organ production is based in thermal time (TT). The inputs of ALAMEDA are: number of organs, and leaf and stem angles (stochastically), phylochron (°Cd), stem delay (°Cd), beginning of flowering and grain filling (°Cd). Senescence process is also included. Internodes are generated using the SAFT empirical growth model described in Durand *et al.* (1999).

<u>Description of the internode growth model</u>:

SAFT considers three compartments for every growing organ: cell division zone (DZ), elongation-only zone (EOZ) and mature zone (M). Growth is produced by fluxes from DZ to EOZ and from this to M. Each compartment dynamics is simulated by empirical differential equations function of time and temperature. The solution is computed using a numerical integration, a subroutine called SOLVFABA based on Fournier (2001). Connecting this subroutine to the L-system, SAFT is applied to every internode. Internode elongation was calibrated from field data (Ruiz-Ramos and Mínguez, 2002).

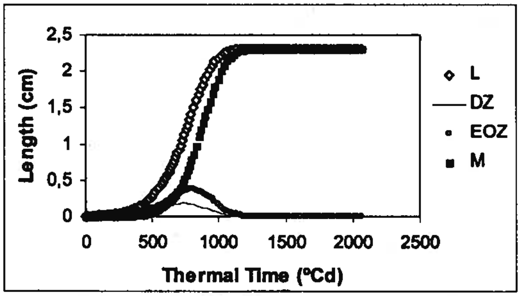

Fig.1 Compartment and total length of the first internode on the main stem

Results.

Fig. 1 shows the simulation of the three compartments DZ, EOZ, M, and the total length (L) of the first internode of the main stem.

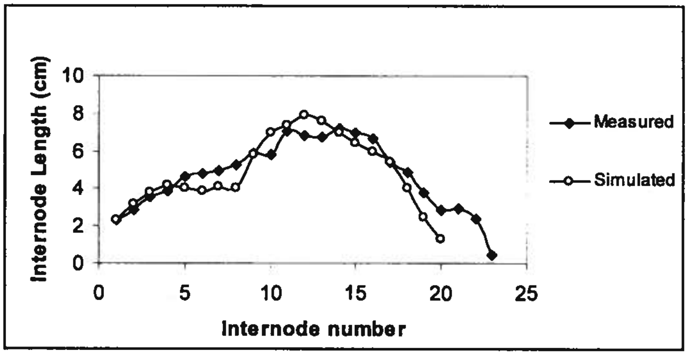

Fig. 2. Measured and simulated maximum lengths of every internode on the main stem

The comparison between measured and simulated maximum internode length, is shown in Fig. 2. The profile of final internode length, was simulated with the following hypothesis: 1) an increase in the initial length of DZ with thermal time (Lyndon, 1998 for peas) and 2) an increase in the flux from DZ to EOZ corresponding to the beginning of the grain filling period.Fig. 3 shows different stages of growth of the main stem (without leaves), including the model compartments for every internode.

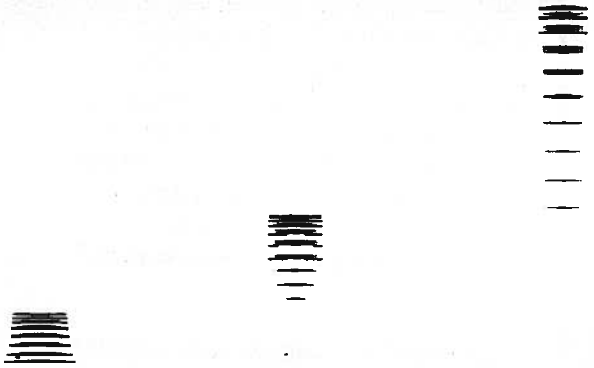

Fig.3. Simulation of internode elongation in one stem, without leaves. Colors represent compartment zones:
DZ: black
EOZ: dark grey
M: light grey

Conclusions

In this work, we have shown that the L-system approach allows to include physiological submodels. Simulation of stem growth will provide the vertical distribution of leaf area, making possible a functional simulation of leaf area generation and growth.

References

Durand JL, Schäufele R , Gastal F, 1999. Annals of Botany, 83, 577-588.
Fournier C, 2001. INRA, UEPF-Rapport interne.
Lyndon RF, 1998. The shoot apical meristem. Cambrigde University Press.
Ruiz-Ramos M, Méndez V, Tarquis A, Díaz-Ambrona CH, Mínguez MI, 2001. In *Proc. 2nd International Symposium of the ESA- Div. 2, Florence* pp. 177-178.
Ruiz-Ramos M, Mínguez MI, 2002. In *Proceedings* of 7th ESA Congress, Córdoba, Spain.

BOLL OPENING RATE BASED UPON GROWING DEGREE DAYS IN COTTON (*GOSSYPIUM HIRSUTUM* L.) CULTIVARS WITH DIFFERING EARLINESS.

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Introduction

The boll maturation period is a particularly delicate phase of the growing season of cotton. During this period the boll grows, fiber develops, and fiber properties are determined. Great attention should be paid to the temperatures that, during this phase, in some Mediterranean regions like southern Italy, could drop to critical values. In such conditions, any crop diffusion programme should take into account the effects of temperature on the aforesaid phase. The calculation of total amount of heat required for a species or a cultivar to develop from one point to another in its life cycle is a simple method of predicting the timing of events that are influenced by temperature.

The aim of the research was to analyse, in cotton cultivars with differing earliness, maturation rate dynamics of the bolls in relation to the amount of growing degree days (GDD) accumulated from the blooming of each flower up to boll opening.

Materials e methods

The field experiment was conducted in 1993 at Gallina (38°10'N., 15°45'E., 252 m a.s.l.), in southern Italy. Four cultivars of cotton (Balcan, Ogosta, Acala SJ2 and PGI 210) were sown on three dates (19 April, 3 and 17 May). Each of the twelve treatments consisted of a single plant grown 100 cm apart from the others. Throughout the growing season, each flower was labelled to indicate date of anthesis and boll opening. The boll maturation period was determined separately in 973 bolls. The accumulated GDD were calculated for each boll period by summing the equation $GDD=[(T_{max} + T_{min})/2]-T_{base}$ (Russelle *et al.*, 1984) for each day from the date of flower opening to the date of boll opening. T_{base}, the base temperature below which development stops (lower developmental threshold), determined, according to the x-intercept method (Arnold, 1959), by the linear regression of the development rate (inverse of the boll maturation period in days) of each boll on mean temperature. It is obtained from the equation $1/d = a+b \cdot t_{med}$ by setting $1/d=0$ and solving the equation. To increase the variability of thermal conditions intercepted during boll development, the sowing date data of each cultivar were pooled.

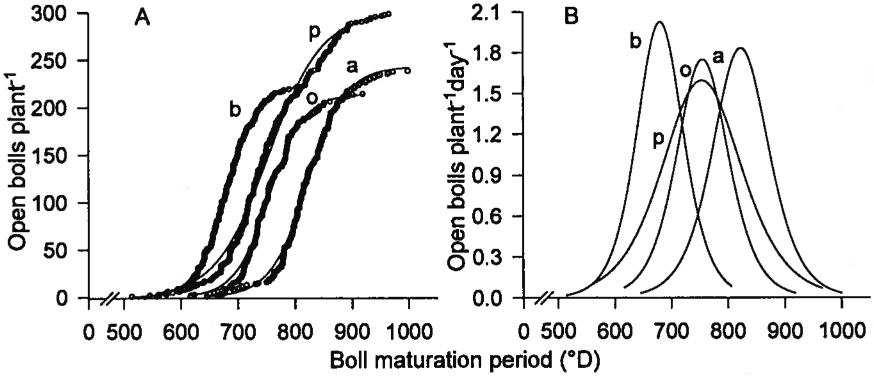
The cumulative distribution of open bolls per plant *vs* growing degree days assumed a sigmoidal shape. Following the regularity of the aforesaid distribution, the data were fitted to a logistic equation cited by Hunt (1982): $Y = a/(1+b \cdot exp^{-c \cdot X})$ where Y and X are the predicted number of open bolls and the amount of GDD required from each boll to open respectively.

The rate of boll opening per plant was obtained from the derivative of the logistic function: $dY/dX = a \cdot b \cdot c \cdot exp^{-c \cdot X}/(1+b \cdot exp^{-c \cdot X})^2$; the peak value of the curves obtained by the derivative corresponds to the mean maturity date (Bilbro and Quisenberry, 1973) based upon degree days.

Results and discussion

The number of open bolls per plant, on all sowing dates, was consistently higher for PGI 210 (299) than Acala (238), Balcan (222) and Ogosta (214). The relationships between the development rate of each boll and the relevant mean temperatures were linear for all cultivars. The base temperatures obtained and used for the calculation of the GDD were, in the same order of cultivars, 12.3, 11.0, 11.8, and 10.5 °C. The regression of boll opening on GDD, estimated by using a logistic equation, fitted the data very closely as indicated by the coefficient of determinations (R^2) that was greater than 0.89 for all cultivars (Fig. 1A).

Figure 1B shows the absolute growth rate in open boll numbers per plant. The rate curves indicate that boll opening peaked at 680 °D in Balcan (2.03 bolls day^{-1}) and at 822 °D in Acala (1.83 bolls day^{-1}). In the same cultivars, 95% of bolls opened between 588 and 772 °D and 710 and 935 °D respectively. For Ogosta and PGI 210, the most rapid opening boll rate occurred at rather similar GDD values: it peaked at 755 (1.75 bolls day^{-1}) and 753°D (1.59 bolls day^{-1}) respectively. The ampleness of the rate curves differed, however, between the above two cultivars: in fact, 95 % of bolls opened from 654 to 857 °D, in the first cultivar, and from 599 to 907 °D, in the second one.



Logistic opening boll curves for cotton grown in southern Italy; b, cultivar Balcan; o, Ogosta; p, PGI 210; a, Acala SJ2: (A) shows open bolls per plant; the derivate, (B) shows absolute growth rates in open bolls numbers per plant.

The results highlighted that the model based on GDD summation can be efficiently used to predict boll opening after flowering. By means of readily available data such as temperature, it is possible to obtain useful information in order to recognise different environments in which specific varieties can develop the last phase of the growing cycle in thermal conditions that allow regular boll opening.

The linear relationship between mean temperature and the development rate of each boll, found in all the cultivars, points out that along the boll maturation period, under the environmental conditions of the experiment, thermal regime held above the lower developmental threshold.

Under non-limiting water conditions as well as appropriate crop management, Balcan was the earliest cultivar; its bolls required, on average, a lower amount of GDD compared to the other cultivars. Among the latter, PGI 210, which in previous trials conducted in the same environment was often found to be more productive than the other tested cultivars (Santonoceto and Abbate, 1988; Abbate and Santonoceto, 1993), provided the highest number of bolls, whereas Acala SJ2 was the latest variety. Both the latter cultivars, at the end of growing season, opened a higher number of bolls than Balcan as a consequence of favourable weather conditions. Consequently, this variety could be proposed for cultivation under environments where, during the maturation period, the bolls cannot accumulate more than 800 GDD above a base temperature equal to 11.8 °C. PGI 210, in virtue of its yielding ability could be more suitable to the environments in which the bolls can accumulate up to 960 GDD during the maturation period with a base temperature greater than 12.3 °C.

References

Abbate, V., Santonoceto, C., 1993. Agricoltura Ricerca 143: 39-42.
Arnold, C. Y. 1959. Amer. Soc. Hort. Sci., 74: 430-445.
Bilbro, J. D. and Quisenberry J. E. 1973. Crop Sci., 13: 392-393.
Hunt, R. 1982. Plant growth curves. Edward Arnold Ed.
Russelle, M. P., Wilhelm, W. W., Olsen, R. A., Power, J. F. 1984. Crop Sci., 24: 28-32.
Santonoceto, C., Abbate, V. 1988. L'Informatore Agrario, 32: 61-63.

TESTING AND IMPROVING SOIL WATER BALANCE OF DSSAT 3.5 MODELS

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Introduction

It is generally accepted that water-deficit is the main limiting factor of crop production, so irrigation is often the most effective way to intensify cropping-systems. Nevertheless, with the different human activities competing for water resources, agriculture has to find cropping strategies to improve grain yield and water use efficiency. During the last 15 years, crop models have proven to be helpful to improve crop management under water limiting conditions but for this purpose their water-balance submodel has to predict satisfactorily crop evapotranspiration and soil water content dynamics (Ruíz Nogueira et al., 2001). The objective of this research was to test default and modified water-balance submodels of DSSAT 3.5.

Methods

For this purpose, we used the CROPGRO fababean model, recently adapted to predict growth and yield of faba bean (*Vicia faba*) (Boote et al., 2002), and data sets of two experiments (irrigated and rainfed treatments; two years), conducted at Córdoba (Spain), which irrigated treatment data had allowed the calibration of the new crop model. A detailed description of these experiments can be found in Sau & Mínguez (2000).

Firstly, the field capacity (drained upper limit; DUL) and wilting point (lower level; LL) of each of the soil layers were established using neutron probe measurements taken periodically to a depth of 195 cm. DUL was estimated as that value shown soon after rainfall or irrigation, while LL was estimated by the soil drying trend measured in the rainfed treatments at the end of the season. Secondly, the model initial conditions of water content of each layer were fit, for each water-balance submodel tested, to predict correctly the first neutron probe measurement. Finally we evaluated the accuracy of different water-balance submodels to predict cumulative crop evapotranspiration over time (ET_c), by comparison to field neutron probe measured time-series ET_c data.

The following water-balance submodels were tested:

(1) Ritchie functional model (Ritchie) (Ritchie, 1985) where the potential evapotranspiration of the crop (E0) is calculated using the equilibrium evapotranspiration concept (EQQ), as modified by Priestley & Taylor (1972). $E0 = \alpha * EQQ$, where α is a coefficient that can vary from 1.0 to more than 1.4 as a function of the advectivity of the environment and is set at 1.1 in the default FORTRAN code. EEQ is calculated through a simplified equation established by Ritchie (1985). This is the default DSSAT 3.5 water-balance.

(2) Penman-FAO (P-FAO). E0 is calculated following the equations proposed by Jensen et al. (1990). This is the second water-balance option available in DSSAT 3.5.

(3) Priestley-Taylor Original (P-T- $\alpha = 1.1$). EEQ is calculated following the equations proposed in the FAO 56 manual (Allen et al., 1998) and α value is maintained at 1.1.

(4) (P-T- $\alpha = 1.2$), (5) (P-T- $\alpha = 1.3$), (6) (P-T- $\alpha = 1.4$) & (7) (P-T- $\alpha = 1.5$). Identical to (3) but α equal to 1.2, 1.3, 1.4 and 1.5, respectively.

(8) Priestley-Taylor Original with α varying with vapour pressure deficit (VPD) as proposed by Steiner et al. (1991) (P-T-S_1). $\alpha = 1 + 0.26 * VPD$ (kPa); VPD is calculated using dew point temperature (T_{dew}) and FAO 56 manual equations, assuming that T_{dew} is equal to daily T_{min}.

(9) P-T-S_2. The same approach of P-T-S_1 but VPD is calculated with actual T_{dew}.

(10) Penman-Monteith with crop coefficient (K_c) (P-M-K_c). Reference evapotranspiration (ET_0) is calculated using the equations proposed in the FAO 56 manual and $K_c = 1+(1.3-1)*LAI/LAI_{max}$, where LAI and LAI_{max} are leaf area index and maximum LAI, respectively.

Results

Table 1. Estimators of the accuracy of cumulative crop evaportranspiration (ET_c) predictions of different water-balance submodels.

Water balance model	Cumulative ET_c (Exp. 1)				Cumulative ET_c (Exp. 2)			
	a	*b*	RMSE	*d*	*a*	*b*	RMSE	*d*
(1) Ritchie	42.7	0.768	38.1	0.968	11.0	0.980	13.7	0.997
(2) P-FAO	45.0	0.879	36.4	0.976	13.1	1.077	32.1	0.984
(3) (P-T- $\alpha = 1.1$)	13.6	0.786	36.9	0.960	2.2	0.843	33.6	0.979
(4) (P-T- $\alpha = 1.2$)	20.3	0.790	33.5	0.967	2.4	0.904	20.8	0.992
(5) (P-T- $\alpha = 1.3$)	25.4	0.808	33.0	0.974	1.5	0.971	10.0	0.998
(6) (P-T- $\alpha = 1.4$)	31.2	0.808	34.1	0.975	1.0	1.026	11.1	0.998
(7) (P-T- $\alpha = 1.5$)	33.5	0.842	31.7	0.980	1.6	1.067	18.8	0.995
(8) P-T-S_1	17.6	0.814	32.9	0.973	1.2	0.924	17.9	0.994
(9) P-T-S_2	18.0	0.811	33.2	0.972	1.45	0.921	18.2	0.994
(10) P-M-K_c	29.3	0.865	29.0	0.983	2.41	1.070	20.2	0.994

[a] *a* and *b* values of linear regression of predicted *versus* observed data, root mean square error (RMSE) and index of agreement *d* (Wilmott, 1982).

All tested models underpredicted ET_c in Exp. 1, specially, in the irrigated treatments. Generally, all the models were more accurate in their ET_c predictions of Exp. 2 than Exp. 1. P-M-K_c seemed to be the more adequate model when both experiments are jointly considered. Nevertheless, this model tended to predict too much early water extraction under rainfed conditions.

Discussion

With a Mediterranean winter crop, the Priestley-Taylor and Ritchie models have the inconvenience of using a constant advective effect (α) throughout all the crop cycle, while actual VPD varies from low values in winter (c.a. 0.3 kPa) to high at the end of spring (c.a. 2.0 kPa). Moreover, VPD regime can be subjected to high interannual variations. P-T-S_1 and PTS_2 tries to solve this problem by varying α linearly with VPD, but both methods underpredict ET_c. The P-M-K_c gives better estimations. This result agrees with Allen et al. (1998) statement, that Penman-Monteith (P-M) is generally the most reliable method. Nevertheless, other variations of the P-M equation should be tried, such as those that allow a dynamic computation of the aerodynamic (r_a) and bulk surface (r_s) resistances. In addition, complementary accuracy criteria, such as the ability of the model to simulate the desiccation trend of the different soil layers or the crop dry matter accumulation, could be used to decide which of the methods is the most adequate.

References

Allen, R.G. et al., 1998, Crop evapotranspiration, FAO Irrigation and Drainage paper 56, FAO.
Boote, K.J. et al., 2002, *Agron. J.*, in press (July-August).
Jensen, M.E. et al. (Eds.), 1990. Evapotransspiration and irrigation water requirements: a manual. Am. Soc. of Civil Engineer, New York.
Ritchie, J.T., 1985, in Fry, E., Atkin, T.K. (Eds.), Wheat growth modeling. NATO-ASI Series, Plenum Press, pp. 293-305.
Ruíz-Nogueira, B. et al., 2001, *Agric. Syst.*, 68, 151-173.
Sau, F. and Mínguez, M.I., 2000, *Field Crops Res.*, 66, 81-99.
Steiner et al., 1991, *Agron. J.*, 83, 240-247.
Willmott, C.J., 1982, *Bull. Meteor. Soc.*, 63, 1309-1313.

MODELLING THE INFLUENCE OF CROPPING SYSTEMS ON GENE FLOW FROM HERBICIDE RESISTANT SUGAR BEET. PRESENTATION OF THE MODEL GENESYS-BEET.

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Introduction

The sexual transfer of genes from sugar beet to weedy beet, which could lead to the apparition of a more persistent weed, is probably the greatest risk of planting genetically modified beet varieties resistant to non-selective herbicides. The agricultural practices must be adapted to limit gene flow. Because of the spatial and multi-annual aspects of the question, field experiments do not suffice to study the impact of regional cropping systems on gene flow. Therefore, a model is developed to quantify the processes involved and to rank cropping systems according to their risk of transgene escape from GM sugar beet.

Input and output variables

The input variables are: (a) the regional field pattern comprising cultivated fields and borders; (b) the crop succession in each field. Various crop types are distinguished: herbicide resistant (transgenic) or sensitive (conventional) sugar beet, winter or spring cereals, peas, unsown, autumn-sown or spring sown set-aside; (c) the cultivation techniques used for each crop (Table 1); (d) daily temperature.
Output variables are, for each field and year, the density and genotype proportions of the seed bank, the adult plants and of the newly produced seeds.

Table 1: Cultivation techniques used as input variables in the model and their effect on the annual beet life-cycle

Cultivation techniques	modelled processes of the beet life-cycle				
	seed input	seed bank movements	seedling mortality	seed export	inducing germination
sowing of sugar-beet	X		X		X
other crop sowing					
tillage		X	X		X
cutting			X		
herbicide			X		
weeding			X	X	
harvest		X	X		X

Model structure.

The model consists of the life-cycle of sugar and weedy beet (Fig. 1) which can be either biennial or annual. Cultivated sugar beet is biennial and accumulates sucrose during the first year. Annual plants are either weedy beets or prematurely bolting cultivated sugar beet. The latter results from sugar beet seeds contaminated by annual wild beet during seed production in South-Western France, or are highly sensitive to vernalisation.
Groundkeepers are pieces of sugar beet lost during the harvest. They can grow and flower in the following crop.

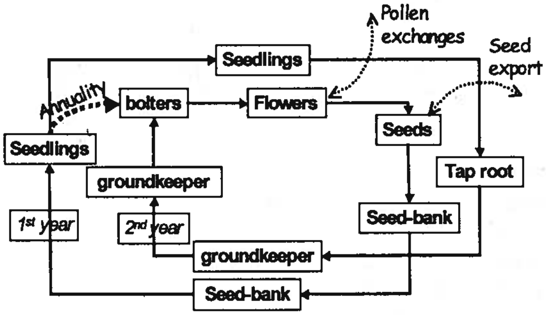

Figure1 : Life-cycle for annual (weedy beet or prematurely bolting cultivated sugar beet) and biennial (cultivated sugar beet).

Each day, for each field, the model calculates the number of individuals per m² for every stage of the life-cycle and every genotype, depending on cultivation techniques and crop environment (Table 1). During flowering and seed production pollen and seed exchanges are modelled, depending on size and distance of neighbouring fields.

Herbicide resistant and sensitive plants only differ in their response to the herbicide against which the transgene confers resistance.

Choice of parameter values.

Parameters describing cultivated sugar beet are found in literature (e.g. Alcaraz,1986; ITB, 2000; Dürr *et al.*, 2001). Processes specific to weedy beet are often unknown, such as seed survival in soil, the evolution of germination ability with seed age, vernalisation of buried seeds, or the competitive effects of crops on the development cycle of weedy beet and of groundkeepers. The development of these two beet types is crucial because they are potential relays for transgene flow. Field experiments have been set up to study these processes and their results will be used to estimate model parameter values.

Simulations

When the parameters values have been estimated, the model can be used to simulate gene flow in time and in space (see example of Fig. 2).

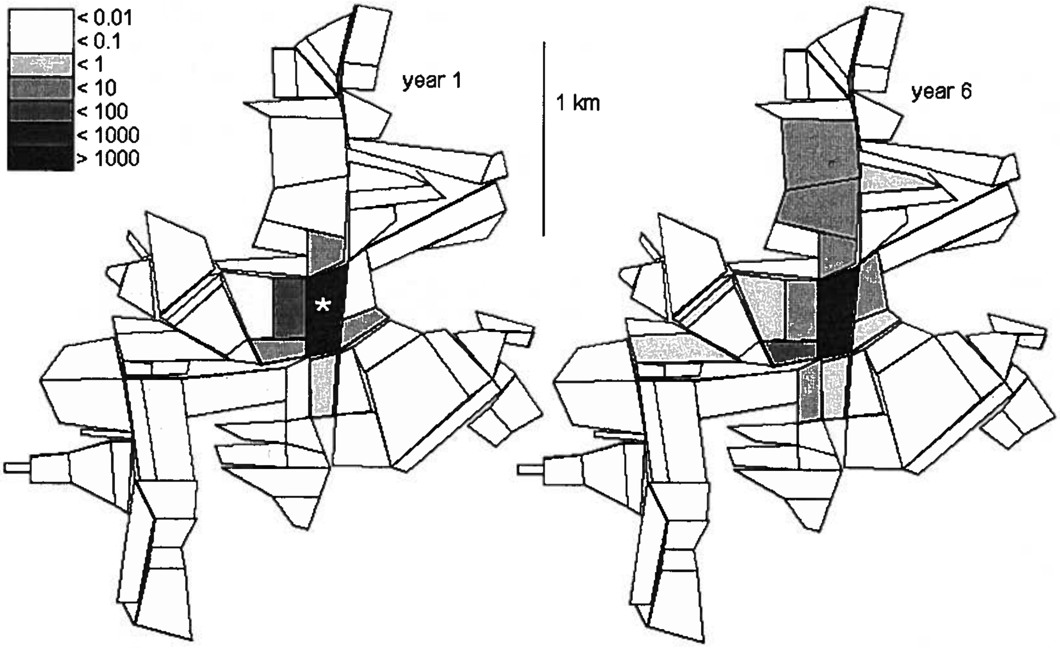

Figure 2: Gene flow in time and in space from a central transgenic herbicide-tolerant crop (field *) in a region cropped with rape/winter wheat/spring barley rotations, with a set-aside every 7 years. Number of transgenic seeds per m² in soil after harvest (Colbach *et al.*, 2001b)

References

Alcaraz 1986 *Bulletin fnams semences n° 97*
ITB 2000 *ITB Editions, 293 pp.*
Colbach N. *et al.* 2001a. *Agriculture, Ecosystems and Environment*, 83, 235-253
Colbach N. *et al.* 2001b. *Agriculture, Ecosystem and Environment*, 83, 255-270
Dürr C. *et al.* 2001 *Soil Sci. Soc. Am. J.* 65, 414-423

MAXIMUM HOURLY CANOPY CONDUCTANCE OF AN OLIVE ORCHARD AS A FUNCTION OF LAI

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Introduction

The assessment of canopy conductance is a primary goal in the parameterization of every advanced transpiration model, in particular for the systems where its contribution to the transpiration process is large, i.e. when the canopy is strongly coupled with the atmosphere, which is the case of olive groves and trees in general. Despite its importance, the determination of canopy conductance is one of the hardest targets to achieve, due to the fact that it includes non-physiological components and that the scaling-up using "easy" measurements of leaf conductance is still unclear. The most widely used method for the determination of canopy conductance is the inversion of a transpiration model (like Penman-Monteith) ran on a dataset of independent canopy evaporation measurements. This work analyzes the maximum hourly values of olive canopy conductance, usually reached under particular conditions (high radiation, low VPD) which are met after sunrise but before the stomata adjust the evaporation rate to increasing VPD.

Materials and methods

The experiment took place in Córdoba, Southern Spain, during the years 1998, 1999 and 2000, in a 4 ha flat uniform olive orchard, planted in 1997 and drip irrigated with no water restrictions. LAI varied from 0.1 to 1, and was measured using a LAI2000 canopy analyzer (LICOR, Lincoln, NE, USA). The canopy evaporation was measured with a differential approach, using two Eddy Covariance systems placed one over the canopy (at a variable height depending on canopy height) and one under the canopy level, fixed at 40 cm from the soil level. Each system was composed of: a sonic anemometer (type CA27 - Campbell Scientific Inc., Logan, UT); a Krypton hygrometer (type KH20 - Campbell Scientific Inc., Logan, UT); two fast-response type E thermocouples (25 μm wire diameter - assembled in the IAS-CSIC laboratory), placed close to anemometer and hygrometer's paths. All sensors were sampled at 10 Hz, and the statistics were calculated and stored every 10 min. Corrections were applied on the raw flux densities as described in Webb *et al.* (1980), Moore (1986), and Tanner *et al.* (1993). Additional measurements of energy balance components were performed with two net radiometers (model Q7, Radiation and Energy Balance Systems, Seattle, WA, USA) placed over two points of maximum and minimum ground cover, and three heat flux plates (model HFT3, Radiation and Energy Balance Systems, Seattle, WA, USA).

The net radiation absorbed by the canopy layer (Rn_{abs}) was calculated as the difference between the net radiation above and below the canopy, being the last one simulated with a modified radiation interception model (unpublished). The aerodynamic conductance (G_a) was calculated according to the model proposed by Raupach (1994).

The corrected flux densities were integrated on an hourly basis, and the canopy conductance G_c was calculated inverting the Penman Monteith model:

$$G_c^{-1}=\left(\frac{Rn_{abs}+\rho\, C_p\, VPD}{LE_c}-\Delta-\gamma\right)\frac{1}{\gamma\, G_a}$$

where LE_c is the canopy evaporation.

Results

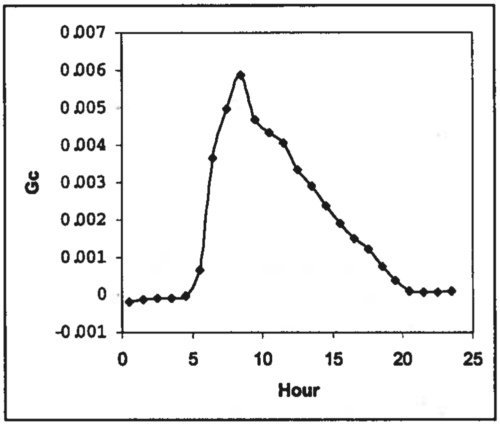
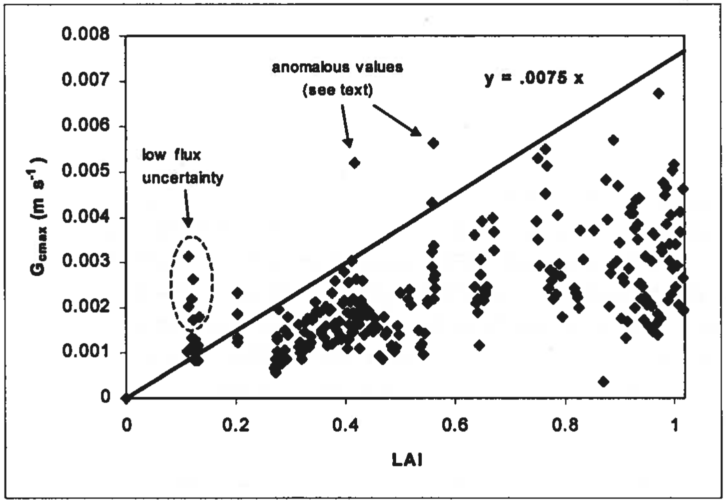


Fig. 1: daily pattern of canopy conductance.

Fig. 1 shows a typical example of the daily course of G_c, in this case July, 4 2000. A maximum G_c is achieved quite early in the morning, decaying then during the day as VPD increases. The decrease of canopy conductance, as well as the peak value, is dependent on plant water status. In our case the orchard was well watered. The maximum hourly values of canopy conductance G_c reached every day are plotted in Fig. 2. The group of points enclosed in the dotted line are of very low significance, as the evaporation flux resembled the Eddy Covariance system intrinsic error. The two points indicated by the arrows are the effect of anomalous low peak values of hourly averaged thermocouples temperature, condition that forced up the calculated value of G_c through a very low VPD, while the evaporation fluxes showed no anomalies.



Conclusions

The slightly negative nighttime values that can be seen in Fig. 1 have no logical significance, and are due to very small negative values of LE_c registered during the night and can be ascribed to water condensation from the atmosphere or (more likely) experimental error. Note that the maximum values of G_c *actually achieved* are dependent on *actual* meteorological conditions and not only on LAI values, so they may be greatly different for the same LAI. Nevertheless, in optimum conditions of radiation, temperature and DPV, the canopy conductance reaches a maximum that must be limited by LAI. The straight line in Fig. 2 is an hypothetical envelope plotted on the following assumptions: 1) the orchard was *in some cases* in the conditions of expressing its maximum conductance, during the 3 years of the experiment; 2) the maximum conductance is a linear function of LAI, assumption that is reasonable for LAI values below one.

References

Moore, C.J. 1986. Boundary-Layer Meteorology 37:17-35.

Raupach, M.R. 1994. Boundary-Layer Meteorology 71, 211-216.

Tanner *et al.*, 1993. Proc. 1993 Management of Irrigation and Drainage Systems, 11–23 July, Park City, UT. ASCE, New York, pp. 105–112.

Webb *et al.*, 1980. Quarterly Journal of the Royal Meteorological Society 106: 85-100.

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THE PARTITION OF ENERGY FLUX DENSITIES OVER A GROWING OLIVE ORCHARD

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Introduction

The net energy flux - of radiative nature - reaching the earth surface is routed into three main processes: air heating (or cooling), soil heating (or cooling) and water evaporation. The energy fluxes used by these processes are respectively named sensible heat flux (H) soil heat flux (G) and latent heat flux (LE). When vegetation is present, the LE component is not limited by the water availability at the soil surface because most evaporation occurs through the stomata, and its magnitude is greatly dependent on the LAI of the vegetation stand - particularly for LAI values < 2 - and on its water status. This work deals on the partition of energy between sensible and latent heat flux as an effect of the increasing LAI of a young, well watered olive orchard in dry soil surface conditions.

Materials and Methods

The experiment was performed during the years 1998, 1999 and 2000 on a 4 ha flat uniform plot, located in the CIFA Alameda del Obispo Agricultural Research Center, in Córdoba, southern Spain, (37.5° N, 4.8° W). The orchard was planted at 3.5 x 7 m in 1997 with olives of cv. "Arbequino" and was drip irrigated with no water restrictions. H and LE flux densities were measured by an eddy covariance system, placed on a 6 m tower in an appropriate position in the plot to get an appropriate fetch (170-180 m). The height of the equipment in the tower was changed from 2.5 m to 4.5 m along with the rise of canopy height. The system was composed of a sonic anemometer (type CA27 - Campbell Scientific Inc., Logan, UT), a Krypton Hygrometer (type KH20 - Campbell Scientific Inc., Logan, UT) and two fast-response type E thermocouples (70 µm wire diameter - assembled in the IAS-CSIC laboratory), positioned close to anemometer and hygrometer's paths. All the sensors were sampled at 10.7 Hz. The statistics (averages, variances and covariances) were computed for 10-min periods and stored. All the raw flux densities were then corrected for the effect of frequency response on sensors response, sensors separation, path-length averaging and signal processing (Moore, 1986). Further corrections were applied to λE to account for air density fluctuations due to heat and vapour transfer (Webb *et al.*, 1980, Tanner *et al.*,1993) and O_2 absorption on the Krypton radiation wavelength (Tanner *et al.*,1993). The fluxes were then corrected symmetrically for energy balance closure. The net radiation was measured using two net radiometers (model Q7, Radiation and Energy Balance Systems, Seattle, WA), placed over the canopy level in the two points of maximum and minimum ground cover of the planting grid. The soil heat flux density was measured in 3 points differing in amount of radiation reaching the soil and soil wetness with 3 heat flux plates (model HFT3, Radiation and Energy Balance Systems, Seattle, WA) at 0.05 m depth. Soil temperature was measured with 2 type K thermocouples (assembled in the IAS-CSIC laboratory) positioned near each flux plate, at 0.025 and 0.075 m depth. Soil heat flux (G) data were computed from the heat flux plates measurements and soil temperature following the combination method (Kimball and Jackson, 1975).

Results

The flux density partition was calculated as the ratio between the daily flux itself and the energy available for its generation, i.e. the available energy AE = (RN -G). The dimensionless quantities examined are thus: $H^* = H/AE$ and $LE^* = LE/AE$. As the number of data available is quite large

(456 days) and the scatter is high for a given LAI, the evolution is presented as the average of the H* and LE* for a given LAI class in Fig. 1. The Bowen Ratio BR =H/LE, calculated with the same aggregation scheme, is shown in Fig. 2.

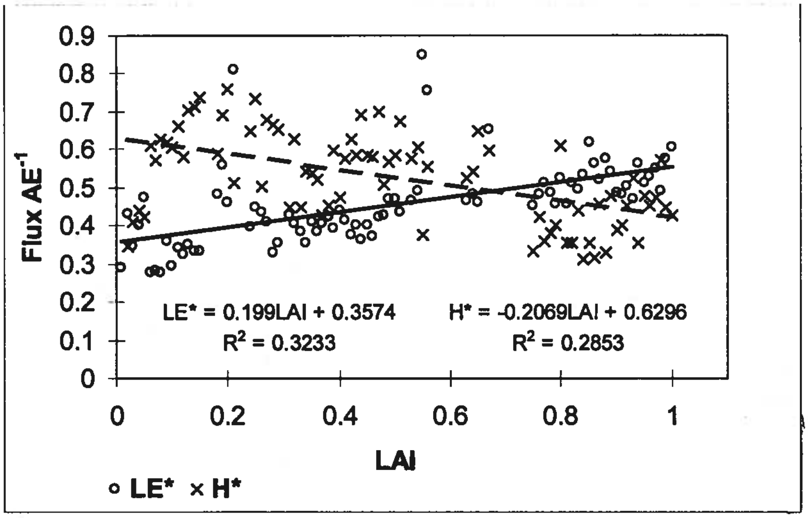

Fig. 1: Evolution of the surface energy fluxes as fractions of the available energy. Regressions: solid line = LE*; dashed line =H*

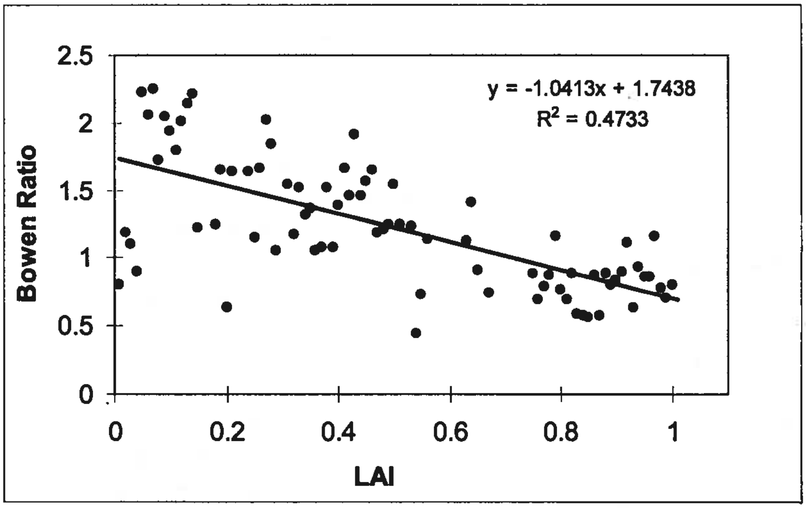

Fig. 2: Evolution of the Bowen Ratio (H/LE) as a function of LAI

Conclusions

As expected, the energy reaching the olive grove surface is converted mainly in sensible heat flux at low LAI, when most of the surface consist of bare dry soil. When the LAI is close to one, the picture is inverted: the evaporating canopy routes the main part of the available energy. The equality in the partition is reached at LAI ≈ 0.65, and the partition is around 0.35/0.65 for LAI = 0, i.e. no vegetation present, when LE is generated only by the emitters wetting spots. The Bowen Ratio, as can be seen in Fig. 2, varies between values greater than 2 for small LAI, to 0.7 at LAI around one.

Bibliography

Kimball *et al.*, 1975. Soil Science Society of America Journal. 40:25-28.
Moore, C.J. 1986. Boundary-Layer Meteorology 37:17-35.
Tanner *et al.*, 1993. Proc. 1993 Management of Irrigation and Drainage Systems, 11–23 July, Park City, UT. ASCE, New York, pp. 105–112.
Webb *et al.*, 1980. Quarterly Journal of the Royal Meteorological Society 106: 85-100.

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USE OF A COHORT POPULATION MODEL TO SIMULATE HARVEST DYNAMICS IN MULTI-CYCLE BANANA CROPPING SYSTEMS

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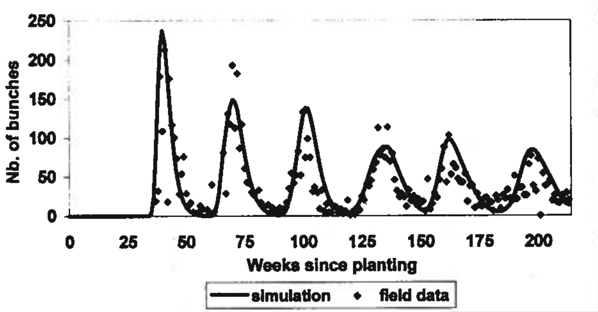
Introduction

Bananas and plantains are rhizomatous herbs with inflorescence arising from the terminal bud. Each plant successively produces a series of bunches, each from a lateral shoot. The sequence can be repeated for 1 to 50 generations or more (Turner, 1994). Banana cropping systems are based on the succession of these individual plant cycles (bud production, sucker selection, inflorescence initiation, harvest) whose inter-plant synchronism determines field harvest dynamics (number of bunches harvested weekly). Harvest dynamics can thus be characterised by oscillations whose amplitude and frequency vary with time, climate, and cultural practices (Fig. 1, field data from Guadeloupe, 2000). Management of these cycles and their prediction are key issues for sustainable production (Cottin R. et al., 1987). Farmers may want to concentrate harvests within a short period of year (requiring synchronous cycles), or, conversely, spread harvests other the year (requiring asynchronous cycles). The long term behaviour of this system must be understood and simulated so as to tailor field management to farmer's objectives and develop sustainable systems. A model was designed to simulate field banana harvest dynamics; it takes the main environmental and management variables that influence the process into account.

FIG.1 Number of bunches harvested per week over time



Methods

A predictive model was constructed on the basis of cohort population dynamics concept used in ecology to simulate animal population dynamics, coupled with environmental factors. The banana population in a plot was considered as a set of individual organisms (corms) that develop (shoot emission), mature (inflorescence initiation and development), give birth (lateral buds), and die (after bunch harvest), according to deterministic or stochastic laws. Phenological stages (analogously assimilated with processes such as birth, reproduction, sterility, death) were considered to be related to temperature (heat-units accumulated by each banana sub-population) and affected by environmental stresses (water, wind) and cropping practices. The presented model (developed from the STELLA HPS modelling platform) is based on a linear cohort succession (Deaton M. L. et al., 2000), and uses a weekly running step. The main equations are represented in Table 1. Cohort *i* represents the stock of banana plants *i* weeks old, and at each step the stock of cohort *i* is transferred to cohort *i+1*. The number of plants in each cohort (except the first one) is calculated with equation 1 . Heat-units accumulated are calculated for each cohort (equation 5). At each step, new suckers are added to the first cohort (birth law) and the number of harvested bunches is calculated (the harvesting rate is calculated by combining heat-units accumulated in the corresponding cohort and a stochastic law following a log-normal curve (Cottin R. et al., 1987). The number of harvested and dead plants are calculated for each cohort with equation 2 and 3, and the total number of plants harvested each week is calculated with equation 4. Hence, the model can take the effects of temperature and sucker management into account, as well as plant loses by falling , a variable that is influenced by plant phenological stage, root parasitism and wind speed.

Table 1. Main equations of the model

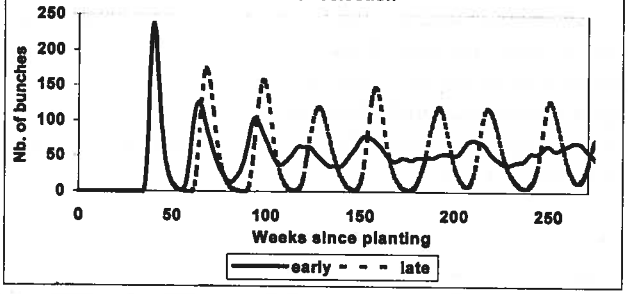
Equation 1 $N_{i,t} = N_{i-1,t-1} - H_{i-1,t-1} - D_{i-1,t-1}$
Equation 2 $H_{i,t} = N_{i,t} * h_i$
Equation 3 $D_{i,t} = N_{i,t} * d_i$
Equation 4 $H_t = \sum^n H_{i,t}$
Equation 5 $SUMT_{i,t} = SUMT_{i-1,t-1} + SUMT_t$

$N_{i,t}$ = number of plants in cohort *i* at step *t*
$H_{i,t}$ = number of harvested plants in cohort *i* at step *t*
$D_{i,t}$ = number of died plants in cohort *i* at step *t*
$SUMT_{i,t}$ = heat-units accumulated by cohort *i* at step *t*
$SUMT_t$ = heat-units accumulated during week *t*
d_i = death rate in cohort *i*
h_i = harvesting rate in cohort *i*
$h_i = a \exp(-0.5((\ln(j/b))/c)^2)$ (log normal curve)
j = number of weeks since j_o
j_o = beginning of harvest (when $SUMT_{i,t} >$ harvesting threshold)

Results

The model was calibrated and validated using data from the French West Indies, i.e. Guadeloupe (16°15'N, 61°32'W) and Martinique (14°36'N, 61°5'W), for various agricultural practices (sucker selection, planting pattern, etc.). It quite accurately simulates harvest dynamics over a long period of time in various environments (an example is presented in figure 1). The model also simulates the effect of particular climatic events, such as hurricanes, and of cultural practices, such as the replanting of new plants after death, or sucker selection modalities. It can be used as a tool to evaluate new management practices and their influences on harvest dynamics and yield. Figure 2 shows two simulations for the same climatic sequence and for two different sucker selection decision rules. The "early sucker selection" treatment reduces the average cycle duration but increases heterogeneity (asynchronism) in the field within a few cycles. In contrast, the late sucker selection treatment allows the maintenance of synchronised cycles with well identified harvest peaks over numerous cycles.

FIG. 2 Simulation of harvest dynamics for two kinds of sucker selection



Conclusions

The population dynamics approach gives a new vision of banana cropping systems that cannot be simulated over cycles with usual cropping simulation models. This model will enable further research on banana crop production simulation, including multiple cycle management. The next step will involve linkage with a plant growth model, including pest dynamics, for a more complete simulation of field banana productivity.

References

Cottin R. et al., 1987. Modélisation de la production bananière. Influence de quelques paramètres en Martinique. Fruits. 42, 691-701.
Deaton M. L. et al., 2000. Dynamic modeling of environmental systems. Springer-Verlag. 194p.
Turner D.W., 1994. Banana. In "Environmental physiology of fruit crops". Vol II., 37-64. CRC Press.

TOWARDS AN INTEGRATED SYSTEM FOR AGRO-ECOLOGICAL AND ENVIRONMENTAL MODELLING

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Introduction

European agriculture, environment and land use face an array of interrelated problems and challenges, such as ideotyping of crops and vegetation, non-sustainability of farming systems, deterioration of the environment, demand for multifunctional land use, extension of the EU and global change. These issues require analysis and design of systems at different scales. Thorough understanding of the functioning of complex agro- and semi-natural ecosystems is needed, much more than presently available.

Systems analysis and modelling can be of great help, both in the understanding of systems and in the design and development of solutions and alternatives. Models of different levels of complexity (from holistic, summary models to detailed, process models) are required for the various issues and questions.

Agro-ecological modelling in Europe

Many groups in Europe are developing or using models of agro-ecosystems and semi-natural ecosystems (e.g. Brisson et al., 2002, Stöckle et al., 2002, Van Ittersum et al., 2002). An international symposium in Florence (Modelling Cropping Systems – Donatelli et al., 2001; highlights of the symposium will be published in 2 special issues of the European Journal of Agronomy, autumn 2002), however, demonstrated a number of shortcomings of European efforts, e.g.:

- there is an array of modules for crops, soil water balances, organic matter etc., but a lack of coupling;
- there is duplication of modules and at the same time important aspects are not covered;
- a lack of feedback between users and developers;
- a lack of common data sets, and rigorous testing of modules for a range of conditions;
- a lack of standardised procedures to evaluate the quality of simulation tools and their applications;
- no direct connection between development of complex modelling tools and higher education.

In summary the potentials of agro-ecological modelling and the full benefit of the existing research thrust within European science are not being realised due to insufficient research capacity, and fragmentation of efforts across countries within Europe.

Developing the means to combine modelling expertise from different domains leads to much increased capabilities to simulate systems, minimise duplication, and ensure quality of simulation tools. Internationally, examples from Australia (APSIM – Keating et al., 2002) and USA (DSSAT – Jones et al., 2002; CropSyst – Stöckle et al., 2002) show the enormous potential that integrated modelling frameworks for cropping systems have. They offer flexibility in all kinds of applications, and they provide a good structure to further enhance the development and use of process knowledge.

Europe would benefit from an integrated framework for agro-ecological and environmental modelling with flexible tools. The Florence symposium was a good platform for discussing the basis of such a framework, but the scope of it should be broader at the same time, e.g. spatial modelling and modelling semi-natural systems and environmental issues must be covered as well.

Outline for an integrated project 6th Framework EU

The 6th framework of the European Union offers excellent opportunities for developing a framework through an integrated project, and perhaps also a network of excellence. The aim of such a project would be the development and integration of agro-ecological and environmental models and databases for the benefit of understanding complex agro- and semi-natural ecosystems. This knowledge can be used to explore sustainable production systems and options for the development of the rural area and land use in Europe. The project comprises four major elements:

1. Identify a number of key scientific and applied questions with respect to the functioning of agro-ecosystems, natural resource management and future land use in the European Union. Presently we think that we may select three issues, at different hierarchical levels, e.g. plot or crop scale (e.g. crop ideotyping, precision farming), cropping or farming system (design of new systems, multifunctional agriculture), land use (e.g. extension of EU, global change).
2. Technical modelling framework that allows flexible plug in and plug out of modules for vegetation, crops, soils, pests, climate, management, etc. The framework should allow spatial computations and representation, as well as visualisation (e.g. of landscapes).
3. Core modules and databases for the various components of the system. This comprises generation of completely new and innovative models and modules of different degrees of complexity, as well as synthesis of existing modules and knowledge. It includes empirical and experimental work to generate data, and to calibrate and validate model components.
4. Use of the framework to tackle the key issues identified under 1., and design alternative resource and land use options at different scales.

Key stakeholders and users (such as scientists, natural resource use agencies, policy makers, farmers and other land users) will be involved throughout the project.

The integrated project will be open to all European scientists, however a common ground is needed. Both the technical framework, the core components/modules and the databases should permit enough openness to attract the interest of the scientific community within Europe and further afield. Openness will allow using components both within and outside the system.

Building a common ground in terms of communication interfaces will not lead to "standardisation" of science. Instead, it will provide new means to further generate knowledge and develop models by making available a building block system, and improving the effective use of research resources. We foresee global embedding and co-operation of the research through institutions such as APSRU (Agricultural Production Systems Research Unit, Australia) and ICASA (International Consortium for Agricultural Systems Analysis). In the presentation the background and elaboration of this initiative will be further discussed.

References

Brisson et al., 2002. An overview of the STICS crop model. Eur. J. of Agron. 17: in review.
Donatelli et al., 2001. Book of Proceedings, 2nd Int. Symposium Modelling Cropping Systems, Florence, 16-18 July, 2001.
Jones et al., 2002. The DSSAT cropping system model. Eur. J. of Agron. 17: in review.
Keating, et al., 2002. The agricultural production systems simulator (APSIM): its history and current capability. Eur. J. of Agron. 17: in review.
Stöckle, et al., 2002. CropSyst, a cropping systems simulation model. Eur. J. of Agron. 17: in review.
Van Ittersum et al., 2002. On approaches and applications of Wageningen crop models. Eur. J. of Agron. 17: in review.

SPATIAL DISTRIBUTION OF REFERENCE CROP EVAPOTRANSPIRATION IN ANDALUSIA

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Introduction

The spatial distribution of reference crop evapotranspiration (ET_o) is one of the most important unknowns of the water planning and management problem in Andalusia. It requires the spatial estimation of ET_o from a limited number of available meteorological variables, measured at a limited number of locations. Previous work (Mantovani, 1993) has shown the adequacy of the Hargreaves equation (Hargreaves, 1994) for estimating ET_o in Andalusia, using only minimum and maximum temperature. Average annual or monthly ET_o maps can then be produced, using the regionalized variable theory and the geostatistical methods that are based on it (Goovaerts, 1997), taking advantage of exhaustive secondary information, as for example elevation. The aims of this work are to establish a feasible and simple methodology for spatial interpolation of ET_o, combining the available information in an optimal way, validate this methodology, and finally produce maps of ET_o for the entire Region of Andalusia.

Methods

The average ET_o for month j (mm month^{-1}), with $n(j)$ days is calculated using an adapted version of the Hargreaves (1994) equation:

$$ET_0^j = \sum_{i=1}^{n(j)} C\, RE_{i,j} \left(T_j + 17.8\right)\sqrt{\Delta T_j}\text{ , with , } C = 0.0005\frac{T_a}{\Delta T_a} + 0.00159 \qquad (1)$$

where $RE_{i,j}$ (mm day^{-1}) is the extraterrestrial radiation for day i from month j, T_j (°C) the average temperature for month j, and ΔT_j (°C) the difference between the average maximum and minimum temperature for month j. The coefficient C, which equals 0.0023 in the original equation, is obtained through an empirical relation (Vanderlinden, 2002) with T_a (°C) the average annual temperature and ΔT_a (°C) the average annual variation of the daily temperature. The average annual ET_o is then calculated as the sum of the monthly values.

The spatial interpolation problem can be tackled in several ways. Ordinary kriging (OK) is a first possibility, but does not consider secondary information. Simple kriging with local varying means, SKlm, (Goovaerts, 1997, §6.1.2) and kriging with an external drift, KED, (Goovaerts, 1997, §6.1.3) offer alternatives for incorporating exhaustive secondary information in the spatial estimation procedure. Block-kriging is used to estimate the ET_o on a support of 1 km^2. Moreover different methodological routes exist to produce an ET_o map. Heuvelink and Pebesma (1999) called these "interpolate first, calculate later" (IC) and "calculate first, interpolate later" (CI). Applied to our problem this translates into interpolating first the input variables of equation (1) and then calculating ET_o at each location (IC) or calculating ET_o at all the observatories and then interpolating (CI). Given the non-linear nature of equation (1), CI should be used. Nevertheless, differences between IC and CI have been found to be generally small. Based on rather practical considerations, as for example goodness of the relationship between the primary and secondary variables, variogram behaviour and working efficiency, CI is preferred. SKlm and KED are implemented using the GSLIB (Deutsch and Journel, 1998) geostatistical Fortran library.

Results

Average annual ET_o was calculated at 190 observatories. Values ranged from 954 to 1460 mm, with an average of 1283 mm and a standard deviation of 99 mm. The highest values occur near the coast during the winter, and in the Guadalquivir river basin during the summer. After removing the coastal stations, a correlation coefficient of -0.86 was obtained between average annual ET_o and elevation. A second order polynomial was fitted to the ET_o-elevation data and used for calculating the local means for SKlm. Figure 1. shows the isotropic variogram, the variogram in the direction of maximal continuity (35° from E-W direction), used for KED, and the residual variogram that is used in SKlm. Figure 2 shows the resulting average annual ET_o map produced by SKlm, with a block support of 1 km^2. Monthly ET_o maps were produced using the same procedure.

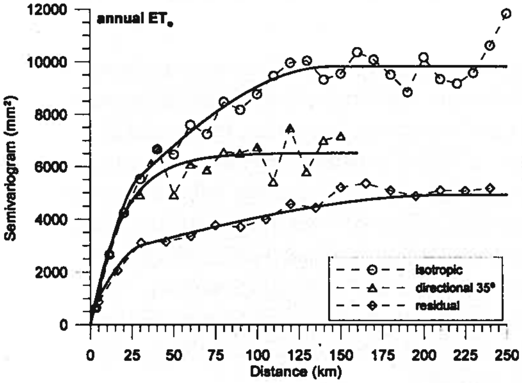

Figure1. Variography of average annual ET_o

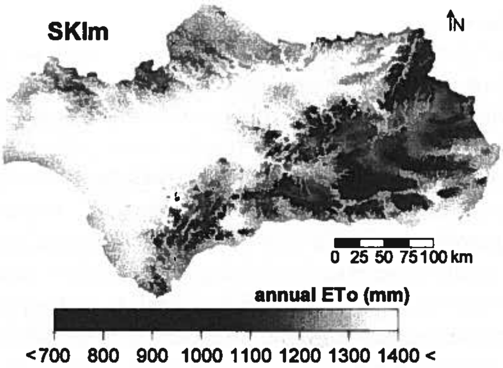

Figure 2. Block kriged map (SKlm) of average annual ET_o.

Discussion

Cross-validation shows that incorporating elevation in the estimation procedure results in better estimates, especially when using SKlm, although the differences with KED are small. The mean error, root mean square error and the correlation coefficient for SKlm are 1.4 mm, 53 mm, and 0.85, respectively. SKlm also reproduces better the descriptive statistics of the original data. The monthly maps show how the spatial distribution pattern of ET_o changes along the year. During the winter months the highest values are observed near the coast, while the lowest values occur in the mountain ranges. During the summer months, the highest values are observed in the medium and upper part of the Guadalquivir river basin, away from the influence of the coast or protected from it by mountain ranges. These maps constitute a valuable tool for regional water resources planning and management in Andalusia.

References

Deutsch, C.V. and A.G. Journel, 1998. *GSLIB. Geostatistical software library and user's guide*, 2nd edition. Oxford University Press, New York.

Goovaerts, P., 1997. *Geostatistics for natural resources evaluation.* Oxford University Press, New York.

Hargreaves, G. H.,1994. Defining and using Reference Evapotranspiration. *ASCE Journal of Irrigation and Drainage Engineering*, 120:1132-1139.

Heuvelink, G.B.M. and E.J. Pebesma, 1999. Spatial aggregation and soil process modelling. *Geoderma*, 89:47-65.

Mantovani, C.E., 1993. *Desarrollo y evaluación de modelos para el manejo del riego: estimación de la evapotranspiración y efectos de la uniformidad de aplicación del riego sobre la producción de los cultivos*. Ph.D. thesis, Department of Agronomy, University of Córdoba.

Vanderlinden, K., 2002. *Análisis de procesos hidrológicos a diferentes escalas espacio-temporales*. Ph.D. thesis, Department of Agronomy, University of Córdoba.

AN INTERNET SYSTEM OF EVALUATION OF POTATO YIELD LOSS AS INFLUENCED BY PRECIPITATION DEFICIENCY IN POLAND

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Introduction

Poland is a major world producer of potato. The crop is cultivated on 1.2 million ha - about 9% of the total arable land of the country. Potatoes are grown predominantly on light soils, on which they frequently experience deficiency of water. In the case of insufficient precipitation the yield goes down considerably. In dry years (as e.g. were 1992 and 1994) the mean yield may be as low as 60-70% of that expected under average weather conditions. Naturally not all localities suffer from drought to the same extent, since its consequences depend also on region and soil water capacity.

The objective of the paper is the presentation of an Internet system for generating information on potential loss of potatoes in different regions of Poland. Three elements have been included in the system: a model of potato yield loss, a model of the spatial distribution of precipitation and an index of influence of soil complex on potato yield.

Materials and methods

Basic material in the development of the system was a model of probability of the mean potato yield loss in Poland [1], developed by Górski (Zaliwski, Górski, 2001).

$$L = 76-1.06\times J+0.0074\times J^2-0.0000214\times J^3-0,42\times A+0.000887\times A^2+0.00145\times J\times A \qquad [1]$$

Where: L – expected mean loss of yield [% of mean yield],
J – normal precipitation in July [mm],
A – normal precipitation in August [mm].

Information about distribution of a normal precipitation in July and August for any place in Poland necessary for the model is based on algorithms developed by Górski et. al. (1998). The user can access this information with a click on a map of Poland, which is a part of the interface of the system. After a point on the map has been selected, the information on the longitude, latitude, elevation and precipitation correction of the point is extracted from the database on the server and the necessary calculations are made which yield precipitation sums.

The model developed by Górski [1] only takes into account variation of climatic conditions, assuming average soil conditions. By taking into consideration yield data for soil complexes 4, 5, 6 and 7 (after Nowak, 1993) an extended model of potato yield loss has been developed to include the influence of soil. Nowak used soil classification based on complexes. This classification is generally accepted in Poland.

The user inputs the soil complex into the system independently of the locality selected on the map, as the representation of climate and soil variability needs a different resolution. It is so because a point on the map corresponds to a region of about 10*10 km^2 in real world units.

Results

Mean potato yield losses as influenced by precipitation deficiency with regard to average soil conditions according to model [1] are presented in fig. 1.

In fig. 2 the Web-page of the system is shown which is the interface between the system and the user. The table on the left serves for data input and the one on the right for displaying the results (precipitation and potato yield loss values). They are displayed after having been computed for the point indicated by the user on the map that pops-up in its own window when the icon of Poland (fig. 2) is clicked.

Before making each computation the user can change the value of elevation of the point selected (and choose the soil complex as well). For instance, when the Pu□awy region was selected and the computation made, the normal precipitation was 88 mm in July and 76 mm in August. The mean yield loss of potato as influenced by precipitation deficiency on different soil complexes (given in brackets) amounted to: 7.8% (4), 9.5% (5), 13.5% (6) and 17.5% (7).

Fig. 1. Spatial distribution of potato-crop mean yield loss caused by precipitation deficiency in Poland.

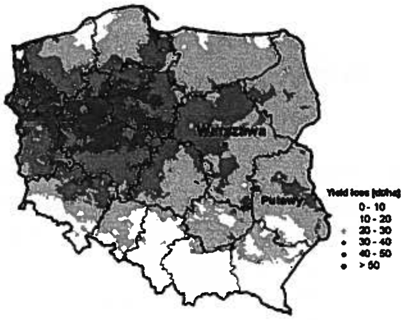
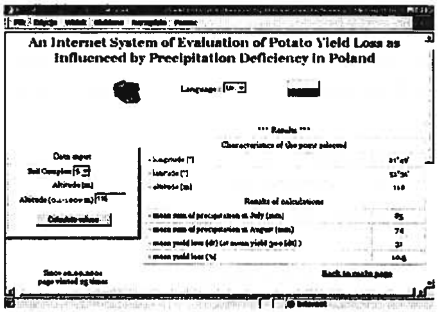


Fig. 2. The Web-page of the system.


An Internet System of Evaluation of Potato Yield Loss as Influenced by Precipitation Deficiency in Poland

*** Results ***

Characteristics of the point selected

Data input

Soil Complex

Altitude (m)

Results of calculations

Back to main page

Conclusion

Modern computation techniques employ new tools and create possibilities of presentation of research results on the Internet. For example, an Internet system of evaluation of potato yield loss as influenced by precipitation deficiency in Poland is implemented at www.ipm.iung.pulawy.pl/Naw_Ziem.asp. The proposed system could be used in decision support on the farm or in investment strategy, e.g. to estimate a need for installation of irrigation facilities. An example of its implementation in the Evaluation Module of Potato Production Technology Variants can be found at http://www.ipm.iung.pulawy.pl/Potato_EVMOD.asp.

References

Górski T., Demidowicz G., Deputat T., Doroszewski A., Zaliwski A., Posielski K., Krakowiak A., Pietruch C., Wróblewska E. 1998. Opracowanie atlasu agroklimatycznego Polski technika komputerowa. Research report, IUNG

Nowak L. 1993. In : Dziezyc J. (ed.). Czynniki plonotwórcze – plonowanie roslin. PWN, Warszawa ; 341

Zaliwski A., Górski T. 2001. Determination of cost-effectiveness of irrigation of the potato in Poland with the aid of GIS. Third European Congress of the European Federation for Information Technology in Agriculture, Food and the Environment (vol. 1); 191-186.

Plant-soil relationships

CONTRIBUTION OF FIELD PEA *(PISUM SATIVUM L.)* TO SOIL N BALANCE IN RELATION TO YIELD, N_2 FIXATION, N PARTITIONING AND INITIAL SOIL N

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Introduction

One common approach to evaluating legume contributions to cropping systems has been to determine net inputs of fixed N_2, calculated by subtracting N removed in the grain from estimates of the amount of N_2 fixed. Other balances, integrating root N (Kumar and Goh, 2000) and N rhizodeposition (Jensen, 1996) have been proposed for better accuracy. Using one of these in a wheat-pea succession we observed significant variation in the contribution of field pea among years (Aveline et al., 1998). It indicated that for practical recommendation, there was a need for a better understanding of the causes of such a variation. The objectives of the present work were to: (i) study the relationship between soil N balance after pea and some major crop productivity components, (ii) develop a practical approach for estimating pea contribution to soil N in farm conditions.

Methods

Data came from three research programmes conducted in Pays de Loire area in loamy textured soil: (A) a long term trial at ITCF 'La Jaillière' where N dynamics in a pea-wheat succession was monitored for 7 years (Aveline et al., 1998), (B) a three-year experiment located at the same research station as A, but where three levels of N fertilization (0, 80, 170, 250 kg $N.ha^{-1}$) were compared, and (C) a two-year on-farm monitoring of organic pea crops aiming at grading factors that limit yield in such low-input systems (Corre and Crozat, 2001). Overall, a total of 37 situations were available : 11 in conventional systems without N application (called 0N), 8 receiving N fertilizer (called N+) and 18 in organic systems (noted Org.).

In all situations, the following data were recorded : shoot dry matter, grain yield, grain N, shoot N and, % N derived from N_2 fixation using ^{15}N natural abundance method with barley as a non fixing reference crop, excepted for trial B were ^{15}N-enriched ammonium nitrate was applied.

The crop N contribution to soil N was calculated as described by Aveline et al. (1998) with N balance = N input (Seed N + N_2 fixed in shoot, root and rhizodeposit) – N Grains.

Results

N balance magnitude was -100 kg N ha^{-1} to + 45 kg N ha^{-1} in the conventional systems without N fertilizer application, and -130 kg N ha^{-1} to + 70 kg N ha^{-1} in organic systems. N balance was always negative (-240 kg N ha^{-1} to –40 kg N ha^{-1}). As shown in Table 1, N balance was negatively correlated to grain yield, total N, grain N as well as Nitrogen Harvest Index (NHI). As a matter of fact, N exported through grains increased with yield and high yields were generally associated with a good partitioning of total N into grains. In contrast, N balance was positively correlated with the percentage of total N uptake derived from fixation (% Ndfa), but it was poorly correlated to the amount of N fixed (Table 1).

The ratio between Ndfa and NHI which takes into account both the entry of N into the system and its partitioning between the exported and the remaining plant parts provided the best prediction of soil N balance (Fig.1). In experiment B, where N fertilisation was the controlled source of variation, % Ndfa over the growth cycle could be predicted as a linear function of soil N content (N-NO3 and N-NH4) of the ploughed layer at sowing (Fig. 2). Voisin et al (2002) reported a similar relationship but with a smoother inhibition rate of N2 fixation.

Table 1 : General correlation coefficients between N balance and crop components

	N balance	Yield	Total N	Grain N	N2 fixed	%Ndfa
Yield	-0,751					
Total N	-0,608	0,870				
Grain N	-0,741	0,870	0,938			
N2 fixed	0,315	0,263	0,488	0,357		
%Ndfa	0,898	0,690	-0,637	-0,674	0,326	
NHI	-0,459	0,285	0,057	0,273	-0,119	-0,169

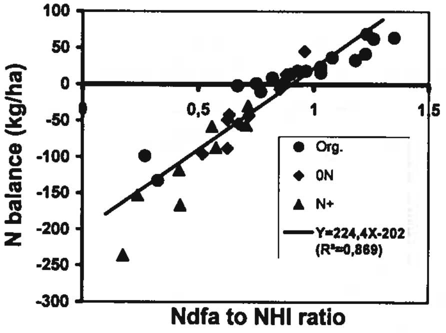

Fig.1: N balance after pea in relation to the ratio between N derived from N2 fixation and N Harvest Index

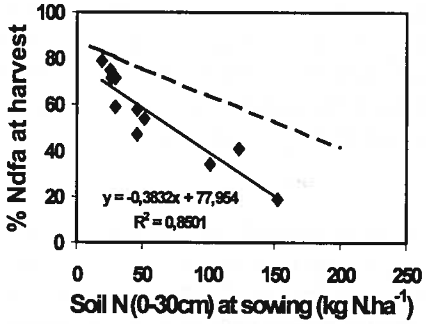

Fig.2: Effect of soil N availability at sowing and % N derived from atmosphere at harvest (--- Voisin et al. 2002)

Conclusions

Variation in grain yield and % Ndfa were the major sources of variation in N balance. Ndfa to NHI ratio could be used as an indicator of the contribution of pea to soil N balance. Moreover, for practical application, potential % Ndfa could be estimated with soil N at sowing. However, this relationship between soil N and N2 fixation may not hold so well where other factors such as water limitation, weeds infestation or pea weevils damage may affect N2 fixation. Integration of these factors is under investigation.

References

Aveline, A. et al., 1998. 3rd Eur.Conf.Grain Legumes, 134-135
Corre, G. et al.,2001. 4th Eur. Conf. Grain Legumes, 46-47
Jensen, E.S., 1996. Soil Biology and Biochemistry. 28: 65-71.
Kumar, K. et al., 2000. Field Crops Research, 68 : 49-59
Voisin, A. S. et al., 2002. Plant and Soil (in press)

FERTILIZATION OF A KIWI PLANTATION WITH WOOD ASH: NUTRITIONAL STATUS AND PRODUCTION.

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Introduction

Wood ash is produced in large quantities in biomass-burning energy plants attached to wood and pulp mill factories. The large amounts of residue generated and the high cost of storage have led to interest in the search for alternative uses (Vance, 1996). Wood ash is highly alkaline and contains large amounts of macronutrients, such as Ca, K, Mg and P, and low levels of N and heavy metals, and it can therefore be used to reduce the acidity and to supply base cations to acid soils (Someshwar *et al.*, 1996). The acid-neutralizing capacity of wood ash is attributed to the oxides, hydroxides and carbonates of Ca, Mg and K that it contains (Etiégni and Campbell, 1991). Wood ash raises the alkalinity of the soil in a similar way to limestone. However, wood ash is highly soluble in water and its application leads to rapid changes in pH, whereas limestone acts more slowly (over six months or so) (Ohno and Erich, 1990). The aim of this study was to assess the efficacy of wood ash as a liming agent and fertilizer of the soil in a kiwifruit plantation, in which the soil was of low fertility and production was relatively low (17 t ha^{-1} of fruits). A previous study carried out in the laboratory showed that application of wood ash improved soil fertility and crop yield (Solla-Gullón *et al.*, 2001).

Material and methods

The kiwifruit plantation under study is located in Tomiño (Pontevedra, NW Spain), where the annual average rainfall is 2000 mm and the temperature, 13ºC. At the time of study, the plantation was 15 years old and comprised a total surface of 32 ha. The soil is developed from quaternary sediments and it contained a large amount of organic matter (12 %), low pH (5.0) and low levels of available P, Ca, Mg and K and the pH was low (5.0). As a consequence of the poor soil conditions, foliage and fruits contained low levels of Ca.

The experiment was carried out in a homogeneous area of 4600 m^2, established in March 2001. The experimental treatments (4 replicates of each), applied to the soil in a randomised block design, were as follows: a) Control (no added wood ash), b) 8 t ha^{-1} wood ash and c) 16 t ha^{-1} wood ash. The residue was applied on the soil surface without any mechanical incorporation to the soil. The nutrients in soil (solid fraction and solution), foliage and fruits were monitored between March and November 2001.

The concentrations of macro (P, Ca, Mg, K) and micronutrients (Mn, Fe, Zn, Ni y Cu) were determined in all samples. The pH and concentrations of NO_3^- and NH_4^+ were also measured in the solid and liquid fractions.

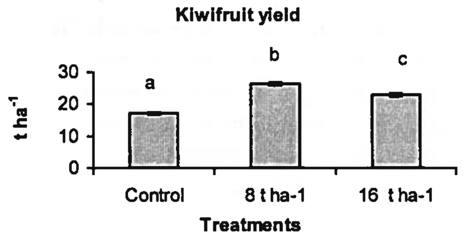
To evaluate production, all fruits were harvested at four different times between September and November. At each time, collection was made of a quarter of the kiwifruits in each experimental plot. The amount and weight of kiwifruits on each plant were measured, using a mechanical packing line with weight sizes. The data for each gauge were obtained. Data was analysed by GLM multivariate analysis (SPSS 10.1.3).

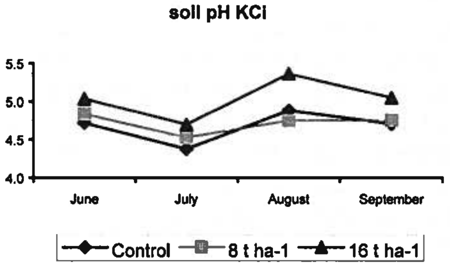
Results

The addition of the highest doses of wood ash led to increases in soil solution pH and levels of soluble P, Ca, Mg and K, although the differences among treatments were not always significant. In the soil fraction, wood ash significantly increased the pH by 0.5 units and also led to increases in available Ca, Mg and K and, to a lesser extent, P. No changes in heavy metals were found.

With the exception of Ca, levels of nutrients in leaves and fruits were within the optimum range for agricultural production. No significant changes in foliar nutrient levels were observed for any macronutrient, even Ca. Unlike the foliage, increases in Ca in fruits were found after ash application. The contents of micronutrients were not altered and did not reach levels considered as toxic.

Fruit production (yield as fresh weight) was significantly from 17,1 up to 26,3 t ha^{-1} reaching the highest rates obtained for this crop (around 25-30 t ha^{-1}) after wood ash treatment with 8 t ha^{-1}. Interesting, the yield of kiwifruits categorized according to preferred commercial size (>65 g) was higher in treated than in control plants.





Conclusions

The results obtained in the first year of the study show that wood ash decreased soil acidity and improved the soil nutrient availability. These effects produced an increase in the macro and micronutrients content in leaves and fruits, although the increases were not always significant. The wood ash treatment led to an increase in both amount and weight of the fruits, especially fruits of commercially acceptable sizes, which may be attributable to the higher concentrations of Ca in fruits.

References

ETIÉGNI L., *et al.*, 1991. Physical and chemical characteristics of wood ash. Bioresource Technology, 37, 173-178.

OHNO T., ERICH, M.S., 1990. Effect of wood ash application on soil pH and soil test nutrient level. Agricultural Ecosystem Environment. 32, 223-239.

SOLLA-GULLÓN, F.; *et al.*, 2001: Evaluación del aporte de cenizas de madera como fertilizante de un suelo ácido mediante un ensayo de laboratorio. Investigación. Agraria.: Producción. y Protección . Vegetal. Vol. 16(3).

SOMESHWAR A. V., 1996: Wood and combination wood-fired boiler ash characterisation. Journal of Environmental Quality, 25, 962-972.

VANCE E. D., 1996. Land application of wood-fired and combination boiler ashes: an overview. Journal. Environmental Quality. 35, 937-944.

EFFECT OF ORGANIC RESIDUES APPLICATION TO SOIL ON MINERAL NUTRITION OF WINTER WHEAT

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Introduction

Excessive or unbalanced use of mineral fertilisers results on an economical and environmental disadvantage. On the contrary, organic wastes can be recycled as a source of plant nutrients, namely N, as well as enhance the future crop production by improving the quality of the soil in terms of organic matter content (Dick & Christ, 1995). With sight to supply part of the plants needs for nitrogen (N) and simultaneously to compensate the losses of organic matter that occur in the majority of the generally poor Portuguese soils, the application of organic residues to winter wheat crops was tested in a Cambic Arenosol.

Materials and methods

Wheat (*Triticum aestivum* L) was grown in a greenhouse, in Kick-Brauckmann pots containing 12 kg of a Cambic arenosol, with 5.9 g kg^{-1} organic matter and 0.34 g kg^{-1} Kj-N, previously amended with one of 6 organic residues dried and ground: municipal solid waste, (MSW), poultry manure (PM), secondary pulp mill sludge (PMS), solid phase from pig slurry (SPPS), composted pig manure (CPM) and horn meal (HM) (table 1). The residues were added in doses equivalent to 80 or 160 kg TKN ha^{-1}. 120 kg of N ha^{-1} were added to control-1 and to half of the pots as NH_4NO_3 (AN). To the remaining pots, no mineral N was applied. Treatments, replicated three times, consisted of: A-control 1 AN, B-MSW80+AN, C-PM80+AN, D-PMS80+AN, E-SPPS80+AN, F-CPM80+AN, G-HM80+AN, H-MSW80, I-PM80, J-PMS80, K-SPPS80, L-CPM80, M-HM80, N-MSW160+AN, O-PM160+AN, P-PMS160+AN, Q-SPPS160+AN, R-CPM160+AN, S-HM160+AN, T-MSW160, U-PM160, V-PMS160, W-SPPS160, X-CPM160, Y-HM160 and Z-control 2 (no residue and no fertiliser). All the pots received a basal dressing of P, K, Ca, Mg, Fe, Cu, Zn and Mn. Soil was kept at 60% field capacity. Plants were cut, dried and analysed for N (NKj+N-NO_3).

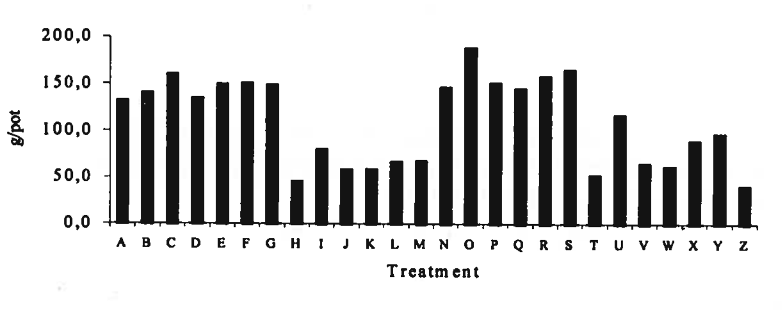
	MSW	PM	PMS	SPPS	CPM	HM
Kj-N (g kg^{-1})	17.8	35.5	42.4	09.1	21.7	116.7
C/N	13.65	11.85	11.70	45.49	21.70	4.2

Table 1 – Some characteristics of the residues applied.

Results and discussion

The application of residues to the soil increased wheat biomass production, as a consequence of the supply of higher amounts of N (fig 1).

Figure 1- Wheat dry weight

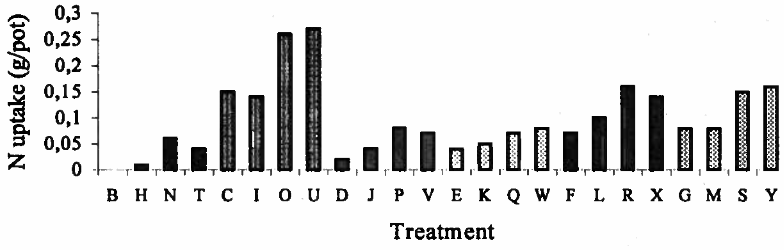


PM was the residue supplying more N in each treatment, and the one that allowed the plants a higher uptake (fig 2). These results are consistent with the literature, since PM presents a larger fraction of labile N than the other organic residues used (Dick & Christ, 1995). The organic nitrogen contained in the MSW and in the PMS appeared to be of more steady nature, as it led to a lower plant yield (fig 1). Contrasting with results obtained by Cordovil *et al.* (2001) in ryegrass, CPM treatments showed better results in terms of plant growth than SPPS. Higher C/N ratio probably led to N immobilisation and therefore less plant growth and N uptake, due to a lower availability of N in the soil. This could probably be the result of the fact that ryegrass was grown for a longer period than wheat, allowing the release of some N previously immobilised.

Figure 2- N uptake (g/pot)

Figure 3 shows the apparent net N mineralisation that was calculated by subtracting N uptake by plants grown in control 1 or 2 from N uptake by plants from other treatments. Control 1 was subtracted from all the AN treatments and the uptake value of control 2 was subtracted from the remaining treatments.

Figure 3- Apparent net mineralization



As expected, PM was the residue with the highest OM mineralisation (fig 3). Regardless of the residue amended to the soil, it did not seem to occur a "priming effect" due to mineral fertiliser application for any treatment (Cordovil *et al.*, 2001; Stevenson, 1982)

References

Cordovil C M d S, F Cabral, J Coutinho, E Vasconcelos e H M Ribeiro 2001. In: *Actas del XV Congresso Latinoamericano de la Ciência del Suelo,* Varadero, Cuba (CD-ROM).
Dick, RP, Christ RA. 1995. *Soil Sci.* 159 (6), 402-408.
Stevenson, F.J. 1982. *Nitrogen in agricultural soils*. SSSA. Agron. 22. Ma, WI, USA. 940 p.

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EFFECT OF THE SOIL TYPE ON THE EFFICIENCY OF DICYANDIAMIDE (DCD) AS NITRIFICATION INHIBITOR IN NITROGEN FERTILIZERS

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Introduction

Nitrogen fertilization is essential to maintain productivity, but the efficient utilization of N applications is of major importance from both agronomic and environmental points of view. The potential advantages of the use of nitrification inhibitors are well known, with special regard to DCD (Amberger, 1989). But retarding the conversion of NH_4^+ to NO_2^-, and subsequently to NO_3^- , the use of nitrification inhibitors in fertilizer industry is justified only (i) if urea is present as N source (Bock *et al.*, 1981) and (ii) if nitrate salts are not used as N source in the stabilised fertilizers. Since the effectiveness of nitrification inhibitors may be affected by the characteristics of the soil, the purpose of the laboratory study reported here was to evaluate and compare the efficiency of DCD as soil nitrification inhibitor in two very dissimilar soil types.

Material and methods

Laboratory incubations during 28 days were conducted to study the effect of the soil type on the persistence of DCD as nitrification inhibitor when urea-ammonium sulphate is applied as N fertilizer. Some properties of the dystric Regosol and the eutric Fluvisol used in the study are present in table 1.

Table 1 –Selected properties of the soils under study

Soil/class of texture	clay $g\ kg^{-1}$	pH H_2O	Egner-Riehm $mg\ P_2O_5\ kg^{-1}$	method $mg\ K_2O\ kg^{-1}$	org mat $g\ kg^{-1}$	Ca	Mg^+	K	Na	Al	CECe	B S %
						cmol + kg^{-1}						
Regosol												
sand	46	5,9	456 VH	112 H	16.9	1,94	0,55	0.21	0,19	0,12	2,91	95,9
Fluvisol												
Silty-clay	496	8,1	304 VH	320 VH	28,3	24,64	5,39	0,83	0,56	0,00	31,02	100,0

The soils were mixed, air-dried and sieved to pass a 2 mm sieve. Samples of 1.5 kg of soil were equilibrated to 70% of field moisture capacity and mixed with urea-ammonium sulphate (UAS) or ammonium sulphate (AS) equivalent to 100 mg N kg^{-1} with or without a rate of 4% of total N from dicyandiamide, supplied by ODDA Smelteverk, Norway. A control treatment with no N and DCD application was also tested. Aerobic incubations were conducted at 25 °C and samples were taken after 7, 21 and 28 days. Mineral N (NH_4^+ and NO_3^-) concentrations in soil were assess after an extraction with KCl 2*M* (1:2) and determined by molecular absorption spectrometry in a segmented flow system. For each soil, apparent net nitrification from fertilizers with or without DCD was calculated. Statistical analyses included analysis of variance and Tukey least significant difference ($p<0.05$) to separate means among treatments within soils.

Results and discussion

Soils presented a distinct potential for N mineralization. In control treatment, net mineralization was low in Fluvisol, 2.5 mg N kg^{-1} after 28 days of incubation, but reached 14.5 mg N kg^{-1} in the Regosol. Nevertheless, concentrations of N- NH_4^+ during all the incubation period were nil, revealing that the activity of nitrifiers, in both soils, was only limited by substrate availability.

In the Fluvisol, nitrogen from both fertilizers without DCD was nitrified within 28 days (fig. 1). The presence of DCD significantly retarded the biological transformation of NH_4^+ from both fertilizers with an effect slightly more pronounced for AS. On average, the nitrification rate was 3.6 mg N kg^{-1} day^{-1} without DCD, and 2.7 mg N kg^{-1} day^{-1} for the stabilised fertilizers.

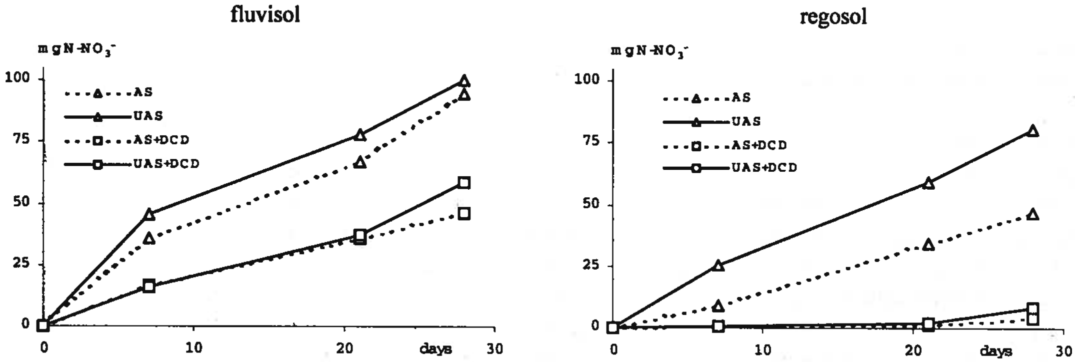

Figure 1 – Effect of the soil on DCD efficiency on the apparent net nitrification from ammonium sulphate (AS) and urea-ammonium sulphate (UAS) application.

In the Regosol, nitrification was lower when compared with the results obtained with the previous soil, as shown in fig 1. Without DCD, nitrification was not complete after 28 days. Concentration of N- NO_3^- was lower than 100 mg N kg^{-1} but N immobilization do not seems to account for this difference, since mineral N (sum of NH_4^+ and NO_3^-) was not significantly different from 100 mg N kg^{-1}. Important differences were observed between AS and UAS. The latter showed a nitrification rate of 2.3 mg N kg^{-1} day^{-1}, significantly higher than the value of 1.4 mg N kg^{-1} day^{-1} for AS. Being an acid soil and the nitrification a pH dependent process, these results may be explained by the alkalinization in soil induced by UAS transformations. The presence of DCD showed a very strong effect, and after 28 days of incubation, the apparent net nitrification was about 4 mg N kg^{-1} from AS and 8 N kg^{-1} from UAS.
This dependent lower efficiency of DCD in clay soils was already referred by Amberger (1989) and may be attributed to the faster decomposition of DCD, which takes place on the surfaces of metal oxides, while the breakdown is much slower in soils poor in clay. A higher persistence of the inhibitor effect in light textured soils was also noted for other compounds (Barth *et al.*, 2001)

Conclusions

Even with a moderate rate, equivalent to 4% of total N in the stabilised fertilizer, DCD showed a significant effect on the inhibition of ammonium bio-oxidation at 25 °C in laboratory conditions. In both soils and for both fertilizers, the persistence of the effect was observed 28 days after its application, with a significant reduction on soil nitrate content. Nevertheless, its efficiency as nitrification inhibitor is soil type dependent. In the dystric Regosol, a very light textured soil, the efficiency of DCD in retarding nitrification was much higher than in the silty clay Fluvisol.

Amberger, A., 1989. Commun. Soil Sc. Plant Anal., 20, 1933-1955
Barth *et al.*, 2001. Biol. Fertil. Soils, 34, 98-102
Bock, B.R. *et al.*, 1981. Technical Workshop on Dicyandiamide, 25-36, TVA/IFDC

ADSORPTION AND DESORPTION OF CHLORIDAZON AND LENACIL IN A SOIL WITH A SUGAR BEET CROP

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Introduction

Pesticide leaching causes serious problems of groundwater contamination in most areas where crops are irrigated. The herbicides that are incorporated into the soil have a specially high potential for contamination, since they are easily leached by the vertical movement of water in the soil. Cuevas et al. (2001) studied the mobility and persistence of chloridazon and lenacil in a clayey soil in the reclaimed marshes of Lebrija, southwest Spain. They carried out field experiments in a plot cropped with sugar beet, where the herbicides were applied and incorporated into the soil in the usual way. In addition, they carried out laboratory experiments with undisturbed soil columns to evaluate the herbicides fate when a high dose is applied. This work reports on the adsorption studies carried out at laboratory conditions with the aim of explaining the herbicides' mobility observed in both sets of experiments.

Methods

On 3 October 2000 (day of year, DOY, 276), blank soil samples were collected from 0 to 0.15 m depth from eight locations randomly chosen within a 12.5 ha plot located in a reclaimed area of the marshes close to Lebrija (37° 1' N, 6° 8' W, elevation 2 m). The soil type is Fluvaquent (USDA) with 69% clay and 30% silt. The climate in the area is typically Mediterranean. On 9 November 2000 sugar beet was sown. On the next day, 150 L ha^{-1} of a herbicide solution containing 1290 g a.i. ha^{-1} of chloridazon plus 500 g a.i. ha^{-1} of lenacil were sprayed on the field. The soil was kept wet during the whole crop season, adding water by irrigation when necessary. Column experiments with undisturbed soil columns were also made. Details are given in Cuevas *et al.* (2001). The blank samples collected on DOY 276 were dried, sieved through a 2 mm mesh and stored in a refrigerator until the beginning of the sorption experiments. These were performed using the batch equilibration procedure. The adsorption experiments were performed with duplicate samples of 10 g of soil treated with 10 mL of cloridazon+lenacil at initial solution concentrations (C_i) of 2.4, 1.2, 0.9, 0.6, 0.3, 0.12 and 0.06 ppm. Aqueous 0.01 M $CaCl_2$ was used as solvent, being 2.4 ppm the maximum lenacil solubility we obtained. The suspensions were shaken at 20±2 °C for 24 h and centrifuged at 12000 rpm. The supernatants were analysed by HPLC. Details on the analysis procedure are given in Cuevas *et al.* (2001). Desorption was measured after adsorption from the initial adsorption concentration of 2.4 and 0.6 ppm, using the consecutive dilution method described in Cox *et al.* (1995). For each herbicide, adsorption and desorption isotherms were determined and fitted to the linear form of the Freundlich equation.

Results

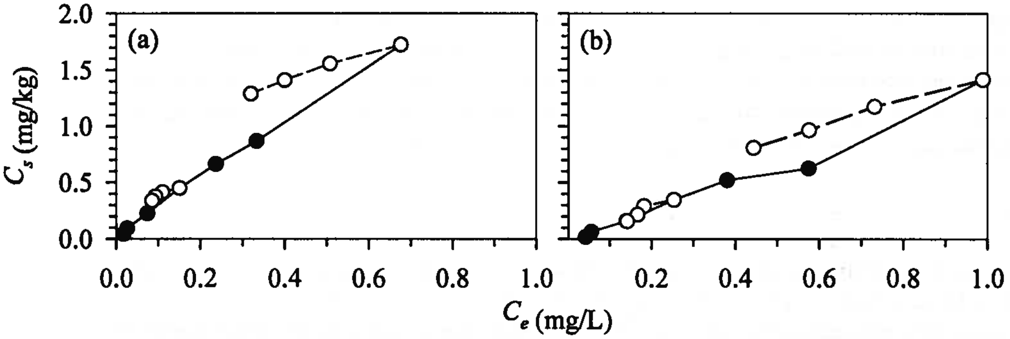
Figure 1 shows the results from the sorption studies. The slope of the adsorption isotherms shows that chloridazon was more adsorbed by the soil than lenacil, as indicated by the corresponding K_f (Table 1). The adsorption capacity of this soil can be considered as high for chloridazon and medium for lenacil. Chloridazon adsorption has been closely related to the clay mineral components, specially to montmorillonite (Sánchez-Martín and Sánchez-Camazano, 1991), whereas lenacil, less polar than chloridazone, might have less interaction with clay components and more attraction by soil organic matter (SOM). The different behaviour of both herbicides is a consequence of their different polarity as developed by their water solubility (400 mg L^{-1} for chloridazon and 6.0 mg L^{-1} for lenacil, at 20 °C). Therefore, the high content of clay, and type of clay minerals (illite and montmorillonite) of this soil must be responsible for the high adsorption of chloridazon, whereas its low SOM content rendered medium adsorption of lenacil.

The role of expandable clay mineral and SOM is also suggested by the hysteresis observed in the desorption branch of both herbicides at high concentration (Fig. 1), corroborating that these soil characteristics are related to strong and irreversible adsorption of pesticides.

Table 1. Adsorption and desorption parameters calculated for chloridazon and lenacil.

	chloridazon			lenacil		
	Adsorption	Desorp. (2.4 ppm)	Desorp. (0.6 ppm)	Adsorption	Desorp. (2.4 ppm)	Desorp. (0.6 ppm)
K_f	2.62	8.22	1.67	1.56	2.13	0.90
n_f	0.96	1.21	1.56	1.24	1.11	1.61
r^2	0.99	0.99	0.87	0.96	0.99	0.86

Figure 1. Adsorption (close symbols) and desorption (open symbols) isotherms of cloridazon in the presence of lenacil (a) and of lenacil in the presence of cloridazon (b).



According to our sorption data chloridazon should be less mobile and more persistent than lenacil in this soil. However, Cuevas *et al.* (2001) found that both herbicides were low persistent (Table 2), and that the dissipation of lenacil was slower than that of chloridazon. In addition, the amounts of both herbicides they found below the top 0.05 m were low, indicating that both had a low mobility. To explain the observed behaviour, we must assume a fast degradation of both herbicides in the soil.

Table 2. Chloridazon and lenacil dissipation time (DT_{50}) (Cuevas *et al.*, 2001) and some experimental characteristics.

	T	θ	O.M.	chloridazon		lenacil	
	(°C)	(m^3 m^{-3})	(%)	DT_{50}(d)	r^2	DT_{50} (d)	r^2
Field	17.2	39	1.03	11	0.89	16	0.97
Columns	18 ± 2	41	1.03	4	0.98	14	0.58

Conclusions

The clay mineral composition of the studied soil caused a high adsorption of chloridazon, while the soil organic matter was responsible for a medium adsortion of lenacil. Despite these high and medium adsorption levels, Cuevas *et al.* (2001) found that the persistence of both herbicides in the soil was low. This suggests a fast degradation of the herbicides under the studied conditions.

References

Cox L., Hermosín M.C., Cornejo J. 1995. Intern. J. Environ. Anal. Chem., 58, 305-314.

Cuevas M.V., Calderón M.J., Fernández J.E., Hermosín M.C., Moreno F., Cornejo J. 2001. Acta Agrophysica, 57, 15-25.

Sánchez-Martín M.J., Sánchez-Camazano M., 1991. Weed Science, 39: 417-422.

MONITORING *IN SITU* SOIL NITRATE CONCENTRATIONS USING TIME DOMAIN REFLECTOMETRY (TDR)

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Introduction

There is an ever increasing demand for measurements of mineral nitrogen in soil, for purposes of increasing fertilizer efficiency, and for monitoring of environmental pollution risks. Measuring mineral nitrogen concentrations with high spatial and temporal resolution is costly and time consuming. Therefore monitoring of mineral N concentrations using non-destructive techniques can prove to be extremely useful as alternative to the direct measurement. In most agricultural soils nitrate is the dominant form of mineral N. In this research we have used the ability of time domain reflectometry (TDR) of simultaneously measuring electrical conductivity and moisture content to monitor nitrate concentrations in the field.

Materials and methods

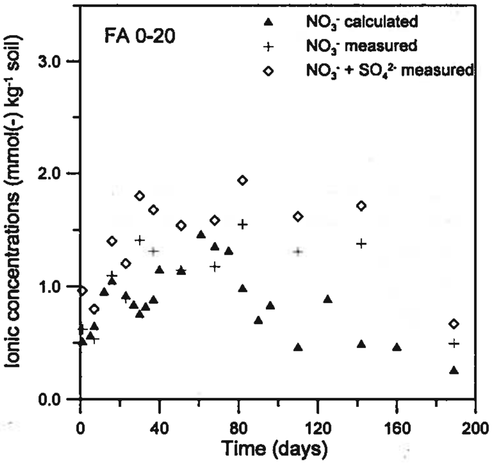
TDR probes were burried in two fields, Gent (FA) and Melle (ME), both with a light textured soil. In the FA soil TDR probes were burried in two depths (0-20 cm and 20-40 cm), in the ME soil probes were burried only in the upper 20 cm. The TDR readings were used to calculate *in situ* NO_3^--N concentrations using the assumption that, together with soil moisture and temperature, changes in NO_3^--N concentrations only were determining the evolution of the soil solution electrical conductivity. First the soil solution electrical conductivity σ_w had to be calculated from the TDR determined soil bulk electrical conductivity σ_a. This involved a series of calibrations were TDR measurements were done at different solute concentrations and different soil moisture contents and electrical conductivity was actually measured in a soil extract. For the calibrations we used the Rhoades model relating σ_w to σ_a (Rhoades *et al.*, 1976):

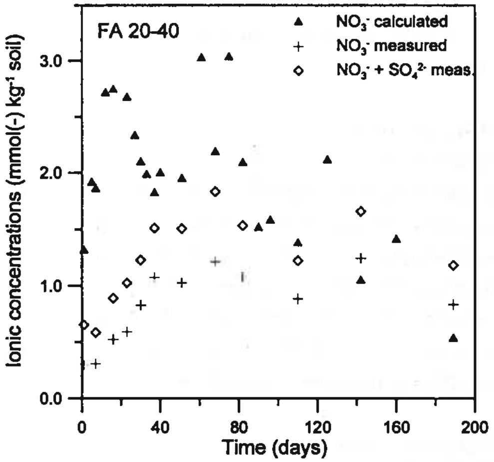
$$\sigma_a = \sigma_w \, \theta \, T(\theta) + \sigma'_s$$

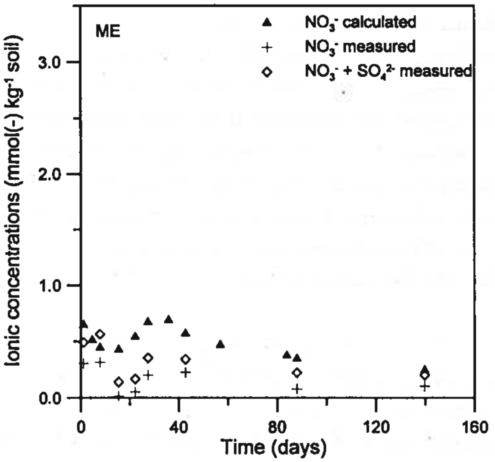
where σ'_s is the apparent electrical conductivity of the solid phase of the soil, θ is the volumetric soil moisture content, and $T(\theta)$ is a transmission coefficient, accounting for the tortuous nature of the current flow through the soil matrix. A calibration for deriving NO_3^--N concentrations from TDR measurments was performed separately for each upper soil layer (FA and ME). For the layer 20-40 cm of the FA soil, which was quite stony, no separate calibration was performed. For more detail on the calibration approach we refer to De Neve *et al.* (2000). TDR calculated NO_3^--N concentrations were compared to measured concentrations on the same plots.

Results and discussion

The measured NO_3^- concentrations in the ME soil were much smaller than in the FA soil, which also reflected the difference in organic matter content. In the FA soil N mineralization resulted in an increase of NO_3^- concentrations during the first part of the experiment (autumn), whereas NO_3^- concentrations decreased in January and February due to leaching. The TDR calculated NO_3^- concentrations were compared to the measured NO_3^- concentrations (Fig.1 and 2). In the calibration only NO_3^- was added, whereas in reality SO_4^{2-} also may play a significant part in soil electrical conductivity build-up. In this particular experiment changes in SO_4^{2-} concentrations were not negligible compared to changes in NO_3^- concentrations, and therefore the TDR calculated NO_3^- concentrations were also compared to the sum of both NO_3^- and SO_4^{2-} concentrations.







The TDR calculated NO_3^- concentrations followed the same trend as the measured concentrations. In FA 0-20 cm measured concentrations were underestimated, whereas they were overestimated in FA 20-40 cm and ME. The absolute deviations in FA 0-20 and ME however were small or very small. In FA 20-40 absolute deviations between measured and calculated concentrations were larger, also when SO_4^{2-} was taken into account. The reason for this probably was the fact that there was no specific calibration for this layer, and that this layer was rather stony, which complicated the insertion of the TDR probes. When comparing the measured and calculated data, one should also take into account the large variability in measurements of mineral N in soil, and the relatively small concentrations that were measured here (no NO_3^- was artificially added to the soil).

From this research it is concluded that in situ monitoring of NO_3^- concentrations using TDR is possible within reasonable error margins if a soil specific calibration is used.

References

De Neve, S., Van De Steene, J., Hartmann, R. & Hofman, G. 2000. Using time domain reflectometry for monitoring mineralization of nitrogen from soil organic matter. *European Journal of Soil Science*, 51, 295-304.

Rhoades J.D., Raats P.A.C. & Prather R.J. 1976. Effects of liquid-phase electrical conductivity, water content, and surface conductivity on bulk soil electrical conductivity. *Soil Science Society of America Journal*, 40, 651-655.

GLUCOSE AND RHIZODEPOSITS AFFECT THE SULPHUR IMMOBILIZATION AND THE ARYLSULFATASE ACTIVITY IN SOIL

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Introduction

Sulphur is necessary for crucifer growth and its application favours the nitrogen assimilation by plant. In order to increase seed production of rape, and to prevent sulphur deficiency, as it was observed 30 years ago, a reasoned sulphur fertilisation must be developed. First of all, a better knowledge of sulphur mineralization / immobilization mechanisms in plant rhizosphere soil is needed. Sulphur mineralization is mainly driven by microbial activity, especially the arylsulfatase enzyme. Some rhizosphere micro-organisms, able to synthesize the arylsulfatase, are stimulated by the rhizodeposits and therefore may contribute to the release of sulphates available for plants. The knowledge of exact composition of rhizodeposits, and particularly that of rape, is still a significant problem because of their spatial and temporal variations. Therefore, our objectives were to study the effects of artificial root rhizodeposits, varying in quantity and quality, on the sulphur immobilization, in relation to microbial biomass-S and soil arylsulfatase activity.

Methods

An equivalent of 40 g of dry calcareous soil, a typical cultural soil of Lorraine, were first weighed into pots, conditioned to 50% of WHC, with distilled water, and pre-incubated one week in the dark at 25°C. Three stock solutions containing glucose or model rhizodeposits, with and without cysteine, (50 mM fructose, 50 mM glucose, 50 mM sucrose, 25 mM succinic acid, 25 mM malic acid, 12.5 mM arginine, 12.5 mM serine and 12.5 mM cysteine) were prepared according to Griffiths *et al.* (1999). Working solutions were prepared by diluting the stock solutions with sterile distilled water to give equivalent rates of 0, 100, 200, 600, 400 or 800 mg C kg^{-1} soil and were then added to bring the final soil moisture to 80% of WHC. For each treatment we had four replicates. All the pots received ^{35}S carrier-free ($Na_2{}^{35}SO_4$, 22.2 kBq pot^{-1}). Soils were then incubated one week in dark at 25°C, before analyses. Afterwards, fresh soil were sampled to estimate the microbial ^{35}S-biomass by the conventional technique of fumigation with $CHCl_3$, and to determine the percentage of ^{35}S immobilised after extraction with 0.01M $CaCl_2$. The remaining soil was air-dried before microbial arylsulfatase activity measurement according to the method of Tabatabai and Bremner (1970).

Results

The percentage of ^{35}S immobilized increased with carbon additions from 26.6 to 84.1% when glucose was added (Fig. 1). This result is in agreement with that of Wu *et al.* (1995) who showed that glucose and plant residues additions resulted in an increase of SO_4^{2-} immobilization. However, the percentage of ^{35}S immobilized remained relatively stable (23.5 to 29.9%) when rhizodeposits with cysteine were added. The explanation may be that micro-organisms immobilized preferentially sulphur from cysteine and not ^{35}S from the $Na_2{}^{35}SO_4$ solution added. We confirm this with the increase of the percentage of ^{35}S immobilized (28.4 to 80.4%) when rhizodeposits without cysteine were added. A significant coefficient ($r = 0.91$, $p<0.01$) was found between the percentages of ^{35}S immobilized and ^{35}S-biomass (Fig. 2) when all studied substrates were considered. In the case of rhizodeposits with cysteine, the relatively low variation of ^{35}S-biomass (2.0 to 8.7%), also explain the no increase of ^{35}S immobilized.

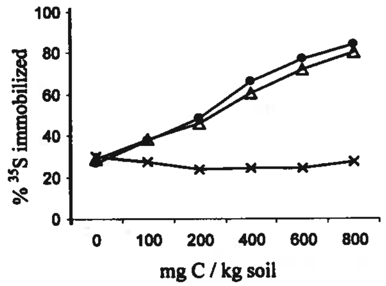

Fig. 1 : Percentage of ^{35}S immobilized in relation with carbon rates, when glucose or rhizodeposits (with and without cysteine) solutions were added to soil.

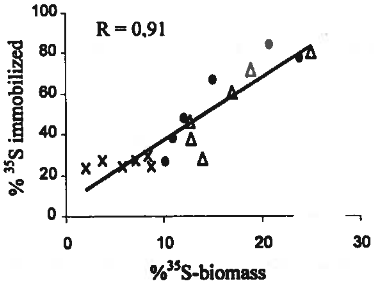

Fig. 2 : Percentage of ^{35}S immobilized in relation with the percentage of ^{35}S-biomass when glucose or rhizodeposits (with and without cysteine) solutions were added to soil.

Correlated to arylsulfatase activity, significant coefficients were found with ^{35}S immobilized and ^{35}S-biomass when glucose was added to the soil (Table 1). With increasing carbon addition as glucose, microbial biomass growth increased, and so, enhanced the synthesis and release of arylsulfatase enzyme. Kertesz (1999) showed that cysteine represses arylsulfatase expression; this may explain why no correlation was found when the cysteine-containing rhizodeposits were added. Like glucose, rhizodeposits without cysteine increased both ^{35}S-biomass and ^{35}S immobilized. Nevertheless, the arylsulfatase activity of microbial biomass developed with rhizodeposits devoid of cysteine was repressed. If the presence of arginine and serine was the main cause, the result suggests that pure organic C compounds such as glucose would be the most energetic source for the arylsulfatase activity.

	Arylsulfatase activity		
Substrates added to soil	glucose	Rhizodeposits with cysteine	Rhizodeposits without cysteine
^{35}S immobilized	r = 0.97 ($p<0.01$)	NS	NS
^{35}S-biomass	r = 0.87 ($p<0.05$)	NS	NS

Table 1 : Correlation matrix between arylsulfatase activity (mg *p*-nitrophénol kg^{-1} soil h^{-1}) and ^{35}S immobilized (kBq ^{35}S immobilized kg^{-1} soil) or ^{35}S-biomass (kBq ^{35}S-biomass kg^{-1} soil), when glucose, rhizodeposists with or without cysteine were added to soil.

Conclusions

It is concluded that sulphate-^{35}S-immobilization increased with glucose-C additions and that micro-organisms preferentially immobilized sulphur from cysteine, instead of sulphate-^{35}S. The quantity and the composition of rhizodeposits influenced differently on arylsulfatase activity and S-immobilization as well as their inter-connexion. Among the substrates constitutive of rhizodeposits, glucose can enhance both immobilization of S and arylsulfatase activity.

References.

Griffiths,B.S., *et al.*, 1999. Soil Biology and Biochemistry 31, 145-153.
Kertesz, M.A., 1999. FEMS Microbiology Reviews 24, 135-175.
Tabatabai, M.A., *et al.*, 1970. Soil Science Science of America Proceedings 34, 225-229.
Wu, J., *et al.*, 1995. Soil Biology and Biochemistry 27, 1363-1370.

EFFECT OF ROOTSTOCKS ON THE MINERAL NUTRITION OF MANGO TREES (*MANGIFERA INDICA* L.) CV. "KEITT"

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Introduction

The cultivation of mangoes (*Mangifera indica* L.) in the southeast of Spain is growing rapidly, due to both the great productive potential of the area as well as to the demand for this product in both the Spanish and European market (FAO, 1999). The region where this crop is grown extends across the coast of the provinces of Granada and Malaga; whereas now approximately 800 ha are used for this purpose; production over the next several years should be more than 5.000 tons. The most commonly used rootstocks "Gomera-1" and "Gomera-3" have their origin in the Canary Islands; there are also others which are imported, such as the "Terpentine" and "Thirteen One". The main cultivars in the zone are from Florida (U.S.A.): Osteen, Keitt, Tommy Atkins, Irwin, Sensation, etc (Galan, 1999). The mango is a species, which easily adapts to different soil conditions and to moisture, compared to other fruit trees; nonetheless, although it is notably tolerant to low-fertility soil, its production substantially increases in fertile soils (Avilan, 1983). One factor which perhaps explains this high degree of adaptability could be the vigorous development of the radical system of rootstock, which satisfies the nutritional demand, and thus also has a positive effect on its production. A two-year study (1999-2000) tracked the monthly development of N, P, K, Ca, Mg, Fe, Zn, Mn and Cu in the leaves of ten-year-old mango trees in the cv. "Keitt"; their state of nutrition was evaluated, which had been influenced by the radical system of the rootstocks: "Terpentine"(Tp), "Thirteen One" (13/1), "Gomera-1" (Go1) and "Gomera-3" (Go3).

Methods

The study was carried out at the experimental site "El Zahori", on a plot containing 40 trees, 10 by each rootstock, at an altitude of 180m. The rootstocks were distributed randomly, the planting grid being 3 x 3 m. During the first fortnight of every month, samples of ripe leaves from fruitful branches were taken from the selected trees. The experimental trees had been subjected to similar cultivation practices as far as fertilizers, irrigation and plant protection were concerned; the irrigation was set up with four drips per tree, each one having a volume of 4 litres per hour. The foliar samples were washed, dried at 70ºC for 48 hours and were then ground up and sifted to a fineness of 0,5 mm. The K was determined by flame photometry; Ca, Mg, Fe, Zn, Mn and Cu, by spectrophotometry of atomic absorption (Chapman et al, 1961). The P was determined by the molybdenum blue method (Fiske, 1925), and the N by the Kjeldahl method (Bremner, 1965).

Results

In general, the way the bioelements evolve is very similar in the four rootstocks. Nonetheless, appreciable differences may be observed in a comparison at specific moments in the yearly cycle. The foliar levels of N, P and K of the cv. "Keitt", due to the effect of the rootstocks, are characterized by decreases in the fructification and in the development of the fruit, and they then increase later, from the harvesting to the flowering. With the microelements, the effect of the rootstocks varies: in general, during the vegetative cycle, the concentration of Fe, Mn and Cu in the flowering decreases, while the fructification increases; when latent, it begins to increase again; the opposite behaviour was observed with Zn. In the average foliar concentration of N, there are no significant difference due to the effect of the rootstock, though the "Go-3" exhibits greater amounts than others; P is higher in the “Tp”, as is K in the case of “Go-1”. The “13/1” has foliar levels which are inferior as far as the three principal nutrients are concerned (Table 1).

Rootsto.	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
13/1	1,70^{a}	0,074^{a}	0,203^{a}	2,50^{a}	0,269^{a}	84,9^{a}	15,4^{a}	207,6^{a}	29,3^{a}
Tp	1,71^{a}	0,129^{b}	0,298^{b}	2,43^{a}	0,205^{b}	72,5^{b}	15,2^{a}	201,3^{a}	25,9^{ab}
Go-1	1,74^{a}	0,111^{b}	0,305^{b}	1,96^{b}	0,206^{b}	87,3^{a}	15,2^{a}	190,7^{a}	22,2^{b}
Go-3	1,76^{a}	0,114^{b}	0,205^{a}	2,52^{a}	0,204^{b}	91,2^{a}	17,3^{a}	250,2^{b}	25,7^{ab}
Values with different letters in the columns are statistically significant different at 95% LSD									

Table 1 Multiple contrast for pairs of averages of nutrients of the cv. "Keitt"

The following have been calculated: physiological balances; the interactions of nutrients, based on the time of sampling; and the evolution of the vegetative index (V.I.) (Pijoan, 1976).

The metabolic activity is intense during the cycle; the foliar level of N, P and K constantly diminishes, as opposed to the Ca and Mg, which increase. The V.I. in the cv. “Keitt”, due to the effect of the rootstocks, responds in a similar fashion; its development shows a decline up till the month of July, which corresponds to the end of flowering; towards September there is a recovery of the nutrients for the fruit set; a decline in October is a consequence of the growth and development of the fruit. In November and December, the time of harvest, an increase occurs; the tree tends to begin the process of foliar recovery. In January (latency period), the decline of nutrients is probably due to an intense emigration towards the reserve points. The balances N:10P:K and K:Ca:Mg with the rootstocks in the cycle are stable with respect to time (no significant correlation); nonetheless, the stability of the first is less than that of the second, as shown by the correlation coefficients which were found.

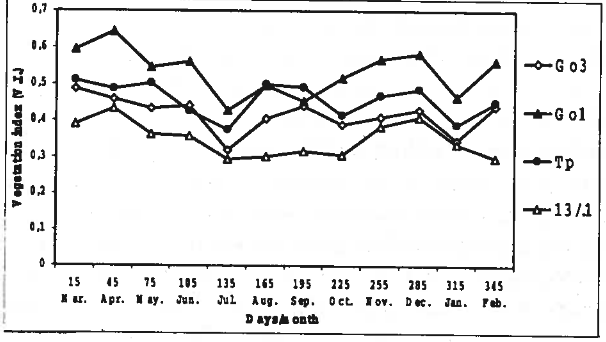

Fig. 1 Veg. index over time

Conclusions

The foliar concentrations of N, P and K of the cv. "Keitt", influenced by one or another rootstock, are characterized by a decrease on having entered into the period of the fruit set or fructification and the development of fruits, only to increase later in the period between the harvesting and the flowering. The cv. "Keitt" shows the effect of the Gomera-3 rootstock in the average concentration of the majority of the nutrients during the vegetative cycle, due to its radical system, capable of supplying a greater amount of these nutrients than the Gomera-1, Terpentine and Thirteen One. As far as the metabolism of the plant was concerned, there was, throughout the cycle, a greater stability of the nutritional balances and of the physiology of the nutrients in the case of Gomera-1; Terpentine, Gomera-3, with Thirteen One being the worst.

References

Avilan, R.L. (1983). La fertilización del mango en Venezuela. *Fruits* 38(7-8) 553-563 pp.

Bremner, J.M. (1965). In: *Methods of Analysis* (Black, C.A., Ed.) part 2. Agronomy 9, Academic Press, New York. 1149-1178 pp.

Chapman, H.D. et al. (1961). Method of analysis for soils plants and waters. Agr. Publ. Univ. of Calif. Riverside.

FAO (1999). Statistical Database. http://apps.fao.org./cgi-bin/nph-db.plsubset=agriculture.

Fiske S. (1925). In *Methods of Analysis of the Assoc. of Official Ana Chemistry,* (1970).

Galan, S. V. (1999). El Cultivo del mango. Coed. Gob. de Canarias CAGPA, Ed. MP, 298 p.

Pijoan, N.J. (1976). L´index vegetatif (V.I.) dans le demaine de la fruticulture et la dinamique des valeurs pendan le cicle vegetatif. Vol. 2, IVth International Colloquium on the control of Plant Nutrition. Gent.

EFFECTS OF DIFFERENT ORGANIC FERTILISERS IN SOUTHERN ITALY: PRELIMINARY DATA ON NITROGEN DYNAMICS IN SOIL-PLANT SYSTEM

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Introduction

The favourable effect of legume crops is mainly due to the symbiotic N-fixing, which allows an increase in N availability which is considered the most important factor in limiting yields in organic systems (Clark et al., 1999). In this context, green manure with legume crops could represent the best solution to improve nitrogen balance of cropping systems (Poudel et al., 2001) without external inputs. Nevertheless, it must be considered that green manure has its utility and perspective if it is economically sustainable. Occupying the intercropping periods it doesn't disturb the regular cycle of the income crops (Mubarik, 1999). Therefore, a trial was carried out in a greenhouse horticultural rotation, with the aim to evaluate the effects of green manure crops grown in the summer period (July-September), during which the cultivation is suspended for temperature excesses.

Methods

Trials were carried out during 2001 in the organic farm " La Colombaia", Capua (CE), Italy. Soil was clay-sandy, neutral (pH=7.0) with low content of organic matter (1.5%) and nitrogen (1.0 ‰). In a 2-years horticultural rotation in greenhouse (tomato-lettuce-watermelon-lettuce) three organic fertilizers were compared: cattle manure (CM), monophyte (Vigna sinensis L.) green manure (MGM), and polyphyte (34 species) green manure (PGM). Green manure crops were inserted between tomato and lettuce periods and were sowed on July 11 and buried on September 22 contemporarily to the burying of 30 t ha^{-1} of CM. The amounts of buried dry matter were 15 t ha^{-1} from CM, 9 from MGM and 21 from PGM. 95% of the latter was composed of *Setaria* spp. and *Panicum* spp. Lettuce was transplanted on October 13 and harvested on February 5. The three manuring treatments were distributed in 3 randomised blocks. Nitrogen fractions (N-Kieldhal, N-NO3 and N-NH4) were determined in soil profile at four phases of crop period: before sowing of GM crops, 1 week after the burying of organic matters, at lettuce transplanting, at harvest of lettuce. Dry matter and N content were determined in organic materials at burying. Yield and nitrates uptake of lettuce was determined at harvest. All the data were subjected to ANOVA. During lettuce crop period, the average temperature was 10.4°C, with values ranging from -5 to 34°C. For a long period (December 25-January 20) the temperatures were below zero.

Results

Crops for GM showed a very high N content: 250-300 kg ha^{-1} N (Table 1). In all the treatments nitrate increased in 0-20 cm layer and N-NH4 decreased after biomass burying (Figure 1). This effect is mainly due to the oxidative conditions determined by rotary hoeing and it does not seem to be influenced by the treatments. CM showed in 20-40 cm layer a sudden increase in N-NH4 and N-NO3 proving to be able to satisfy nitric requirements of crops, more readily than GM. Nevertheless, this increase of N-NO3 could be dangerous for pollution due to nitrate leaching in watertable. GM showed an increase in N-NH4 only in February, because of the beginning of humification and mineralisation of organic matter of these plants.

Lettuce yield (Table 2), injured by the frost during January, which determined a 30% mortality, ranged from 15 to 17 t ha^{-1}, without differences among the treatments. CM determined higher value in N-NO3 content in lettuce, also if all the values were very low in this trial.

Treatments	Input with Manuring Dry matter	Nitrogen	Lettuce Uptake Dry matter	Nitrogen
Cattle Manure	15006 b	65 b	666	28
Monophyte green manure	9397 c	258 a	634	27
Polyphyte green manure	20687 a	315 a	636	26

Table 1. Dry matter and Nitrogen input and uptake (kg ha^{-1}) during lettuce crop period.

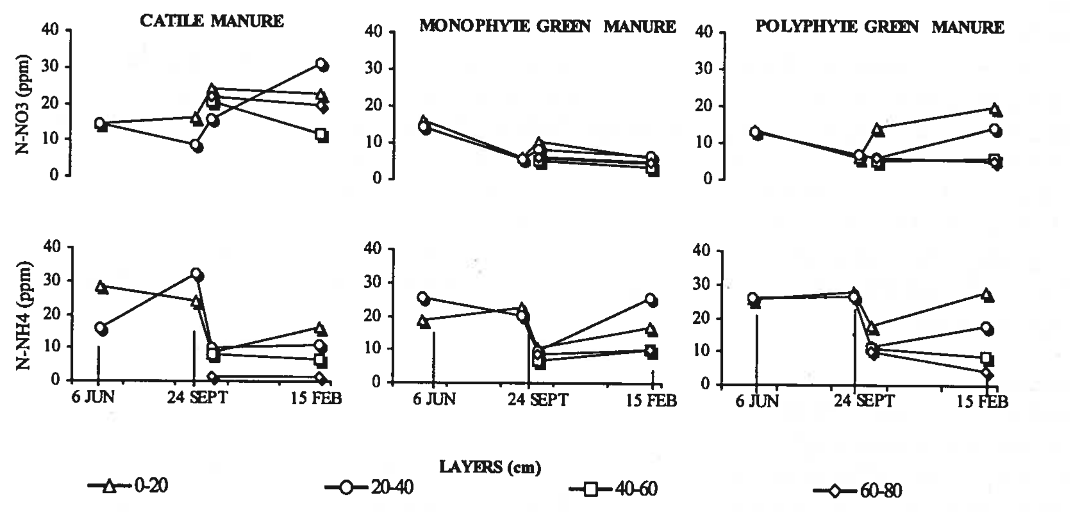

Figure 1. N-NO3 and N-NH4 trends in relation to the different treatments

Treatments	Marketable Yield (kg ha^{-1})	Total N (mg plant^{-1})	Nitrate content (mg kg^{-1} fr.w.)	(mg plant^{-1})
Cattle Manure	175	345	824 a	173 a
Monophyte green manure	152	288	624 b	97 b
Polyphyte green manure	156	318	638 b	124 b

Table 2. Yield and nitrate accumulation in lettuce.

Conclusions.

GM effect on N content in the soil seems to be very weak in a short time. Only after 5 months the mineralisation of its organic matter seems to start. In conditions of this trial, no differences was noticed between MGM and PGM. On the contrary CM, the organic matter of which is already partially humificated, determine a sudden increase of nitrates that could cause water pollution in sandy soils and nitrate accumulation in lettuce. CM, applied with reduced doses, seems more suitable in the short time, while GM could be useful to increase soil fertility in the long period.

References

Poudel, D.D. et al., 2001. *Agricutural Systems*, 68, 253-68.
Clark, M. S. et al., 1999. *Agriculture, Ecosystems and Environment*, 73 (1999) 257–270
Mubarik Ali 1999. *Field Crops Research*, 61 (1999) 61-78

ROOT LENGTH DENSITY VARIATION IN MODERN WINTER WHEAT CULTIVARS

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Introduction

Yield development and accumulation of nitrogen from the soil late in the season depends to some extent on root activity. Nitrogen uptake and partitioning needs to keep pace with the accumulation of dry matter in the grain if protein concentrations in the grain are to remain high. Root activity varies widely amongst crops but earlier work showed that the size of the root system in cereals often declines after flowering as resources are preferentially directed towards the growing grain (Gregory, 1994). This may limit the ability of the crop to take up nitrogen, thus limiting grain growth and grain protein accumulation. Root activity is highly dependent on environment and crop management. Fungicides are important inputs to modern UK wheat production and strobilurin fungicides have been shown to delay crop senescence and to improve yield and nitrogen uptake (Bryson, 2000). Previous root studies have shown some variation in root characteristics between cereal cultivars (reviewed in Hoad *et al.*, 2001), however, very little is known about root characteristics in modern wheats under high input management. This work examined root density at anthesis and during grain filling in modern wheat cultivars receiving different fungicide programmes.

Methods

A field experiment was conducted in the 2000/2001 growing season on a well-draining, sandy loam overlying coarse, red-brown sand at the Crops Research Unit, The University of Reading, UK (51°29'N, 0°56'W). Six UK modern winter wheat cultivars were sown in cultivar main plots randomised in three blocks. Main plots were divided into six 10 x 2m plots, each receiving one of three fungicide treatments (T1, T2 and T3); T1 was 63g a.i. ha^{-1}epoxiconazole at Growth Stage (GS) 31, T2 was T1 plus 63g a.i. ha^{-1} epoxiconazole and 125g a.i. ha^{-1} azoxystrobin at GS 39 and T3 was T2 plus 63g a.i. ha^{-1} epoxiconazole and 125g a.i. ha^{-1} azoxystrobin at GS 59. Soil cores between and within the row were sampled from T1 and T3 treated plots at anthesis and four weeks later during grain filling. Cores (80cm deep x 7.5cm diameter) were cut into 10cm sections, with those from the same plot and depth bulked together for analysis. Roots were washed from the soil, dead roots and other organic matter were removed. Live roots were scanned (Delta T Ltd) and root length density calculated. Samples were oven dried at 80° C for 48 h then weighed.

	Root Length (cm root cm^{-3}soil)			
	0-30cm soil depth		31-80cm soil depth	
Cultivar	Anthesis	Grain filling	Anthesis	Grain filling
Shamrock	3.78	6.18	1.45	1.88
Claire	3.64	4.94	0.93	1.40
Consort	3.38	5.35	0.96	1.10
Hereward	4.68	4.90	0.94	1.15
Savannah	3.87	6.74	0.66	0.80
Malacca	2.87	3.91	0.82	1.29
SED 1		0.507		0.265
SED 2		0.504		0.108

Table 1. The effect of sampling time on root length density in modern cultivars of UK winter wheat. SED 1 refers to the SED when comparing means across cultivars and SED 2 refers to means within cultivars.

Results and discussion

The UK recommended list cultivars used in this experiment differ in their root length density both in the 0-30 cm section of the soil profile and below (Figure 1a). The expected reduction in live root length between anthesis and grain filing was not observed even though soil water was substantially depleted during this period. Overall, there was an increase in

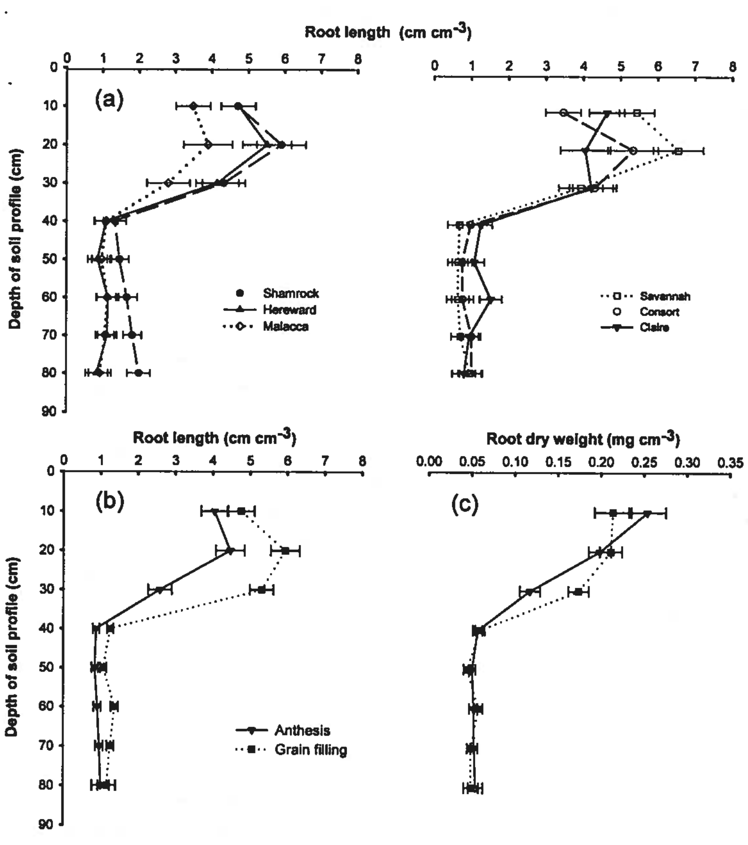

Figure 1(a) Variation in root length between winter wheat cultivars (mean from both sampling times). (b) Effect of time on mean root length and (c) Effect of time on mean root dry weight .

root length density between sampling times in the 0-30 cm section of the soil profile (from 3.70 to 5.34 cm cm^{-3}, P<0.001), an increase in the lower section also occurred but was not statistically significant (Figure 1b). Root length density of the cultivars Shamrock, Claire, Consort and Savannah significantly increased (Table 1) but root length increases in Hereward and Malacca were not significant. In contrast to root length density, root dry weight did not increase between sampling times (Figure 1c). These results suggest that between sampling times, a proliferation of fine roots occurred whilst some of the thicker, mature roots died. There was no evidence in this experiment for significant effects of fungicide on the roots. The canopy and wheat quality assessments for this experiment are described in this proceedings (Pepler *et al.*, 2002). Fungicides were shown to significantly increase grain yield and fungicide interacted with cultivar with regards to time to flag leaf senescence and grain protein concentration. The combined results suggest that the fungicide effects on grain yield and delayed flag leaf senescence were not associated with effects on root activity.

References

Bryson, R.J., 2000, *HGCA Report No. 221*. Home Grown Cereals Authority, London.
Gregory, P.J., 1994, In *Resource Capture by Crops*, (Eds. Monteith J.L., Scott R.K., and Unsworth M.H.), 77-97.
Hoad S.P., Russell G., Lucas M.E. & Bingham I.J., 2001, *Advances in Agronomy*, 74, 193-246.
Pepler S., Ford K.E., Gooding M.J. & Gregory P.J., 2002, This proceedings.

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NUTRITION AND MYCORRHIZATION ROLE IN A GYPSIFEROUS SOIL AFFORESTATION PROGRAM

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Introduction

For increasing effectiveness of plants in a gypsiferous soil afforestation program and minimizing excessive fertilization supplies, it is necessary to design the best nutrient application (Eymar *et al.*, 2000) and to take into account the role of mycorrhyzae in this process (Amaranthus & Perry, 1987). This is achieved by means of slow release fertilisers evaluating the best doses during the growing cycle and the best ways of applying them (Eymar *et al.*, 2000). Effects of fertilization on mycorrhizae have also been considered (Erland & Söderström, 1991).

Mycorrhizal symbiosis allows improves survival and growth rate of plants (Marx *et al.*, 1991), but fertilization use to be negative for mycorrhizal settlement and development (Molina & Chamard, 1983). With regard to this topic, it can be of great interest to make compatible both aims using slow release fertilizers that minimize environmental pollution and improve plant quality and survival.

Methods

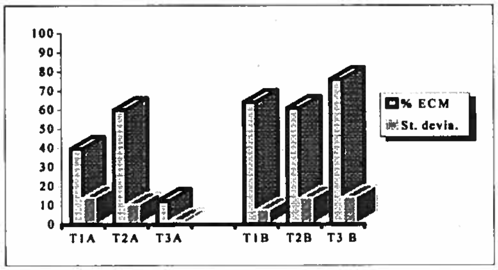
The species *Pinus halepensis* Miller was used as the reference plant. Two treatments were considered with a minimum nutrient application (2 Kg per tree). One with a fertilization of organic compost (C) as N source, apatite (A) as P source and moscovite (M) as K source, a mica type, called treatment T2; other with the same mineral fertilization and a mycorrhizal inoculum application of the gasteromycete fungus *Pisolithus tinctorius* (Persoon) Coker & Couch, called treatment T3, and a control, called T1. Each treatment had five plants, which were two years old and approximately 40 cm tall. These plants were growth in a gypsiferous soil placed in a semiarid place in SE of Madrid province, Spain.

The analytical control of the plant mycorrhizal infection was performed in the two periods, during fall season of 2000 and 2001. Three replicates of each treatment were considered for determining mycorrhizal infection counting number of active mycorrhizal tips (Harvey *et al.*, 1976). Two mycorrhizal types have been taken into account, ectomycorrhizae (ECM) and ectendomycorrhizae (ETM). Total mycorrhization percentage (ECM + ETM) has also been considered.

Results

Although other biological parameters have been studied, this study only show results corresponding to mycorrhizal infection values. Pine trees have showed a good survival and growth rate in both treatments.

Ectomycorrhizal percentage of infection has suffered an important increase between first and second period of study (Figure I). In this respect, it is convenient to highlight the great increase of T3 treatment, which seems to be related with the performance of mycorrhizal inoculation. No incidence of fertilization has been detected on ectomycorrhizal settlement and development. In relation with ectendomycorrhizal infection (Figure II), a decrease has been detected between first and second year. It seems to be related with the normal evolution of this symbiosis in plants that have changed from greenhouse to field conditions (Pachlewski *et al.*, 1991-1992). Incidence of fertilization on ectendomycorrhizal settlement is not clear. Finally, no incidence at all has been detected for total mycorrhization infection (Figure III).



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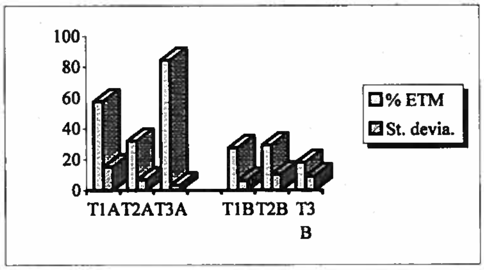

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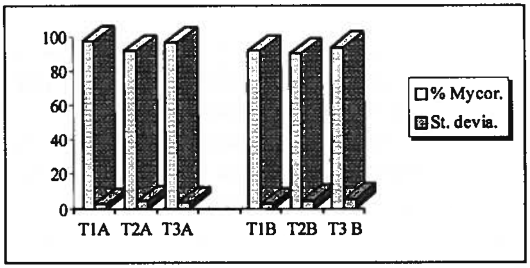

III

Figures I, II and III: T1= control 1, T2= treatment CAM and T3= treatment CAMm. A= 2000 year and B= 2001 year. St. devia. = Standard deviation for 3 values.

Conclusions

Using an appropriated fertilization and mycorrhization techniques a gypsiferous soil has been successfully afforestated. Slow release fertilizers used in these experiments had no incidence on mycorrhizal settlement and development.

References

Amaranthus, M.P. and Perry, D.A. 1987. *Canadian Journal Forest Research., 17*: 944-950

Erland, S. and Söderström, B. 1991. Effects of liming on ectomycorrhizal fungi infecting Pinus sylvestris L. *New Phytologist, 117*: 405-411

Eymar, E., Cadahia, C., Sánchez, A. and López-Vela, D. 2000. Combined effect of slow release fertiliser and fertigation on nutrient use of Cupressus glabra grown in nursery conditions. *Agrochimica, XLIV*(1-2): 39-48.

Harvey, A.E., Larsen, M.J. and Jurgensen, M.F. 1976. Distribution of ectomycorrhizae in a mature Douglas-fir/larch forest soil in western Montana. For. Sci., 22 (3): 393-398

Marx, D.H., Ruehle, J.L. and Cordell, C.E. 1991. Methods for studying nursery and field response of trees to specific ectomycorrhiza. In: Norris, J.R., Read, D. J. and Varma, A.K. (eds.) *Methods in Microbiology*, *Vol. 23*. Techniques for the study of mycorrhiza. Academic Press. Londres. p. 384-411

Molina, R. and Chamard, J. 1983. Use of the ectomycorrhizal fungus Laccaria laccata in forestry. II. Effects of fertilizer forms and growth of container-grown Douglas-fir and ponderosa pine seedlings. *Canadian Journal Forest Research, 13*: 89-95

Pachlewski, R., Kermen, J., Chrusciak, E. y Trzcinska, M. 1991-1992. Studies on pine ectendomycorrhizae in nurseries. Acta Mycologica, 27 (1): 49-61

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UNDERSTANDING THE ARCHITECTURE OF ROOT SYSTEMS BY GEOSTATISTICS

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Introduction

Geostatistics was originally applied to mining engineering and geology, aiming at estimating soil mineral distribution (e.g., ore reserves) (Matheron, 1962), although more recently even meteorology and ecology have taken advantage of its applications for mapping climatic and biological variables (Monestiez et al., 1994). If we assume that all the parts of any biological system are spatially inter-dependent, then root systems are more suitably studied by geostatistics than by classical statistical tools, and unsampled locations can also be estimated. Unfortunately, until now only a few applications of geostatistics to the study of root architecture are found in the literature, and a standard procedure is still lacking on this topic (Bengough et al., 2000).
The use of geostatistics is presented here to study the soil distribution of volumetric root length density (RLD) and diameter in two maize hybrids cultivated in conditions of limited nitrogen and water availability. Variogram components (i.e., nugget, sill, range) and application of kriging are taken into account, to explain differences between root architecture in the two hybrids.

Methods

Two maize hybrids (Dekalb – Mosanto), DK585, a new highly productive hybrid, and Santos, an older and less productive one, were compared in a randomised block field experiment replicated 4 times, at the Experimental Farm of the University of Padova at Legnaro (Padova, NE Italy). Sowing (0.75 m inter-row; 0.18 m apart in row) and harvest took place respectively on April 23 and September 25, 2000. Since only a mall amount of N was given (32 kg ha^{-1}) and no irrigation was applied throughout the season, a certain level of stress was imposed. Its effects at root level were checked at complete flowering by means of the auger sampling method, which was performed on different positions: on plants (A) and at 18 cm (B) and 37 cm (C) from plants in the inter-row. Soil cores (1-m long, 8 cm Ø) were subdivided into 10-cm long sub-samples and washed to separate roots from soil. Roots collected in a 500-µm sieve were stored at 4°C in ethanol solution (10% v/v.). Both root length and diameter were measured with an automatic image analysis procedure on binary root images with 300 DPI resolutions, acquired through a flatbed scanner.
After removing trends from the data set, in order to make it stationary, spatial correlations were evaluated by variogram analysis. During variography, a 10-cm lag interval was adopted, this being the minimum distance between sample points, and various models (linear, spherical, exponential, quadratic, rational quadratic, wave and power) were tested in order to find the most suitable one for root studies. Subsequently, point ordinary kriging (BLUE, best linear unbiased interpolator) was applied to residuals, and contour maps of RLD and diameter were obtained by adding back the surface trends. Both variography and kriging were performed using Surfer® 7.0 software (Golden, CO, USA).

Results

A reciprocal logarithmic-linear function was found as a reliable model to describe the general trend of root distribution in maize, which must be subtracted from original root length density (RLD) data as a necessary step for proper application of geostatistics.

Different models were chosen for the two hybrids, rational quadratic (for DK585) and gaussian (for Santos), both having the same highest coefficient of determination (R^2=0.88). *Nugget* (microscale and measurement error), *sill* (maximum variance value) and *range* (distance at which the sill is reached) were lower in Santos than in DK585, as was the rate of explained variance [(1-nugget)/sill] (Table 1).

Hybrid	Model	Nugget	Sill	Range (cm)	R^2	Explained variance (%)
Santos	Gaussian	0.22	0.29	33	0.88	57.1
DK585	Rational quadratic	0.26	0.66	70	0.88	71.9

Table 1 – Components and parameters of variograms for two maize hybrids.

Analysis of root maps indicates that, even though differences in average RLD were not found, a faster decrease over depth was observed in Santos. As a consequence, in this hybrid a larger proportion of rooted area had RLD values below 1 cm cm^{-3} (3% vs. 29%), especially in deeper layers (Figure 1).

As previously reported by Vamerali et al. (2001), the grain yield of DK585 was significantly higher than that of Santos, as result of 5-year-long research experiments in northern Italy (10.3 vs. 9.92 t ha^{-1} d.w., $P \leq 0.05$).

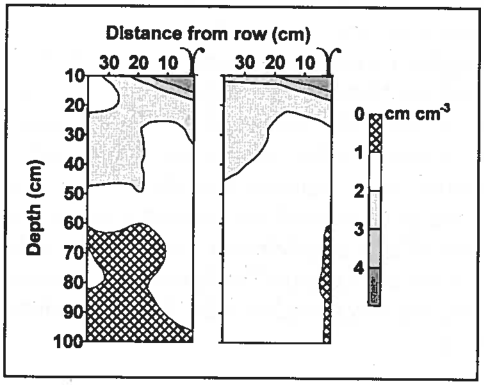

Fig. 1 – Maps of root length density (RLD), orthogonal to crop row, for two maize hybrids, Santos (left) and DK585 (right).

Discussion and conclusions

Geostatistics may be successfully used in root studies to overcome the typical drawback of point-confined methods for root investigation (e.g., auger sampling, minirhizotrons), allowing whole root systems to be mapped. This tool is very suitable for describing the architecture of root systems as well as the degree of root clumping. The latter is deduced from parameters of variograms, e.g., the range, which roughly indicates the size of cluster: the smaller the range, the stronger the spatial correlation. A high degree of clustering is related to marked sensitivity to changes in soil fertility, as found in Santos. The reciprocal logarithmic-linear function found for estimating trends of root distribution in maize may be considered an expression of the typical form of adventitious root systems in gramineous plants. Relations among all parts of the root apparatus could only be represented accurately if a specific variogram model was chosen for each hybrid. Although few data were used (30 minimum) variogram accuracy was sufficiently good, because a low kriging standard deviation was calculated for each sampled point (cross-validation). This analysis means that the estimated model, although not correct, is not grossly incorrect (good stability).

The more recent and productive hybrid (DK585) had thinner roots and more uniform colonisation of soil volume than Santos, as a large portion of its rooted profile had RLD higher than the critical value (1 cm cm^{-3}) for water and nitrogen uptake.

References

Bengough, A.G., et al., 2000. In *Root Methods – A handbook*, 147-173.
Matheron, G., 1962. *Memories de Bureau de Recherches Geologiques et Minieres*, 14.
Monestiez, P., et al., 1994. *Theoretical and Applied Genetics*, 88 (1), 33-41.
Vamerali et al., 2001. In *Proceedings of 6th ISRR Symposium*, Nagoya, Japan, 324-325.

BIO-AVAILABILITY OF MACRO AND MICROELEMENTS IN CLAY SOILS IRRIGATED WITH SALINE WATER

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Introduction

Sodium sulphate and chloride salinity is a frequent problem in irrigation water extracted from wells located in coastal areas in arid and semi-arid regions (Lavini, 2000). For instance, in central and southern Italy several wells used for irrigation show salinity levels from moderate to high, and the salinity is often due to sulphate.
The effect of artificially salty water on biomass of Alfalfa (*Medicago sativa L.*) was studied in pots. The biomass and Fe, Mn, Zn, Cu and P contents in three harvest times were measured, to find out nutritional unbalances.

Methods

The experiment was carried out in the Co.T.Ir.'s greenhouse. The experimental plot was a completely randomised design, with two treatments (five types of irrigation water and three periods of sampling) and three replications. The pots were filled up with 12.4 kg of clay-loam soil and the F.C. (field capacity) was computed on an experimental basis, with Richard plate at 0.33 bars. After seed emergence the crop was irrigated when the soil water consumption was higher than 45% of F.C.; after one month this limit was raised to 70%. The characteristics of the irrigation water are shown in Table 1.

Water type	EC_w (µS cm^{-1})	Na (mg l^{-1})	SAR	Cl^- (mg l^{-1})	SO_4^{2-} (mg l^{-1})
0	221	14,0	0,8	2,4	11,5
1	798	125,9	8,1	209,6	11,8
2	1325	257,1	16,6	446,7	21,0
3	762	132,5	8,5	4,1	302,7
4	1211	263,3	16,9	3,4	584,0

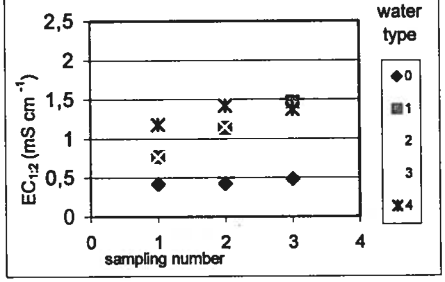
Table I – Characteristics of irrigation water

The crop was evaluated three times taking samples over a four months period at flowering stage. At each sampling evaluation total biomass fresh weight and dry weight were measured. P was determined on nitric acid digests of the dried plant material by UV/vis spectrometry (molybdenum blue method); Cu, Fe, Mn and Zn were also measured on the same digests by A.A. flame spectrometry. $EC_{1:2}$ was analyzed on soil samples from the pots.
Statistical analysis (ANOVA, Duncan test, correlation analysis) was performed at a probability level $\alpha = 0,05$.

Results

The soil salinity levels increased during the experiment. Biomass production at flowering showed significant differences among sampling periods, and it was negatively correlated to soil salinity ($EC_{1:2}$). The biomass decreased from 250.14 g m^{-2} at the first sampling to 148.71 g m^{-2} at the last one. In relation to crop response to water salinity level, a decrease in dry matter production was observed only at the highest level of chloride (446.7 mg l^{-1}). There was no significant interaction between treatments. The results of mean dry matter production are reported in Table 2 and Table 3.

FIG. 1 - $EC_{1:2}$ variation during the experiment



Sampling	Biomass (g m^{-2} of dry matter)
1	250.14 a
2	180.57 b
3	148.71 c

Table 2 – Biomass for each harvest time (the means having the same letter didn't show significant difference)

Water type	Biomass (g m^{-2} of dry matter)
0	201.86 a
1	200.14 a
2	170.00 b
3	199.71 a
4	194.00 a

Table 3 – Relationship biomass – water salinity

Fe, Mn, Cu, Zn and P content was influenced by sampling period, too.

Sampling	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	P (%)
1	83.2 a	52.2 a	12.6 a	37.6 a	0.14 a
2	46.7 b	50.6 a	13.7 b	39.4 ab	0.18 b
3	53.6 b	57.3 b	12.6 a	40.9 b	0.16 ab

Table 4 – effect of sampling period on Macro and microelements plant content

On the contrary, water salinity influenced only Mn content:

Water type	Mn (mg kg^{-1})
0	45.6 a
1	60.2 b
2	65.0 b
3	46.0 a
4	46.6 a

Table 5 – Effect of water salinity on Mn plant content

Discussion

The results were obtained in high evapotranspiration conditions, where it was expected a decrease of dry matter production with the increase of water salinity. According to FAO (1986), the irrigation waters of type 1, 2, 3 and 4 are unsuitable for irrigation (EC>700 µS cm^{-1}, Na > 3 meq l^{-1}, SAR > 8, chloride > 4 meq l^{-1}), however it was observed that only the highest level of chloride (446.7 mg l^{-1}) decreased biomass production of about 15%. Alfalfa appears to be more tolerant to sulphate-salinity than to chloride-salinity. In fact, alfalfa is moderately tolerant to soil and water salinity, and the effect of chloride is greater than sulphate, because it is absorbed faster (Rogers, 1998). In this experiment probably part of Na_2SO_4 precipitated as $CaSO_4$, due to the high content of Ca of the water used reducing the effective salinity. It was observed an increase of soil salinity over time, affecting negatively biomass production.

With regard to plant chemical composition, it was observed that Fe and P contents are at normal level, and Fe level is lower when the soil salinity is higher. The other nutritional elements are at sufficient level (Orcutt, 2000). On the other hand Mn increases as Fe decreases, and this may produce nutritional unbalances. Furthermore, plant nutrients uptake by the crop is unaffected by salinity type, except for Mn, which is absorbed preferentially when salinity is due to chloride.

References

FAO,1986. *Soil Survey investigations for irrigation*, 67.
Lavini, A., 2000. *Riv. di Irr. e Dren.*, 47, 2, 25-32.
Orcutt, D. M., et al, 2000. *The physiology of plants under stress*, 68.
Rogers, M. E., et al, 1998. *Plant and soil*, 202, 271-280.

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MUNICIPAL SOLID WASTE COMPOST AS A TOMATO TRANSPLANT MEDIUM

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Introduction

The production of container-grown vegetables, fruits and ornamental plants has expanded in recent years. The growth medium used in this process is a determining factor, given its close correlation with plant development. At present, *Sphagnum* peat is used in the majority of commercial substrates due to its excellent chemical, physical and biological properties. In the last decade, the demand for peat as a substrate has increased continuously, while its availability is decreasing. Thus, finding substitutes for peat is an important task. A particularly interesting example is the possible use of municipal solid waste (MSW) compost as substrate.

Methods

Three experiments were conducted with tomato (*Lycopersicum esculentum* Mill. cv "Atletico") nurseries during three years (1998-2000). All experiments used polystyrene trays. These were filled with the following substrate mixtures (% v/v): OP + WP (Old peat 65% + White peat 30% + Perlite 5%); OP + MSW (OP 65% + MSW Compost 30% + Perlite 5%); MSW + WP (MSW Compost 65% + White peat 30% + Perlite 5%); MSW (MSW Compost 95% + Perlite 5%); MSW + CF (MSW Compost 50% + Cocofiber 50%). The trays were placed in a controlled-temperature greenhouse. The growth period of the seedlings in the nursery was 40 days, during which time no fertilizer was applied. Seedling emergences were counted 20 days after sowing. Seedling height, stem diameter, height/diameter (H/D) ratio; height of the first internode; number of leaves and leaf area per seedling were measured 40 days after sowing. (DAS). At the start of the period of nursery growth, and once the experiment had been completed for each substrate, pH and electrical conductivity (EC) were determined.

Results and discussion

Municipal solid waste (MSW) compost from 1998 had better chemical characteristics than in 1999 and 2000. The pH value was close to neutral, the EC level was lower and higher organic matter content and total nitrogen content levels were recorded. This affected the percentage of germination and emergence (Table 1); in 1998, higher values were recorded than in the other two years.

The high EC value of the components of the mixture of MSW + CF and high pH and EC levels of the MSW compost as a single substrate had a negative impact on seed germination, prompting a decrease in the percentage of seedling emergence. According to Ribeiro *et al.*, 1997, this may be due to a decrease in water retention by the substrate. The increase in EC that occurred when increasing the percentage of MSW compost used in the substrate mixtures prompted a decrease in the volume of readily-available water for the seedlings and a slight reduction in reserve water. The mixtures of MSW compost with old or white peat displayed characteristics suitable for the emergence of tomato seedlings, yielding emergence percentages similar to, or higher than, the standard mixture of old and white peat . Furthermore, as a result of the pH and EC values of MSW compost used in 1998 and its high nutrient content, the plants grown in OP + MSW mixtures and MSW as a single component were taller and no significant differences were observed between the diameters of the seedlings obtained in the MSW mixtures (Table 2). In 1999 and 2000, taller plants grew in the mixture of OP + MSW, with significant differences on both occasions with respect to the standard mixture (OP + WP). According to the values obtained in terms of the H/D ratio, seedling growth in this mixture (OP + MSW) was as balanced as in the standard mixture. Generally, the presence of high contents of soluble salts in MSW compost has a negative influence on seedling growth;

TABLE 1. %Emergence (20 DAS)

Substrates	10/2/98	21/1/99	9/2/00	Mean (Substrates)
OP + WP	96.7	88.3	85.3	90.1b
OP + MSW	98.0	91.5	84.7	91.4a
MSW + WP	98.6	91.5	90.3	93.5a
MSW	90.0	81.0	78.0	83.0c
MSW + CF	96.7	84.7	82.0	87.8c
LSD ($P<0.05$)	4.01	1.47	3.33	2.10

something similar occurs with pH. The best quality MSW compost in 1998 had a positive influence on seedling growth. In terms of the different substrates used, the values achieved for all variables did not present significant differences, since the successive irrigations induced salt leaching, yielding adequate EC values for tomato growth,; the fact that this species is tolerant to slightly basic pH and salinity also influenced results. The commercial yield of tomatoes is linearly proportional to the length and stem diameter of the transplanted plant (Pimpini and Gianquinto, 1991); it may therefore be assumed that the seedlings obtained in the OP + MSW mixture will achieve adequate production levels, similar to those obtained with the standard mixture. This suggests that the tomato seedlings from the OP + MSW mixture will have sufficient capacity to complete the transplant with good subsequent development. The number of leaves per plant and leaf area were only greater in MSW and OP + MSW in 1998, OP + MSW in 1999 and MSW in 2000, with significant differences in all with respect to the standard mixture. According to Pimpini and Gianquinto (1991), tomato production increases on a logarithmic scale with the leaf area of the seedlings to be transplanted. These findings suggest that these seedlings develop well after transplant and therefore obtain optimum production levels.

TABLE 2. Seedling growth

Index	Year	Substrates					LSD ($P <$ 0.05)
		OP + WP	OP + MSW	MSW + WP	MSW	MSW + CF	
Height (H) (mm)	1998	187	227	207	254	174	28.93
	1999	132	158	128	97	117	12.85
	2000	109	164	158	154	149	28.13
Stem diameter (D) (mm)	1998	2.8	3.3	3.3	3.7	3.7	0.57
	1999	2.5	3.1	2.8	2.4	2.7	0.28
	2000	2.5	2.9	3.2	3.4	3.3	0.44
H/D	1998	66.1	68.8	62.6	70.2	47.0	8.10
	1999	52.7	51.5	45.9	40.4	43.8	3.08
	2000	44.4	56.7	49.1	45.5	45.7	6.75
Height 1st node (mm)	1998	47	56	55	63	45	9.87
	1999	46	34	31	30	28	5.80
	2000	22	50	54	41	41	13.90
Leaves/ seedling	1998	4.8	5.8	5.0	6.2	5.5	0.82
	1999	4.0	5.6	5.1	5.1	4.8	0.46
	2000	3.1	3.9	4.2	4.7	3.9	0.53
Leaf area (cm^2)	1998	32	56	54	66	50	10.26
	1999	21	37	27	13	20	5.90
	2000	15	26	37	43	34	7.94

Conclusions

The quality of the MSW compost used, particularly in terms of its pH and EC, influenced the % of seedling emergence and subsequent seedling development; pH values close to neutrality and EC levels not exceeding 9 dSm^{-1} of the MSW compost gave better results and enabled its use as a nursery substrate when mixed with peat. The growth and development of tomato seedlings in the mixture of OP + MSW was similar to, and in some cases better than, that obtained in the standard mixture (OP + WP). Therefore, the OP + MSW mixture may substitute the standard mixture (OP + WP) in the nursery production of tomato seedlings. The MSW compost used as a single substrate and the mixture MSW compost+cocofiber showed highly irregular seedling growth and therefore less favourable performance; this was not the case with mixtures of MSW compost and peat.

References

Pimpini, F. and G. Gianquinto. 1.991. 2º Convengo Nazionale "Il vivaismo Octicolo". Foggia.
Ribeiro, H.M.F. and J.Q. Santos. 1997. Actas de Horticultura. Vol. 18-II.

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DCD AND DMPP NITRIFICATION INHIBITORS RESPONSE TO TEMPERATURE

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Introduction

Use of N based fertilizers in combination with several nitrification inhibitors (NI) lengthens N presence in ammonium form in soil (N-NH_4^+), resulting in a number of benefits for agriculture and related ecosystems (Bronson *et al.*, 1992; Trenkel, 1997). The effectiveness of these inhibitors depends on several factors, soil temperature being the most relevant of them. New fertilizers have been recently traded containing a new nitrification inhibitor called 3,4-dimethylpyrazole phosphate or DMPP (Pasda *et al.,* 2001). No information is available about their response to temperature. In this research paper is assayed the effect of DMPP on N-NH_4^+ soil content at different temperatures, and is compared with dicyandiamide (DCD) a traditional NI.

Methods

For a 105 day period three chambers, each one containing twelve 500 g dry soil containers were kept at 10, 20 and 30° C. Characteristics of the soil employed are shown in Table 1.
Ammonium sulphate (21%N-NH_4^+) was applied to one third of the containers on each chamber; in another third of the containers Basammon stabil® was used (19,6% N-NH_4^+ + 1,6% DCD), while Entec 26® (18,5% N-NH_4 $^+$+ 0,2% DMPP) was employed on the remaining third. N-NH_4^+ soil content was periodically determined for each container (Kempers, 1974).

Parameter		Parameter	
Granulometry	%	Organic mater	1,47 %
Sand	78.6	N (Kjeldahl)	0.13 %
Silt	7.6	N min	Inapp.
Clay	13.7	P (Olsen)	18 ppm
pH (1:2.5)	7.5	K (amm. Acet.)	215 ppm

Table 1- soil used in incubation tests

Results

Figure 1 shows N-NH_4^+ content evolution at incubation temperatures 10, 20 and 30°C by type of fertilizer. At 10°C without NI, N-NH_4 disappears in 21 days, while in presence of Basammon stabil or Entec 26, N-NH_4^+ stays for more than 105 days. With increasing temperature N-NH_4^+ concentration declined significantly in time, regardless of the fertilizer being employed. This declining is smaller in the presence of NIs, being the effect of both inhibitors similar. At 20°C NIs lengthened N-NH_4^+ permanence in soil from 12 to 35 days, but only from 7 to 14 days at 30°C. Giraud and Marol (1992) found out that DCD fully prevented nitrification at temperatures lower than 15 °C and that any increase in temperature resulted in a corresponding decreased effect. The microbiological degradation of DCD is hastened with temperature, reaching maximum values between 25 and 33°C (Hauser *et al.*, 1990). No reference has been found to DMPP. In South-Europe soil temperature during summer season is usually higher than 20°C (Table 2). So, in these areas the effectiveness of DCD or DMPP extending N-NH_4^+ presence in soil could be shorter than one month.

Conclusions

The likely effects on crops and related agrosystems resulting from using fertilizers are strongly limited by high soil temperature. So, in Mediterranean areas soil temperature should be specially taken into account in summer crops.

References

Bronson, K.F., Moiser, A.R. and Bishnoi, S.R., 1992. Nitrous oxide emissions in irrigated corn as affected by nitrification inhibitors. *Soil Sci. Soc. Am. J.,* 56, 161-165

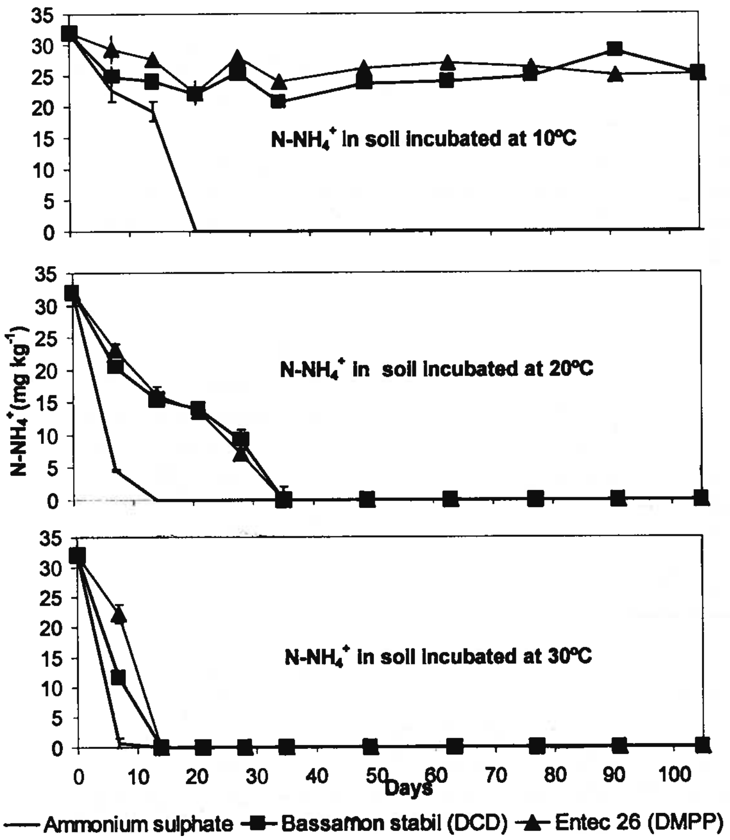
Guiraud, G. and Marol, C., 1992. Influence of temperature on mineralization kinetics with a nitrification inhbitor (mixture of dicyandiamide and ammonium thiosulphate). *Biol. Fertil Soils*, 13, 1-5

Hauser, M. and Haselwandter K.,1990. Degradation of dicyandiamide by soil bacteria. *Soil Biol. Biochem,* 22, 113-114

Kempers, A.J., 1974. Determination of sub-microquantities of ammonium and nitrates in soils with phenol, sodiumnitroprussiade and hypoclorite. *Geoderma*, 12, 201-206

Pasda, G., Hähndel, R. and Zerulla, W., 2001. Effect of fertilizers with a new nitrification inhibitor DMPP (3,4-dimethylpyrazole phosphate) on yield and quality of agricultural and horticultural crops. *Biol. Fertil soils,* 34, 85-97

Trenkel, M. E., 1997. Improving fertilizer use efficiency: Controled-release and Stabilized fertilizers in Agriculture. International Fertilizer Industry Association (IFA). Paris.



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Cities	Jan	Feb	Mar	Apr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dec
Stockholm	-3$^{(1)}$	-3	-1	3	9	13$^{(2)}$	17	15	11	6	2	-2
Frankfurt	-1	0	4	7	13	15	18	17	14	9	4	1
Paris	3	4	6	10	13	17	20	20	15	10	6	3
Madrid	6	7	9	12	16	20	24$^{(3)}$	24	20	15	9	6
Barcelona	9	10	11	13	16	20	23	23	21	17	13	10
Sevilla	11	12	14	16	20	23	27	27	24	20	14	11

Table 2- mean temperatures and expected period during which N-NH_4^+ could persist in soil after NI application in some European cities. Persistence period of N-NH_4^+: $^{(1)}$ >105 days, $^{(2)}$ 35-105 days, $^{(3)}$ 7-35 days.

CHANGES IN MINERAL NITROGEN CONTENT IN SOIL DEPENDING ON FERTILIZING IN WINTER WHEAT

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Introduction

Water, nutrients and ambient soil and air temperature are usually limiting factors for crop growth. If soil water and nutrient conditions during the growing season could be controlled better, those resources could be more efficiently utilised (Tivy,1990). To confine the amount of fertilizer applied to just being adequate to the requirements of the specific crop, at the end of season all the applied fertilizer should be completely taken up by plants so that nothing is left for leaching out during the following fall season. Theoretically, nitrogen losses could be substantially reduced by perfectly matching nutrient availability with total nutrient requirements to crops. However, under field conditions this is sometimes difficult to achieve, therefore split application in two or three doses help a lot: 1) to adapt nitrogen application better to the plant growth; 2) to avoid temporarily toxic fertilizer concentrations in the soil solution; 3) to reduce potential losses by leaching and volatilization (Haynes,1986, Amberger,1983). Experiments were established to study the effect of N added on yield, N uptake by winter wheat and recovery as well as on the leaching of mineral nitrogen from the top soil layer.

Methods

A two year (1998-1999) field experiment was conducted at the Experimental Station of Latvia University of Agriculture on sod-calcareous medium loam, humus content 1,7 - 2,3 %, soil pH 6,6 - 7,0, P_2O_5 - 130 mg kg^{-1}; K_20 - 150-210 mg kg^{-1}. Before sowing, fertilizers NPK (6:24:30) 200 kg ha^{-1} were applied.

There were two winter wheat (*Triticum aestivum* L.) varieties with different nitrogen applications: early variety 'Sirvintas-1' with two fertiliser regimes (N-0, and N-60+60); and late variety 'Moda' with three nitrogen regimes (N-0, N-60+60, and N-60+70+40). Split nitrogen dressing was applied in the following way: at an early period of vegetation for the first time; at an end of shooting into stalks for the second time; at an end of shooting into ears for the third time.

During the experimental period, meteorological conditions differed year by year. In 1998, the start of the vegetation period was favourable; rainfall in May and July was more than 288 % and 160 % of the norm, respectively. In 1999, spring was early. The mean temperature exceeded the norm by 3,4°C in April and by 2,8°C in June. April and May were characterised by lack of rainfall (54 % and 70 % of norm). Rainfall in June exceeded the norm by 112 %. July was also dry (rainfall 67 % of norm). The plants suffered from drought.

The soil samples for analyses was collected at the Zadoks Growth Stage (ZGS) 32 (beginning of shooting into stalk) of winter wheat, at the ZGS 51 (beginning of shooting into ears), and at the ZGS 69 (end of flowering) at 0-20. 20-40, 40-60 cm depth layers. The soil mineral nitrogen content ($N\text{-}NH_4^+ + N\text{-}NO_3^-$) was determined by Kjeldal method.

Results.

The results of the experiment on mineral nitrogen content showed that mineral nitrogen content in the soil is dependent not only on the duration of the vegetative growth, but also on the level of nitrogen fertilisation. Application of optimal fertilizing rates is a main factor for obtaining high wheat yields (Mouchova et.al., 1996). Higher mineral N content in soil was observed in ZGS 32, obtaining maximum 0,29 % for late maturity variety 'Moda' with fertilizing variant N-170.

Mineral nitrogen content decreased till ZGS 69 for early winter wheat variety ‘Sirvintas-1’, but for late variety ‘Moda’ mineral nitrogen content decrease till ZGS 51, but then it increased till ZGS 69.

Close correlation was found between mineral nitrogen content of top layer and wheat yields at ZGS-51 – r=0,97, but in ZGS 69 - r=0,51, and in ZGS-32 – r=0,16.

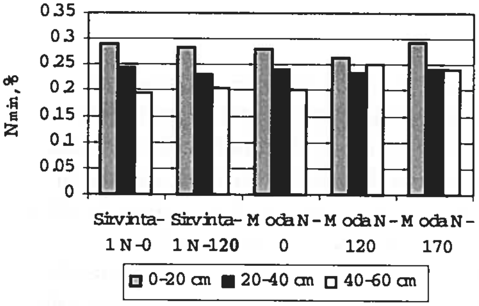

Fig.1. Mineral nitrogen content in soil at winter wheat ZGS 32, %

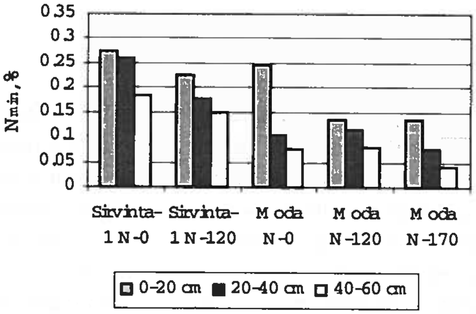

Fig.2. Mineral nitrogen content in soil at winter wheat ZGS 51, %

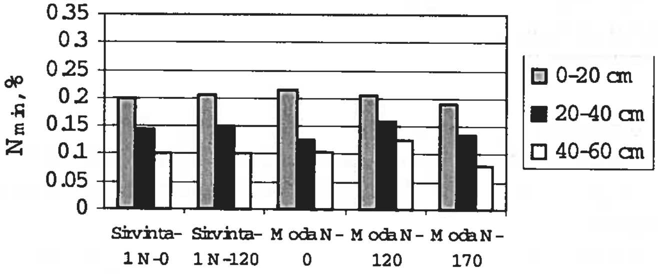

Fig.3. Mineral nitrogen content in soil at winter wheat ZGS 69, %

Conclusions

Obtained results show that mineral nitrogen content in soil depends strongly on rates and time of N fertilizers application. The maximum of mineral N content in the soil was observed at the beginning of shooting . The relation of the mineral nitrogen content in the soil layer 0-20 cm has a high correlation with the grain yield in ZGS 51 growth stage.

References

Amberger A., 1983, Efficient Use of Fertilizers in Agriculture. The United Nations, New York, 145-171.

Haynes R. J., 1986, Mineral Nitrogen in the Plant-Soil System. Academic Press Inc., Toronto, 379-443.

Mouchova H, et al.,1996, Progress in Nitrogen Cycling Studies, Q.Van Cleemput et.al. (eds.). Kluwer Academic Publishers, 237-241.

Tivy J., 1990, Agricultural ecology. Longman Scientific & Technical, New York, 63-74.

DENITRIFICATION WITH PROGRESSING ABILITY OF SOILS TO REDUCE NITROUS OXIDE : COMPARISON BETWEEN MODELS AND EXPERIMENTS

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Introduction

Nitrous oxide is involved in the global greenhouse effect and the chemistry of O_3 in the upper troposphere and lower stratosphere [3]. Its emission from soils results from nitrification and denitrification. The $N_2O/(N_2O+N_2)$ ratio of the terminal denitrification products varies greatly [2]. A small bias in the estimate of N_2O consumption or N_2O production can result in large errors in N_2O emission calculations. Competition between NO_3^- and N_2O as electron acceptors seems to vary with time, suggesting soil N_2O reducers adapt to high levels of NO_3^- [4]. It may then be necessary to account for temporal variations in the concentration of N oxide reductases [1] and microbial dynamics. The aims of this work were to (i) propose a new denitrification model that accounts for microbial activities and microbial dynamics, including the progressing ability of denitrifiers to reduce N_2O and (ii) check the model with a set of experimental data obtained from a typical loamy soil from Northern France.

Methods

Soil and experimental procedures

Experiments were performed on an Orthic Luvisol sampled in a maize crop. We have studied the influence of the concentrations of NO_3^- and N_2O on NO_3^- and N_2O reduction processes. Three treatments with different initial conditions were applied:

- treatment 1: C_2H_2 addition to characterize total denitrification (N_2O reduction is blocked),
- treatment 2: no addition to determine the net N_2O production,
- treatment 3: N_2O addition to measure the net N_2O production under N_2O enriched atmosphere.

Additional measurements were made: microbial biomass by fumigation-extraction technique; enumeration of heterotrophs and denitrifiers by MPN method.

Microbial processes modeling

NO_3^- and N_2O reductions through denitrification were simulated assuming Michaelis Menten kinetics, including non enzymatic competition between NO_3^- and N_2O as electron acceptors. Microbial dynamics were simulated considering two denitrifier groups: group 1 being able and group 2 being unable to reduce N_2O, respectively. We compared three models varying in terms of their ability to reduce N_2O:

Model A : there is no induction of N_2O reductase already present; changes in bacteria groups *1* and *2* result only from the respective growth of these groups;

Model B : N_2O reductase that was initially absent is induced for each bacteria over a period short enough to consider that the relevant bacteria move suddenly from group 2 to group 1;

Model C : changes in the N_2O reductase concentration and other components in the respiratory chain are progressive and identical for all bacteria belonging to group 1.

Results

The capability of *Models A, B* and *C* to reflect experimental data was assessed for each treatment. The 3 models are equivalent with respect to treatment 1. There was a good agreement between experimental data and simulated ones (figure 1). In addition, the estimate of denitrifier biomass calculated by model fitting was consistent with the denitrifier biomass measured from fumigation extraction and microbial enumeration

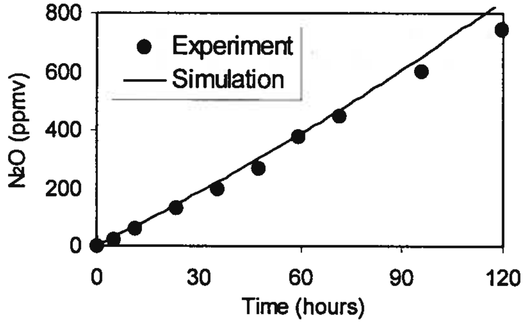

Figure 1 : comparison between experimental and simulated [N_2O] for treatment 1

The three models were then evaluated in treatment 2, using all the parameters previously estimated from treatment 1. Figure 2 clearly showed that there was simultaneous production and consumption of N_2O. The N_2O kinetics could not be reproduced by *model A* because this model does not account for an increase in the ability to reduce N_2O. *Models B* and *C* which consider the possibility of N_2O reductase induction could reproduce much better the observed kinetics. The comparison between these 2 models indicated that *model C* was more appropriate for reflecting experimental data (figure 2). However, *model B* simulated better treatment 3 than *model C* (figure 3).

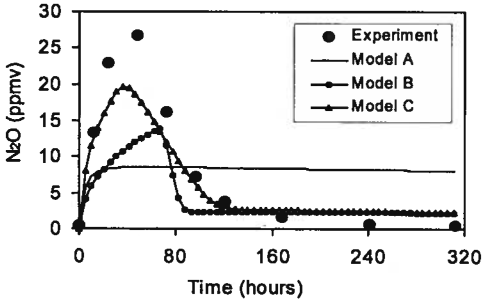

Figure 2 : comparison between experimental and simulated [N_2O] for treatment 2

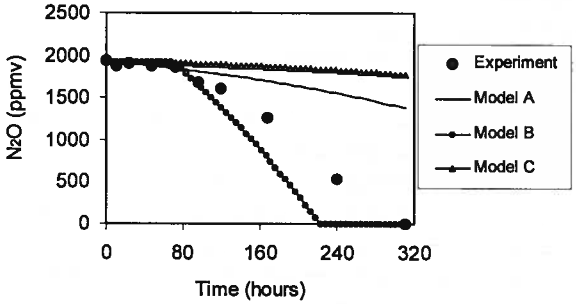

Figure 3 : comparison between experimental and simulated [N_2O] for treatment 3

Conclusion

The *model A* which accounts for microbial growth without any increase in N_2O reduction ability, was not able to reproduce experimental data. *Models B* and *C* account for the induction of N_2O reductase, with either the progressive synthesis of this reductase simultaneously for all N_2O reducers or the sudden synthesis of this reductase distributed over a range of times for N_2O reducers. These models were able to approximately describe experimental kinetics, although some biases remained. It was necessary to consider that some denitrifiers initially unable to reduce N_2O into N_2 became able to undertake this process in order to explain the low N_2O emissions *in situ* during wet events.

References

[1] Baumann *et al.* 1996. Dynamics of denitrification activity of paracoccus denitrificans in continuous culture during aerobic-anaerobic changes. *Journal of Bacteriology*, 4367-4374.

[2] Granli *et al.* 1994. Nitrous oxide from agriculture. *Norv. J. Agri. Sci.* 12 : 1-125.

[3] Smith, K.A. 1990. Greenhouse gas fluxes between land surfaces and the atmosphere. *Prog. Phys. Geograph.* 14 : 349-372.

[4] Terry *et al.* 1980. The effect of nitrate and nitrous oxide reduction in organic soils and sediments. *Soil Sci. Soc. Am. J*. 44 : 744-746.

ESTIMATING A CROP ROOT SYSTEM FROM LIMITED CORE SAMPLES.

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Introduction

The investment in time and labour required to measure root systems in the field has always been a limiting factor for research into this crucial part of the crop. Here we report a technique that significantly reduces the effort required to accurately quantify root systems. In the recent development of a model of resource capture by root systems (King *et al*,. 2001), the distribution of roots with depth was described by a single-parameter model. The model describes the distribution of all roots between the surface and the maximum depth of penetration (d_{max});

$$Y = 1-\beta^{d} \qquad \text{(Eqn. 1)}$$

where Y is the fraction of the root system accumulated from the soil surface to depth, d, and β is a parameter that describes the shape of the cumulative distribution with depth. This raises the questions ; 1) what is the minimum number of points (or sampling depths at which roots are measured) needed to reliably estimate β, and 2) if β is adequately estimated, can an estimate of the total root length be made from the same minimum number of points?

Methods

This model (Eqn. 1) was proposed to describe the distribution of tree roots with depth (Gale *et al.,* 1987), and has subsequently proved very robust at describing root systems by both mass and length, across many different biomes, including grassland and crop species (Jackson *et al.*, 1996). As β approaches one, there is a greater proportion of the roots deeper in the profile. Obviously, if the total amount of the root system and its maximum depth of penetration are known then its distribution over depth can also be quantified provided that there are sufficient data to determine β, the shape of the curve. In Eqn. 1, Y can be re-written as L/L_{max}, where L is the length of root per unit area (km m^{-2}) to depth d *(cm)*, and L_{max} is the total length of the root system to maximum depth d_{max} *(cm)*. The total length of the root system can then be estimated from measurements to depth d by Eqn 2.

$$L_{max} = L / (1-(\beta^{d})) \qquad \text{Eqn. 2}$$

Here, we use data from wheat roots sampled to a depth of 2 m (taken as the maximum depth) with root length measured in four replicates at each 10 cm depth increment (Gregory *et al.*, 1978). Measurements were taken three times in the growing season (early-April, mid-May and mid-June) of two years (1975 &1977). The values of β and L_{max} were fitted for the full root profile at anthesis (when maximum) and compared to the values measured in the cores. This was repeated, with progressive restriction of the number of cores used in the analysis, such that β and L_{max} were eventually estimated from only three cores to 30 cm depth. In all cases it was important to note that direct non-linear methods using a Maximum Likelihood Program (Ross, 1987) were used for fitting rather than linearising transformations.

Results

Estimates of β tend to increase from early spring to the main growth period, but are relatively stable from then until harvest (King *et al.*, 2001; and Table1). At all of the times of measurement in Table 1 estimates of β made using only the surface 6 or 3 data points, were within 5% of those made using the whole dataset.

Table 1 Estimates of β for wheat root systems measured on three occasions in the growing season.

Year	Date	Actual measurements		Estimates of β			
		d_{max}	L_{max}	All data	0-90 cm	0-60 cm	0-30 cm
1975	April	100	9.94	0.953	0.953	0.955	0.974
	May	150	11.44	0.962	0.958	0.948	0.909
	June	200	20.74	0.958	0.955	0.952	0.947
1977	April	110	8.14	0.940	0.940	0.941	0.947
	May	170	12.33	0.954	0.955	0.958	0.968
	June	200	15.69	0.965	0.967	0.969	0.973

The agreement was not quite so promising when Eqn. 2 was used to estimate the total root length from the restricted dataset, (Table 2). However, the estimates for L_{max} were always within the standard error L_{max} when taken from 9 points, even when the total depth of rooting was more than twice this. Also on 5 out 6 occasions the estimate from only 6 points (Table 2) was within the standard error of L_{max}. On only one occasion was this the case for estimates for only 3 points, though estimates made at maximum root biomass (June) were only just outside the error term.

Table 2 Estimates of total root length (L_{max})(km m^{-2}) for wheat root systems measured at three times during the growing season. (± s.e. in parentheses, n=4).

Year	Date	Actual measurements		Estimates of L_{max}			
		d_{max}	L_{max}	All data	0-90 cm	0-60 cm	0-30 cm
1975	April	100	9.94 (0.994)	10.07	10.08	10.23	14.67
	May	150	11.44 (0.572)	11.36	10.95	9.97	7.72
	June	200	20.74 (1.866)	20.61	20.12	19.56	18.56
1977	April	110	8.14 (1.384)	8.09	8.09	8.12	8.55
	May	170	12.33 (1.603)	12.29	12.41	12.81	15.16
	June	200	15.69 (1.569)	15.75	16.18	16.78	18.26

Conclusions

The use of this technique seems to offer hope of adequately estimating crop root distribution with depth from only 3-6 measurements in the upper profile. These measurements are relatively easily to obtain and coincidentally cover the region of most active fertiliser and water uptake for common crops. This approach is particularly advantageous for mature root systems, when measurements from depth are most difficult. However, this technique would not be appropriate where the normal pattern of root development is obstructed. Estimates of the total root length (or biomass) would also seem to be possible if a high degree of precision is not required. In this case the natural variability of the system is important. It may actually make better use of resource to take more replicate measurements from fewer upper layers to estimate the total system more reliably, than take only few replicates from the full depth of penetration.

Further work is being carried out, on other data to explore the practical limits of this approach.

References

Gale M.R. 1987. *Canadian Journal of Forest Research* 17: 829-834.
Gregory P.J. 1978. *Journal of Agricultural Science* 91: 91-102.
Jackson R.B. 1996.. *Oecologia* 108: 389-411.
King J.A. 2001. *Report to MAFF. AR0902.*
www.defra.gov.uk/research/Projects/Reports/PDF/ar0902.pdf
Ross G.J.S. 1987. *A Maximum Likelihood Program; Numerical Algorithms, Oxford, UK*

SOME CHANGES IN PHYSICAL AND WATER PROPERTIES OF SOIL AFTER TREATMENT WITH ORGANIC-MINERAL FERTILIZER

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Introduction

Humic substances because of their specific structure take part in all processes in soils and influence on their physical, chemical and biological properties (Mc Conell et al., 1993, Nogales et al., 1984). Natural water retaining capacity and infiltration of rainwater are characteristic features of soils, which are very limited in case of sandy soil (Brady, 1984). Ability to store a large quantity of mineral components in these soils, is limited by the low content of organic and mineral colloids. In case of farmyard manure shortage, which is the main organic fertiliser, limitation in the selection of plants grown on sandy soil might results in the depletion of soil organic matter and further to the debasement of the soil fertility (Adamus et al., 1998). Among nonconventional sources of organic matter in soil larger and larger meaning is acquired by brown coal because of his porosity and buffer capacity. Soil fertility amelioration is connected with the improvement of water properties and the increase of sorption capacities (Maciejewska et al., 1997). Since arable land in Poland comprises two thirds of light soil methods for improving soil productivity have been searched for (Maciejewska et al., 2000). One of such methods is agromelioration treatment with brown coal which has the positive effect on water soil properties. The results are due to the strongly developed porosity structure of brown coal and its capability to ions exchange. The doughty variety of brown coal with high content of humodentrynite macerals causes the porous texture and steaming moisture between 50% and 60 %.

Methods

The long-term experiment was carried out on typical lessive developed from loamy sand on medium loam under 50 cm (FAO, Haplic Luvisoils) in years 1995-1997. The soil was characterised with low water retention, high permeability and ventilation. The soil was also permanently dry, of low fertility, and with low sorption capacity, humus and nutrient deficiency. These parameters indicate low fertility and very low agricultural usefulness. Organic-mineral fertilizer, contains 85% of brown coal, was applied into the soil in spring 1994 in doses 66.5 t·ha^{-1} or 133.0 t·ha^{-1}. Soil samples with non-disturbed structure into the measuring 100 cm^3 cylinders were collected from Ap horizon layer (0-25 cm) every year after crop harvesting. Bulk density by piknometr method in soil samples were determined. Porosity total of soil was counted on the base of bulk and specific density. In this paper the results of experiment from first year after application of organic-mineral fertilizer into the soil (1995) and from next experimental year (1997) were described.

Results

According to the results it can be stated that this fertilizer contributed to favourable changes of physical and water properties of the soil (FAO, Haplic Luvisoils) having applied both single dose (66.5 t·ha^{-1}) and double dose (133.0 t·ha^{-1}) application (see table 1). The analysis of changes of the physical and water properties due to application of non conventional organic-mineral fertilizer were on the similar level in first year (1995) after application of this fertilizer and in the next of the experimental year (1997). In result the decrease from 2.32 to 2.21 g·cm^{-3} of specific density was observed. Bulk density also decreased in tested soil and ranged from 1.48 to 1.64

g·cm^{-3}. The applied fertilizer caused significant increase in total porosity in tested soil. Greater water retention capacity was observed after applying brown coal fertilizer in comparison to control treatment. The increase in total porosity causes the decrease of mass capacity.

Dose of organic-mineral fertilizer [t·ha^{-1}]	Year	Moisture content at sampling [% weight]	Capillary water capacity [% weight]	Porosity total [%]	Bulk density [g·cm^{-3}]	Specific density [g·cm^{-3}]
0	1995	8.41	18.64	30.33	1.63	2.34
	1997	9.09	17.06	27.78	1.64	2.30
	mean	8.75	17.85	29.06	1.63	2.32
66.5	1995	9.07	21.81	33.14	1.52	2.28
	1997	10.98	21.20	33.35	1.48	2.28
	mean	10.03	21.51	33.25	1.50	2.28
133.0	1995	9.49	22.00	33.79	1.50	2.22
	1997	11.50	22.82	33.13	1.53	2.19
	mean	10.50	22.41	33.46	1.52	2.21
$LSD_{0.05}$		0.42	0.62	0.83	0.020	0.039

Table 1 - Some of physical and water properties of the soil. Mean values of 1995 and 1997 $LSD_{0.05}$ for dose of organic-mineral fertilizer

Conclusions

Organic-mineral fertilizer from brown coal remarkably influenced the improvement of physical and water properties in arable layer of sandy soil. The influence of this fertilizer was direct and indirect. The direct impact resulted from its chemical composition, that is the content of nutrients and humic acids. Whereas, the indirect impact was caused by the structure of preparation, especially the strongly developed porosity system. Changes of these properties depended on the quantity of applied fertilizer and were the highest after applying 133 tons of the preparation per ha. The using of this fertilizer caused the increase of the total porosity of soil and the ability to rainwater retention. Under the influence of this fertilizer the bulk density decreased in unison with the specific density of soil. These results indicates that there is a possibility of using this fertilizer to regulate physical and water properties of soil for a period longer than three year.

References

Adamus M., Drozd J., Stanislawska E. 1998., *Wspóldziazanie nawozów organicznych i mineralnych w kształtowaniu przemian materii organicznej i wlasciwosci fizykochemiczne gleb lekkich.* In: Mat. Konf. Nawozy organiczne. Szczecin 1998, 118-123.(in Polish).

Brady N.C. 1984. *The nature and properties of soils*. Macmillan Publishing Company. N. Y.

Maciejewska, A., Kwiatkowska J. 1997, *The influence of mineral-organic fertilizer obtained from brown coal on physico-chemical properties of soil.,* International Conference of PHD Students. Miskolc, Hungary, 10.

Maciejewska, A., Kwiatkowska J. 2000, *Using of brown coal to enriching content of organic matter in soil.,* Third International Congress of The European Society for Soil Conservation, Valencia, Spain. 248.

Mc Connell D. B., Shiraliapour A., Smith W. H., 1993. *Compost application improves soil properties*. BioCycle 3: 61-63.

Nogales L., Ortega E., Gallardo-Lara F., Delgado M. 1984. Agronomica 28: 192-201.

NITRATE REDUCTASE ACTIVITY IN MAIZE INBRED LINES DEPENDS OF NITROGEN SUPPLY

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Introduction

Many authors underline the significance of activity of enzymes of nitrogen pathway in plant; especially nitrate reductase (NR; E.C.1.6.1.1) – first enzyme of nitrates assimilation (Lea nad Ireland, 1999). Good relationship between activity of nitrate reductase (ANR) and nitrates uptake has been demonstrated (Rizzi *et al.*, 1996). However, at the N defficiency, higher ANR is observed in the roots (ANR_{ro}), than in the leaves (ANR_{ab}) (Murphy *et al.*, 1987, Agbaia *et al.*, 1985). So, more nitrates are assimilated and utilised in the roots with the decrease of biomass of aboveground part of plant. For breeding maize hybrids adapted to the low N fertilization more interesting will be genotypes with ANR_{ab}/ANR_{ro} ratio under nitrogen stress not smaller ANR_{ab}/ANR_{ro} ratio under N full supply. Significant genetic variability of the ANR observed in maize (Bertin *et al.*, 1996, Reed and Hageman, 1980, Rizzi *et al.*, 1996) makes possible effective selection. These assumptions were ones of the backgrounds of scientific project of the research for the criteria's of maize genotypes selection for low N supply.

Methods

Sixteen genotypes were chosen from large genetic base of maize inbred lines. Activity of NR was evaluated in the 5-days old maize seedlings grown in the water cultures with standard Hoaglands solution thinned with water (1:3). The experiment consists two N level in the nutritive solution: 5 mM of NO_3^- (N_1) and 0,5 mM of NO_3^- (N_0) in 5 replications. The NR activity was calculated as nmoles of NO_2- formed per gram of fresh matter (of roots or aboveground part of plant) per hour (after Buczek, 1976). The ANR measures were compared with the results (N content, dry matter weight) of the pot experiment realised at the same time under nitrogen stress condition (N_0) and nitrogen full supply (N_1) (scheme after Lipski, 2002). N content were evaluated at the 6-7 leaves of maize, dry matter was measured at the beginning of tasseling.

Results

The N deficiency leads to reduction of NR activity for most genotypes. The bigger decrease of ANR was measured for roots: meanly from 1954 to 660 nmoles of NO_2-/g/h. In the case of aboveground part of plant, decrease was smaller: from 3148 to 2156 nmoles of NO_2-/g/h. For all maize lines and nitrogen supply conditions ANR_{ab} is bigger than ANR_{ro}. The average ANR_{ab}/ANR_{ro} ratio was greater in the condition of N stress – 5,8, than in the full N supply where it was equal 3,0. But only 6 genotypes had significantly lower ANR_{ab}/ANR_{ro} ratio in the N_0 than in the N_1 condition. Simultaneously others lines respond increase of ANR_{ab}/ANR_{ro} ratio.

Characters	ANR_{ab}		ANR_{ro}		ANR_{ab}/ANR_{ro}	
	N_1	N_0	N_1	N_0	N_1	N_0
N content in roots	0,37*	-0,45*	0,73*	0,68*	-0,64*	-0,58*
N content in aboveground part of plant	0,86*	0,45*	0,38*	0,27	0,77*	0,82*

* - significant for $\alpha=0,05$

Table 1. Coefficients of correlations between ANR_{ab}, ANR_{ro} and N content in maize

Nitrogen content in the roots has been closely connected with the activity of NR in the roots (table 1). At the same time, the amount of nitrogen in the aboveground part of plant was more related with activity of nitrate reductase in this organ. But, much bigger coefficient of correlation has been observed in the plants grown at the full N supply. ANR_{ab}/ANR_{ro} ratio has been very well correlated with nitrogen content in the aboveground part of plant. Relatively good, but reciprocal correlation was observed between ANR_{ab}/ANR_{ro} ratio and N content in the underground part of maize seedlings.

To find relationships between nitrate reductase activity and maize biomass production correlation between ANR and dry matter weight of roots or aboveground part of plant has been analysed (table 2). Generally, activity of nitrate reductase in the studied plant organs has been less correlated with plant d.m. weight than N content in the plants. Except relationship between ANR_{ab} and weight of aboveground part of plant d.m. which were stronger than correlation ANR_{ab} and N content. Interesting is, than ANR_{ab}/ANR_{ro} ratio still was reciprocally correlated with roots d.m. (as N content in roots). Relationships between ANR_{ab}/ANR_{ro} ratio and d.m. weight of both roots and aboveground part of plant were stronger under N deficiency than under full N supply conditions.

Characters	ANR_{ab}		ANR_{ro}		ANR_{ab}/ANR_{ro}	
	N_I	N_0	N_I	N_0	N_I	N_0
Roots d.m. weight	0,21	0,32*	0,43*	0,61*	-0,55*	-0,78*
Aboveground part of plant d.m. weight	0,47*	0,66*	0,28*	-0,29*	0,62*	0,87*

* - significant for α=0,05

Table 2. Coefficients of correlation between ANR_{ab}, ANR_{ro} and d.m. weight of maize

Discussion

In the studied genetic material were found significant relationships between activity of nitrate reductase and N content or dry matter weight. We may suppose, that high ANR in specific plant parts is related with high N content or d.m. weight in these parts. It will be in agreement with the results of Rizzi *et al.* (1996), which found that low protein maize strains had low activity of NR compared with high protein and high productive strains of maize. But Eichelberger *et al.* (1989) after the cycle of field trials stated that selection for high NRA in stover and grain had little effect on the N traits evaluated (N content, yields), contrary selection for low NRA resulted in significant reduction for many traits. Our study underlines also significance of the ratio NRA in aboveground part of plant and NRA in roots, who is very well related with N accumulation and biomass production. This parameter may be good criteria for future selection of maize genotypes

References

Agbaia H., Heuer B., Zieslin N., 1996, Plant Physiology, 149: 559-563.
Bertin P., Charcosset A., Gallais A., 1996, Colloque „Mais Ensilage" Nantes 1996, Ed. AGPM.
Buczek J., 1976, Acta Soc. Bot., 45: 77-92.
Eichelberger K.D., Lambert R.J., Below F.E., Hageman R.H., 1989, Crop Sci., 29, 1398-1402.
Lea P.J., Ireland R.J., 1999, Plant amino acids, 1-47. Ed. B.K. Singh, M. Dekker Inc, New York, Basel, Hong Kong.
Lipski, 2002, Proc. of the 7th Congress of ESA, 15-18 July, Cordoba, Spain.
Murphy A.T., Lewis O.A.M., 1987, The New Phytologist, 107: 327-333.
Reed A.J., Hageman R.H., 1980, Plant Physiology, 66: 1179-1183.
Rizzi E., Balconi C., Bosio D., Nembrini L., Morseli A., Motto M., 1996, Maydica, 41, 325-332.

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PYTHIUM SPP. AND TOTAL FUNGI RESPONSE TO GREEN MANURING.

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Introduction

In recent years, interest has increased in the use of cover crops to enhance soil fertility (Elmer and LaMondia, 1999). This practice stimulates the increase in soil microbial biomass which can suppress soil-borne pathogens by competing for organic C availability. Many authors, have however observed a significant increase in *Pythium* spp. in soil amended with fresh plant tissues. Many *Pythium* species cause yield losses for crops worldwide. *Pythium* root rot is often associated with soil management practices that increase crop residues in soil, such as direct drilling or green manure (Cook *et al.*, 1980). In fact, *Pythium* spp. has a high ability to survive as a saprophyte in cultivated soil and cultural techniques can easily alter the interaction *Pythium*-microbial community. Soil subject to intensive cultivation, requiring amendment with organic matter, is the most frequently affected by unbalanced *Pythium*-microflora conditions. A study was carried out under field and controlled conditions to evaluate *Pythium* and total fungal response after plant tissue incorporation in soil with a high natural *Pythium spp.* population. This soil was chosen for its high pathogenic *Pythium* spp. population (mainly *P. ultimum* and *P. deliense*) following several years of continuous strawberry cultivation.

Methods

The field experiment was performed in the Cesena area (eastern Po Valley) in 1998, on a silty clay loam soil (39% clay, 49% silt, 12% sand), naturally infected with *Pythium* spp. Barley (spring sowing) green manure was compared with untreated soil. The trial was organized in a randomized block design with four replicates (10 x 12 m). Soil samples (five soil cores, 0-20 cm, in each plot) were collected from March to September, air dried for one week and sieved through a 5-mm mesh screen.

Pythium spp and total fungal populations were recorded with the soil dilution plate method on selective media: PARP (cornmeal amended with 5 mg l^{-1} Pimaricin, 250 mg l^{-1} Ampicillin, 10 mg Rifampicin, 100 mg PCNB and 1 g l^{-1} Ox-gall) and water agar + 3 g l^{-1} Ox-gall and 200 mg l^{-1} streptomycin sulfate. After incubation, the colonies were counted and expressed as Colony Forming Units (CFU) g^{-1} soil.

A separate trial was performed in pots with soil from the trial field. Above-ground plant tissues were collected at green manure time, chopped in a razor blender, and incorporated into the soil in the pot. The plant biomass used was a realistic field rate (30 g kg^{-1} of soil). The trial was organized in a randomized design with three replicates (1 pot=1 replicate). *Pythium* and total fungi were recorded as above at four sampling times.

Results

Pythium spp. and total fungal populations grew rapidly after biomass incorporation into the soil and then decreased with the reduction in the availability of organic C. This response was observed both in field and pot experiment (Fig. 1 and 2).

Pythium growth response to fresh biomass incorporation was faster than total fungi. In the field trial, where *Pythium* and total fungi have a variable trend during the year, the *Pythium* population reached its peak within 45 days and then rapidly decreased while total fungi began to increase later than *Pythium* (Fig 1).

Fig. 1 In soil *Pythium* and total fungi response to green manure in full field.

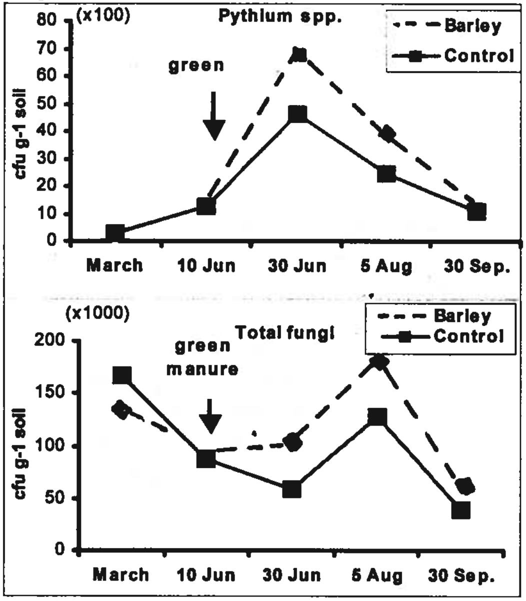
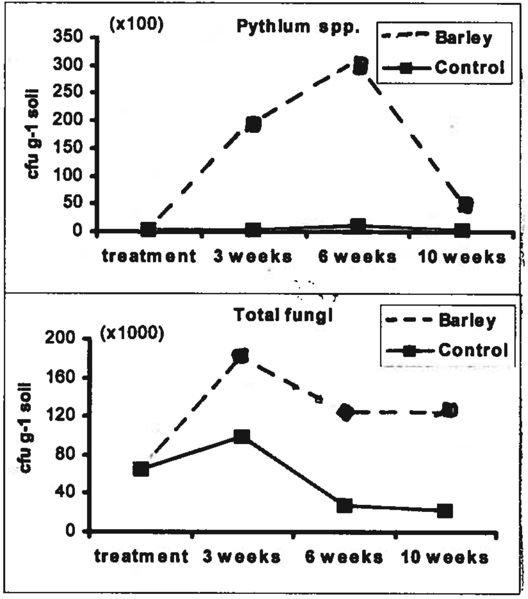


Fig. 2 In pot response of *Pythium* and total fungi to fresh matter incorporation



The simulation in pot gave the same *Pythium* and total fungal response to fresh tissue incorporation, but to a much higher extent. This was probably due to the controlled conditions: fine plant tissue grinding, weekly watering, sieved, and consequently, more aerated soil (Fig. 2).

Discussion.

Green manure is a common practice in organic farming, to maintain organic matter in soil and improve physical and nutritional soil characteristics. Depending on the existing conditions, saprophytic soil-borne pathogens in soil can be either actively suppressed by organic amendments (Lumsden *at al.* 1983) or enhanced. This can be dangerous when the soil-borne population is selected with previous soil management and short crop rotation. The results reported here show that 3 – 12 weeks after green manure *Pythium* populations increased. When the pathogenic *Pythium* population is high, total fungi, an important component of biomass, are unable to suppress them as observed by several authors under other experimental conditions (Erhart *et al.*, 1999). The rapidity of *Pythium* response indicates that this pathogen can be particularly dangerous during the first weeks after green manure.

Pythium and total fungal response to available organic C suggests several considerations for cover crop and plant debris management:

a. organic debris soil incorporation must take into account previous soil management (monoculture, crop rotation).

b. Unbalanced soils, with *Pythium* population selected by monoculture or short rotation, require a reduction in pathogenic population by appropriate crop rotation before using green manure.

c. Saprophytic pathogens and total fungi are strongly enhanced by plant tissue incorporation. Whether this can have a negative or positive effect on soil microflora, depends on the soil microbial balance.

References

Cook RJ, JW Sitton, & JT Walder. 1980. Plant Dis. 64: 102-103
Elmer WH & JA. LaMondia. 1999. Plant Dis. 83: 119-123.
Lumsden RD, JA Lewis & CG Papavizas. Environment. Sound. Agricult. (51-57). Praeg Scent.
Erhart E., K. Burian, W. Harti & K. Stik. 1999. J. Phytopathology 147: 299-305.

STUDY OF SUPPRESSIVE RESPONSE IN CULTIVATED SOILS TO *PYTHIUM* SPP.

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Introduction

The most important "root rot complex" soil-borne pathogens for crops are *Rhizoctonia* and *Pythium* spp., two non-lethal pathogens, which live saprophytically in soil. The aggressiveness of these pathogens is increased by continuous cropping or short rotations, often adopted in conventional farming. Several authors have shown that organic or reduced-input farming reduces disease incidence, due to the suppressive activity of soil microbial communities and to a less specialized level of the pathogenic fungal population (Workneh & van Bruggen, 1994; Manici *et al.*, 2002). *Rhizoctonia* is a sterile fungus and so it is impossible to evaluate the inoculum level directly in soil, while the *Pythium* spp inoculum can be counted directly and expressed as Colony Forming Units (CFU) g^{-1} soil. Moreover, *Pythium* is the soil-borne pathogen most sensitive to microflora suppression, therefore in comparative studies of cultivated soil fertility its level can be indicative of soil suppressiveness. A comparative study was carried out, in two sites of southern Italy, using *Pythium irregulare* artificially inoculated, to evaluate the suppression of *Pythium* spp. in two different soil management systems.

Methods.

Two fields with similar soil texture were chosen in southern Italy. The first (ALSIA, Az. Pantanello, Metaponto - Matera), had been fumigated five year earlier, then cultivated with strawberry for two years and left fallow the year before the trial. The second was non-fumigated soil (CIF, Villasor - Cagliari), subjected to a four year crop rotation, with periodic organic amendments, where strawberry had been cultivated the previous year.

Table 1. Some fisical, chemical and biological parameters of two field of the trial.

	ALSIA, Metaponto (MT) Italy	CIF Villasor (CA) Italy
Soil texture	sandy loam	sandy loam
Organic Matter	1 %	4 %
Total fungi	1.5^a x10^4 cfu g^{-1} soil*	3.6^a x10^4 cfu g-^{1} soil**
Total bacteria	1.3^a x 10^7 cfu g^{-1} soil	1.5^a x 10^7 cfu g^{-1} soil
Fluorescent bacteria	1^a x 10^5 cfu g^{-1} soil*	8.5^a x 10^4 cfu g^{-1} soil**
Previous management	Fumigated - no crop rotation	No fumigated – crop rotation

^{a}Mean of three sampling times *low variability ** high variability

Oospores of *P. irregulare* were added to 500 g soil samples to obtain 600 CFU g^{-1} soil: The samples were placed in cloth bags and buried 20 cm deep in three sites of the two fields. The inoculation was performed at the beginning of May 2000. Soil samples were collected every 21 days for two months. *Pythium* inoculum was evaluated with the plate dilution method on selective media (PARP$_5$). Total fungi, bacteria cultures and fluorescent bacteria were recorded with the soil dilution plate method on water agar, Thorton and King's B media respectively. After a appropriate incubation time, *Pythium*, total fungi and bacteria colonies were counted and expressed as Colony Forming Units (CFU) g^{-1} soil.

Results

In the ALSIA field (Tab.1), fumigated in the past, the *P. irregulare* artificially inoculated, added to the *Pythium sylvaticum* (150 CFU g^{-1} soil) naturally present, maintained its level in soil from the first to the last sampling time (Fig. 1). This soil did not show any ability to suppress *Pythium*. Total fungal (Tab.1) population were mainly represented by *Alternaria* spp. and *Fusarium oxysporum*, two fungal species often isolated from rotted strawberry root.

P. irregulare was strongly suppressed in non-fumigated soil (CIF), from 600 to 200 CFU g^{-1} soil at the first sampling time and maintained this level up to the last sampling time (Fig.2). Total fungi (Tab.1) showed a high variability, many species belonging to *Penicillium Aspergillus*, *Mucor*, *Trichoderma* genera and several *Fusarium* species were isolated. Culturable and fluorescent bacteria levels in bulk soil from the two fields did not differ, but there was a high variability in colony morphology in samples from the CIF field.

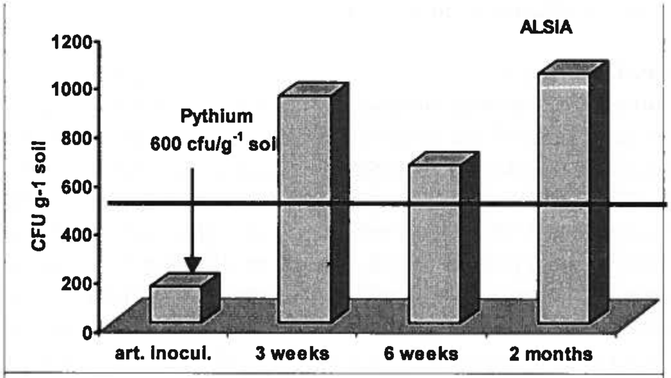

Figure 1. Response of *P. irregulare* artificially inoculated in ALSIA field.

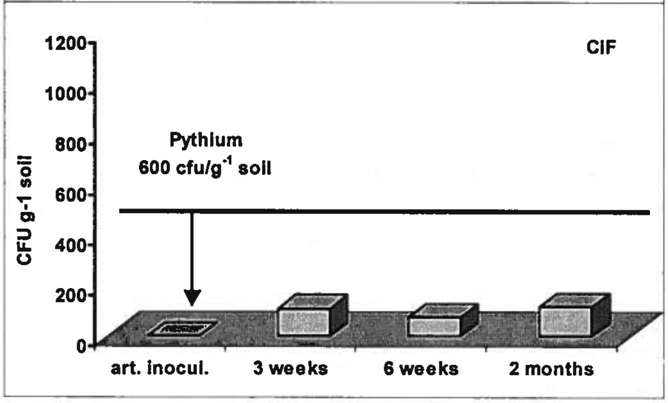

Figure 2. Response of *P. irregulare* artificially inoculated in CIF field.

Discussion

The response to *Pythium,* artificially inoculated, as well as several other microflora parameters, made it possible to assess the suppression potential in this comparative study. Organic matter content, total fungi and variability of fungi and culturable bacteria, all higher in non-fumigated soil (CIF), were the components related to the suppressiveness toward *Pythium*. The microbial biomass, of which fungi are the most important component, and its biodiversity are confirmed to be factors involved in the natural suppression of saprophytic fungal pathogens in soil (Erhart *et al.*, 1999; Mazzola, 1999). Root rot incidence in subsequent strawberry crops in the two fields confirmed the health of the CIF field soil and the lack of health of ALSIA field soil (data not shown).

In conclusion, previous soil management (fumigation, organic amendment, frequency and quality of crop rotation, etc.) and organic matter in soil affect the microbial balance and suppressiveness toward non-lethal pathogens. Therefore these must be considered when deciding the best soil treatment before planting subsequent crops.

References

Erhart E., K. Burian, W. Harti & K. Stik. 1999. J. Phytopathology 147: 299-305.
Mazzola M. 1999. *Phytopathology* 89:920-927.
Manici L et al. 2002. Proc. ECO-FRU-VIT 2002. pp 218-223.
Workneh F. & van Bruggen A.H.C. 1994. *Phytopathology* 84. 688-694.

EFFECT OF LONG-TERM APPLICATION OF ORGANIC AND MINERAL FERTILISERS ON SOIL WATER HOLDING CAPACITY

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Introduction

Maintenance and improvement of soil quality in continuous cropping systems is critical for sustaining agricultural productivity and environmental quality for future generations. Soil organic matter has been recognised as one of the most important indicators of soil quality and productivity. The parameter is related to many biological, chemical and physical characteristics of the soil. Among the latter, the water holding capacity (WHC) is one of the most important. There are different opinions regarding the effect of organic matter on WHC. Several authors reported that the addition of organic matter increased WHC (e.g. Felton and Ali, 1992), others found the opposite (Sommerfeldt and Chang, 1987). Often the decrease in bulk density caused by the incorporation of organic matter tends to counterbalance any increase of WHC on a weight basis, resulting in only a slight increase on a volume basis (Khaleel et al., 1981).
The objective of this work was to evaluate the effect of a long-term application (40 years) of different organic and mineral fertilisers on water holding capacity.

Methods

A long-term experiment has been underway since 1962 at the experimental farm of the University of Padova. A continuous maize succession has been subjected to eight different fertilisation treatments: no fertilisation (0), no fertilisation with residues incorporation (0+R), mineral fertilisation without (M2) and with residues incorporation (M2+R), mixed mineral and 30 t ha^{-1} solid manure fertilisation (L1M1), mixed mineral and 30 t ha^{-1} liquid manure fertilisation (Lq1M1), 60 t ha^{-1} solid manure fertilisation (L2) and 60 t ha^{-1} liquid manure fertilisation (Lq2). In the fertilised plots on average 300 kg ha^{-1} N, 150 kg ha^{-1} $P_2 0_5$, 420 kg ha^{-1} K_2O were distributed per year. The experimental layout was a randomised block with three replicates.
To measure the WHC, 6 undisturbed samples (8 cm diameter, 5 cm height) for each treatment (2 per block, for a total of 48) were collected in the root zone. The water retention curve was determined using the Stakman apparatus for low-range potentials (-1, -2, -3, -4, -5 kPa) and a pressure plate apparatus for mid and high-range potentials (-10, -33, -100, -1500 kPa).
To be able to compare the water retention curves, data were analysed by regression analysis applying the dummy variables method (Draper and Smith, 1966).
Starting from the van Genuchten model, the following complex model was initially tested considering the *l* treatments separately:

$$\theta = \sum_{i=1}^{l} Z_i \theta_{r_i} + \sum_{i=1}^{l} Z_i \left(\theta_{s_i} - \theta_{r_i}\right) \left[\frac{1}{1 + \left(\left(\sum_{i=1}^{l} Z_i \alpha_i \right) h \right)^{\sum_{i=1}^{l} Z_i n_i}} \right]^{1 - 2 / \sum_{i=1}^{l} Z_i n_i} \qquad [1]$$

where θ is the volumetric soil moisture content at tension *h*, θ_r and θ_s are the residual and saturated volumetric water contents, α is a scaling factor, *n* is a dimensionless curve-shaped parameter and Z is the dummy variable. Subsequently, reduced models assuming common θ_r, θ_s, α and n for different treatment combinations were fitted to the data. Partial F tests revealed whether complex models could be reduced to more simplified models.

Results

The application of the dummy variable method allowed the complex model [1] to be reduced to the model [2]. Four different types of retention curve were identified, differing by θ_s and α parameters; n and θ_r remained constant for the eight treatments (Fig 1). The treatments with solid manure (L2 and L1M1) had the greatest WHC (Fig. 1). They had an initial part in common with mixed and mineral treatments, but in the mid-range potential the WHC was clearly greater. This behaviour is related to the high pore-size density in the range 5-30 µm. In the treatments with mineral fertilisers the macropore fraction prevailed. The treatments without fertilisation had the lowest WHC, particularly 0+R. It is worth noting that the application of 60 t ha^{-1} liquid manure (Lq2+R) contributed towards reducing the WHC in the potential range considered. Probably the long-term application of liquid manure had a negative effect on the soil structure.

$$\theta = \theta_r + \left(\sum_{i=1}^{l} Z_i \theta_{si} - \theta_r\right) \left[\frac{1}{1+\left(\left(\sum_{i=1}^{l} Z_i \alpha_i\right) h\right)^n}\right]^{1-2/n} \qquad [2]$$

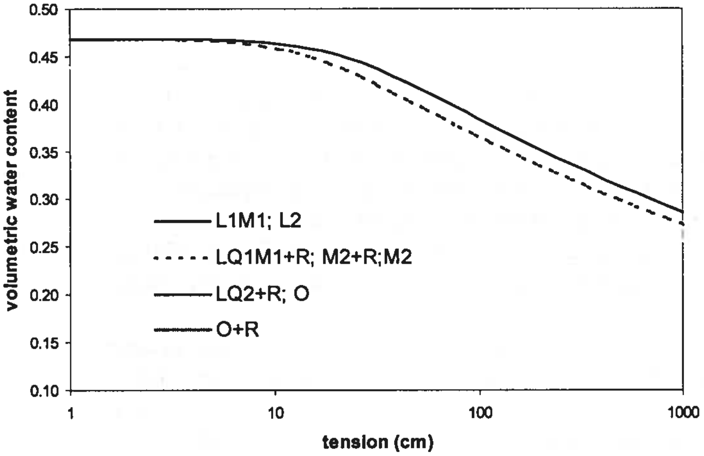

Figure 1: Soil retention curves for the different treatments considered.

Conclusions

The long-term application of different mineral and organic fertilisers influenced WHC. The highest amount of organic matter applied with fertilisation increased the WHC only in the case of the solid manure distribution. The treatment with an intermediate distribution of liquid manure gave the same WHC as the mineralised treatment. Moreover, the highest application of liquid manure negatively influenced the WHC.

Treatments	α	θs	θr	n
L1M1, L2	0.045 ± 0.007	0.468 ± 0.003	0.020 ± 0.006	2.138 ± 0.058
Lq1M1+R, M2+R, M2	0.065 ± 0.010	0.468 ± 0.003	0.020 ± 0.006	2.138 ± 0.058
Lq2+R, O	0.045 ± 0.007	0.440 ± 0.004	0.020 ± 0.006	2.138 ± 0.058
O+R	0.065 ± 0.010	0.440 ± 0.004	0.020 ± 0.006	2.138 ± 0.058

Table 1 – Estimated parameters of the simplified model (± standard errors)

References

Draper N.R. et al., 1966. Applied regression analysis. John Wiley & Sons, Inc
Felton et al., 1992, Trans. ASAE, 35, 1153-1159
Khaleel R. et al., 1981, J. Environ. Qual., 10, 133-141
Sommerfeldt et al., 1987. Soil Sci. Soc. Am. J., 51, 7-9

APPLICATION OF TDR TO WATER FLOW MEASUREMENTS USING TENSION DISC INFILTROMETERS

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Introduction

Access to simple, fast and reliable techniques for in situ measurement of soil hydraulic properties is essential in agricultural and environmental research dealing with water storage and transport in soils. Generally, field determination of water infiltration into the soil is made manually by noting visual observations of water height in a water supply reservoir. This standard technique is time consuming and implies a tedious work. The objective of this study was to develop a simple, rapid, and accurate automated technique for continuous, unattended measuring water level change in mariotte-type reservoirs by using time domain reflectometry (TDR). The technique was primarily designed for in situ water infiltration determination by tension disc infiltrometry to estimate both saturated and unsaturated soil hydraulic properties.

Methods

Generally, TDR applications involve the determination of the propagation velocity of an electromagnetic pulse by measuring its transit time along parallel metallic probes embedded in the medium of interest. Over the TDR frequency range and for some materials (i.e. air and water), the transit time, *t*, of a pulse launched by a TDR pulse generator through a medium along a probe of length *L*, can be expressed (Topp *et al.*, 1980) as

$$t=\frac{2L\sqrt{\varepsilon}}{c} \qquad (1)$$

where ε is the apparent dielectric constant of the medium and *c* the velocity of light in free space. In the case of a probe vertically inserted in a stratified medium, the total travel time of the pulse is a summation of the travel times in the different phases (Ferré *et al.*, 1996):

$$t=\Sigma_i t_i \qquad (2)$$

where t_i is the time required for the pulse to propagate through phase *i*. In the case of a TDR probe of length *L* traversing from top to bottom a mariotte reservoir partially filled with water, the probe length in contact with air, *x*, can be calculated by combining Equations (1) and (2) as

$$x=L\frac{\sqrt{\varepsilon_{TDR}}-\sqrt{\varepsilon_{water}}}{\sqrt{\varepsilon_{air}}-\sqrt{\varepsilon_{water}}} \qquad (3)$$

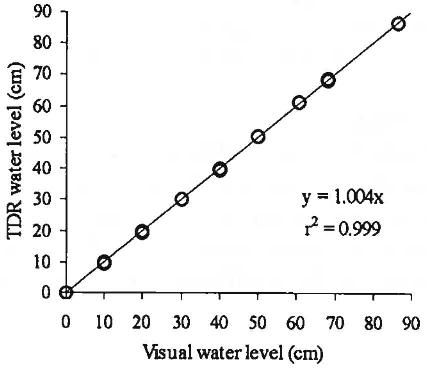
where ε_{TDR} is the dielectric constant measured by the TDR pulser and ε_{air} and ε_{water} are the dielectric constant of air and water measured previously with the same probe.

On the basis of the above theoretical considerations, the water-supply reservoir of a 0.25 m diameter tension disc permeameter, constructed following the design of Perroux and White (1988), was equipped with a three-rod coaxial TDR probe, which was placed in the centre and firmly fixed from top to bottom of the reservoir. Copper rods with a diameter of 1.6 mm and a separation of 10 mm for the outermost rods were used. A pulse generated by a TDR cable tester (Tektronix 1502C) propagates along the TDR probe and its reflection is automatically transferred through a SP232 module to a computer for waveform analysis using the software WinTDR'98 (Or *et al.*, 1998). The water level height (*L-x*) in the infiltrometer reservoir is then calculated from Equation (3). To evaluate the precision of this TDR-based water level sensing technique, a vertical water column, consisting of a 90 cm tube made of clear plastic with 4.2 cm of internal diameter, was instrumented with a TDR probe 86.5 cm long similar to that described above. Simultaneous manual and TDR water level measurements were made at intervals of approximately 10 cm from 0 cm (reservoir full of water) down to 86.5 cm (reservoir full of air). In all cases, three TDR measurements were made for each visual reading. A second experiment was carried out in the field and consisted in measuring water infiltration into a loamy soil at four tensions (ψ_o = -14, -4, -1, and 0 cm of water potential) using a tension disc infiltrometer. For each tension, the cumulative infiltration was calculated from water level drop in the reservoir, which was measured by TDR every 10 seconds and manually with the standard technique.

Results

Figure 1 shows the correlation between standard visual measurements of water level height in the mariotte column and simultaneous readings obtained automatically using the proposed TDR method. The agreement between the two measurements is excellent, indicating that the TDR technique can be used satisfactorily for water level measurement in this type of mariotte reservoirs. The variation observed among the three TDR water level readings is very low (CV between 0.001 and 0.13 %).
Figure 2 summarises the results of the infiltration experiment conducted in the field. The agreement between visual and TDR measurements is again remarkable. In this case, the correlation for all the infiltration values obtained at the four pressure heads is again very high ($r^2 = 0.998$).

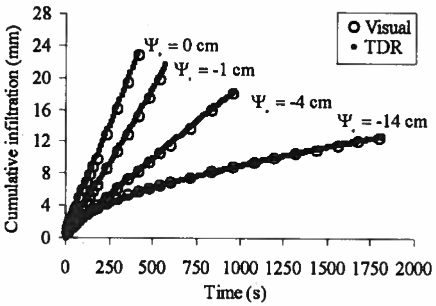
Fig. 1 - Correlation between TDR and visual measurements of water drop in a mariotte column



Conclusions

In summary, the TDR-based technique here proposed for automated measurement of water flow with disc infiltrometers is precise, simple, and easy to implement. It allows multiplexing several infiltrometers and is especially suited to characterise unsaturated soil hydraulic properties in field experiments where subtle differences due to treatments require a large number of measurements (i.e., comparison of tillage systems).

Fig. 2 - Cumulative infiltration measured with a tension disc infltrometer using the visual and TDR techniques



References

Ferré, P.A. et al. 1996. *Water Resources Research,* 32, 271-279.
Or, D. et.al. 1998. *WinTDR 98 V.4.0 –Users Guide.* Utah State University, Logan, UT.
Perroux, K.M., White, I. 1988. *Soil Science Society of America Journal,* 52, 1205-1215.
Topp, G.C. et al.1980. *Water Resources Research,* 16, 574-582.

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EFFECT OF APPLICATION OF DIFFERENT DOSES OF SEWAGE SLUDGE AND LIMING ON SOIL CHARACTERISTICS AND PASTURE PRODUCTION AND QUALITY, IN SILVOPASTORAL SYSTEMS IN GALICIA (NW SPAIN)

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Introduction

pH is an important factor that affect to availability of nutrient in soils. That factor acquires a relevant importance when heavy metals are added with fertilisers like sewage sludge into the soil, because they can go through the trophic change and reach human beings. On the other hand, sewage sludge has higher pH than acid soils which can prevent from bioavailability of heavy metals in some degrees.

Methods

The experiment was located in Pol (lugo, NW Spain). Sward was sown in the autumn of 1997 with a mixture of 25 kg *Lolium perenne* cv Brigantia ha^{-1}, 10 kg *Dactylis glomerata* cv Artabro ha^{-1}, and 4 kg *Trifolium repens* cv Huia ha^{-1} in 27 plots of 96 m^2 under *Pinus radiata* D. Don plantation (7 years old and at a density of 1666 trees ha^{-1}).

Soil pH (soil:water 1:2,5) was very acidic (pH=4.5) and the percentage of saturated aluminium very high (92.2%). Three sewage sludge doses were applied every year at the start of 1998, 1999 and 2000, meaning 160, 320 and 480 kg total N ha^{-1}. Half of the plots treated were initially limed with 2,5 t ha^{-1}. Treatments consisted of liming and no fertilisation (NFL), no liming and traditional mineral fertilisation (Min), doses low (LL), medium (ML) and high (HL) with liming, and the same (NFUL) low (L), medium (M) and high (H) doses without liming. The experiment was completely randomized, with three replicas and three harvests were made in 1999 and 2000, respectively, and samples transported to laboratory for pasture production and botanical composition determinations and chemical analyses (Zn and Mn, digested in microwave with nitric acid and determined by atomic absorption spectrophotometer). Soil samples were taken in each cut and pH was measured on water (soil:water, 1:2,5).

Results

Soil pH did not show a significant interaction of doses and liming. pH of April 1998 and Novembre 1999 was significantly affected by liming and fertilisation (Figure 1). pH from mineral treatment was significantly reduced, in comparison with no fertilised treatment. Liming also increased the pH, but only in the second year.

Pasture production was higher in the second than in the first year, as can be seen in no fertilisation treatment (Figure 1) Pasture production was higher in mineral treatment and in those plots fertilised with the higher dose of sewage sludge, in the first year. But mineral treatment production was significantly lower than in the medium and the high doses fertilised plots in the second year. That fact can be explained because mineral treatment reduced significantly the pH, and this effect was higher in the second than in the first year. Differences between medium and high dose treatments in the second year can be explained because of the residual effect of the medium dose, that equals higher dose in the second year, as no more answer of pasture production can be expected.

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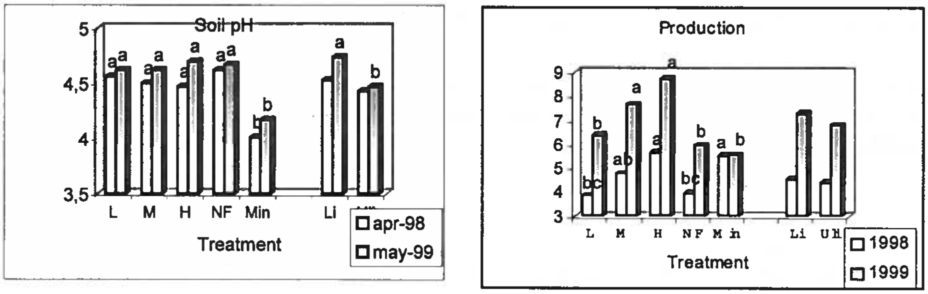

Figure 1. Liming, sludge application and mineral nitrogen fertilisation effect on pH and production (means for limed (Li) and no limed (Uli), and means for L(low), medium (M), High (H), No fertilised (NF) and Mineral (Min) treatments. Letters diffferent mean significant differences between treatments.

Zinc and Manganese pasture concentration response to treatments can be seen on Table 1. The effect of treatments on Zn depended on the year, as there was not effect in the first year, but there were a significant interaction harvest*dose and a significant and negative liming effect in the second. The medium sewage dose increased significantly the zinc conentration of the pasture in the last harvest of the second year. On the other hand, manganese level of pasture was only significantly affectd by limed treatment in the first year, and an interaction limed*dose was found in the second year, when liming was applied, no fertilised treatment had hihger manganese concentration, but when liming was not applied this treatment had the lower Mn concentration.

	Treatments				
	NF	L	M	H	Min
2 year 1 cut Zn	16.04	13.72	14.70	16.52	20.97
2 year 2 cut Zn	13.72	12.87	15.97	16.82	14.73
2 year 3 cut Zn	15.82b	20.98b	51.75b	24.60b	17.8b
2 year unlimed Mn	51.47c	72.71ab	75.93ab	85.53a	60.60bc
2 year limed Mn	35.73b	50.86b	46.50b	-	84.67^a
	Limed	Unlimed		Limed	Unlimed
2 year Zn	17.22a	21.18b	1 year Mn	62.60a	80.56b

Table 1.Significant effects on Zn and Mn pasture concentrations ($g\ kg^{-1}$) in NF, low (L), Medium (M), High (H) and Mineral (Min) treatments (means from limed and no limed tretaments), and in those plots limed and no limed, in the first and second year experiment.

Sewage sludge increased pasture production as well as mineral treatment in the first year, but fertilisation with inorganic fertilisers in very acid soils reduced soil pH and it causes no pasture production answer in the second year to mineral treatment. Sewage sludge increased zinc pasture concentration in the autumn cut of the second year, as well as Mn concentration when liming was not applied. Liming improved soil pH in the second year, but no effect on pasture production was found. Liming reduced the Zn and Mn concentration in pasture

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VARIABILITY OF SEWAGE SLUDGE PARAMETERS. IMPLICATIONS ON FERTILISATION USES

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Introduction

Sludge is a residue originated from the process of treatment of waste water. It is a secondary product rich in nutrients such as nitrogen and phosphorus, and contains valuable organic matter, that is useful when soils are depleted or subject to erosion. The organic matter and nutrients are the two main elements that make useful this kind of waste on agricultural land as fertiliser. However, the main problem concerning to use this residue as fertiliser is the higher content of heavy metals than in soils. For this reason the European Union (EU) has elaborated a directive trying to protect the environment when sewage sludge is used in agriculture, in order to prevent harmful effects on soil, vegetation, animals and man (Directive 86/278/EEC). Nowadays, there is a draft or a working document on sludge, trying to reduce even more damages on environment (EU, 2000). This draft proposes to include aspects related to pathogenic and organic component control in the sludge that is going to be used in agriculture. On the other hand, it reduces considerably the limits of main heavy metals that are required for using this residue as fertiliser, at the same time that proposes to increase the number o analyses per year, in order to control the variability between samplings and prevent environment damages. Two are the main characteristics in order to evaluate the agronomic aptitude of a residue as fertiliser: its macronutrient and heavy metal content.

Methods

The experiment consisted of sampling the anaerobic urban waste water treatment plant from Lugo (around 100000 inhabitants) gestioned by GESTAGUA S.A.; 53 samples of sewage sludge were taken from 1996 until 2001 (2 samples in 1996, 1997, 1998 and 1999; and 15 and 30 samples in 2000 and 2001, respectively). Samples were taken from fresh filtrates and transported to laboratory, in order to make analyses. Dry matter (DM, 48 h x60ºC), Organic matter (OM, Guitián and Carballas, 1976), pH (soil:water, 1:2,5), Nitrogen (N, Castro, 1990) and Phosphorus (P, Castro, 1990) were determined. Ca, K, Na, Mg, Mn, Fe, Cd, Ni, Cr, Zn, Pb and Cu were also measured by employment of Absorption Atomic spectrophotometer, after nitric digestion on microwaves. The objective of this experiment was to evaluate the quality and the variability of the main chemical parameters of the sludge from the same plant in order to describe its aptitude and predictability as fertiliser.

Results

Chemical characterization of sewage sludge of the overall period can be seen on table 1. OM, DM and pH indicated that it is a solid sludge with an important OM content and a pH that can be very suitable for rising the pH of acid soils of Galicia. Major plant nutrient contents show that Nitrogen was in higher proportion on the sludge, followed by phosphorus, calcium, iron, magnesium and potassium. This indicates that, if the sludge had heavy metal concentration under limit values given by legislation, doses should be calculated based on nitrogen content of sludge and needs of the crop. If we want to reach a low dose meaning a total nitrogen input of 160 kg/ha (taking in account a mineralization rate around 25%), dry sludge mean application should be 6,2 t ha^{-1}; but if nitrogen content was (taking in account standard deviation) 1.74 or 3.44 per cent, then doses would be 4,6 and 9,2 t ha^{-1}, respectively, for applying the same nitrogen target dose. This fact means that nitrogen proportion variation in urban sewage sludge plant is high enough, and it is important to make nitrogen analyses frequently, due to the implications of this element on environment. This will acquire more importance if nitrate mean content of sewage sludge is taking in account (1,33±0,66). Phosphorus, calcium, potassium and magnesium have also and important variability between samples, but the concentrations in the sludge are lower than nitrogen percentages. It is specially important to point out the lower content of potassium of sludges.

Table 1. Mean and standard deviation of pH and percentages of dry matter (DM), Organic matter (OM), total nitrogen (N), phosphorus (P), Calcium (Ca), Potassium (K), Magnesium (Mg), iron (Fe) and mg kg^{-1} of Manganese (Mn), Chromium (Cr), Copper (Cu), Zinc (Zn), Cadmium (Cd), Nickel (Ni) and lead (Pb).

DM	OM	pH	N	P	Ca	K	Mg
22.23±3.9	28.9±11.1	6.84±0.2	2.59±0.85	1.52±0.83	1.56±2.0	0.21±0.1	0.50±.0,1
Fe	Mn	Cr	Cu	Zn	Cd	Pb	Ni
1,32±0,6	187,3±89,6	73,9±36.7	177.3±79.5	1127.4±595.0	3.2±4.2	293.4±183	22.9±11.6

Minor element contents in different samples of the sludge were quite similar for Fe, Mn and Zn in comparison with those values described by Smith (1996) for UK. The rest of the heavy metals were under those described for this author. Copper, Zinc and lead were the heavy metals with highest values, and this affect to some grass species when this residue is applied as fertiliser (Mosquera et al., 2001). All mean values were under limits described by Spanish normative (RD 1310/1990), and with the exception of the lead, under the limits proposed by EU for 2025 (EU, 2000). Variation is also important in most of the cases, and must be solved through the control of the water, that should reach the plant more clean, and for more frequent analyses, in order to reduce the possible impact of this elements.

The sewage sludge evaluated is very adequate for using in agriculture, but calculation of doses should be based on more frequent analyses of the parameters of the sludge, in order to reduce environment impact.

Acknowledgments

We wish to thank to Mercedes Pino and GESTAGUA S.A., for helping in sampling supply, and to Mª Teresa López Piñeiro and Alberto Lamas-Díaz, for laboratory analyses.

References

Castro, P., González, A., Prada, D. (1990). Determinación simultánea de nitrógeno y fósforo en muestras de pradera. XXX Reunión Científica de la Sociedad Española para el estudio de los Pastos:200-207.

Guitián, F., Carballas, R., (1976). Técnicas de análisis de suelos. Editorial Pico Sacro. Santiago de Compostela.

Mosquera-Losada, M.R., López-Díaz, M.L., Rigueiro-Rodríguez, A., (2001). Sewage sludge fertilisation of a silvopastoral system with pines in northwestern Spain. Agroforestry Systems, 53:(1), 1-10.

Smith, S.R. (1996). Agricultural recycling of sewage sludge and the environment. Smith S.R. (eds). CAB International, WRC Marlow Buckinghamshire, United Kingdom.

EFFECTS OF DIFFERENT ORGANIC FERTILISERS IN SOUTHERN ITALY: PRELIMINARY DATA ON SOIL MICROFLORA

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Introduction

Nitrogen fertilization of crops using inorganic minerals such as ammonium nitrate has been practiced for many years to enable the achievement of maximum crop yields. However, indiscriminate use of inorganic minerals can lead to substantial losses of nitrogen through leaching into waterways (Addiscott et al. 1991) Alternative agricultural practices, including crop rotations, increased use of green and cattle manures, reduced chemical input, contribute to high soil organic matter levels and improve soil quality (Parr et al., 1992). In addition, these practices might well have an impact on microbial composition, which complexity will result in greater yield stability (Cook and Baker, 1983).

In the present study we investigate changes in the populations of aerobic N_2-fixing bacteria, total soil bacteria, fungi and actinomycetes isolated from bulk soil as affected by different organic fertilizers, such as green (mono and polyphyte) manure *vs* animal manure.

Methods

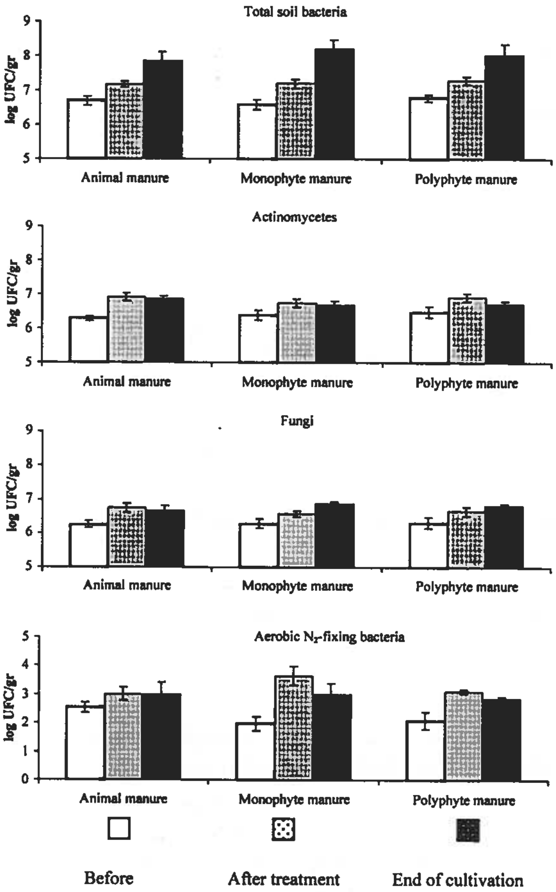
Trials were carried out during 2001 in Southern Italy near the organic farm “Colombaia”. Soil was clay-sandy, neutral (pH=7.0) with low content of organic matter (1.5%) and nitrogen (1.0 ‰). In a 2-year horticultural rotation in greenhouse (tomato-lettuce-watermelon-lettuce) three organic fertilizers were compared: cattle manure (CM), monophyte (*Vigna sinensis* L.) green manure (MGM), and polyphyte (34 species) green manure (PGM). Manuring was made during the 1st year of rotation. Green manure crops were sown on July 11 and were buried on September 22 contemporarily to the burial of 300 kg of cattle manure. Lettuce was transplanted on October 13 and harvested on February 5. The three manuring treatments were distributed in 3 randomised blocks. Soil samples were collected in the 0-0.2 m layer at three different times: before sowing of green manure crops, 1 week after the burial of organic matters and at harvest of lettuce.

Determination of microbial populations. Microbial populations were counted by the dilution plate technique using Casein peptone-yeast extract-dextrose agar (Oxoid, Milano) for total soil bacteria and modified Starch-casein-nitrate agar and Malt extract agar pH 5.5, for total actinomycetes and fungi, respectively (Lorch et al., 1995). The inoculated agar plates (three replicates) were incubated at 28°C for 5 d for bacteria and 5 d for fungi and actimomycetes before the colonies were counted. Populations of aerobic N_2-fixing bacteria were estimated by a standard dilution series in sterile distilled water, followed by plating on Burk’s N-free medium as described by Martinez-Toledo et al. (1988). Inoculated petri dishes (three replicates) were incubated at 28°C for 5 d.

Results

The amounts of buried dry matter were 15006 kg ha^{-1} from CM, 9397 kg ha^{-1} from MGM and 20697 kg ha^{-1} from PGM. The latter at burial time consisted of 95% of *Setaria* spp. and *Panicum* spp.

As shown in Fig. 1, the plate count data referred to total soil bacteria (panel A), actinomycetes (panel B) and fungi (panel C) indicated that only total soil bacteria in agricultural soil treated with three different organic substances were significantly stimulated. We did not find differences statistically significant among MGM and PGM *vs* CM. However, an interesting result emerged from analysis of the populations of aerobic N_2-fixing bacteria (Fig. 1, panel D) which were significantly stimulated by the two *green* manure. In addition, the manure with *Vigna sinensis* alone determined an increase of the populations of aerobic N_2-fixing bacteria of 21% and 17% respect to animal and polyphyte manure, respectively.



Conclusion

It is well known that soil microorganisms, particularly bacterial communities, exert strong positive effects on plant growth and health by nutrient solubilization, N_2-fixation, or the production of plant hormones (Hoflich et al., 1994). Therefore, our preliminary data suggest that the application of organic fertilizers, particularly the manure with *Vigna sinensis,* could contribute to improve soil quality increasing the populations of so-called "Plant Growth Promoting Rhizobacteria" as aerobic N_2-fixing bacteria. Further studies are in progress to confirm our results. Particularly, the effect of these practices on soil microbial communities and, therefore, on the soil quality, will be investigate by analysis of their 16S ribosomal DNA, by using DNA directly extracted from soil samples as template in PCR experiments.

References

Addiscott, T.M., Whitmore, A.P. and Powlson, D.S. (1991) CAB international, Wallingford, UK pp. 31-44.
Cook, R.J. and Baker, K.F. (1983). American Phytopathological Society, St. Paul, MN.
Hoflich, G., Wiehe, W. and Kuhn, G. (1994) Experimtia 50: 897-905.
Lorch, H-J., Benckieser, G. and Ottow, J.C.G. (1995). In Alef, K. and Nannipieri, P. (Eds.) "Methods in applied soil microbiology and biochemistry" Academic Press, San Diego, pp. 146-161.
Martinez-Toledo, M.V., Gonzalez-Lopez, J., de la Rubia, T., Moreno, J. and Ramos-Cormenzana, A.(1988) Biol. Fertil. Soils 6; 170-173.
Parr, J., Papendick, R., Hornick, S. and Meyer, R. (1992). Am. J: Altern. Agric., 7: 5-11.

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ANATOMICAL ASSESSMENT OF THE WHOLE ROOT SYSTEM WHEN INNOCULATED WITH ARBUSCULAR MYCORRHIZAE

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Introduction

In many herbaceous and woody species, mycorrhization improves plant growth by improving root system growth and activity, mainly through larger root mass and greater branching due to increased lateral root frequency (Berta *et al.*,1995; Citernesi *et al.*, 1998). Little is known, however about how mycorrhization affects the anatomical differentiation of the root system, information which could provide valuable insights as to the modes of interaction involved in this symbiotic system. Sampling root tissues for developmental studies is difficult due to its morphogenetic behaviour, in which lateral organs are not produced with regular spatial or temporal patterns, as well as its hidden, underground location for growth. The most common sampling methods use distance increments along the root axis (Horsley and Wilson, 1971; Ciamporova, 1981; Fernández *et al.*, 1994) or central samples midway between the root apex and the first lateral root junction (Nobel and Huang, 1992). Other authors have examined root anatomy on the basis of external appearance or morphology (Richards and Considine, 1981) or have defined developmental indices which permit the comparison among treatments of root zones with similar development (Danilova, 1981; Kevekordis *et al.*, 1988; Fernéndez *et al.*, 1994). The current study uses a procedure to characterise whole root-system development by simultaneously processing and sampling the root mass. This procedure was used to examine the morphogenetic response of olive rooted cuttings to inoculation with arbuscular mycorrhizae.

Method

Three-month-old olive (*Olea eurpaea* L. cv. Picual) plants from rooted cuttings were treated with arbuscular mycorrhizal inoculum *Glomus intraradices* and transplanted to 1 L pots with sterile soil mix; control plants underwent similar washing and transplanting procedure but without inoculum. At 11 months after inoculation the roots were washed, weighed and conserved in fixative.

Microscope preparations were made for groups of roots by a unique procedure that yielded transverse sections representative of the complete root system, thus permitting quantification of developmental characteristics of that system. After removal of all roots thicker than 2.5 cm diameter, the entire root system was grouped in bunches and tied with sewing thread. One to four root bunches were obtained per plant, depending on the size of the root system. Large paraffin blocks containing the root bunches were obtained with standard infiltration procedures (Jensen, 1962) adapted to the bulky samples by extended time and the use of vacuum. Each large block was then subdivided to obtain 3 units from which 12 µm transverse sections of groups of roots were prepared and stained with tannic acid, iron chloride, safranin and fast green (modified from Jensen, 1962)(Fig. 1).

Ten roots in each transverse section field were chosen at random using a numbered grid. The roots were classified in three developmental stages, primary development, transitional between primary and secondary development, and secondary development, on the basis of xylem and phloem differentiation, initiation and development of the vascular cambium, degree of lignification of the medulla, and the presence of cortex and pericycle or peridermis. Tissue areas were measured using image analysis.

Results and Conclusions

Mycorrhization stimulated the formation of root systems with greater biomass and branching, similar to previously obtained results (Berta *et al.*; 1995; Citernesi *et al.*, 1998), which were composed of significantly greater numbers and proportions of young roots than uninoculated root systems. The transverse areas of roots at all three stages of development were lower in the mycorrhizal treatment, and the percentage of small-area roots was greater, possibly due to a shift in the priority for assimilate use toward lateral root production. Mycorrizal fungi were observed in approximately half of the roots of the inoculated treatment; the arbuscular structures were located principally in the root cortex, close to the vascular cylinder (Fig. 2). No differences were observed between treatments in proportions of different tissues, number of root hairs nor numbers of protoxylem poles. The innovative processing methodology proved quite useful in allowing the quantitative assessment of anatomical development of the whole root system.

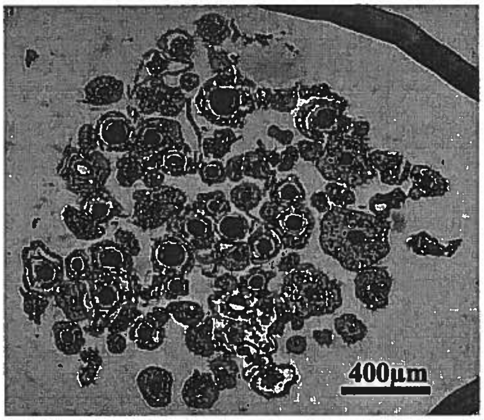

Fig.1. Transverse section of root group

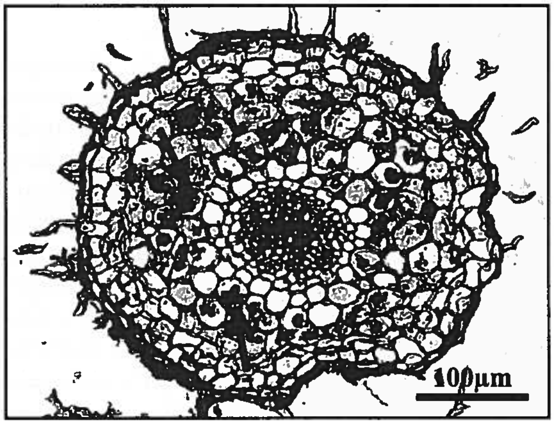

Fig.2. Primary root with mycorrhizae (arrows)

References

Berta, G. *et al.* 1995. Arbuscular mycorrhizae induced changes to plant growth and root system morphology in *Prunus cerasifera* L. Tree Physiology 15: 281-293.

Ciamporova. 1981. Ultrastructure of maize root cells under water stress. p. 319-322. *In* R. Brouwer *et al.*, (ed.) Structure and Function of Plant Roots. Martinus Nijhoff/ Dr.W. Junk, The Hague.

Citernesi, A. *et al.* 1998. Plant growth and root system morphology of Olea europaea L. rooted cuttings as influenced by arbuscular mycorrhizas. Journal of Horticultural Science and Biotechnology 73: 647-654.

Danilova, M. F. 1981. Correlative morphogenesis of endodermis and xylem elements in the developing barley root. p. 77-83. *In* R. Brouwer *et al.*, (ed.) Structure and Function of Plant Roots. Martinus Nijhoff/ Dr.W. Junk, The Hague.

Fernández, J. E. *et al.* 1994. Anatomical response of olive roots to dry and irrigated soils. Advances in Horticultural Science 8: 141-144.

Horsley, S. B., and Wilson, B. F. 1971. Development of the woody portion of the root system of *Betula papyrifera*. American Journal of Botany 58: 141-147.

Jensen, W. A. 1962. Botanical Histochemistry. W.H. Freeman and Co., San Francisco.

Kevekordes, K. G. *et al.* 1988. Late maturation of large metaxylem vessels in soybean roots: significance for water and nutrient supply to the shoot. Annals of Botany 62: 105-117.

CHARACTERISATION OF DAIRY AND MUNICIPAL SEWAGE SLUDGE AS FERTILISERS

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Introduction

Nowadays and in the near future, important problems of European Union (EU) will arise from the increase in sewage sludge production as a result of EU directives (Council Directive 91/271/EEC), which specify the need to find adequate disposal of urban sludge). Sewage sludge can act as fertiliser and is used on pasture in some EU countries. An increase in the use of sewage sludge will be essential as EU guidelines prohibit the dumping of sludge at sea and incineration and dumping in landfill sites of that residue are environmentally unacceptable and expensive (Bontoux *et al.*, 1998). Applying sludge to agricultural land has the advantage of increasing soil fertility and removing nutrients that would otherwise contribute to leaching, eutrophization and pollution of water.

The main problem of this product is the high content of heavy metals, which is controlled by EU (86/278/CEE) and national directives. Total content of heavy metals in the sludge will be determined by total inputs of this element in the water previous treatment in the plant in a specific area. The objective of this experiment was to characterise as fertiliser different sewage sludges biologically stabilised from different Galician plants.

Methods

The experiment consisted of sampling five milk dairy sewage sludges and twelve urban sewage sludges from cities of Galicia with more than 10000 inhabitants, which estabilised sewage sludge through digestion. Samples were collected from each plant and transported to the laboratory, where were dried (60 °C x 48 h) and mowed. Dry matter (DM), organic matter (OM), pH (1:2,5) in water, total nitrogen and phosphorus were determined (Castro *et al.*, 1990). Potentially toxic main elements were also measured by employment of Absorption Atomic spectrophotometer (Cd, Ni, Cr, Zn, Pb, Cu y Hg) after nitric digestion on microwaves.

Results

DM percentages and pH were very similar for both kind of sludges (Table 1). DM was around twenty percent, as the sludges were not liquid, that is an important characteristic for the sludges because it reduces considerably transport costs. pH value was around 6.7, which can be very beneficial for Galician acid soils. Organic matter concentration is also high, so this residue will improve the organic matter content of soils, because OM in arable soil is ranged from 3 to 4 percent, increasing cation interchange capacity and improving biological and physical properties of soil.

Table 1. Mean and standard deviation of pH and percentages of dry matter (DM), Organic matter (OM), total nitrogen (N) and phosphorus in the urban and dairy sludge

Plant type	%DM	%OM	pH	N	P
Urban	20.62±7.3	38.33±20.5	6.64±0.72	3.49±1.8	1.80±1.68
Dairy	23.00±10.8	19.79±04.5	6.89±0.30	2.21±3.1	0.31±0.36

Nitrogen and phosphorus concentration (table 1) of urban sewage sludge is one point higher than dairy sludge, however variability between plants is quite important. Phosphorus percentage is very low in dairy in comparison with urban and lower than that described by Smith (1996) in

United Kingdom. Variability between plants in nitrogen and its high proportion in the sludge makes quite difficult to give a general dose recommendations for agronomic use of this residue, which should be analysed in each case.

All the heavy metal means were under limit indicated by spanish law (RD 1310/1990). All heavy metal concentrations were lower in dairy sludge than in the municipal sewage sludge, which indicates the importance of the original material for determining sludge quality. However, the most important result is the high variability found in most of the cases. Heavy metal levels of United Kingdom were always over Galician values. This could be explained because the spanish region studied has not important metallurgic industries, coming most of the economic resources from grassland and forest outputs, and for the type of population distribution in the region (lots of cities with low number of inhabitants). If we take in account the limit values for concentrations of heavy metals in sludge for use on land at long term (about 2025), the sewage sludges studied here are under the levels considered in this proposed normative in all of cases.

Table 2. Cu, Zn, Cr, Ni, Pb, Cd and Hg mean concentrations (mg kg^{-1}) in sewage sludges of the municipal and dairy plants sampled in the experiment, and mean of these elements in UK (Smith, 1996), and limit values indicated by spanish law (RD 1310/90). FValue: It is the provisional future values given for heavy metal concentrations of sludge by the working document on sludge (DG Environment) for long term (about 2025).

	Cu	Zn	Cr	Ni	Pb	Cd	Hg
Urban	319.1±268.6	506.4±317.9	42.6±38.7	26.7±23.1	90.2±78.9	0.56±0.4	1.8±3.14
Dairy	16.46±16.74	62.47±65.76	33.1±37.9	4.26±7.11	7.66±7.39	0.34±0.5	0.11±0.21
UK	473	889	86	37	217	3.2	3.2
Law	1000	2500	1000	300	750	20	16
FValue	600	1500	600	100	200	2	2

Parameters like pH, OM and N concentration of Galician sludges made them adequate for using as fertilisers, but phosphorus should be complemented, as it is in low proportion in the sludges. Dairy sewage sludge has lower heavy metal contents than urban sewage sludge, which make it more sustainable for using as fertiliser, but all the studied urban sewage sludge plants (except one) have values under levels considered in the normative proposed for UE for 2025.

Acknowledgements
We wish to thank to Severiano Ónega, from AGROAMB-PRODALT, for helping in sampling supply; and to Mª Teresa López Piñeiro and Alberto Lamas-Díaz for laboratory analyses.

References

Bontoux, L.; Vega, M.; Papameletiou, D. 1998: Tratamiento de las aguas residuales urbanas en Europa: el problema de los lodos. Instituto de prospectiva tecnológica (eds) IPTS, abril, report nº 23. Comisión Europea. Bruselas.

Castro, P, González, A., Prada, D. (1990). Determinación simultánea de nitrógeno y fósforo en muestras de pradera. XXX Reunión Científica de la Sociedad Española para el estudio de los pastos:200-207.

Smith, S.R., 1996. Agricultural recycling of sewage sludge and the environment. Smith S.R. (eds). CAB International, WRC Marlow Buckinghamshire, United Kingdom.

RESIDUAL RESPONSE OF MUNICIPAL SEWAGE SLUDGE ON ACID SOILS

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Introduction

Plants developed in acid soils are more susceptible to suffer from damage caused by sewage sludge inputs, due to the higher bioavailability of the most heavy metals in this kind of soils. This can have an effect or not on the swards growing up in acid soils fertilised with sewage sludge (Mosquera-Losada, 2001). The main advantage of using this residue in soils is that the recycling of main nutrients is produced and it is solved the main problem related to elimination of this residue.

Soil pH in acid soils is increased after several years application and this causes a reduction in the bioavailability of heavy metals, but when the application of sludge is stopped, then the abundant rainfall of the area, as well as the extractions made by harvesting and mineralisation of residues in soils will continue and reduce the pH of the soil at a long term. This residual effect should be analysed in order to see how pH is reduced and how affects to production, chemical properties and heavy metal cycling at soil. The objective of this experiment was to evaluate the effect of inorganic fertilisation on sard previously fertilised during three years with three different sewage sludge doses.

Methods

The experiment was located in Pol (lugo, NW Spain). Sward was sowing in the autumn of 1997 with a mixture A mixture of 25 kg *Lolium perenne* cv Brigantia ha^{-1}, 10 kg *Dactylis glomerata* cv Artabro ha^{-1}, and 4 kg *Trifolium repens* cv Huia ha^{-1} was sown in the autumn of 1997 in 27 plots of 96 m^2 under *Pinus radiata* D. Don plantation (7 years old and at a density of 1666 trees ha^{-1}). Soil pH (water 2.5:1) was very acidic (pH=4.5) and the percentage of saturated aluminium very high (92.2%). Three sewage sludge doses were applied at the start of 1998, 1999 and 2000 meaning 160, 320 and 480 kg total N ha^{-1}. Half of the plots were initially liming with 2,5 t ha^{-1}. Initially treatments consisted of liming and no fertilisation (NF), no liming and mineral fertilisation (Min), doses low (LL), medium (ML) and high (HL) with liming and the same low (L), medium (M) and high (H) doses without liming. In the fourth year, and with the object of increase the reduction of the pH all plots were fertilised with 250 kg ha^{-1} of 8:24:16 with the exception of two square meters in each plot. Sampling was made by took four square samples per treatment of 30 x 30 cm in the two harvest made at the end of the spring and autumn. Soil samples were took at a depth of 15 cm.

Results

Soil pH and organic matter did not show a significant interaction of doses and liming. Residual effect on soil pH was maintained, and Min treatment, as well as no limed treatments, had a significant lower pH than sludge fertilised and limed treatments, respectively (Figure 1). The comparison between plots fertilised or not with nitrogen in 2001 showed that the fertilisation reduced OM of soil, which indicates that this fertilisation accelerated the rate of descomposition of soil organic matter, because the proportion of C/N is reduced.

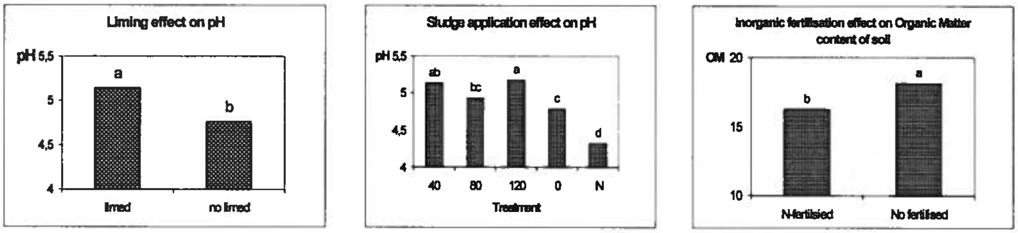

Figure 1. Liming, sludge application and nitrogen fertilisation effect on pH and OM.

Pasture production response to treatments can be seen on Table 1. There was a single significant effect of sewage sludge application and a significant interaction limingxnitrogen feritlisation. There was a clear residual sludge effect after one no sludge application year, as production for low and medium dose was double than for min and NF treatment, that could be explained by the pH increment when sludge was applied and for the release of nutrients applied in the previous years. Pasture production was increased in those plots limed previously, as pH was higher and when nitrogen fertilization was applied in the last year as nutrient release was accelerated (the organic matter content of this treatment was reduced) in comparison with no nitrogen fertilization treatment. The same tendency was found when no liming was applied, but differences did not result significant, it can indicate that the effect of mineral nitrogen fertilisation is limited when no liming is applied as the pH of that plots is lower.

	Treatments				
	NF	L	M	H	Min
Pasture prod	608.1c	1055.5a	1213.0a	862.9ab	498.2c
	Limed			No limed	
	Treated	Untreated		Treated	Untreated
Pasture prod	962.0a	442.5b		1181.5	913.2

Table 1. Pasture production (t ha^{-1}) in NF, low(l), Medium(M), High (H) and Mineral (Min) treatments (means from limed and no limed tretaments) and in those plots fertilised and no fertilised inorganically in the fourth year experiment for those plots limed and no limed.

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References

Mosquera-Losada, M.R., López-Díaz, M.L., Rigueiro-Rodríguez, A. (2001). Sewage sludge fertilisation of a silvopastoral system with pines in northwestern Spain. Agroforestry Systems, 53 (1), 1-10.

EFFECTS OF THE ADDITION OF A DAIRY SEWAGE SLUDGE ON SOIL PARAMETERS IN AN AGROFORESTRY SYSTEM

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Introduction

The use of sewage sludge in agriculture is promoted by the EU, as a suitable method of disposing of this waste residue. However, the characteristics of the sewage sludge are rather variable and depend on different factors such as their origin (urban, industries...), type of digestion (anaerobic, aerobic) or the method of processing (digestion, liming, composting...). Liming of sewage sludge until the pH reaches a value of 12 adds considerably to the value of the residue, because it can then be applied to acid soils, to lower the pH of the soil while at the same time acting as a fertilizer.

Methods

The experiment was begun in October, 1998 in Ames (A Coruña, NW Spain). The experimental plot was established in a plantation (under 7 years old) of *Pinus radiata* D. Don, at a density of 2600 trees per hectare. A randomised block design was used, with three replicates of each treatment, applied after clearing the above ground biomass from the experimental area. There were six treatments in total, consisting of different combinations of ploughed (P) and unploughed (UP) soil and sewage sludge doses of: 0 t ha^{-1} (NF), 10,83 t ha^{-1} (LF) and 21,56 t ha^{-1} (HF) (corresponding to 200 and 400 kg N ha^{-1} for the low (L) and high (H) doses, respectively).The treatments were as follows: unploughed, no fertilizer (UPNF), ploughed, no fertilizer (PNF), unploughed and low dose of fertilizer (UPLF), ploughed and low dose of fertilizer (PLF), unploughed and high dose of fertilizer (UNHF), and ploughed and high dose of fertilizer (PHF). At the time of application, the pH of the dairy sewage sludge was 12 and the heavy metal concentrations were below the limits outlined in European regulations (D. 86/278/CEE, D.O.C.E. June, 1986). Soil sampling (at 25 cm) was carried out at regular intervals over two years. The soil was air dried and pH_{H2O} measured (using a soil:solution ratio of 1:2.5). Cation bioavailability was determined in extracts obtained using Mehlich 3 reagent and concentrations of calcium, magnesium, zinc and manganese were measured using an ICP-OES equipment.

Results

Application of dairy sewage sludge, increased the pH of the soil in proportion to the dose applied. In addition, the levels of macronutrients, such as available Ca, Mg, K and P were augmented and levels of Al reduced. Application of the sludge also increased microbial activity and led to an increase in levels of mineral N. However, levels of Zn, Cd, Co and Cu in the soil also increased slightly.

The increase in soil nutrients led to improved pasture production, particularly at the first harvest following sludge application. Regarding plant diversity, sludge application led to an increase in the presence of *Agrostis sp.* at the first harvest, whereas *Dactylis glomerata* dominated at the second harvest .

There was an increase in tree growth in the second year after sludge application, with differences of up to 2 cm in diameter and 0.5m in height.

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References

Omil B., Mosquera M.R., Rigueiro A. And Merino A. (2000). Chemical and biological properties of agroforestry soil treated with dairy-plant waste.International Symposium. Managing Forest Soils for Sustainable Productivity, 231.

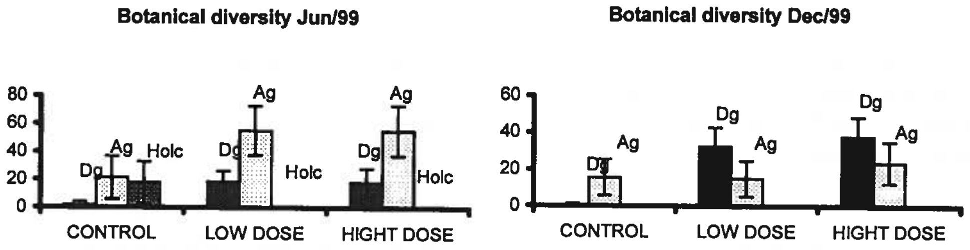

Figure 1 Botanical diversity of June and December

INFLUENCES OF SOIL WATER LEVEL ON THE RESPONSES OF YOUNG PLANTS TO NUTRIENT IMBALANCES

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Introduction

Crop responses to nutrient imbalances and soil water stresses may vary with several factors such as plant species, varieties and growth stages.

As soil water is an important factor in K diffusion in the soil, its availability is considerably controlled by water content. It is also important that maintaining a sufficient soil potassium level is required to avoid the unfavourable effects of soil water stress. Several experimental data have reporting the greater efficiency of potassium with increasing water content (Mengel and von Braunschweig 1972, Sárdi and Fülöp 1994 etc.) as soil water content affects the availability of K in soils (Kuchenbuch et al. 1986). On the other side, interactions of nutrient imbalances and extreme soil water levels are poorly documented.

Methods

Pot experiments were carried out under greenhouse conditions at temperatures between 16 and 28 °C to study the influences of soil water content on the responses of young plants to nutrient imbalances or stresses. Corn *(Zea mays L.)*, DK 471 hybrid was used as test plant. Four plants were grown for 4 weeks in a brown forest soil (Eutric cambisol) in pots containig 1 kg of soil. Soil water was kept at 35 and 70 % of WHC by daily watering. Increasing rates of potassium resulting in deficit and excess K were applied in the following treatments in 4 replicates: $N_0P_0K_0$, $N_1P_1K_1$, $N_0P_0K_3$, $N_1P_1K_6$, $N_3P_3K_0$ and $N_6P_6K_1$ where $N_1 = 120$ mg N, $P_1 = 80$ mg P_2O_5 and $K_1 = 100$ mg K_2O per kg soil.

DM production of plant shoots and roots, and NPK quantities taken up by young plants were determined after the harvest. Nutrient ratios were calculated and compared to optimum ranges (Sardi and Csitari 1997), and shoot and root nutient contents were correlated. Results of the analyses were evaluated by analysis of variance using the „STATGRAPHICS FOR WINDOWS" program package.

Results

Under different soil water conditions, significant differences were obtained in most plant parameters compared to the control (Table 1). Shoot:root ratios also showed considerable changes depending on the extent of K imbalances and soil type (values ranged between 68 and 170, expressed in percentages of the balanced NPK supply). There was a dramatic decrease in DM production of young plants under the constant soil water deficit, average DM was 51.2 percent compared to that of control plants obtained at optimum water content (Figure 1).

Beneficial influences of K nutrition on water use efficiency and DM production could be observed under soil water stress conditions. This finding was in good agreement with results of other experiments (Höfner 1971).

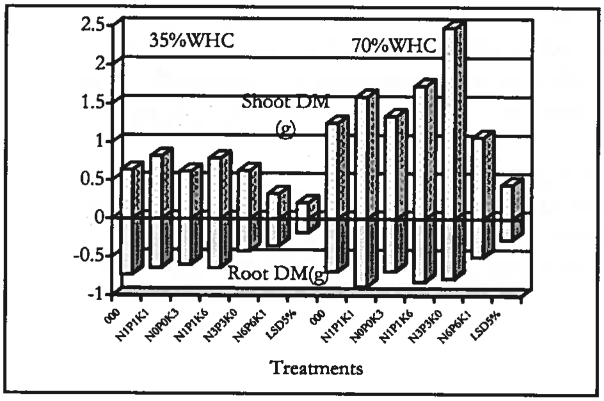
Responses of plants were highly significant also in the amounts of K taken up by plants, with the differences depending on K rates and soil water content.

Both potassium excess and deficiencies resulted in significant changes in nutrient ratios of plants e.g. N/P rates were significantly below the optimum (10.-11.7) when K was deficient (see Table 1).

Table 1 Responses of young corn plants to K imbalances at different soil water

Treat Ments	Plant height Cm	Shoot: Root Ratio	N%	P%	K%	N/P	N/K	K/P	N taken up mg	P taken up mg	K taken up mg
35%WHC											
000	25.33	0.88	3.05	0.273	3.41	11.17	0.894	12.50	19.52	1.75	21.84
111	28.00	1.29	3.12	0.294	5.00	10.61	0.624	14.02	25.58	2.41	41.03
003	28.33	1.03	2.87	0.257	5.92	11.17	0.485	23.04	17.79	1.59	36.71
116	23.67	1.24	3.33	0.296	6.16	11.25	0.54	20.82	26.31	2.34	48.69
330	21.83	1.49	4.35	0.481	4.11	9.04	1.06	8.54	27.26	3.01	25.73
661	18.17	0.93	4.77	0.579	5.32	8.24	0.90	9.18	15.74	1.91	17.54
$LSD_{5\%}$	1.09	0.25	0.52	0.063	0.43	1.71	0.069	2.15	7.61	0.738	11.93
70%WHC											
000	30.83	1.83	2.19	0.259	3.58	8.46	0.612	13.82	27.45	3.25	44.87
111	36.50	1.82	3.21	0.297	4.69	10.81	0.683	15.82	51.15	4.73	74.84
003	37.17	1.96	2.47	0.234	6.21	10.56	0.397	26.56	33.10	3.14	83.27
116	31.33	2.11	3.02	0.294	5.91	10.27	0.511	20.10	52.35	5.09	102.4
330	30.00	3.16	3.54	0.486	3.65	7.28	0.970	7.51	87.67	12.04	90.35
661	28.17	2.13	3.98	0.467	5.31	8.52	0.749	11.37	42.45	4.98	56.65
$LSD_{5\%}$	0.67	0.72	0.29	0.106	0.42	2.87	0.075	4.50	11.80	2.13	21.28

Figure 1 Shoot and root DM production of young corn plants at different soil water content.



Conclusions

In order to avoid or minimize the unfavourable effects of stresses resulting from extreme soil water content levels, sufficient or good soil K levels are required at least during the rapid nutrient uptake period of young crop plants. Possible differences in variety responses also provide important information on these questions.

References

Höfner, W. 1971. Influence of potassium on water economy. In: Potassium in biochemistry and physiology. Proc. Colloq. Int. Potash Inst. 8. pp. 125-129.

Mengel, K.and Braunschweig, von L.C. 1972. The effect of soil water upon the availability of potassium and its influence on the growth of young maize plants (Zea mays L.) Soil Sci. Vol. 114, pp. 142-148.

Kuchenbuch, R., Claassen, N. and Jungk, A. 1986. Potassium availability in relation to soil moisture. Plant and Soil Vol. 95, pp. 221-231.

Sardi, K. and Fülöp P. 1994. Relationship Between soil Potassium Level and Potassium Uptake of Corn affected by Soil Moisture. Comm. Soil Sci. Plant Anal. Vol. 25, Iss. 9 and 10, pp. 1735-1745.

Sardi, K. and G. Csitari 1997. Responses of Corn and Sunflower to Nutrient Stress. 11th International World Fertilizer Congress: Fertilization for Susainable Plant Production and Soil Fertility. Proceedings Vol. I. (Eds. Van Cleemput et al.) pp. 526-534.

AVAILABILITY OF PHOSPORUS IN COMPOSTED ORGANIC GARDEN AND HOUSEHOLD WASTE

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Introduction

About 90 % of the phosphate mined is used for fertiliser production. At the present consumption rate, global known deposits of rock phosphate will only last about 400 years. To spare non-renewable resources, recycling of nutrients from organic wastes should be increased wherever environmentally compatible.

In Germany, about $4 \cdot 10^6$ t compost year^{-1} are produced from different organic wastes with a mean total P concentration between 0.4 to 0.8 % in d.m.. In the case of composts with the lower P concentration with the recommended amount of 10 t of compost dm ha^{-1} about 75 kg P_2O_5 are applied. The availability of P from composts is less known and still a matter of debate. We thus aimed at evaluating the P availability in municipal compost from organic garden and household waste.

Materials and methods

The experiment was run over a 2-yr period from 1999 to 2000 as a completely randomised factorial greenhouse experiment with four replicates. 10 different composts (composition of the raw material: garden waste : household waste = 100 : 0; 80 : 20; 50 : 50; 20 : 80) have been used in this experiment. In 1999 the basal dressing, providing all nutrients save P, was incorporated into 9 kg pot^{-1} of a 1:1 mixture of top- and subsoil of a luvisol derived from loess (pH_{CaCl2}: 6.0; 1.9 mg CAL- (Ca acetate + Ca lactate) extractable P · kg^{-1} soil). 1 g P pot^{-1} was supplied as compost. Ryegrass (*Lolium perenne,* cv Turilo) was grown and cut six times, dried, and analysed for nutrient concentration. In spring 2000, roots and stubble were incorporated into the soil together with the basal dressing (without P) before sowing ryegrass again, which was harvested another six times.

"Net P uptake" was calculated from the P concentration in the tissue and the upper dry matter yield per pot minus P uptake of a control treatment without P fertiliser application.

Statistical evaluation was done by the Tukey test. Data with the same letter in a column are not significantly different at □ = 0.05

Results

Table 1: Dry matter yield of ryegras (g pot^{-1})

Comp no.	Harvest no. (1999)						Harvest no. 2000					
	1	2	3	4	5	6	1	2	3	4	5	6
1	10.9^{ab}	10.6^{a}	14.9^{a}	13.1^{a}	14.1^{b}	10.2^{a}	12.5^{cd}	11.7^{a}	17.8^{abc}	16.4^{cd}	17.0^{bc}	14.2^{cd}
2	11.3^{b}	12.7^{bc}	14.5^{a}	11.8^{a}	12.1^{a}	11.0^{ab}	10.2^{ab}	13.9^{ab}	14.7^{a}	12.2^{ab}	15.8^{ab}	7.3^{a}
3	10.8^{ab}	14.2^{cd}	15.0^{a}	12.3^{a}	13.1^{ab}	11.8^{abc}	9.1^{a}	14.0^{ab}	15.2^{a}	11.7^{a}	15.4^{ab}	8.8^{ab}
4	13.1^{c}	20.0^{e}	16.2^{a}	12.1^{a}	12.2^{a}	12.0^{abc}	11.2^{bc}	16.0^{bc}	16.3^{ab}	13.1^{abc}	16.8^{bc}	11.5^{bcd}
5	9.5^{a}	11.3^{ab}	16.4^{a}	21.2^{b}	16.9^{c}	14.0^{c}	14.7^{e}	14.8^{bc}	22.2^{d}	18.3^{d}	19.8^{c}	14.9^{c}
6	14.9^{d}	15.5^{d}	15.7^{a}	9.26^{a}	12.5^{ab}	11.4^{ab}	12.7^{d}	16.2^{bc}	19.1^{bcd}	15.7^{bcd}	13.8^{ab}	11.9^{bcd}
7	14.0^{cd}	16.0^{d}	15.4^{a}	10.0^{a}	12.4^{ab}	11.3^{ab}	13.0^{d}	16.4^{bc}	21.0^{cd}	17.1^{d}	13.6^{ab}	10.8^{abc}
8	14.5^{cd}	20.2^{e}	15.5^{a}	9.82^{a}	13.0^{ab}	12.0^{abc}	13.2^{d}	16.2^{bc}	19.1^{bcd}	15.9^{cd}	13.0^{a}	10.7^{abc}
9	13.5^{cd}	20.2^{e}	14.9^{a}	9.54^{a}	12.0^{a}	13.3^{bc}	12.0^{cd}	17.7^{c}	19.4^{bcd}	16.9^{cd}	15.3^{ab}	13.5^{cd}
10	$14,1^{cd}$	19.9^{e}	16.1^{a}	10.7^{a}	12.3^{ab}	12.6^{bc}	12.9^{d}	16.9^{c}	$20,4^{cd}$	18.5^{d}	14.4^{ab}	12.5^{bcd}

Although the same amount of total P was applied with the different composts, dry matter yield of ryegrass of the compost treatments differed significantly in both years (Table 1).

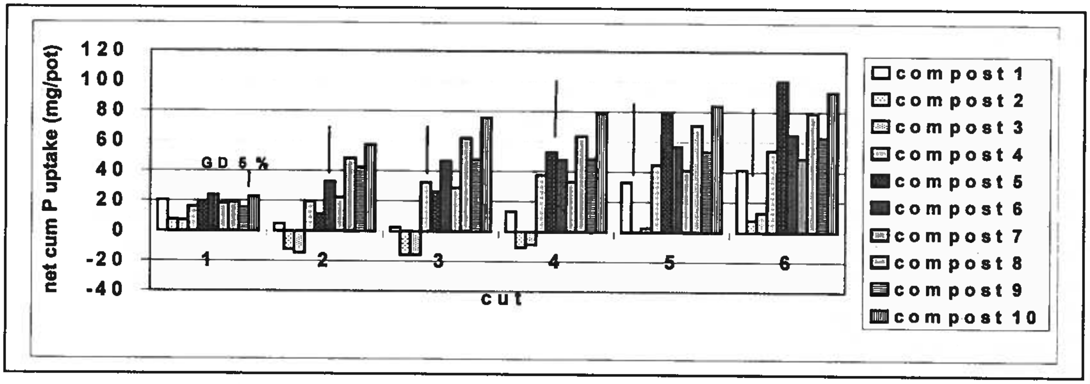

Fig. 1: Net cumulated P uptake of ryegrass (1999)

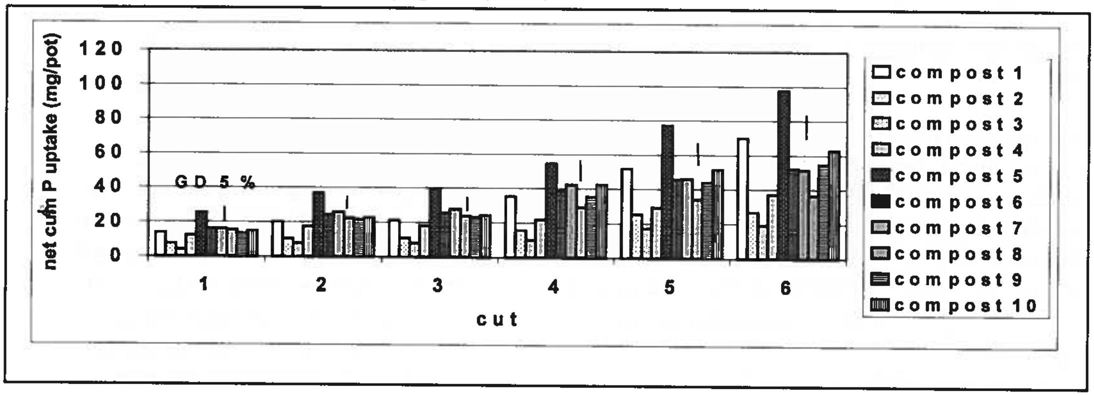

Fig. 2: Net cumulated P uptake of ryegrass (2000)

In both years the net cumulated P uptake differed significantly between treatments (Fig. 2 and Fig. 3). In 1999 in the compost treatments 2 and 3 P uptake was even lower than in the control treatment without P fertilisation.

Discussion

As shown in Table 1, ryegrass yields differed between the different compost treatments. However, the yield differences were not the result of a differential N supply, as N was applied additionally in the basal fertilisation and N dry matter concentrations did not differ significantly. Differences in yield and P uptake were consequently caused by differences in P availability of the composts. The plant available P applied with the composts ranged between 16.2 and 45.0 % of the total compost P. P efficiency on basis of the plant available P ranged between 3.7 and 45.4% in the first year. In total, between 16.2 and 89,3 % (mean value 38.0 %) of the plant available compost P were taken up by the plants as compared to 26,3 % supplied with mineral P fertiliser. However, there was no significant relationship between P uptake of ryegrass and CAL-extractable P in composts. CAL extraction is thus not suitable to predict plant availability of P from composts. Based on the total amount of P supplied with composts between 3.6 and 22.1 % P were taken up in two years of intensive cropping.

It should be emphasised that plant availability may be over-estimated in pot experiments due to different temperature conditions and a usually narrower root to soil ratio. Further studies for long-term availability under field conditions are needed.