DURUM WHEAT QUALITY AND PRODUCTIVITY IN RELATION TO CROPPING SYSTEM AND FERTILIZATION

Noto F., Caruso A., Saladino S., Ferrotti F., Mirabile C.

Dipartimento di Agronomia, Coltivazioni erbacee e Pedologia - Università di Palermo (Italy) - viale delle scienze - 90128 Palermo- Tel: +39916650236; - e-mail: POMAIGN@UNIPA.IT

Introduction

In Italy, research activity aimed to agriculture environment impact reduction, identified fertilization management as the most important tool to limit environment pollution.

During last year, strictly relationships between fertilization and grain qualitative and quantitative characteristics and environment pollution control needs, induced to improve research to evaluate, in several areas, durum wheat productive, qualitative and commercial response to fertilization (Desiderio et al.,1998, 2000). Due to the new international interest for agro-ecological agriculture seems to be very important verify technical suitability of fertilization and crop rotation in the Sicilian semi-arid environment (Noto F. et al., 1998; Poma I. et al., 2000).

This paper reports results of a one-year research aimed to evaluate previous crop and fertilization effects on qualitative and commercial production of two durum wheat varieties. In the long term, environment impact for cereal production sustainability will be evaluated.

Methods

The trial was carried out during 1997-98 in the clayey inland of Sicily (Cammarata, Agrigento – 37° 37' N, 13° 42' E) (450 m asl), on a regosoil characterized by average-low fertility (N 0.99 ‰; P 17.2 ppm; K 327 ppm).

Seed bed preparation required a 30 cm deep plowing and two weedings. Sowing was performed on 12/01/98 using 350 germinable seeds m^{-2} using a split plot design with three replications. Three crop rotation (durum wheat-legume crop (CS_1), two year durum wheat monocropping (CS_2) and three year durum wheat monocropping (CS_3)), were compared in interaction with two fertilization levels (F0 - 96 kg ha^{-1} of P_2O_5 - and F1 -96 kg ha^{-1} of P_2O_5, 50 kg ha^{-1} of N were pre-sowing distributed, 50 kg ha^{-1} of N were top-dressed) and two varieties (Trinakria and Valbelice).

All needed parameters were recorded for a good interpretation of results, but in this paper only some productive characters are reported stressing on qualitative and commercial ones (Norme UNI).

Results

Anova showed the significant effect due to the studied factors (fertilization, crop rotation and variety) on about 80 % of the recorded characters whereas only 40 % of interactions were statistically affected (Tab. 1). Grain yield was influenced by crop rotation and fertilization; cv Valbelice yielded more than cv Trinakria; cv Valbelice also produced more than 3.50 t ha^{-1} if a high fertilization level was used.

Hectolitre weight varied depending on genotype and interaction "cropping system x fertilization"; 1000 seeds weight was significatively affected by all single effects (fertilization, cropping system and genotype) and by all interactions. Non – wholly vitreous ranged between 6.16 and 7.56 % respectively for high fertilization level and for cv Trinakria. Crop rotation and fertilization positively affected protein and gluten content.

Discussion

Obtained results seem to be very interesting in relation to studied cropping system and fertilization. Between tested varieties, cv Trinakria confirmed its good grain qualitative characteristics; on the contrary cv Valbelice showed a high productive capacity in the semi-arid environment.

Factors	Characters	Plant height (cm)	Grain yield ($t \cdot ha^{-1}$)	Hl weight (Kg/hl)	1000 seeds weight (g)	Non wholly vitreous (%)	Protein (% d.m.)	Dry gluten (% d.m.)	Gluten index	S.D.S. (ml)
Previous crop	CS1	102.87 a	3.18 a	86.82	44.91 a	11.14	14.20 a	8.44 a	52.14	39.00
	CS2	90.77 b	2.49 b	86.48	42.49 b	19.50	13.51 b	7.93 b	53.38	37.50
	CS3	88.14 b	2.23 c	86.53	42.11 b	14.13	13.08 c	7.72 b	50.26	38.08
Variety	Trinakria	93.61	2.37 b	86.19 b	43.73 a	7.56 b	14.21 a	8.54 a	81.39 a	42.61 a
	Valbelice	94.24	2.89 a	87.03 a	42.61 b	21.42 a	12.98 b	7.52 b	22.46 b	33.78 b
Fertilization	F_0	83.09 b	2.11 b	86.67	42.32 b	22.67 a	13.12 b	7.81 b	50.08	36.83 b
	F_1	104.76 a	3.15 a	86.55	44.02 a	6.16 b	14.07 a	8.25 a	53.78	39.56 a
CS1	F_0	96.03 b	2.79 c	87.12 a	45.07 a	31.67 a	12.79	7.49	50.06	36.00 c
	F_1	109.7 a	3.57 a	86.52 b	44.75 a	4.90 cd	14.23	8.38	56.70	42.00 a
CS2	F_0	79.12 c	1.90 d	86.49 b	41.55 bc	17.50 b	13.62	8.14	50.63	35.50 c
	F_1	102.42 ab	3.08 b	86.48 b	43.43 ab	3.50 d	14.78	8.75	53.65	39.50 ab
CS3	F_0	74.13 c	1.64 e	86.42 b	40.33 c	18.83 b	12.95	7.80	49.54	39.00 b
	F_1	102.15 ab	2.81 c	86.65 b	43.88 a	9.42 c	13.21	7.64	50.98	37.17bc
Trinakria	F_0	82.92	1.99 d	86.29	42.23 b	11.56	13.6 b	8.21	85.75	41.00
	F_1	104.30	2.75 b	86.09	45.23 a	2.43	14.83 a	8.87	77.03	44.22
Valbelice	F_0	83.27	2.24 c	87.06	42.40 b	33.78	12.64 b	7.41	14.40	32.67
	F_1	105.21	3.55 a	87.01	42.81 b	9.06	13.32 b	7.63	30.52	34.89
CS1	Trinakria	103.42	2.96	86.41	46.02 a	12.00	14.09 ab	8.42	80.35 a	43.83
	Valbelice	102.32	3.39	87.23	43.80 b	25.75	12.93 cd	7.45	26.41 b	34.17
CS2	Trinakria	89.23	2.18	86.07	42.83 bc	5.80	14.79 a	8.95	80.46 a	41.67
	Valbelice	92.30	2.80	86.90	42.15 c	15.58	13.61 bcd	7.94	23.82 b	42.33
CS3	Trinakria	88.18	1.97	86.10	42.35 c	5.33	13.76 bc	8.27	83.37 a	42.33
	Valbelice	88.10	2.49	86.97	41.87 c	22.92	12.4 d	7.18	17.15 b	33.83

Table 1 - Morphological, productive, qualitative and commercial characters (Duncan's test)

Durum wheat after the leguminous crop yielded more than two year durum wheat and to continuous durum wheat and also showed the highest gluten and protein content.
Traditional fertilization on durum wheat using about 100 kg ha^{-1} of P_2O_5 and N, performed better, determining however protein content, gluten, gluten index and SDS increase and non – wholly vitreous percent decrease.
Positive results due to interactions "variety x fertilization" and " fertilization x crop rotation" displayed optimism for a Sicilian sustainable durum wheat production, even if agronomic, economic and environmental validation need more controls in the long period.

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YIELD, PLANT STRUCTURE AND SEED QUALITY OF BUCKWHEAT RESPONSE TO NITROGEN APPLICATION

Podolska G., Wielgo B.
Institute of Soil Science and Plant Cultivation, Czartoryskich 8 st., 24-100 Pulawy (Poland)

Introduction

Buckwheat has very high yield potential. In good and very good conditions the yield varied from 2,4-4,0 t/ha but very often the yield is below 0,6t/ha. Nitrogen fertiliser is one of the agrotechnical factors that determine the yields of crops (Oleg). The efficiency of nitrogen fertilisers varies in different regions of the country due to the specific biological features of the crops, variety, soil conditions (Noworolnik). The aim of this research was to determine yielding, yield structure and seeds quality of buckwheat depending on different nitrogen fertilisation application.

Methods

The field experiment was performed on acid brown soil in 1998-2000 year at the experiential station Osiny (51^0 28 min N, 22^0 5 min E), Poland. The first factor was dose of N, the second - way of N application (table 1). Buckwheat Kobra cv. was sown in row spacing 15 cm, sowing density 90 kg/ha, and sowing term 15-20 May. After harvest the grain yield per ha, plant structure and grain quality were estimated.

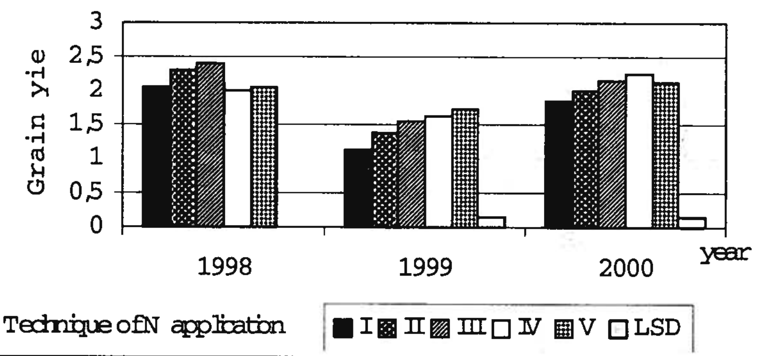
Table 1 Different ways of N application in buckwheat

No	N doses in kg/ha (a)	Form and technique of N application (in kg N/ha) (b)
I	0	
II	20	Before sowing - granular form
III	40	20-before sowing +12 blooming + 8 - flowering -granular form
IV	60	20-before sowing +12 blooming + 8 - flowering -liquid form
V	80	20-before sowing (granular form)+12 blooming + 8 - flowering (liquid form)

Results

Results are presented in figure 1 and in table 2 and 3

Fig 1 Grain yield of buckwheat depending on nitrogen fertilization



In the 1998 year the highest Seeds yield was obtained under 40 kg N/ha. 1999 and 2000 year significant low yield was obtained on the field without N fertilisation and on 20 Kg N/ha, There were not significant differences in yield between applied 40, 60 and 80 kg N/ha.

Table 2 Buckwheat plant structure depending on N applications (means from 1998-2000 year).

No	Main stem			Branches		
	No of inflorescences	No of seeds	Weight of seeds	No of inflorescences per 1 branch	No of seeds per 1 branch	Weight of seeds per 1 branch (g)
I	3,7	28,1	0,71	1,4	9,3	0,33
II	4,1	31,6	0,79	1,7	9,9	0,26
a_1b_1	4,1	30,3	0,74	1,6	10,1	0,26
a_1b_2	3,7	24,3	0,64	1,7	9,1	0,27
a_1b_3	4,4	31,7	0,81	1,6	8,3	0,30
a_2b_1	4,5	31,8	0,77	1,9	11,0	0,31
a_2b_2	4,3	33,8	0,81	2,2	10,6	0,27
a_2b_3	4,5	32,8	0,88	2,8	16,2	0,53
a_3b_1	4,1	32,5	0,84	2,0	8,3	0,29
a_3b_2	4,0	25,8	0,99	2,0	9,0	0,23
a_3b_3	4,4	34,9	0,91	2,2	12,8	0,35

Table 3 Seed quality of buckwheat depending on nitrogen fertilisation doses

N dose kg/ha	% of dry matter	Content in % of air dry matter								Content in mg/1 kg air dry matter		
		N	P	K	Ca	Mg	Na	crude fat	monosacchar ides	Cu	Fe	Zn
0	87,20	1,62	0,37	0,49	0,07	0,18	0,01	2,39	1,33	6,34	27,1	32,8
20	87,35	1,62	0,37	0,51	0,07	0,18	0,02	2,39	1,25	6,57	33,5	35,6
40	87,30	1,64	0,36	0,49	0,08	0,18	0,01	2,33	1,22	6,46	27,5	33,5
60	87,30	1,70	0,37	0,52	0,08	0,17	0,01	1,94	1,29	6,52	30,7	35,3
80	87,33	1,76	0,37	0,52	0,08	0,18	0,01	1,97	1,28	6,79	35,9	37,3

Conclusions

The highest seeds yield of buckwheat was obtained when 40-60 kg N/ha was apply. The plant's structure was modifying by N application. Together with N increase the seeds weight on main stem and number of seeds increase. Also the number of inflorescences on branches, but when the 80 kg N/ha was applied the number of seeds and weight of seeds per 1 branch decreased. Increases of N fertilisation doses have no significant influence on nutrition content in grains, cruse fat and monosacharides, but the N content increase together with increase of N fertilisation. Also (Bubicz) in her research point at influence of quality of buckwheat seeds in dependence to fertilisation. First of all together with increase of NPK fertilisation the protein content, crude fat and monosacharides increase (Bubicz).

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YIELD AND GRAIN QUALITY OF WINTER WHEAT RESPONSES TO NITROGEN FERTILIZATION AND ENVIRONMENTAL CONDITIONS.

Podolska G.,[1] Stankowski SI.[2]

1 Institute of Soil Science and Plant Cultivation, Czartoryskich 8 st., 24-100 Pulawy (Poland)
2 Agricultural University, Biometry Dept., Papiela Pawla VI 3, 71-442 Szczecin (Poland)

Introduction

Receiving high yield and good seed quality of winter wheat is a main goal of farmers and breeders. The quality mainly depends mainly on genetics properties, climate conditions and on agrotechnical factors. From agrotechnical factors the biggest influence on grain quality has nitrogen fertilization (Goodling 1998, Wrobel 1999,). It plays a significant role in gluten components formation and changes of gliadins and glutenins amount (Cacak-Pietrzak 1999, Daniel 1998).
The aim of this research was to estimate influence of different N fertilization doses on yield and seed quality of winter wheat in different environmental conditions.

Methods

The field experiment was performed in the years 1998-2000 at the Experimental Stations in Blonie Topola (52^0 15 min N, 19^0 10min E), Osiny (51^0 28 min N, 22^0 5min E) and Jelcz-Laskowice (52^0 5 min N, 17^0 25 mmin E) Poland. The experiment was conducted on good wheat soil complex. The 6 nitrogen fertilization doses was investigated (0, 40, 80, 120, 160, 200 kg N/ha). The sowing term was optimum and sowing density 4,5 mln. seeds/ha.The potassium and phosphorus fertilization was applied before sowing on the grounds of nutrient resources of the soil. The Mikon , Kobra, Korweta winter wheat varieties used in research characteristic in very good Milling and baking quality. After harvest the grain yield per ha and grain quality properties were estimated.

Results

The weather conditions during vegetation period were different for each station where the experiments were located (table 1).

Tabela 1 Monthly precipitation's in the vegetation period 1998/99 and 1999/00

Month	1999 year			2000 year		
	Localization					
	Blonie-Topole	Osiny	Jelcz-Laskowice	Blonie-Topole	Osiny	Jelcz-Laskowice
III	38,5	17,0	57,5	64,2	64,8	76,9
IV	71,7	96,6	56,4	12,7	48,7	17,8
V	35,3	38,4	35,6	85,5	5,9	76,5
VI	183,6	147,7	79,1	27,1	29,7	38,1
VII	44,0	51,2	183,6	138,7	173,9	165,8
VIII	11,3	45,1	17,4	42,5	62,4	51,8

As a consequence of this the winter wheat differ in length of vegetation period, yielding and grain quality (table2,3,4).

Table 2 Grain yield of winter wheat (t/ha) depending on nitrogen fertilisation doses (1999/2000 years)

Exp. Station	N fertilization kg/ha						LSD
	0	40	80	120	160	200	
Blonie-Topola	3,8	4,6	4,9	5,1	5,3	5,3	0,428
Osiny	5,6	6,8	7,3	6,9	6,9	6,4	0,418
Jelcz-Laskowice	4,3	5,1	5,0	5,4	5,3	5,2	0,671

The nitrogen fertilization had essential influence on grain yield (table 2) and grain quality (table 3). In the 1999 year winter wheat growing in Osiny had the best seed quality, but in the 2000 year in Blonie -Topola and Jelcz-Laskowice. In 2000 year winter wheat cultivated in Osiny has the low falling number (table 4).

Table 3 Effect of nitrogen fertilization on grain quality of winter wheat

Traits	Nitrogen fertilization (kg N/ha)						LSD
	0	40	80	120	160	200	
Test weight (kg/hl)	77,2	77,1	77,5	77,1	77,1	75,9	n.o
Falling number (s)	255	265	266	256	250	256	n.o
Gluten content (%)	25,1	27,4	31,2	33,3	33,9	38,1	2,23
Gluten weaking (mm)	1,89	2,24	3,08	3,08	3,15	3,46	1,37
Zeleny test (cm^3)	20,5	24,0	25,8	28,2	29,6	31,6	2,169
Water absorption(%)	65,2	65,8	68,0	69,0	69,6	70,0	1,436
Dough resistance (min)	3,48	4,25	5,50	6,23	7,12	7,57	2,495
Dough weaking (j.Br)	72,5	80,0	65,0	45,0	42,5	50,0	14,06
Valorimeter value(j.u.)	48,8	50,4	56,0	59,9	64,4	65,9	6,34

Table 4 Grain quality of winter wheat depending on field localization, varieties and years

Traits	Locality						LSD
	B□onie-Topola		Osiny		Jelcz-Laskowice		
	Year						
	1999	2000	1999	2000	1999	2000	
	Variety						
	Mikon	Korweta	Kobra	Korweta	Kobra	Korweta	
Test weight (kg/hl)	77,0	74,7	76,5	79,5	77,4	77,2	0,28
Falling number (s)	258	258	281	199	269	268	9,37
Gluten content (%)	24,9	38,7	33,7	39,7	30,2	36,6	0,63
Gluten weakening (mm)	1,56	1,97	4,82	3,55	4,04	2,36	0,45
Zeleny test (cm^3)	19,2	40,4	27,2	34,8	21,5	35,4	0,96
Water absorption(%)	68,3	72,2	63,5	73,4	63,9	69,8	0,74
Dough resistance (min)	3,6	11,06	4,97	8,06	2,76	9,74	0,37
Dough weaking (j.Br)	62,5	7,5	54,6	15,4	68,7	11,3	8,36
Valorimeter value(j.u.)	48,2	80,8	54,2	76,9	44,0	75,8	1,64

Conclusions

It was found that the yield and grain quality of winter wheat depended on nitrogen fertilization, weather conditions during vegetation period and on varieties. Together with N fertilization increase of gluten content, sedimentation value, weather absorption, valorimeter value was observed, but the gluten quality was getting worse. This results show that for good grain quality the N fertilisation above 120 kg N/ha and adequate adjust variety to climate conditions is required.

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THE EFFECT OF ADDING STROBILURIN FUNGICIDES TO A TRIAZOLE PROGRAMME ON THE BREADMAKING QUALITY OF WINTER WHEAT

Ruske R. E. & Gooding M.J.

Crops Research Unit, Department of Agriculture, The University of Reading, Earley Gate, PO Box 237, Reading, RG6 6AR (UK).

Introduction

Strobilurin fungicides have been proven to give greater protection of cereal grain yields than that previously achieved with triazole-based programmes when infection pressures from foliar diseases have been high. Controlling severe disease is frequently associated with increased grain yields and improved specific weights. Such improvements can be associated with an extension in the life of the flag leaf, and fungicide applications at flag leaf emergence are particularly important to maintain yields of wheat in the UK. Most UK wheat farmers apply fungicides at at least two growth stages (Gooding *et al.*, 1997) and, to conform to guidelines for limiting the development of fungicide resistance within pathogens, it is not recommended to apply strobilurin fungicides more than twice. The question that then arises, therefore, is that if one application is at flag leaf emergence, when should the second strobilurin application be? Application of fungicides at, and after, flag leaf emergence have sometimes been associated with reduced Hagberg falling numbers and grain protein concentrations (Gooding *et al.*, 2002). There is little information, however, as to the effect of strobilurin fungicides applied at the start of stem extension on quality of winter wheat, relative to applications at ear emergence.

Methods

Similar experiments were conducted in two contrasting seasons at the Crops Research Unit ($51^0$29'N, 0°54 W,), The University of Reading, UK. Cultivars Hereward, Malacca, Charger and Consort were drilled in both years into well draining sandy loam. A split-plot factorial design was used in which cultivar main plots were randomised in three blocks. Each main plot was subdivided into plots (4 x 10 m) each receiving a different fungicide treatment (Table 1). Green leaf area and disease were assessed weekly on 20 randomly selected flag leaves per plot from GS 59 to harvest. The data were used to fit a modified Gompertz curve (Gooding *et al.*, 2000) allowing time to senescence (37% green leaf area) to be estimated. After harvest grain from each plot was measured for yield, specific weight, Hagberg-falling number (HFN), and protein concentration.

Table 1. Fungicide treatments and the timing of their application (GS, growth stage, Zadoks et al., 1974)

	Epoxiconazole/Azoxystrobin (g a.i./ha)		
Treatment	GS 31	GS 37 (except cv. Charger, GS 39	GS 59 (except cv. Charger, GS 73)
1[a]	0/0	0/0	0/0
2	63/0	38/0	0/0
3	63/0	38/250	0/0
4	63/125[b]	38/250	0/0
5	63/0	38/250	0/125

[a] = treatment only included in 2000/2001 season, [b] = picoxystrobin in 2000/2001 season

Results

In 2000, adding the strobilurin to the triazole programme at flag leaf emergence significantly increased grain yield and grain specific weight, and significantly reduced grain protein concentration and Hagberg falling number (Table 2). An analysis fitting linear contrasts for total amount of strobilurin applied suggested that these effects were increased when further applications of strobilurin were made at either the first node detectable growth stage or ear emergence. The reduction in grain protein concentration occurred because improvements in dry matter accumulation and partitioning were greater than improvements in nitrogen accumulation and partitioning (Ruske *et al.*, 2001). In 2001, applying fungicide again increased grain yield and specific weight, and reduced Hagberg falling number but differences between fungicide treatments were smaller than in the previous year. There was no effect of fungicide on grain protein concentration in 2001.

Table 2. The effect of adding a strobilurin fungicide to a triazole only programme on the grain yield and quality of winter wheat.

	DM Yield (t/ha)		Specific weight (kg/hl)		HFN (s)		Protein concentration (% DM)	
Harvest Year	2000	2001	2000	2001	2000	2001	2000	2001
Treatment								
1	n/a	7.04	n/a	75.0	n/a	318	n/a	12.7
2	6.65	7.77	78.4	76.1	303	297	12.8	12.7
3	7.22	8.25	79.8	76.5	290	297	12.2	12.5
4	7.33	8.37	80.0	76.6	288	286	12.1	12.6
5	7.46	8.40	80.3	77.0	280	283	12.1	12.7
s.e.d. (df)	0.140 (18)	0.168 (24)	0.31 (18)	0.34 (24)	4.94 (18)	6.20 (24)	0.08 (18)	0.14 (24)

Conclusion

The results presented here confirm the ability of strobilurins to increase yield and specific weight. The smaller effects observed in 2001 may have been due to lower disease pressure and increased soil moisture deficits in May and June compared with the previous year. The lack of an effect of fungicides on the grain protein concentration 2001, confirms the observation that yield increases following disease control do not inevitably lead to dilution of protein (Dimmock *et al.*, 2002). The small reductions in Hagberg falling number were not sufficient to alter the grading of the grain with respect to baking potential. There was some evidence that applying strobilurin at the start of stem extension, rather than ear emergence, had less effect on Hagberg falling number, but this remains to be confirmed.

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INFLUENCE OF NITROGEN FERTILIZERS ON WINTER WHEAT VARIETIES ZELENY SEDIMENTATION VOLUME

Ruza A.[1]**, Linina A.**[2]

1, 2 Dep. Crop Production, Latvia Univ. of Agriculture, 2 Liela iela, Jelgava, Latvia, LV-3001

Introduction

High - quality wheat grains are required for the milling and baking industries. Zeleny sedimentation volume (ZSV) of wheat is mainly determined by the genetic basis, although it may be influenced by management techniques end environmental conditions (Ruza, Linina 2000; Grausgruber et.al., 2000). Addition of nitrogen fertilizer in accordance with the plant requirement is necessary to attain high yields and quality of winter wheat. In general it was observed that the PK fertilization without N fertilizer caused a decrease in Zeleny sedimentation volume (Tanacs et al., 1994; Jolankai, Ragasits 1997). Zeleny sedimentation volume significantly positively correlated with protein and wet content (Mladenov et al., 2001). The change of sedimentation volume in winter wheat between years was studied under variable meteorological conditions and applied nitrogen fertilizer.

Methods

Field experiments with 13 winter wheat *(Triticum aestivum L.)* varieties were conducted on sod calcareous soils of the Research and training farm "Peterlauki" of the Latvia University of Agriculture (LUA) from 2000 to 2001. In addition, the experimental varieties also differ in terms of their geographical origin. Conventional agricultural practices were applied. NPK (6:26:30) 200 kg ha^{-1} was applied before sowing. Split nitrogen dressing was applied in the following way: early in spring at the beginning of vegetation period for the first time, at the end of tillering the second time and the end of shooting in to stems. The fertilizer background was four nitrogen fertilizer (N kg ha^{-1}) treatments for all studied winter wheat varieties. The treatment variants for mid - early varieties 'Donskaja polukarlikovaja'(Russia), 'Sakta'(Latvia) and 'Krista'(Latvia) were as follows: N1 - N_{60}, N2 - N_{60+30}, N3 - $N_{60+30+30}$, N4 - $N_{60+30+60}$, but for others mid - late – varieties 'Pamjati Fedina (Russia),'Moda' (Latvia), 'Kobra' (Poland), 'Kosack' (Sweden), 'Bussard' (Germany), 'Ibis' (Germany), 'Portal' (Germany), 'Kontrast' (Germany), 'Zentos' (Sweden) were: N1 - N_{90}, N2 - N_{90+30}, N3 - $N_{90+30+30}$, N4 - $N_{90+30+60}$.

During the study years the meteorological conditions were significantly different. In 2000, comparatively dry and warm conditions prevailed during the first half of the growth period, however there set in the rainy season from mid - June up to the end of harvest period. In 2001 excessive rainfall and hot conditions prevailed during growing season.

The ZSV was determined in the Laboratory of the Department of Crop Production, Latvia University of Agriculture by Brabender equipment (ICC- Standard No. 116+118).

Experiments were analysed statistically by standard deviation (s) and coefficient of variation (s%).

Results

Results of two - year experiment indicate, that the reaction of diverse winter wheat to growth conditions was significantly different. The average ZSV in 2000 for all varieties was 42 ml independently of N fertilizer, but that in 2001 was 54 ml. These grains were useful for direct baking or mixing up with comparatively weak flour. Responsiveness of diverse winter wheat varieties to weather conditions was different. ZSV was stable for varieties 'Kontrast (61 - 62 ml) and 'Donskaja polukar□ikovaja' (56 - 50 ml). The greatest amplitude ZSV was observed in varieties 'Kosack' - 22 ml (s - 12,6; s % - 28,6), 'Krista' - 20 ml (s - 10,9; s % - 22,7). Spilt nitrogen fertilizer influenced ZSV. Standard deviation (s) was in the range 11,3 - 15,0 ml, but coefficient of variation (s%) 5,8% - 7,8%. ZSV was stable for varieties 'Kontrast' (s –1.7, s % -

2.7), 'Kobra' (s – 1.6, s % - 3.6), 'Sakta' (s - 1.4, s % - 3.7) and 'Moda' (s – 2.2, s % - 4.8). In treatment variants N3 and N4 ZSV was significantly increase for varieties 'Kosack' (s – 5.2, s % - 11.8), 'Bussard (s – 5.8, s % - 11.4), 'Stava' (s – 5.2, s % - 10.8),'Portal' (s – 8.4, s % - 16.2) and 'Zentos' (s – 9.0, s % - 15.8).

Varieties	Average 2000 and 2001 per variants						Average 2000 and 2001		
	N1	N2	N3	N4	s*	s %**	ZSV	s*	s %**
Donsk. poluk. (Russia)	51	50	51	56	3,0	5,7	53	6,2	11,7
Sakta (Latvia)	38	37	39	40	1,4	3,7	38	4,1	10,8
Krista (Latvia)	45	48	50	51	2,7	5,6	48	10,9	22,7
Pamjati Fedina (Russia)	40	39	43	44	2,4	5,8	41	11,2	27,3
Moda (Latvia)	45	44	49	46	2,2	4,8	46	4,9	10,6
Kobra (Poland)	42	44	46	44	1,6	3,6	44	9,0	20,5
Kosack (Sweden)	38	42	49	48	5,2	11,8	44	12,6	28,6
Bussard (Germany)	43	54	53	56	5,8	11,4	51	11,9	23,3
Ibis (Germany)	42	44	48	48	3,1	6,7	46	8,7	18,9
Portal (Germany)	42	47	57	60	8,4	16,2	52	10,0	19,2
Kontrast (Germany)	61	62	64	60	1,7	2,7	62	4,8	7,8
Zentos (Germany)	46	53	60	67	9,0	15,8	57	11,8	20,7
Stava (Sweden)	47	42	51	54	5,2	10,8	48	6,2	12,9
Average	45	47	51	52			48		
s	6,1	6,8	5,8	7,8	3,4			7,1	
s %	13,5	14,5	11,3	15		7,1			14,8

*s -standard deviation, **s % - coefficient of variation

Table 1 – Zeleny sedimentation volume of winter wheat varieties

Conclusions

In the studied winter wheat cultivars, estimation of ZSV stability on the influencing factors (meteorological conditions, nitrogen fertilizer) showed that 'Kontrast' particularly excelled with stability (s % - 7,8); among stable varieties should be noted 'Moda' (s – 4.9, s % - 10.6), 'Sakta' (s – 4.1, s % - 10,8), 'Donskaja polukarlikovaja'(s – 6.2, s % - 11,7) and 'Stava'(s – 6.2, s % - 12,9). Widely distributed 'Pamjati Fedina' (s – 11.2, s % - 27,3), 'Kosack (s – 12.6, s % - 28,6) were comparatively unstable winter wheat varieties and their ZSV were greatly dependent on weather conditions in the growing season. It is concluded that ZSV was dependent on genetic peculiarities of a crop variety, meteorological conditions in the growing season and, to some extent, on the rate and split applications of N fertilizer.

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CHANGES IN LEAF NITROGEN CONTENT OF BURLEY TOBACCO PLANTS GROWN UNDER DIFFERENT IRRIGATION AND NITROGEN FERTILIZATION REGIMES

Sifola M.I.
Department of Agricultural Engineering and Agronomy, University of Naples "Federico II", Via Università 100, 80055 Portici (Naples), Italy.

Introduction

Leaves of tobacco are usually harvested when they reach agronomic ripeness. The assessment of the degree of leaf ripeness is rather subjective, as it generally considers changes in colour, angle of leaf insertion on the stem and droop of leaf lamina. In cases when whole plants are harvested, basal leaves are overripe while apical ones are unripe at harvest. From the physiological point of view, ripeness reflects the onset of leaf senescence, which in turn is correlated with leaf nitrogen (N) metabolism. To elucidate the role of irrigation and N fertilization on leaf N accumulation or depletion in field-grown Burley tobacco plants, we determined the N concentrations of green leaves at different stalk positions during the growing season.

Methods

Burley tobacco plants were grown in the Sele River Plain of the Campania region (Southern Italy) over two growing seasons. Soil characteristics are reported in Table 1.

Table 1. Soil physical (ISSS) and chemical properties in 1994 and 1995.

	Sand (%)	Silt (%)	Clay (%)	Total carbonates (%)	PH	Organic matter (%)	N (Kjeldahl) (%)
1994	45.0	23.5	31.5	1.5	7.2	1.2	0.091
1995	48.7	27.3	24.0	1.5	6.7	1.4	0.105

Two water regimes (NI, rainfed; I, irrigated with 100% of crop evapotranspiration) and two fertilization rates (0 or 120 kg N ha^{-1}) were factorially combined in each year. The experimental design was a split-plot with three replications; the water regime was the main plot and N fertilization the sub-plot.

Plants were sampled four and three times during the growing season in 1994 and 1995, respectively: at the beginning of rapid growth (36 days after transplanting, DAT, in 1994 only), during the rapid growth and stem elongation phase (43 and 50 DAT) and at harvest (91 and 96 DAT in 1994 and 1995, respectively). The total N content of green leaves was determined by the Kjeldahl method. The N content of basal, middle and apical leaves was calculated by multiplying the Kjeldahl nitrogen content (% dry matter) by the corresponding dry matter. The leaf dry matter of leaves was determined after oven drying at 60 °C. Accumulation or depletion of N was calculated for each group of leaves as the difference in N content between two consecutive sampling dates.

Results

In 1994, early in the growing season (from 36 to 43 DAT), there was a net accumulation of N under all experimental conditions (Fig. 1a). Unirrigated plants fertilized with 120 kg N ha^{-1} accumulated more N than other treatments. During the 43-50 DAT interval leaf N was depleted in unirrigated plants in 1994 (Fig. 1a). Nitrogen accumulation still occurred in leaves of irrigated plants. In 1995, a net accumulation of leaf N was measured for all treatments during the 43-50 DAT interval (Fig. 1b). During the interval from 50 through harvest the N budget of green leaves was virtually zero for all treatments in 1994 and for I-F plants in 1995 (Fig. 1). Depletion of N was measured for NI-F, I-NF and to a less extent for NI-NF treatments in 1995 (Fig. 1b). The amount of N partitioned to middle leaves accounted for 84 and 69% of the total N accumulated in the leaves in 1994 and 1995, respectively. In both years, there was no effect of irrigation or N fertilization on the N partitioning to middle, apical or basal leaves (data not shown).

Conclusions

In both years green leaves accumulated N during the period of rapid stem elongation, when Burley tobacco plants showed the highest rates of growth and leaf emergence (Sifola, unpublished data) in agreement with results reported for other types of tobacco (McCantz et al., 1967).
The rate of N accumulation is highly correlated with the rate of growth in many species (Below, 1995), including Burley tobacco grown under irrigated conditions (Sifola et al., submitted). In 1994 the NI-NF treatment accumulated more N than other treatments during the 36-43 DAT period, but in the following interval N was rapidly depleted.
From 50 DAT through harvest (leaf ripening) the N budget of green leaves was virtually zero in 1994; N depletion prevailed in 1995. The N depleted during this period was presumably partitioned to stems and roots. Roots are an important sink for N partitioning in flue-cured tobacco in the late part of the season, particularly when water availability is inadequate (Goenaga et al., 1989).
Changes in leaf N were quite consistent across the treatments indicating that the pattern of accumulation and depletion was mainly driven by developmental processes.

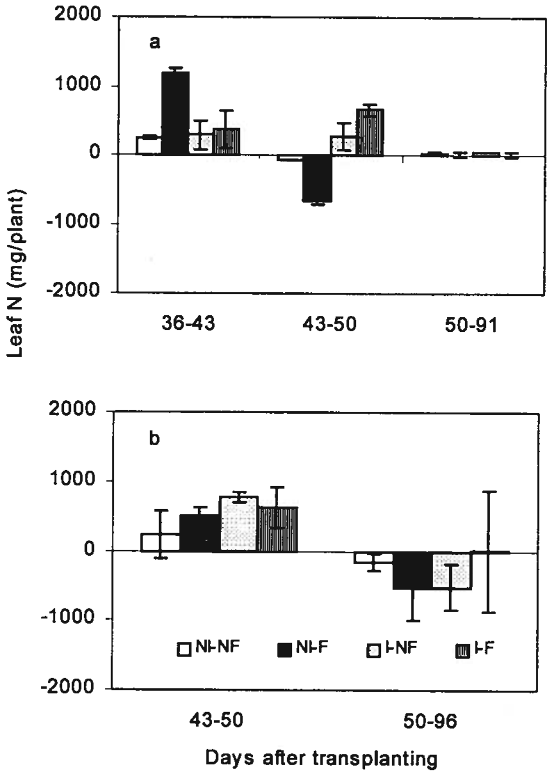

Fig. 1. Leaf nitrogen budget determined at different time intervals during the growing season in 1994 (a) and 1995 (b). Legend: NI, non irrigated; I, irrigated; NF, non fertilized; F, fertilized. Data are means ± standard errors of three replicates.

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THE YIELD AND QUALITY RESPONSE TO SUPPLEMENTARY MICROELEMENT NUTRITION OF WINTER WHEAT AND SUGAR BEET

Vach M., Javurek M.

Research Institute of Crop Production, Drnovská 507, 16106 Prague Ruzyne (Czech Republ.)

Introduction

Cost reduction and competition ability are the basic aims of agricultural production in our country. To achieve these objectives it is necessary to increase the profitability of crop production by a more effective use of agrochemicals applied to reach high yields and required quality. It can be attained not only by balancing all usual growing factors but also by utilization of new supplementary foliar fertilizers.

Methods

In our 1995–2000 field experiments there was evaluated the effect of foliar fertilizer Hycol M on yield and its components and also on some quality indices of winter wheat and sugar beet under stepped up nitrogen fertilization. These experiments were carried out at three different sites (on *luvisol* in Prague-Ruzyne, on degraded *chernozem* in □áslav and on *cambisol* in Lukavec). The evaluated microelement fertilizer is a concentrate of biologically active natural oligopeptides and amino acids with magnesium and microelements (B, Mn, Fe, Zn, Cu, Mo) and it considerably influences the physiology of crop yield formation.

Results

Analysed yield results (Table 1) showed that grain yield of winter wheat increased by influence of use of supplementary fertilizer in average of 6 experimental years by 0.25-0.33 $t.ha^{-1}$ compared with control variants without treatment. At all sites the highest statistically significant effect was mostly found in variants with lower level of nitrogen fertilization. The application positively influenced thousand kernel weight (TKW), number of fertile spikelets and number of developed grains in a spike of winter wheat. At the site on *cambisol* we found the average increase of TKW by 1.84 g, on *chernozem* by 1.25 and on *luvisol* by 1.16 g in comparison with control variant. From the point of view of baking quality of winter wheat there was observed an increase of gluten content by 1.3-1.8 % and a slight increase of values of the sedimentation test. Significant increase of yield of sugar beet bulb was found again in the variants with lower level of nitrogen fertilization. It means at site on *luvisol,* where the average increase was 3.4 $t.ha^{-1}$, which is + 6.4 % and at site on *chernozem* 3.7 $t.ha^{-1}$, which is 6.7 %. Supplementary nutrition significantly influenced also the yield of white sugar.

Conclusions

In our field experiments there was shown that exogenous application of supplementary foliar nutrition in optimal term and in recommended concentration can significantly positively influence the yield elements formation of winter wheat and their grain quality and also technological quality of sugar beet. There was found economic efficiency of this treatment, especially in conditions of lack of nitrogen. Higher intensity of nitrogen fertilization decreased the stimulation effect of supplementary nutrition.

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Tab. 1:The impact of Hycol M on grain yield and some quality parameters of winter wheat and sugar beet

WINTER WHEAT	Nitrogen dose /kg.ha^{-1}/					
	0		60		100	
	control	Hycol M	control	Hycol M	control	Hycol M
PRAHA - RUZYNC						
Yield of grain (t/ha)	5.69	6.01*	5.81	6.12*	5.88	6.13
%	100	105.6	100	105.3	100	104.3
Volume weight (g/l)	797.2	798.1	796.1	798.6	800.4	802.5
Gluten content (%)	24.7	24.8	27.6	28.9	29.5	30.4
Gluten index (%)	77	79	81	81	82	81
SDS - test (ml)	66	66	66	67	67	68
Fall number (s)	259	264	268	280	287	298
Protein content (%)	12.08	12.26	12.43	12.58	12.77	12.90
VÁSLAV						
Yield of grain (t/ha)	5.45	5.75*	5.66	5.92	5.71	5.98
%	100	105.5	100	104.6	100	104.7
Volume weight (g/l)	783.7	783.9	788.6	789.4	792.6	793.0
Gluten content (%)	24.6	25.1	25.4	26.3	27.7	28.5
Gluten index (%)	77	78	81	82	81	83
SDS - test (ml)	65	66	66	67	68	68
Fall number (s)	254	260	268	271	274	282
Protein content (%)	11.95	12.18	12.34	12.47	12.56	12.61
LUKAVEC						
Yield of grain (t/ha)	4.17	4.43*	5.42	5.75*	5.65	5.94*
%	100	106.2	100	106.1	100	105.1
Volume weight (g/l)	792.1	797.2	793.5	800.2	799.3	801.2
Gluten content (%)	22.5	22.7	23.4	23.9	24.8	25.6
Gluten index (%)	74	75	78	77	77	79
SDS - test (ml)	64	64	65	65	66	67
Fall number (s)	272	275	287	295	299	306
Protein content (%)	11.64	11.72	11.81	11.90	12.17	12.24

SUGAR BEET	Nitrogen dose /kg.ha^{-1}/					
	0		60		120	
	control	Hycol M	control	Hycol M	control	Hycol M
PRAHA - RUZYNc						
Yield of root (t/ha)	52.76	56.15*	55.89	59.30*	57.16	60.71*
%	100	106.4	100	106.1	100	106.2
Digestion (%)	19.7	19.9	19.4	19.5	19.2	19.3
α-amino N content	2.49	2.49	2.65	2.53	2.79	2.72
White sugar yield (t/ha)	7.57	8.11*	7.73	8.25*	7.82	8.33*
%	100	107.2	100	106.7	100	106.5
□ÁSLAV						
Yield of root (t/ha)	54.69	58.37*	57.08	60.86*	58.75	62.28*
%	100	106.7	100	106.6	100	106.0
Digestion (%)	18.6	18.6	18.4	18.5	18.1	18.3
α-amino N content	2.49	2.34	2.79	2.65	3.14	3.14
White sugar yield (t/ha)	7.08	7.52*	7.25	7.66*	7.19	7.54
%	100	106.2	100	105.7	100	104.9

* Significant level $P< 0.05$

CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF ALPINE PASTURE'S SPECIES IN NORTH-EASTERN ITALY

Ziliotto U., Scotton M., D'Ottavio P.
Dipartimento di Agronomia ambientale e Produzioni vegetali, Università degli Studi di Padova, Agripolis, Strada Romea 16, 35020 Legnaro (Padova), Italy

Introduction

In order to prevent negative impacts deriving from the reduction of the grazing animals actually recorded in the Italian Alpine regions and to promote the rational utilisation of the pastures, the assessment of the stocking rate needs to be based on botanical composition and production of the grassland. In fact, only stocking rates proportioned to the pastoral value of the surfaces allow both a sustainable and an economically advantageous utilisation. In this context, this research aims to contribute to assess the quality of the mixed forage and of some abundant species of an alpine natural pasture treated with and without NPK fertilisation.

Materials and methods

The research was conducted on the pastures of Monte Pradazzo (Belluno), located between 2110 and 2210 m a.s.l., that, according to their characteristics, are traditionally grazed during the summer by different animals (cows, horses and sheep). The rocks are porphyritic and the soils belong to the "Rankers" type. The climate of near Valles pass (2031 m a.s.l) is characterised by a mean annual precipitation of 1300 mm and by a mean annual temperature of 2.6 °C. From the beginning to the end of the grazing season in 1998 and 1999, the chemical characteristics of the mixed forage and of the most abundant species (*Nardus stricta*, *Carex sempervirens* and *Leontodon helveticus*) were assessed in a *Nardus stricta* - pasture fertilised (F) with 80-80-80 Kg ha^{-1} $year^{-1}$ of N, P_2O_5 and K_2O respectively or not fertilised (NF). Three samples for each forage type were collected with about 2-weeks intervals at each of the following 4 dates: 25/7; 8/8; 22/8; 12/9. The forages, dried at 65 °C, were analysed in order to determine: Crude Protein (CP, Kjeldhal method), Crude Fibre (Weende method), NDF, ADF, ADL (Van Soest method), Ash, Calcium and Phosphorus contents. The nutritive value expressed in MJ of Net Energy for Lactation (NEL) was assessed according to I.N.R.A. (1978).

Results

Table 1 shows as regard to ADF, among the analysed species, *N. stricta*, *C. sempervirens* and *L. helveticus* presented the highest, the medium and the lowest contents respectively. It changed according to a seasonal trend only in the mixed forage. Considering the fertilisation, ADF content varied consistently resulting in higher values in the NF treatment in all forages but significantly in the mixed forage.
The CP, differently to the ADF results, was higher, medium and lower in *L. helveticus*, *C. sempervirens* and *N. stricta* respectively. In addition, the variations were more consistent, in appearance especially in the F treatment, during the season both in the mixed forage and in any single species, particularly in *L. helveticus*. In general, the fertilisation increased significantly the CP content both in the mixed forage and in all species.
As regards to NEL the comparison among species highlights results comparable to those obtained for the CP content. The variations recorded during the season were limited and apparently more consistent in the F treatment. As observed for CP, the fertilised treatment produced forage with higher values of energy.
The ASH content, a part from the relatively high value recorded in *L. helveticus*, was rather low in all forages. Globally no significant variations were during the season and between F and NF.

With regard to P and Ca, *L. helveticus* and *C. sempervirens* presented higher contents. Especially in the F treatment, P decreased and Ca increased during the growing season. In general, the fertilisation increased the P and Ca contents.

Table.1. Chemical composition (% of DM) and nutritive value (MJ kg DM^{-1}) of the mixed forage and of the species in the fertilised (F) and not fertilised (NF) treatment. Means of 2 years.

Characteristics		ADF			Crude Protein			NEL			Ash	P			Ca		
Forage/Species	Date	F	NF	Me * **	F	NF	Me * **	F	NF	Me * **	Me * **	F	NF	Me * **	F	NF	Me * **
Mixed forage	25/7	27,1	29,8	28,5 a ab	19,7	13,6	16,6 a b	6,5	5,9	6,2 d b	6,0 a b	0,24	0,13	0,18 a b	0,29	0,16	0,23 d b
	8/8	26,2	29,9	28,1 b	16,7	12,2	14,4 b	6,6	6,0	6,3 c	5,7 b	0,23	0,11	0,17 b	0,31	0,18	0,24 c
	22/8	25,4	29,7	27,5 c b	14,7	11,3	13,0 c b	6,7	6,0	6,4 b b	6,0 a b	0,21	0,13	0,17 b ab	0,36	0,22	0,29 b a
	12/9	26,6	26,7	26,7 d	11,6	10,4	11,0 d	6,4	6,4	6,4 a	5,4 c	0,17	0,10	0,13 c	0,39	0,24	0,32 a
Mean***		26,3 b	29,8 a	28,1	15,6 a	12,3 b	14,0	6,6 a	5,9 b	6,2	5,8	0,21 a	0,12 b	0,16	0,34 a	0,18 b	0,26
N. stricta	25/7	30,6	31,1	30,8 c a	15,3	11,2	13,2 a c	6,1	5,6	5,9 b b	5,8 a b	0,22	0,12	0,17 a b	0,18	0,18	0,18 b b
	8/8	31,4		31,4 b	14,8	11,3	13,0 a	6,0	5,6	5,8 c	5,5 b	0,19		0,19 b	0,21		0,21 c
	22/8	30,9	33,8	32,4 a a	13,9	10,2	12,0 b b	5,7	5,2	5,5 d c	5,9 a b	0,21	0,09	0,15 c ab	0,21	0,15	0,18 d ab
	12/9	29,5	29,4	29,4 d	10,7	11,3	11,0 c	6,0	5,9	6,0 a	5,2 c	0,16	0,12	0,14 b	0,22	0,19	0,20 a
Mean***		30,5	31,1	30,8	13,6 a	10,9 b	12,2	6,0 a	5,5 b	5,7	5,6	0,19 a	0,11 b	0,15	0,20	0,17	0,18
C. sempervirens	25/7	26,0	29,0	27,5 b b	20,5	15,0	17,7 a b	6,2	6,0	6,1 b b	5,3 b b	0,37	0,14	0,25 a ab	0,27	0,20	0,23 c b
	8/8	25,9		25,9 c	17,3	12,5	14,9 b	6,3	6,4	6,4 a	5,6 a	0,25		0,25 c	0,29		0,29 b
	22/8	28,7		28,7 a b	14,8	11,9	13,4 c b	6,4	5,8	6,1 c bc	5,7 a b	0,31		0,31 d a	0,35		0,35 d ab
	12/9	26,6	28,7	27,6 b	12,1	11,5	11,8 d	6,1	6,1	6,1 c	5,1 c	0,18	0,13	0,15 b	0,39	0,22	0,30 a
Mean***		26,2	29,0	27,6	16,2 a	13,5 b	14,8	6,3	5,9	6,1	5,4	0,27 a	0,14 b	0,20	0,32 a	0,20 b	0,26
L. helveticus	25/7	17,2	18,6	17,9 c	26,4	18,6	22,5 a a	8,5	7,7	8,1 a a	8,3 a	0,39	0,23	0,31 a	0,85	0,58	0,71 a
	8/8				21,2		21,2	7,9		7,9	9,9						
	22/8				20,0	13,3	16,6 b a	8,0	6,4	7,2 b a	8,2						
	12/9	15,1		15,1	16,9		16,9	8,4		8,4	8,4	0,22		0,22	0,78		0,78
Mean***		17,2	18,6	17,3	23,2 a	18,6 b	19,8	8,3	7,7	8,0	8,6	0,39	0,23	0,31	0,85	0,58	0,71

*, **, *** Duncan test: means with no common letter differ significantly at the 0.05 level. *, comparison among dates within forage/species. **, comparison among 1st date values and among 3rd date values of the four forages. ***, comparison between F and NF within the same forage considering only dates where both F and NF values were available. Me: mean.

Conclusions

The obtained CP contents were higher compared with those recorded by Schubiger *et al.* (1999) and by Grignani *et al.* (1990) in similar *N. stricta* alpine pastures. The NEL values were comparable to those recorded by the second authors and higher as regards to the first ones. According to the cited references, the forages resulted poor of mineral elements. Besides, according to Schubiger *et al.* (1999), the P and Ca contents respectively decreased and increased during the growing season and both contents resulted higher in *L. helveticus* than in *N. stricta* and *C. sempervirens*.

With reference to the cows, the chemical composition of the analysed forages was not found suitable for suckling animals. However the CP content and NEL were found sufficient for young growing animals and for the maintenance of dry cows. On the other side, the P and Ca contents appeared too low also for the requirements of young growing animals for which an extra-pasture integration of such elements would be required.

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Cropping and farming systems

AUTOMATIC DETECTION OF RESIDUE COVER FRACTION IN CONSERVATION AGRICULTURE SYSTEMS

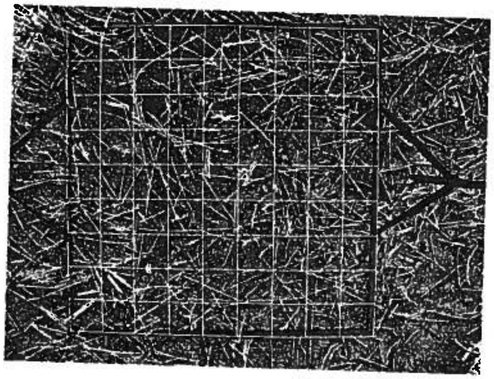
F. Agrela[1] , J.A. Gil[1] , F. Pla[2] , J.V. Giraldez[3] , F. Perea[4]
1 Dpto. de Ingeniería Rural, ETSIAM, Universidad de Córdoba, P.O. Box 14080 Córdoba, ir2agsaf@uco.es
2 Dpto. de Inteligencia Artificial, Universitat Jaume I de Castellón, Campùs de Riu Sec,
3 Dpto. de Agronomía, ETSIAM, Universidad de Córdoba, P.O: Box 14080 Córdoba.
4 Universidad de Sevilla, Dpto. Ciencias Agroforestales, Cra. Utrera, Km 1, 41080 Sevilla

Introduction

The increased concern caused by the high soil loss rates occurred in the andalusian countryside, is forcing the farmers to adopt new agricultural techniques, like the tillage reduction in extensive systems, (e. g. Perea , 2000). In order to assess the efficiency of the alternative systems as a soil conservation method the degree of surface cover needs to be evaluated the purpose of this work is the comparison of the evolution of the residue cover of the soil surface under different tillage systems using several methods, from the mechanical, conventional ones to th newest image based methods.

Materials and methods

The surface residue may be measured by either determing the surface mass density or the fraction of any protection of the surface covered by the strubble and weeds. Many of the current methods to assess the fraction of surface cover are based on the line transect estimation (Morrison et al 1998). In this method, the fraction of intersections where a piece of strubble or a weed is found over the whole number gives an estimate of the fraction, as suggested earlier by Buffon. This method (1) is compared with the following: (2) subjective estimation of zonal occupation of stubble and weeds; (3) image-analysis of shots taken in the field; and (4) cover true contrast method in previous images.



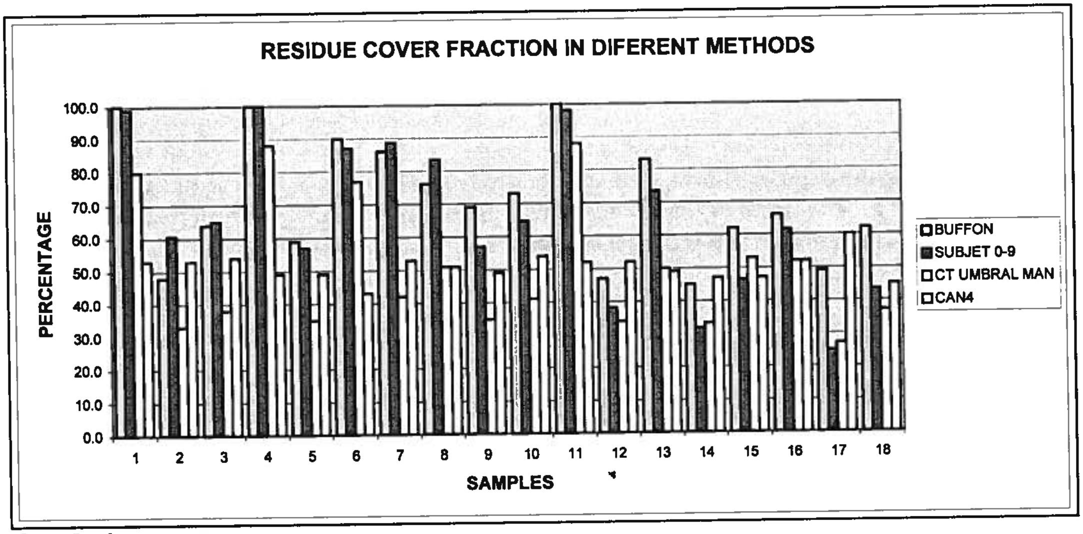
The subjective estimation (2) determines the cover in small square units of 9 cm, within a larger square of 95x95 cm2 . The value given to any square range between 0 bare soil, and 10m, full cover. The image analysis method (3) explores the field acquired images delineating the internal boundaries with the canny method.

After it defines a histogram of the boundary pixels with the maximum value is the threshold in a grey colour scale between 0 and 255. Segmented image is evaluated in this way estimating the ratio of lighter pixels to the total amount.
The cover true method is a contrast technique (Corak S.J. 1995). Every single image is analysed combining methods by texture, histogram treatment and threshold setting in the colour range of sharper contrast, usually in the red region. This method allows a more accurate estimate of the cover fraction.

The images were captured in the field with a digital camera, with 3.3 Mpix of maximum resolution, enough for the resolution used in this work 1200x900 pixels. The camera was located in a metallic frame used as a mechanical support and a reference setting, with the help of an iron grid of 50x50 cm2, where several grids may be placed.

Results

The results of 18 samples are shown in fig nº 2. Buffon and subjective estimates were larger than the other two methods. Therefore these methods in spite of their simplicity should be corrected to yield more reliable.



Conclusions

It is convenient to adopt a more accurate method to assess surface cover fraction in conservation tillage systems. Even though image analysis and cover true methods are harder to install. The simple procedure in field and laboratory and the reliability of the results favour their adoption for residue cover studies.

Acknowledgements:

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USE OF DISCRIMINANT ANALYSIS TO DISTINGUISH BETWEEN WHEAT AND MAIZE CROP SEQUENCES IN A LONG-TERM EXPERIMENT

Z. Berzsenyi, D.Q. Lap
Agricultural Research Institute of the Hungarian Academy of Sciences, 2462 Martonvásár (Hungary)

Introduction

At present no quantity of mineral fertilisers or pesticides is capable of completely compensating for the rotation effect, and an analysis of the individual factors is generally unable to explain the yield increases achieved in crop rotations. The aim of the research was to use discriminant analysis (DA) to determine multivariable differences between maize and wheat grown in various crop sequences or in continuous cropping in long-term experiments carried out in Martonvásár over the last 40 years.

Methods

The bifactorial split-plot crop sequence experiment set up with four replications in 1961 includes seven crop sequences and five fertilisation treatments (Berzsenyi et al. 2000). Each of the crop rotations and continuous cropping treatments were characterised by their yield responses to the five fertilisation treatments, which represented different systems of nutrient replacement, as a quantitative variable. The significant difference between the group centroids was analysed using the canonical variables, the Wilks'lambda and an F-statistic computed from a Mahalanobis D^2.

Results

The rotation effect could be characterised by the two main parameters determining the yield response pattern of crop rotations, the mean (fixed, systematic effect) and the variance (random component). DA revealed the importance of fertilisation systems, as predictive variables, in distinguishing between crop sequences and continuous cropping systems. It was found that in maize crop rotations the difference between sequences including legumes (alfalfa, peas) and continuous cropping could be attributed primarily to fertilisation effects. In wheat crop rotations the rotation effect could primarily be explained by factors, processes and mechanisms other than fertilisation. This is in agreement with experimental results showing that in wheat crop rotations the rotation effect was not modified greatly by fertilisation, while in maize crop rotations fertilisation reduced the rotation effect to around half. The distance between the group centroids was proportional to the rotation effect of the crop sequence, being greatest between continuous cropping and the triculture, and between continuous cropping and the Norfolk rotation (Figs. 1-2). The discriminance of the group centroids suggests that the joint application of organic and mineral fertilisers creates favourable conditions for the manifestation of the rotation effect.

Conclusions

The use of multivariable biometric methods is becoming more and more important in determining the interactions between factors related to crop sequences and how these contribute to the rotation effect. In the present studies the stepwise method of DA proved to be especially useful for selecting the predictive variables most important in distinguishing between crop rotation and continuous cropping groups and for determining the significance of the difference between the group centroids for each pair.

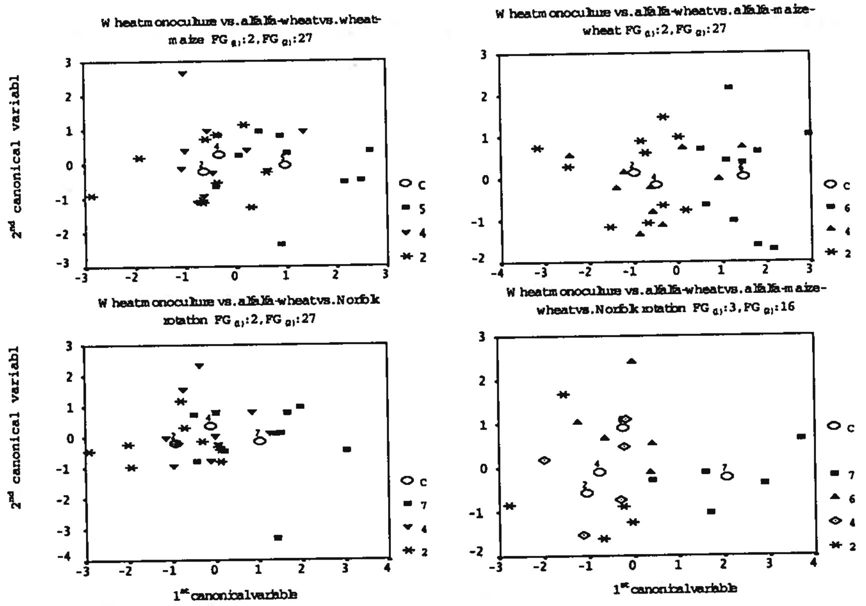

Fig. 1. Multivariable discrimination of wheat crop rotations vs. continuous cropping using discriminant analysis. C: group centroids; 2: continuous wheat cropping; 4: alfalfa-wheat; 5: wheat-maize; 6: alfalfa-maize-wheat; 7. Norfolk rotation

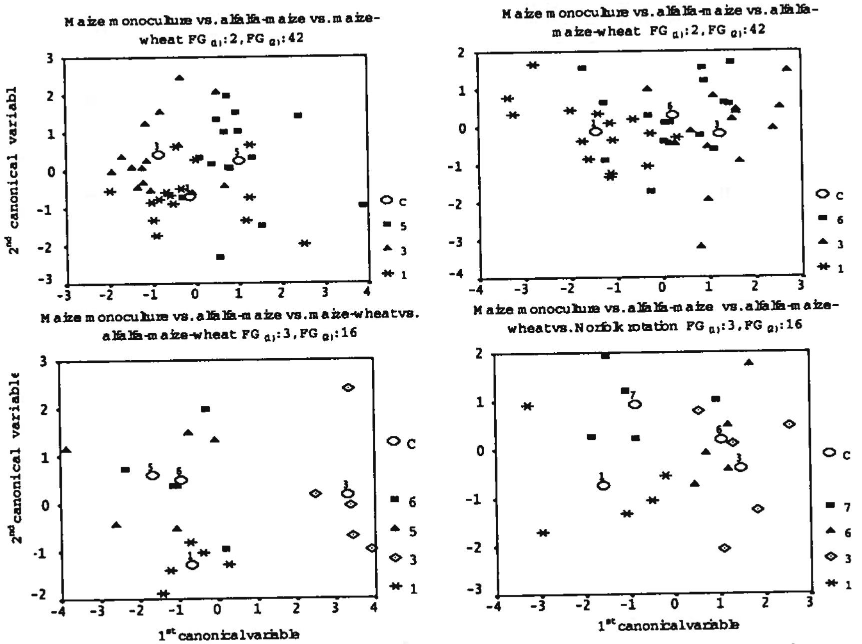

Fig. 2. Multivariable discrimination of maize crop rotations vs. continuous cropping using discriminant analysis. C: group centroids; 1: continuous maize cropping; 3: alfalfa-maize; 5: maize-wheat; 6: alfalfa-maize-wheat; 7. Norfolk rotation

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COMPARISON OF TRADITIONAL AND OPTIMISED DOUBLE CROPPING SYSTEMS IN A WINTER WHEAT – SUMMER MAIZE ROTATION IN THE NORTH CHINA PLAIN NEAR BEIJING

Böning-Zilkens M. [1,2]**, Horlacher D.** [2]**, Fan ZX.** [2]**, Li ZY.** [2]**, Chen XP.** [2,3]**, Wang P.** [2]**, Zhang FS.** [2]**, Römheld V.** [3]**, Schulz, R.** [3]**, Pekrun C.** [1]**, Graeff S.** [1]**, Claupein W.** [1]

1 Institut für Pflanzenbau und Grünland (340), Universität Hohenheim, 70593 Stuttgart (Germany)
2 China Agricultural University, Yuanmingyuan Xilu, 100094 Beijing, (PR China)
3 Institut für Pflanzenernährung, Universität Hohenheim, 70593 Stuttgart (Germany)

Introduction

Due to urbanisation, desertification and a still increasing population growth, the PR China faces the problem of producing more food on decreasing arable land. Total arable land in China per capita is 0.08 ha, compared to the EU with 0.2 ha per capita. To increase land-use index, two or more crops in one year are cropped. Near Beijing in the North China Plain, the main cropping system is a winter wheat - summer maize rotation. The research objective was to increase yields and at the same time avoid negative environmental effects. This means to maximise water- and nitrogen use efficiency for the above mentioned cropping system. Two questions were at the core of the research work:

- Are there possibilities to reduce the amount of irrigation water, used by the traditional way of irrigation, without negative effects on yield?
- Are there possibilities to reduce the amount of N-fertiliser, used by the traditional way of fertilisation, without negative effects on yield?

Materials and Methods

A three factorial field experiment (Table 1) with four replications on a Calcaric Cambisol embedding a winter wheat – summer maize double cropping system was set up near Beijing (40° N; 116,5° E) from 1999 to 2001. Each growing year in mid-October winter wheat was sown after ploughing. After the harvest in mid-June, summer maize was sown directly into the winter wheat stubble and was harvested in the beginning of October. Plants were harvested manually on 9 m² per plot for winter wheat and 40 m² per plot for summer maize. The samples were dried at 105°C to obtain total dry matter. The statistical procedures were conducted with the SAS System, Release 6.12.

Table 1:The three factors and their respective treatments (split-split plot design). Amounts of irrigation water and N-fertiliser for the optimised treatment are shown in Table 2.

Factor	Treatment
1. Irrigation Main plot Plot size: 70 m*50 m	1. Suboptimal irrigation: sprinkler system 2. Traditional irrigation: controlled basin irrigation 3. Optimised irrigation: sprinkler system with modulation*
2. Straw-Residues Sub-plot Plot size: 60 m * 15 m	1. Straw is removed from the field 2. Straw remains on the field
3. N-fertilisation Sub-sub-plot Plot size: 20 m * 15 m	1. Control: no N-fertilisation 2. Traditional N-fertilisation: 600 kg ha^{-1} a^{-1} 3. Optimised N-fertilisation: according to N_{min} content in the soil

*Optimised irrigation was done according to plant available soil water content. (Threshold values 45-80 % plant available soil water content).

Table 2: Amounts of irrigation water and N-fertiliser. Means over four replicates and two straw treatments. (For factors and treatments see Table 1).

Crop and Year	Pre-cipi-tation [mm]	Irrigation [mm] and fertilisation [kg N ha^{-1}]	Suboptimal irrigation			Traditional irrigation			Optimised irrigation		
			Cont. fertilisation	Trad.	Opt.	Cont. fertilisation	Trad.	Opt.	Cont. fertilisation	Trad.	Opt.
Winter wheat 1999/2000	69	Irrigation	184	184	184	330	330	330	319	319	319
		Fertilisation	0	300	25	0	300	59	0	300	86
Summer maize 2000	353	Irrigation	0	0	0	0	0	0	0	0	0
		Fertilisation	0	300	45	0	300	31	0	300	32
Winter wheat 2000/2001	132	Irrigation	236	236	236	384	384	384	310	310	310
		Fertilisation	0	300	45	0	300	63	0	300	84
Summer maize 2001	240	Irrigation	37	37	37	37	37	37	37	37	37
		Fertilisation	0	300	65	0	300	68	0	300	68

Result and Discussion

The results (Table 3) show that zero N-fertilisation resulted in significantly lower yields than the traditional and optimised treatments (except for summer maize 2000). For the irrigation treatments, the suboptimal irrigation treatment resulted in significantly lower yield, compared to the traditional and optimised irrigation. The optimised and traditional irrigation strategies had no significant effect on yields. The reason is that winter wheat 2001 was highly infected with aphids during milking stage, so it could not fully develop its genetic yield potential. A similar problem was observed in summer maize 2000, which was highly infected with Asian Maize and Spotted Stem Borer, so that the differences between the treatments were blurred. Whether straw was removed or remained in the field was irrelevant for wheat and maize yields.

Table 3: Dry matter grain yield (t ha^{-1}) for the years 2000 and 2001 (*MSD = minimum significant difference, $\alpha = 0.05$).

Factor	n	Winter wheat 1999/2000 Mean	Sig.	Summer maize 2000 Mean	Sig.	Sum of 1999/2000 Sum	Winter wheat 2000/2001 Mean	Sig.	Summer maize 2001 Mean	Sig.	Sum of 2000/2001 Sum
Irrigation											
Suboptimal	24	4.18	b	4.86	a	9.40	3.56	b	6.47	a	10.03
Traditional	24	5.40	a	4.86	a	10.26	4.13	a	6.76	a	10.89
Optimised	24	5.45	a	4.81	a	10.26	4.26	a	6.72	a	10.98
MSD		0.505		0.268			0.356		1.054		
Straw											
Without	36	4.95	a	4.78	a	9.73	3.98	a	6.53	a	10.51
With	36	5.07	a	4.91	a	9.98	3.98	a	6.77	a	10.71
MSD		0.236		0.265			0.097		0.251		
Fertilisation											
Control	24	4.69	b	4.90	a	9.60	3.65	b	6.26	b	9.90
Traditional	24	5.17	a	4.84	a	10.01	4.05	a	6.84	a	10.90
Optimised	24	5.18	a	4.78	a	9.95	4.25	a	6.84	a	10.19
MSD		0.203		0.278			0.22		0.419		

Conclusion

Under the experimental conditions it was possible to achieve the same grain yield with only a quarter of the traditional fertiliser amount. This implied nitrogen fertilization taking into account the N_{min} content of the soil.

Despite the problems in pest management, results of the experiment show that it is possible to get the same yield of winter wheat with an amount of irrigation water that is 20% below the traditionally applied one.

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SEASONAL GROWTH RATE AND PRODUCTION OF A MIXED SWARD IN THE NORTHEASTERN PLAIN OF ITALY

M. Carlassare, U. Ziliotto
Dipartimento di Agronomia ambientale e Produzioni vegetali dell'Università degli Studi di Padova, Agripolis, Strada Romea, 16-35020 Legnaro (PD) Italy.

Introduction

Agro-environmental measures in the current Common Agricultural Policy encourage the adoption of low-input agricultural practices that would reduce the impact of farming on the environment. The Regulation (EEC) No 2078/92 implements a financial support for the conversion of arable land into low-intensity pasture as one of the alternatives to intensive livestock systems. In this experiment, we studied the potential production and seasonal growth rate of a mixed pasture sward established on an area previously managed as arable land.

Materials and Methods

The experiment was conducted on a mixed pasture established the 14 March 1994 at the Research Farm of the University of Padova in Legnaro (8 m a.s.l.; 12,2° C average temperature; 824 mm annual precipitation). In 1995 and 1996, we studied the sward seasonal growth rate according to the Corrall-Fenlon method (1978). In the spring of both years, pasture botanical composition was determined from herbage samples harvested immediately before the first grazing cycle that began when 10 % of *Taraxacum officinale* Weber plants in the pasture were flowering.

Each year, we chose in the pasture a representative area where we set out two replicate blocks with four randomized plots (1m x 5m) that corresponded to four weekly scattered initial harvest dates. Each plot was mechanically harvested every 28 days at 2 cm from soil level. In agreement with Regulation No 2078/92, the pasture did not receive any fertilizer and irrigation input during the experimental period. Seasonal production curves were calculated following the procedure indicated by Corrall and Fenlon (1978). In addition, the monthly yields of plots harvested at the four initial dates were analyzed to study the dry matter production as if the pasture were rotationally grazed with four paddocks. These data were analyzed with GLM of SAS as a split block design, with time as the whole plot and initial harvest dates as sub plots.

Results

Major species in the sward were *Dactlylis glomerata* L., *Festuca arundinacea* L., and *Trifolium pratense* L.. In the spring of 1995, grasses and legumes in the sward produced 32% and 54% of the total green dry matter respectively; in 1996, grasses were 82% and legumes 3 % of the green dry matter. In 1995, sward growth rate exhibited a first period of fast growth in the spring, and a second and higher peak of productivity in June (Figure 1). In 1996, sward growth peaked at the

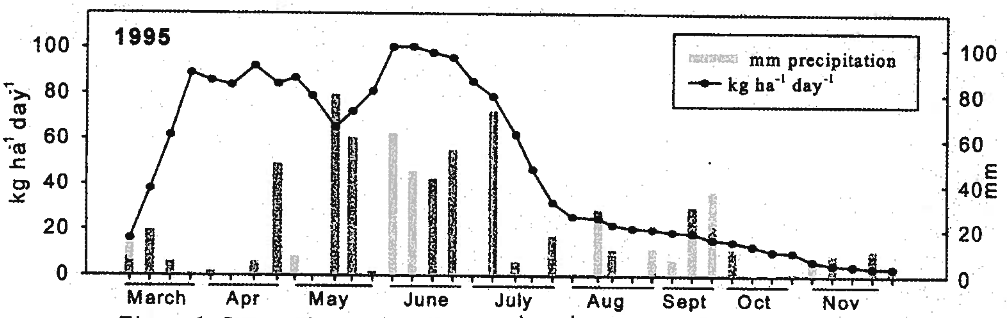

Figure 1. Seasonal growth rate (kg ha^{-1}day^{-1}) of the mixed sward, and weekly precipitation (mm) in 1995

end of April-beginning of May and remained below 40 kg ha^{-1} day^{-1} from June on (Figure 2).

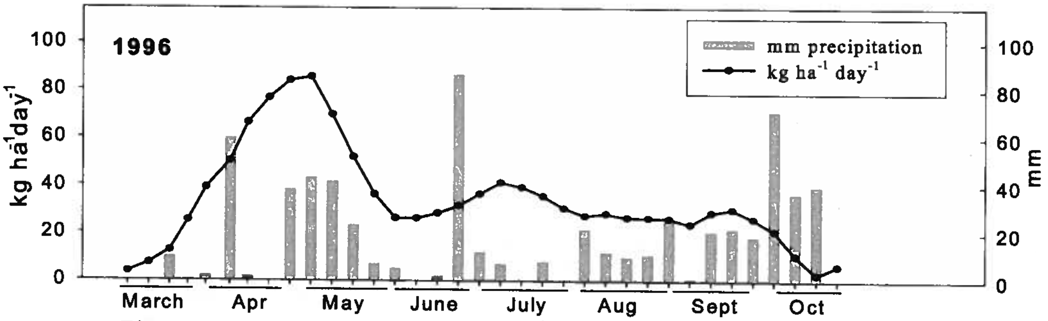

Figure 2. Seasonal growth rate (kg ha^{-1} day^{-1}) of the mixed sward, and weekly precipitation (mm) in 1996

Date of initial harvest did not influence total dry matter production, but changed its seasonal distribution over the growing season. We report in Figure 3 yield data of plots initially harvested in the spring the last week of March (week 1) or the third week of April (week 4). Early initial harvest dates lead to a more uniform distribution of yields compared to late initial harvest dates, particularly in spring and early summer. In 1995, total dry matter productions were on average 13,1 t ha^{-1}; these values were similar to the ones measured with the Corrall and Fenlon procedure in N-W of Italy on cool season swards kept under no limiting nitrogen and water conditions (Grignani, 1991). In 1996, annual dry matter productions decreased on average by 37% compared to the previous year.

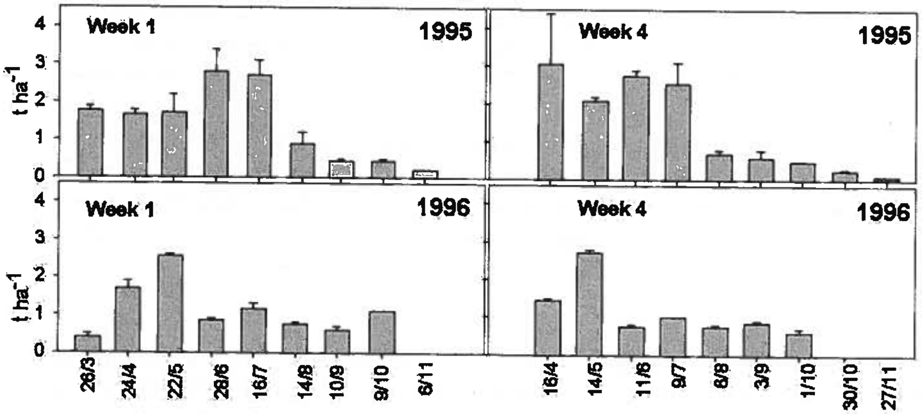

Figure 3. monthly dry matter production (t ha^{-1})of plots harvested the first time in the spring at the end of March (week 1) or the third week of April (week 4)

Conclusions

Changes in botanical composition and precipitation pattern during the two years of the trial influenced seasonal production curves and total dry matter production. Variability of herbage dry matter production during the growing season was reduced when we anticipated the first initial harvest date in the spring.

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INFLUENCE OF DIFFERENT TILLAGE SYSTEMS AND CROP ROTATIONS IN SEMIARID SPAIN ON WEED POPULATION

Catalán G. [1], Hervella A. [1], de Andrés EF [1], Esteban E. [2], Tenorio JL [1]

[1] INIA. Dto. de Medio Ambiente. Apdo. 1045. 28800 Alcalá de Henares. Madrid. España
[2] Dpto. de Química Agrícola. UAM. Crta. Colmenar Km 15 Cantoblanco. 28049 Madrid. España

Introduction

One of the more important factors in a crop is the weed population as it can compete with the crop for the same resources, naturals or not. Because of that, in this work we have studied the influence of three tillage systems and three crop rotations in the semiarid Spain on weed evolution. Also we have studied the effects of the postemergence herbicide used for barley on the weed population of these tillage systems and crop rotations.

Methods

The trials started at INIA's experimental farm "La Canaleja" in central Spain (Alcala de Henares, Madrid) in 1994. Soil type is a *Calciorthidic Haploxeralf*, average annual rainfall is 470 mm and altitude reaches 610 m.a.s.l.
Three tillage systems have been compared (CT: conventional tillage, MT: minimum tillage, NT: no tillage) and three crop rotations (BB: barley-barley, FB: fallow-barley, VF: vetch-barley) in a block design, being the principal treatment the tillage system, with four replicates. The influence of the herbicide has been tested dividing the plots in two new treatments (NH: without herbicide, H: with herbicide). The herbicide application was 2,5 l/ha of brioxil (IOXINIL 7,5% + MECOPROP 37,5% + BROXINIL 7,5%) and it has been applied when the barley was evolving from tillering to shooting.

The study of weed evolution was done in 2000/2001 campaign. Samples of the weeds were taken in three samplings, 1st sampling: 3rd week of march (between tillering and shooting of the barley), 2nd sampling: 2nd week of april (between shooting and earing of the barley), 3rd sampling: 3rd week of may (between earing and harvesting of the barley). In the three cases, an area of 0.225 x 0.5 m^2 was sampled. Later, the number of individuals (IND), the number of species (SPE), and biomass production of weed (BMS) were evaluated in the laboratory, all of them were identified later. Data were analysed using GLM procedures included in the SAS statistical package (SAS Institute Inc. 1988). Significant differences between means were estimated using Duncan's Multiple Range Test P = 5%. (Duncan. 1955)

Results

For the 1st sampling results showed that the IND, the SPE and the BMS depended on herbicide aplicattion fundamentally, while the tilling system is not significant and there is a little signification in the crop rotation employed for the IND and BMS (table 1)

For the 2nd sampling the BMS, the SPE and the IND depended on herbicide application fundamentally. IND was affected for all the treatments (tilling system, crop rotation and herbicide application). BMS presents also different values for the crop rotation employed (table 1).

For the 3rd sampling both herbicide application and crop rotation were significant for all the variables studied. Also for BMS the interaction between the tillage system and the crop rotation and between the crop rotation and herbicide application are significant. For IND, there is significant interaction between the tilling system and the crop rotation (table 1).

Table 1:Effects of the tillage system (T) the crop rotation (C) and the herbicide application (H) on weeds. Analysis of variance for the individual number (IND), species number (SPE) and biomass production in g (BMS).

	DF	1st SAMPLING			2nd SAMPLING			3rd SAMPLING		
		IND	SPE	BMS	IND	SPE	BMS	IND	SPE	BMS
T	2	ns	ns	ns	**	Ns	ns	**	ns	**
C	2	*	ns	*	***	Ns	**	***	***	***
H	1	***	***	***	***	***	***	***	***	***
T x C	4	ns	ns	ns	ns	Ns	ns	**	ns	***
T x H	2	ns	ns	ns	ns	Ns	ns	ns	ns	ns
C X H	2	ns	ns	ns	ns	Ns	ns	ns	ns	**
T x C x H	4	ns	ns	ns	ns	Ns	ns	ns	ns	ns
Error	71									
R-Square		0.58	0.48	0.55	0.57	0.56	0.37	0.60	0.62	0.72

* Significant at the 0.05 level ** Significant at the 0.01 level *** Significant at the 0.001 level

Conclusions

In our trial conditions the herbicide aplication is fundamental in the control of weeds, for all the tilling systems. This application is more important in minimum and no tillage because these tillage systems have no other weed control. For this reason it is important to carry out a weed control by the appropriate crop rotations to control the progresive increase of weeds that the consecutive implantation years of the conservation tillages involve (Liebman and Davis 2000)

Barley monoculture has pernicius results in the weed population. There are not evident differences in the weed control between fallow barley rotation and the vetch barley rotation.

Acknowledgements

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ENERGY BALANCE OF FOUR FARMING SYSTEMS IN NORTH-EASTERN ITALY

P. Ceccon and F. Danuso
Dipartimento di Produzione Vegetale e Tecnologie Agrarie, Università di Udine, via delle Scienze 208, 33100 Udine, Italy

Introduction

The assessment of farming system (FS) sustainability should be performed under a broad perspective, where crop yield and environmental impact are but incomplete indicators. The energy analysis was developed during the 70's as related to the oil crisis and was also applied in FS evaluation (e.g. Refsgaard et al., 1998). Reserches considered both the gross energy requirement method, which takes into account only the energy flow of non-renewable sources applied at the farm level together with the energy incorporated into commodities (Jones, 1989), and the analysis of non-renewable sources use, which is preferred when the abatement of excess energy use should be pursued (Pimentel and Heichel, 1991).

Methods

A field experiment was established in 1993 in Palazzolo dello Stella (45° 85' N, 13° 05' E), in the coastal side of Friuli-Venezia Giulia alluvial plain. The experimental units simulate cases of different models of agriculture for North-Eastern Italy, where low input FS – with a high share of meadows and poor requirements in agricultural requisites –could be preferred in a next future to the currently widespread high input FS. Four FS are compared in a 12 ha area: i) low input permanent meadow, using only farmyard manure without agrochemicals (PM); ii) high input, two-year crop rotation (silage maize – italian ryegrass + soybean as catch crop), using both farmyard slurry, mineral fertilizers, and agrochemicals as required (2Y); iii) intermediate input, four-year crop rotation (silage maize – winter wheat – alfalfa – alfalfa), using farmyard manure, mineral fertilizers, and agrochemicals as required (4Y); iv) high input, five-year cash crop rotation (grain maize – soybean – grain maize – winter wheat – sugarbeet), using mineral fertilizers and agrochemicals as required (5Y).

FS have been compared according to an energy balance sheet. The gross energy method has been used for the determination of the energy inputs (AA.VV., 1989), taking into account only the fossil energy sources directly or indirectly used in crop production, while both renewable sources and human labor are not considered. On the output side of the balance sheet, energy conversion rates suggested by Pimentel (1980) for commodities were considered. When buried after harvest, crop residues were accounted for a null input-output energy balance.

Results

On the average of the 1993-99 period, the rank of FS' energy use was 2Y > 5Y > PM > 4Y, ranging from more than 20 GJ ha^{-1} $year^{-1}$ to less than 30 GJ ha^{-1} $year^{-1}$. Among single crops, maize (33.5 to 36 GJ ha^{-1} $year^{-1}$) and sugarbeet (about 29 GJ ha^{-1} $year^{-1}$) used the highest amounts of energy, while soybean and wheat showed significantly lower values (16 to 18 GJ ha^{-1} $year^{-1}$). The share of maize on energy input of the whole crop rotation was never lower than 50% (4Y), but in 2Y it was close to 60%. On the average of FS, machinery and fertilizers accounted at least for 75% of total energy use, where seeds and agrochemicals represented less than 5%. Fertilizers represented the most relevant energy input in 2Y, 4Y, and 5Y FS, while machinery was in PM. Machinery significantly contributed to the total use of energy mainly in hay crops, whereas fertilizers were highly impactive in cereals, and irrigation in soybean. Most of machinery was spent for harvest (mowing, as well as hay raking and conditioning) in PM or in red clover, alfalfa, and sugarbeet in the other FS. The other crops had much larger energy requirements for tillage and fertilization: roughly 50% of machinery energy use was spent for tillage by maize, soybean (as a main crop), and wheat. On the average of the rotational FS, tillage was therefore the most relevant item in machinery energy use, while the cost of energy for fertilization exceeded the cost for harvest only in 2Y. Among fertilizers, nitrogen accounted for at least 75% of total energy requirements in all FS, where phosphorus contributed by roughly

10% and potassium by 5%. Phosphorus and potassium indeed represented a larger percentage of fertilizer requirements in PM and in legumes.

Farming system / Crop	Energy Input ($GJ\ ha^{-1}\ year^{-1}$)	Energy Output ($GJ\ ha^{-1}\ year^{-1}$)	Net Energy ($GJ\ ha^{-1}\ year^{-1}$)	Energy Efficiency
PM	23.6	134.5	110.9	5.70
2Y Italian ryegrass	14.3	70.1	55.8	4.89
Soybean	9.9	59.6	49.7	6.00
Silage maize	34.4	283.6	249.2	8.24
average	29.3	206.7	177.4	7.04
4Y Silage maize	33.5	277.4	243.9	8.27
Winter wheat	18.3	56.1	37.8	3.07
Alfalfa	16.3	73.4	57.1	4.51
average	20.7	123.9	103.2	5.98
5Y Grain maize (after sb)	36.1	187.1	151.0	5.18
Soybean	16.7	71.6	54.9	4.29
Grain maize (after so)	36.1	189.2	153.1	5.24
Winter wheat	16.2	64.8	48.6	4.00
Sugarbeet	29.2	125.6	96.4	4.30
average	26.9	127.7	100.8	4.75

The table resumes the main variables of the input/output balance sheet. On the average of the seven-year trial, PM, 4Y, and 5Y FS produced similar amounts of energy, while 2Y showed a much larger energy output. FS' output mainly depends on single crop output, where silage maize by far produced the highest amounts of energy as compared to the other crops. The energy efficiency shows a similar variability among FS, as the most efficient (2Y) was about 50% higher than the less efficient (5Y) value. Some crops grown under different FS had a rather different energy efficiency: this is the case of soybean and wheat, the former better using resources when grown as a catch crop, the latter more efficient in 5Y.

Conclusions

Owing to the intrinsic stability of FS, research on these topics typically requires large-scale and long-term experiments. Data discussed in the present paper might be considered as representative of transient states of the systems; nevertheless, some remarks can be pointed out:

- the yearly-averaged use of energy by FS ranged over a large span, maize crop representing at least 50% of total energy use; machinery and fertilizers roughly accounted for 75% of total energy use;
- both net energy and energy efficiency evaluated on a whole FS basis emphasize large differences among the models of agriculture under comparison; energy efficiency seemed mainly correlated with system outputs, among which the total system nitrogen offtake.

The energy analysis provides powerful information on FS properties. However, integration of data from different sources by a common tool is nowadays required in order to add value to the findings of conventional experiments. The application of LCA and dedicated multicriteria analysis tools to FS research can provide opportunities in selecting sustainable agronomic strategies under a broader perspective.

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PREDICTING WHEAT GRAIN NUMBER FROM NITROGEN AND PHOSPHORUS NUTRITION INDEXES IN LOW INPUT CROPPING SYSTEMS.

Colomb B.[1], Duru M.[1], Jeuffroy M.H.[2]
1 INRA Agronomie. BP 27 Auzeville. 31326 F. Castanet-Tolosan. – colomb@toulouse.inra.fr
2 Unité Mixte de Recherche INRA INA-PG. BP 01. 78850 Thiverval-Grignon, France.

Introduction

In low nitrogen input cropping systems, it is widely established that wheat yields largely depend on grain number per unit area. Jeuffroy et al. (1999) improved our ability to assess the relative grain number (RGN) for wheat in various environmental conditions with N as the main limiting factor. The recognized role of phosphorus as a triggering factor of water eutrophication and the increasing costs of industrial P fertilisers during the last decade have drastically reduced P consumption in conventional agriculture. Consequently, cropping situations subjected to both N and P limitations are likely to occur in Western Europe. The aim of this work was to test our ability to assess RGN on wheat from N and P deficiency indexes, in situations characterized by simultaneous N and P deficiencies.

Methods

Table 1: Dates and amounts (kg N ha^{-1}) of N applications on each P treatment.

Date :	2/6/01	2/20/01	4/20/01
Day after Sowing :	91	105	164
N1	25	50	0
N2	25	50	40
N3	25	115	0
N4	25	115	40

The study was carried out in 2000-2001 at the INRA Toulouse Research Center (43.5° N, 1.43°E) on a long-term P experiment presented in Colomb et al., 2000. Since 1968, P treatments were P0 (no P), P1 (17.5 or 11 kg P ha^{-1} yr^{-1}, depending on year), P2 (35 or 22 kg P ha^{-1} yr^{-1}) and P4 (70, 33 or 22 kg P ha^{-1} yr^{-1}). In 1999, mean P concentrations in soil solution were 23, 49, 87, 378 µg P L^{-1} in the four P treatments respectively. Wheat cultivar Soissons was sown on November 7, 2000 and harvested on July 4, 2001. On each P treatment, we aimed at creating various crop N status ranging from very deficient to sub-optimal with different N-NH_4NO_3 application rates (Table 1), leading to 16 experimental treatments (2 repetitions for each treatment) varying in both P and N nutrition. Nitrogen deficiency was characterised using an index (DNNI) derived from the index proposed by Jeuffroy & Bouchard (1999), and based on the nitrogen nutrition index (NNI) calculated according to Lemaire & Gastal (1997). The index DNNI is calculated as the area delimited by a NNI threshold and the time-course curve of NNI, when it is lower than the threshold during the period between the beginning of stem elongation and anthesis. A phosphorus index (DPNI) was calculated following the same principles, based on the time-course of the instantaneous index (PNI) proposed by Duru & Thelier-Huche (1995) for grasses. In a first step, the decrease of RGN was analysed as a linear function of DNNI for non P deficient plots, with a leave-one-out cross validation method to determine the NNI threshold giving the best RGN prediction. Then the gap (ERGN) between the estimated RGN from DNNI and the observed RGN for the P deficient plots was analysed as a linear function of DPNI, using a leave-one-out cross validation method to find out the PNI threshold and the period of calculation giving the best RGN prediction. In a third step, the relationship between RGN and both nutrient indexes was analysed.

Results :

Wheat yield was highly related to grain number per unit area (Fig 1). Thousand grain weight did not significantly differ among treatments (average=35 g). The reduction in grain number was mainly accounted for by low spike fertility in case of N deficiencies, and by low spike numbers for P deficiencies. A close linear relationship between RGN and DNNI was observed. The most explicative NNI threshold was 0.8 ($r^2 = 0.89$, RMSEp = 0.033).

Table 2 : Yields & yields components for N & P treatments (mean separation with Bonferroni's test)

Yield Components	N Treatments				P Treatments			
	N1	N2	N3	N4	P0	P1	P2	P4
Yield (g. m^{-2})	400 a	503 bc	462 ab	556 bc	414 a	482 b	510 b	515 b
Grain m^{-2}	11370 a	14037 b	13461 b	15979 c	11651 a	14093 b	14650 b	14454 b
Spike m^{-2}	442 a	476 a	473 a	491 a	413 a	489 b	484 b	496 b
Grain $spike^{-1}$	26.3 a	28.5 ab	30 ab	32 b	28.6 a	29.0 a	29.4 a	29.9a

Phosphorus deficiency affected grain number set up at an early stage through reduction of the number of ears produced per m². The gap ERGN, calculated from the equation given on fig.2, was closely linked to DPNI, calculated over the period between the onset of stem elongation and heading (Fig 3). The most explicative PNI threshold was 0.625 (r^2 =0.68 , RMSE of prediction = 0.048). The final regression based on both deficiency indexes [RGN = 0.93 - 0.0018 DNNI – 0.0022 DPNI] accounted for 87% of the variability in RGN (Fig 4).

Fig.1 - Wheat grain yield vs grain number m^{-2}

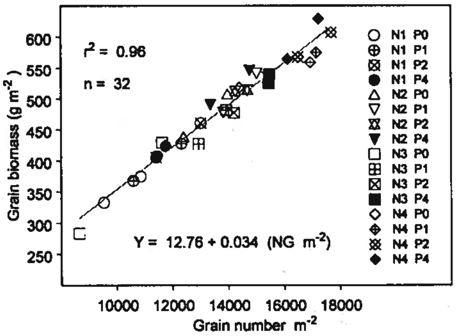


Fig.2 - Relative Grain Number vs Deficiency Nitrogen Nutrition Index

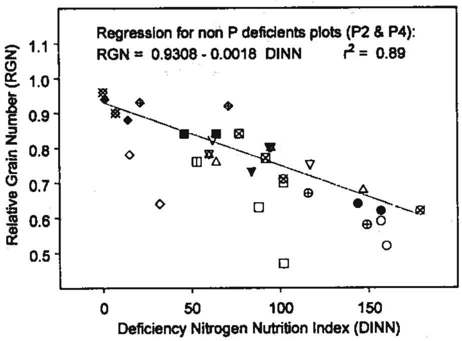


Fig.3 - (Predicted RGN from DINN - observed RGN) vs Deficiency P Index

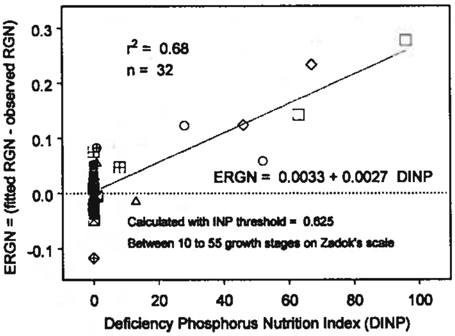
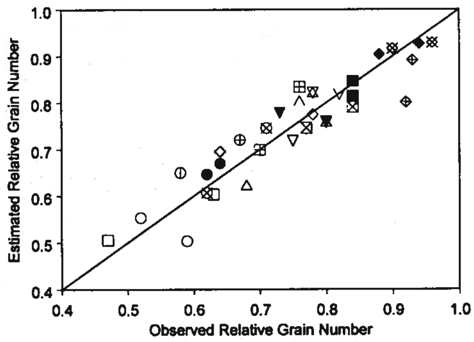


Fig.4 - Predicted RGN from DINN & DINP vs observed RGN



Conclusions

In cropping situations suffering from restricted N and P resources, it is possible to predict wheat RGN predicted from the proposed integrated N and P indexes, representing the nutrient status of the plant over the period of grain number formation. Nevertheless, the DPNI index could probably be improved, by estimating a specific curve of critical P concentration during the vegetative period for wheat instead of using the curve calibrated for grasses.

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SYSTEMATIC GENERATION AND EVALUATION OF CROP ROTATIONS

S. Dogliotti[a, b, c], W.A.H. Rossing[b], M.K. van Ittersum[c]
[a]Facultad de Agronomía, Av. Garzón 809, CP 12900, Montevideo, Uruguay.
[b] Group Biological Farming Systems, Wageningen University, Marijkeweg 22, 6709 PG Wageningen, The Netherlands.
[c] Group Plant Production Systems, Wageningen University, Haarweg 333, P.O. Box 430, 6700 AK Wageningen, The Netherlands.

Introduction

Crop rotation plays a central role in the development of sustainable farming systems. This is because the yielding ability of each crop and the quantity and type of inputs required to realise a given yield level depend not only on the management of each crop, but also on the long term effects of the crop rotation on soil fertility and health. In principle, all crops that may be grown in a particular production environment can be combined into numerous cropping sequences. Not all of these combinations are agronomically feasible, but even the total number of feasible combinations may be huge. Expert knowledge is often invoked to select a subset of rotations, but this inherently introduces arbitrariness and the risk of overlooking important alternatives. This paper addresses the problem of how to generate crop rotations in a transparent manner. The method is made operational in a software tool called ROTAT. Method and tool are applied to a case study from the Netherlands.

Methods

ROTAT combines crops from a predefined list to generate all possible different rotations. The maximum number of rotations is limited through a number of filters or rules controlled by the user. The filters eliminate, during early stages of generation, those crop successions that do not make sense from an agronomic point of view and that are, for farm-specific reasons, not practical or desirable. They are based on expert knowledge capturing the timing of the crop growth periods in the growing season, restrictions on agronomically undesirable sequences and crop frequencies, and restrictions on the complexity of the rotation. The user can parameterise ROTAT for any situation by controlling these filters through input parameters that describe timing constraints, sequence and frequency constraints and farm-specific feasibility and applicability. To illustrate the potential contribution of ROTAT to the process of designing crop rotations, we used a case study in Flevoland (The Netherlands), reported by Vereijken (1997). Based on the same crop list as 'pilot farm n° 6', we generated all possible crop rotations for this farm. We used rules identical to those used by Vereijken (1997). The maximum rotation length was set to 12 years, the maximum average frequency of each crop in the rotation was set to 1:6 years and the minimum time period before repeating cultivation of a crop was set to 6 years. The share per crop group was limited to a maximum of 1:3 years. The model was forced to schedule crops with a beneficial effect on soil structure after crops with a detrimental effect and to select successive crops from different groups. In contrast to Vereijken (1997), we used gross margin of the rotation per ha per year and labour requirement per ha per year to evaluate and compare the crop rotations once they were created, while he used a heuristic approach by selecting the most profitable crop first. We used the same semi-quantitative ratings as Vereijken (1997) to evaluate the effect of crop rotation on soil cover, soil structure and N need. Rotations generated by ROTAT were evaluated by calculating average values per ha per year for all characteristics (i.e. frequencies of crop species and groups, soil cover and structure, N need, gross margin and labour) using a spread-sheet program.

Results

ROTAT generated 840 rotations based on the list of crops and design rules used by Vereijken (1997). From these, 12 rotations showed the same performance in soil cover, soil structure and N need and better results for gross margin and labour than the one implemented on pilot farm n° 6 (being the result of the prototyping approach - Table 1). If a poorer value in soil cover is accepted, we can choose from 12 rotations with better values for soil structure, N need, gross margin and labour. Compared to the rotation on pilot farm n° 6, 24 rotations performed better in N need and gross margin while being equal in soil cover and soil structure, and worse in labour.

Table 1. Performance, compared to pilot farm n° 6 and in absolute terms, number of rotations and example for subsets of rotations selected from the total of 840 crop rotations generated by ROTAT. Performance compared to pilot farm n° 6 is indicated as equal (=), poorer (-) or better (+). Cover, structure and N need are rated in a qualitative fashion, with a low value meaning poor cover, poor structure and low N need and vice versa.

Performance compared to pilot farm n° 6		Number of rotations	Example	Cover	Structure	N need	Gross margin ($\varepsilon.ha^{-1}.yr^{-1}$)	Labour ($h.ha^{-1}.yr^{-1}$)
soil cover soil structure N need gross margin labour	= = = = =	72	Carrot-Pea-Potato-Grassclover-Onion-Wheat-SugBeet-Pea-Potato-Grassclover-Celeriac-Wheat	-1.83	-0.167	1.75	3,842	134
soil cover soil structure N need gross margin labour	= = = + +	12	Carrot-Grassclover-Potato-Wheat-Onion-Pea/bean-Carrot-Grassclover-SugBeet-Wheat-Potato- Pea/bean	-1.83	-0.167	1.75	4,334	113
soil cover soil structure N need gross margin labour	- + + + +	12	Carrot-Wheat-Potato-Grassclover-Onion-Pea/bean	-2.00	0.000	1.67	4,862	114
soil cover soil structure N need gross margin labour	= = + + -	24	Carrot-Grassclover-Potato-Wheat-Celeriac-Pea/bean-Carrot-Grassclover-Onion-Wheat-Potato- Pea/bean	-1.83	-0.167	1.67	4,587	158

Conclusions

The results demonstrate the usefulness of ROTAT for generating large numbers of theoretical rotations based on existing knowledge before further evaluating and subsequently testing them in practice. ROTAT may be used as a stand alone tool in farming systems design processes and as an instrument in explorative land use studies that use Linear Programming. Information requirement for evaluation in a more comprehensive case study would involve inputs such as labour, machinery, fertilisers and pesticides, as well as, desired and undesired outputs such as crop yields, gross margin, soil erosion and emissions to the environment. Data from the application of ROTAT combined with quantitative evaluation tools in a explorative land use study for sustainable farming systems in southern Uruguay will be presented.

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SOIL N-NITRATE EVOLUTION FOR RAINFED WHEAT IN NORTHEAST OF CATALONIA (SPAIN)

Domingo F. [1], **Serra J.** [1], **Teixidor N.** [2]

1 IRTA-Estació Experimental Agrícola Mas Badia, Mas Badia, E-17134 La Tallada d'Empordà, Girona (Spain)
2 Servei de Producció Agrícola, Subd. General d'Agricultura, DARP, Generalitat de Catalunya

Introduction

The area of study, where wheat is widely cropped, has a large climatic variability. So, three main agro-climatic areas have been defined: i) 'Mediterranean Coast' (MC) with hot and dry spring and warm and wet weather during winter, ii) 'Inland' (I) area with cold and wet winters and warm and wet springs, and iii) 'Medium Inland' (MI) with intermediate meteorological characteristics. Some parts of these areas have been considered as vulnerable zones for nitrate pollution. So, especial management must be carried out in order to improve N efficiency. Soil organic matter can be an important contribution to nitrogen crop nutrition. Leaching due to winter precipitation can produce considerable losses of soil N-nitrate. This work studies the evolution of N-nitrate in soil for a rainfed wheat crop on the three agro-climatic zones defined above.

Methods

Six field experiments (two in each agro-climatic area; one each year 2000 and 2001) were carried out for wheat (*Triticum aestivum* var: Soissons). A randomised block design with 4 replicates and 4 treatments was used in all experiments. Treatments consisted on different N application rates (0, 40, 80 and 120 Kg N ha^{-1}) applied at late winter as ammonium nitrate.

Soil in each experiment was sampled (0-30, 30-60 and 60-90 cm) prior to seeding, at late winter prior to fertiliser application and at harvest. $N\text{-}NO_3^-$ soil content was determined by soil extraction with water (1:1) and ulterior analysis of the extract by colorimetry. At harvest, grain yield, straw production and N extracted by plant were determined. N-leached during winter was estimated being the difference between $N\text{-}NO_3^-$ soil content at late winter and before seeding for treatment where 0 Kg N ha^{-1} were applied (T0). Soil contribution to N crop nutrition was calculated as the addition of N extracted by the crop, N leached during winter and the increase of soil $N\text{-}NO_3^-$ between harvest and seeding for the same T0 treatment.

Results

Wheat yield (Table 1) did not increase ($p<0.001$) with increasing N fertilisation rates for any of the experiments carried out. In each agro-climatic area, there were large differences between years for grain yield. These were related to weather conditions, mainly rainfall, occurred over the cropping season.

Area	*Year*	Treatment (N rate; Kg N ha^{-1})			
		0	***40***	***80***	***120***
Mediterranean Coast	*2000*	8916	8649	8886	9267
	2001	5867	5941	5677	5085
Medium Inland	*2000*	3152	3174	3439	3303
	2001	6222	5848	6107	5696
Inland	*2000*	8988	9247	9177	8965
	2001	7142	7059	7055	6730

Table 1. Average grain yield (Kg N ha^{-1}) for different N application rates at late winter, different years and areas in the Northeast of Catalonia on a rainfed wheat crop.

N-nitrate soil content (Table 2) at seeding was high for all sites, although quite variable between years for MI experiments. Those in Inland area were the ones where this value was higher. In all cases, the amount of N-nitrate in that moment was higher than N uptake by the crop at harvest. Soil organic matter content was higher at Inland experiments (Depth 0-30 cm: 1.85 % and 2.10 %; Depth 30-60 cm: 1.25 % and 1.21 %; Depth 60-90 cm: 1.17 % and 2.10 % for years 2000 and 2001 respectively) than at MC (Depth 0-30 cm: 1.83 % and 1.30 %; Depth 30-60 cm: 1.14 % and 1.01 %; Depth 60-90 cm: 0.34 % and 0.80 % for years 2000 and 2001 respectively) and MI (Depth 0-30 cm: 0.99 % and 0.70 %; Depth 30-60 cm: 0.90 % and 0.61 %; Depth 60-90 cm: 0.28 % and 0.31 % for years 2000 and 2001 respectively) ones. Soil organic matter mineralization could explain those high values for N-nitrate soil content (Stevenson, 1982).

Area	*Year*	*Average yield (Kg ha^{-1})*	*Crop N uptake (Kg N ha^{-1})*	*N-NO_3^- at seeding (Kg ha^{-1})*	*Winter rainfall (L m^{-2})*	*Winter N-leaching (Kg N ha^{-1})*	*Soil N contribution (Kg N ha^{-1})*
Mediterranean Coast	*2000*	8930	166	161	148	81	212
	2001	5643	180	205	318	168	309
Medium Inland	*2000*	3267	88	109	123	47	74
	2001	5968	133	317	271	269	193
Inland	*2000*	9094	243	268	53	88	102
	2001	6997	133	370	155	0	163

Table 2. Experiment average yield and Winter rainfall and different N related measurements for treatment without N application, for different years and areas in the Northeast of Catalonia on a rainfed wheat crop.

Nitrate leaching contributes (Addiscott *et al.*, 1991) to groundwater pollution. Winter rainfall, from November to February, was high at MC and MI areas during year 2001. In these sites was where the highest winter N-nitrate leaching occurred (Table 2). For MI-2001, N leached accounted for twice N crop uptake at harvest.

Contribution of soil to N crop nutrition (Table 2) is quite important for all sites (from 42 % till 171 % of crop N uptake). Figures for MC area are the highest ones although soil organic matter content was higher for Inland area. Warmer weather over the cropping season for MC area can produce a higher mineralization rate on these sites than on Inland ones where soil organic matter content was even higher than for MC area. Nevertheless, these figures are higher than those suggested by other authors (Stanford and Smith, 1972).

Conclusions

The amount of mineral N present at the soil at seeding for a wheat crop is higher than crop N uptake for all sites. N-nitrate leaching is very important when winter rainfall is very high (winter 2001 for MC and MI areas, in this paper). Contribution of soil to N crop nutrition is significant (at least 42 % of crop N uptake), specially at MC area (150 % of crop N uptake on average). Under these conditions, there is no effect of N fertilization on grain yield for rainfed wheat.

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ARE CATCH CROPS AN EFFICIENT WAY TO PREVENT NITRATE LEACHING AND FAVOUR NITROGEN AVAILABILITY FOR THE NEXT MAIN CROP IN THE CASE OF ORGANIC PRODUCT APPLICATION IN SUMMER?

Dorsainvil F. [1,2], **Thiébeau P.** [1] **and Justes E.** [1,3]

1 INRA, Unité d'Agronomie Laon-Reims-Mons, BP 224, 51686 Reims, Cedex 2, France
2 Present address: Faculté d'Agronomie et de Médecine Vétérinaire, BP 1441, Port-au-Prince, Haïti
3 Present address: INRA, Unité d'Agronomie, BP 27, 31326 Castanet-Tolosan Cedex, France

Introduction

In farming systems where nitrogen is in excess, farmers often spread organic products (manure, liquid waste, sewage sludge, organic product like vinasse) in their fields during summer in order to recycle nitrogen and other elements. The control of nitrogen in the soil during the fallow period between two main cash crops is then necessary to reduce the nitrate concentration in the drained water in temperate climates. The efficiency of catch crops in preventing nitrate pollution has been widely demonstrated in the absence of organic-N application (e.g. Meisinger *et al.*, 1991). The potential of N uptake by catch crops like white mustard can be large ($\geq$ 300 kg N.ha^{-1}) for the emergence period 15/08-01/09 (Dorsainvil, 2002). However, additional work is needed to analyse how well catch crops can simultaneously: *i)* absorb large amounts of N derived from the mineralisation of organic products, *ii)* reduce nitrate leaching during winter, and *iii)* favour N nutrition of the next main crop after incorporation. In a previous study, we parameterised and validated for white mustard and Italian ryegrass (Dorsainvil, 2002) the generic STICS soil-crop model, which was initially developed for wheat and corn (Brisson *et al.*, 1998; 2002). In addition, the SIMPLE model, which is a simulator of seed emergence in field conditions developed and validated for sugarbeet (Dürr *et al.*, 2001), was parameterised and satisfactory tested for white mustard (Dorsainvil, 2002; Dorsainvil *et al.*, submitted). The objective of the present study was to analyse by simulation, using SIMPLE and STICS, the effect of catch crop mustard on N leaching and on the available-N for the next crop when concentrated vinasse is spread in summer.

Methods

First the SIMPLE model was used to simulate the date and rate of seed emergence of mustard (sown at 200 seeds.m^{-2}), assuming a "typical" seedbed structural state and distribution of sown seeds in the soil after disk ploughing. Next these output variables were introduced as input variables to STICS in order to simulate N uptake of mustard and its effect on N leaching during the fallow period and, after its incorporation (01/12), the amount of available-N in the soil for the next crop. Four scenarios, representing farmers management practices in the case of wheat-sugarbeet rotations, were compared: *i*) Bs+S, bare soil with 6 t.ha^{-1} of straw (C/N=70) incorporated at wheat harvest on 31/07, *ii)* Bs+S+Vin, Bs+S scenario plus application of 3.5 t.ha^{-1} of concentrated vinasse (C/N= 6, indicating a rapid N mineralisation; 250 kg organic-N.ha^{-1}) on 31/07, *iii*) CC+S, white mustard sown on 01/08 with 6 t.ha^{-1} of straw incorporated, and *iv*) CC+S+Vin, CC+S situation with application of 3.5 t.ha^{-1} of concentrated vinasse. The simulations were carried for the pedoclimatic conditions of the French Champagne region (Fagnières, 48.9°N; 2.1°E), using the meteorological data of all the years of the last decade. The soil was a typical chalky soil of 90 cm depth containing 40 kg N.ha^{-1}. Various output variables are considered here: *i)* the emergence date and rate of catch crop seeds, *ii)* the average nitrate concentration in drained water on 25/04, and *iii)* the soil mineral-N available for the next sugarbeet crop (on 15/07) and its distribution in the first 90 cm. The results are expressed in terms of means and standard errors over years.

Results

The dates and rates of white mustard seed emergence varied greatly between years (Table 1), due to soil dryness which is highly probable in summer. However, the emergence rate was in general higher than 70% and the date of emergence often occurred only 2 to 3 weeks after sowing.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Emergence rate (%)	95	27	65	91	73	96	95	71	90	73	95
Emergence date	16/8	18/8	12/8	04/9	16/8	14/8	12/8	28/8	10/8	16/8	09/8

Table 1: Rate (% of sown seeds) and date of emergence simulated using SIMPLE model (sown on 01/08).

The nitrate concentration in drained water was much higher for bare soil (Table 2). The white mustard significantly decreased nitrate leaching. Nitrate concentration here was lower than the threshold value of 50 mg $NO_3^-.L^{-1}$ in drained water, even with vinasse application (Table 2). However, vinasse application greatly increased nitrate leaching for bare soil, indicating the risk of nitrate pollution when organic products like vinasse are spread in summer on bare soil.

Simulated scenario	*Bs+S*	*Bs+S+Vin*	*CC+S*	*CC+S+Vin*
Nitrate concentration (mg $NO_3^-.L^{-1}$)	99 (18)	148 (40)	17 (9)	21 (10)

Table 2: Simulated average and (standard error) nitrate concentration in drained water (by default on 25/04).

The available mineral-N in soil on 150/7 varied from 80 to more than 190 kg $N.ha^{-1}$ between scenarios (Figure 1), which will induce an effect on the N status on the next crop. Surprisingly, the highest content was simulated for Bs+S+Vin, indicating that nitrate-N release from vinasse was not leached below 90 cm during winter. Lower amounts of N were obtained for CC+S and CC+S+Vin, due to *i)* the efficacy of mustard N uptake and *ii)* net N immobilisation after mustard incorporation.

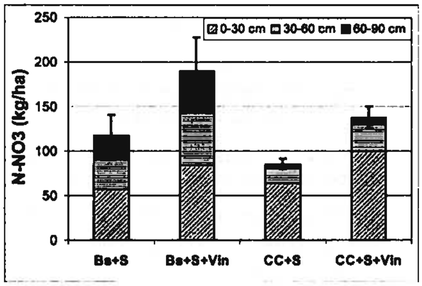

Figure1: Mineral-N in soil on 15/07

Discussion and Conclusions

The variation in rate and date of emergence did not reduce the effectiveness of mustard with respect to nitrogen uptake and nitrate leaching reduction under the conditions tested here. Nevertheless, it would be preferable to spread vinasse after emergence to avoid the risk of nitrate pollution in case of non-emergence, since this product releases a high rate of NO_3-N in the 2 months after spreading. Despite net N immobilisation due to wheat straw incorporation, nitrate concentration in drained water was unsatisfactorily high in the case of bare soil. This illustrates that catch crops are worthwhile and in general necessary to control nitrate leaching during a fallow period even when residual mineral-N of the preceding crop at harvest was low or reasonable.

Finally, as defined and shown by Thorup-Kristensen (1994), our results illustrate the pre-emptive competition effect of catch crops versus the next main crop -less N is available for the next after catch crop in comparison to bare soil situation- when the amount of drainage is low, as in our simulation results (< 100 mm). The consequence is surprisingly that the fertiliser-N amount for the next crop must be increased after catch crops to compensate nitrate immobilisation.

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LONG – TERM TILLAGE MINIMIZATION IN MAIZE (*ZEA MAYS L.*) GROWN IN MONOCULTURE.

Dubas Andrzej, prof., Drzymala Stanislaw, prof., Menzel Leszek,dr.

August Cieszkiwski Agricultural University
ul. Wojska Polskiego 28, 60-783 Poznav, Poland

Introduction

The growing of maize requires a high input of labour and energy. The conventional technologies of maize cultivation are based on the application of many different treatments and the use of many production means like machines, fertilizers, plant protection agents. In order to improve the economic production efficiency, possibilities are looked for to simplify the procedure particularly in the range of tillage going as far as to eliminate the annual ploughing and sowing directly into the stubble.

Methods

Field experiments, the results of which are presented in this work, were carried out in the years 1996 – 2000 in the light sandy loam soil containing 1,3 to 1,5 % of organic matter. In the successive years of maize growing in monoculture for grain crop, the following treatments were repeated:

A - deep ploughing / 30 cm / in autumn and cultivator plus roller in spring
B - shallow ploughing / 10 cm / in autumn and cultivator plus roller in spring
C - no tillage in autumn and deep ploughing / 25 cm / plus harrow in spring
D - no tillage in autumn and in spring , direct sowing into the stubble.

Plots A, B and C were treated with Azoprim 50 WP + Dual 960 EC while plots D with Roundup 360 SL.

The effect of the applied method of tillage were defined by changes in the physical properties of the soil and their influence on the plant quantity after germination and before harvest, on the spread of weeds, and on the yield of grain and its structure. Also the energy efficiency of grain production expressed by the index of energy efficiency /IEE / was defined.

Results

With the simplification of tillage, from A to D, after 5 years, the bulk density of soil distinctly increased from 1,55 Mg/m^3 with conventional tillage / A / to 1,73 Mg/m^3 with direct sowing / D /, while the soil porosity decreased and in treatment / A / it was 39,6 % v/v, while in treatment / D / it was only 31,5 % v/v. This changes in bulk density and porosity of soil occurred most drastically in the first three years and than they stabilised.

The simplification in tillage deteriorated the thermal conditions in the soil but they improved the moisture conditions having an influence on the germination of maize and causing that the quantitative condition of the plants after germination in the treatments without tillage / D / was almost by 20 % smaller that in the remaining treatments.

Estimation of weed infestation after application the tested tillage treatments through 5 years allowed to confirm that the total amount of weeds and their fresh weight were significantly highest in the no – tillage plots / D /.

Grain yield depended both on the weather course in the particular years and on the applied methods of tillage. However, in all years under study, maize gave the highest yields in treatments where ploughing was applied in the autumn independent of ploughing depth / A and B /, but the yield were significantly lower when ploughing was done in the spring / C /, and the lowest yield was in the treatment with no – tillage and direct sowing / D /. It was demonstrated that among the factor of grain yield structure, grain yield depended in an essential degree on the number of plants and the number of developed cobs which always were on the lowest level in the treatments without tillage / D /.

The calculated value of crop energy / CEV / and energy input / EI/ permitted to determined the indices of energy efficiency / IEE / for the studied methods of tillage. On the average, for 5 years, the index was significantly the lowest in case of no – tillage / D / making 3,30 and for the remaining treatments it was : 3,69 / C /, 4,09 / B / and 4,27 /A /.

Conclusions

In the environmental condition in which experiment was carried out after 5 years of tillage minimization in maize grown in monoculture the grain yield obtained from no-tillage plots was significantly lower than from plots where deep or shallow ploughing were applied. Lower energy inputs on no-tillage plots did not compensate the reduction of total grain yield energy obtained from no-tillage plots.

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WEED CONTROL IN SOYBEAN USING CULTURAL MANAGEMENT TECHNIQUES

Ferrero A.[1], Vidotto F.[1], Busi R.[1], Barbero L.[1]

1 Dipartimento di Agronomia, Selvicoltura e gestione del Territorio. Via L. da Vinci, 44. 10095 Grugliasco (Italy)

Introduction

Cultural practices play an important role in weed management. Soil tillage can greatly affect weed germination and growth. Tillage can in fact influence soil temperature and humidity and modify seed distribution in the soil profile (Buhler *et al.*, 1991). Managing crop row spacing can also be a valuable tool which affects weed growth (Esbenshade *et al.*, 2001). Reduced crop row spacing can improve the crop's ability to intercept sunlight and suppress weed growth (Nelson *et al.*, 1998), while increased row spacing can facilitate the weed control with mechanical means.

Methods

This research, carried out in the 2000-2001 periods was aimed at studying the effect of tillage, applied for seedbed preparation and soybean row spacing, on the efficacy of different mechanical weed control methods. The study was conducted in an organic farm located near Turin (NW Italy). The compared treatments were different combinations of row spacings and mechanical interventions:

2000 - a) 15 cm and 1 (2 leaves) *vs* 2 (2 and 4 leaves) harrowings; b) 30 cm and 1 (2 leaves) *vs* 2 (2 and 4 leaves) harrowings; c) 75 cm and 1 (2 leaves) *vs* 2 (2 and 4 leaves) harrowings + inter-row cultivation.

2001 - a) 15 cm and 2 (2 and 4 leaves) *vs* 3 (2, 4 and 6 leaves) harrowings; b) 30 cm and 2 (2 and 4 leaves) *vs* 3 (2, 4 and 6 leaves) harrowings; c) 75 cm and 2 (2 and 4 leaves) *vs* 3 (2, 4 and 6 leaves) harrowings + inter-row cultivation. For each row spacing an untreated check was included. The additional intervention with mechanical means carried out in 2001 was required by the heavy infestation. All treatments were tested in soil that was subjected to stale seedbed which was applied with either mouldboard ploughing or minimum tillage, and which were carried out about 1 month before crop planting. The planting operation was performed on 27 May and 31 May in the years 2000 and 2001, respectively. In order to obtain the same unitary density, in all the planting systems the same quantity of soybean seed (70 kg ha^{-1}) was used in all inter-row conditions. Harrowing was carried out on the total plot surface using of a comb harrow equipped with flexible tines. Inter-row cultivation was performed with a rotary harrow.

Results

At the moment of the first mechanical intervention in soybean post-emergence the weeds were mainly *Amaranthus retroflexus, Echinochloa crus-galli, Polygonum persicaria, Portulaca oleracea* and *Chenopodium album.* The stale seedbed technique carried out with mouldboard ploughing remarkably limited weed growth in comparison to the same technique applied with minimum tillage (Table 1).

The greater infestation in plots subject to stale seed bed with minimum tillage was mainly due to *A. retroflexus*, which showed both a higher density and greater growth in this tillage condition. The efficacy of mechanical weed control carried out in soybean post-emergence proved to be directly related to the row spacing. The best weed control was obtained by combining mechanical interventions with 75 cm row spacing. In these conditions, the efficacy on weeds was as high as 95% for both years in almost all the treatments. The lower efficacy recorded in plots planted with 30 and 15 cm inter-row was most likely related to the reduced activity of the comb harrow, because of a more uniform distribution of the crop on the soil.

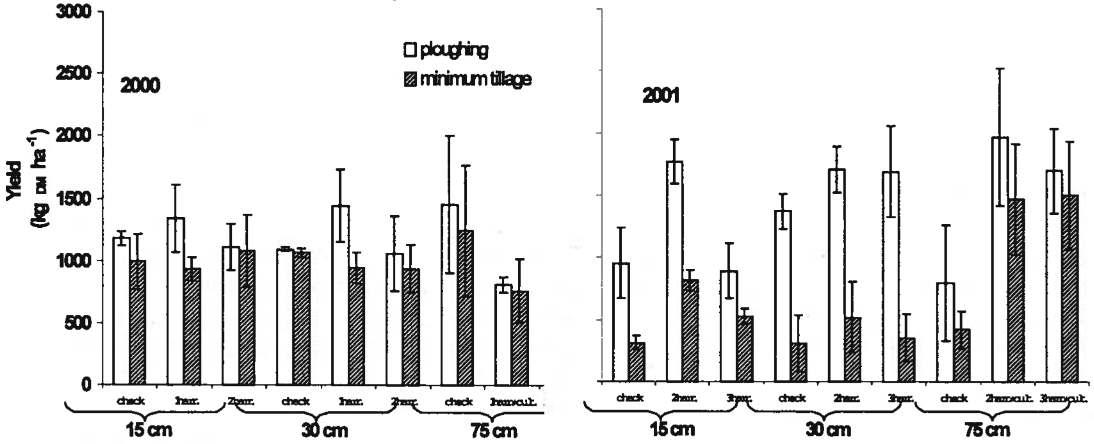
Year	Tillage in stale seedbed	Average weed density		Average weed biomass
		20 DAP	42 DAP	70 DAP
2000	minimum	12.8	141.4	987.2
	ploughing	5.4	72.6	385.1
2001	minimum	90.5	42.0	1105.4
	ploughing	53.8	29.1	1067.3

Table 1. Average weed density and biomass in untreated plots, in 2000 and 2001 experiments (DAP: days after planting).

The highest grain yields were obtained for both years in the plots in which the stale seedbed with ploughing was applied (Fig. 1).

The best yield results were obtained in the plots with 30-cm row spacing in the year 2000 and in 75-cm in 2001. These results can most likely be related to the poorer weed control recorded in

Fig. 1 - Soybean yield in 2000 and 2001



the 30-cm row spacing and the greater pressure of the weed infestation recorded in 2001. Within the same row spacing, in general, the greatest grain yields were recorded in the plots which were subject to the lowest number of harrow passes.

Conclusions

The results of these experiments demonstrate that stale seedbed, combined with mouldboard ploughing, can be an effective means of preventative the control of weeds in soybean. Increasing the soybean row width to 75 cm may result in a better weed control when using mechanical means and in a greater crop yield under heavy infestation conditions.

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EFFECT OF CROP SYSTEM ON THE INFESTATION OF FUSARIUM HEAD BLIGHT IN WINTER WHEAT AND ON THE ACCUMULATION OF MYCOTOXINS IN THE GRAIN.

Jean-François Fourbet[1], Agnès Champeil[1], Laure Malmauret[2], Thierry Doré[1], Philippe Verger[2]

[1] UMR d'Agronomie INRA-INAPG 78850 Thiverval-Grignon - France
[2] INRA, Direction Scientifique Nutrition Humaine et Sécurité des Aliments
147 rue de l'Université 75338 Paris cedex 07 - France

Introduction

During the last months, one attended a renewal of interest for the diseases of wheat up to there considered as minor in France : *Fusarium* head blight. More than in their negative effect in the yield, it is in their capacity to produce mycotoxins which calls to the responsibles for health service. The harmfullness of these molecules is strongly suspected (carcinogenic risk) or demonstrated (estrogenicity). The conditions of conservation of grains intervene in a variable way according to toxins (Homdork *et al,* 2000). As far as toxins consecutive to *Fusarium*, the conditions of wheat production play an essential role on the production of mycotoxins (European Commission, 1994) : the efficiency of fungicidal treatments during the growth of wheat is not a sufficient guarantee and the development of surfaces cultivated in organic system implies greater knowledge of this system in relation with food risks

Materials and methods

A field experiment on cropping systems is carried out since 1997 on a plot at the experimental station of Versailles (78) by the UMR of Agronomy INRA-INAPG. Four systems - conventional (C), biologic (B), integrated(I), direct drilling (ST) - are compared in crop rotations as " culture X - Wheat - culture Y - Wheat " in a two blocks experimental design. Wheat crop is present every year in all the systems. . Every system has its appropriate coherence, and corresponds so to a joining of technical choices : for example, the choice of the cultivar is different if fungicidal products are used or not These systems are compared about their environmental consequences, their profitability, their performances in terms of technological quality of products
Experimental sub-treatments were besides integrated, to improve the understanding of the determining factors of the pathogenic attacks.:
- a sub-treatment without fungicide in the conventional treatment (Cnf) on the cultivar *Charger*
- a sub-treatment without fungicide using the cultivar of the conventional system in the organic, integrated and direct drilling systems (respectively Bc, Ic and STc). Toxicological analyses were realized on these sub-treatments

Program concerned the agricultural years 1999/2000 and 2000/2001.

Results and discussion

Contrast between the two years about the level of *Fusarium* attacks, calls few comments, so much is already known the influence of wet conditions since flowering stage of the crop. In connection with the strong rainfall, the observed levels of attack are sometimes important in 1999/00 ; especially, they are very variable from a crop system to an other.

Table 1 - Evolution of *Fusarium* head blight by treatment (1999-2000)

treatment	Spikelets % with *Fusarium* symptoms (1/3 or more of the surface of glumes attacked)			
	16-06-00	*22-06-00*	*27-06-00*	*03-07-00*
C	01.9	06.2	06.8	23.4
C_{nf}	04.2	11.7	13.8	30.6
I_c	04.0	08.0	06.2	10.7
I	01.8	02.5	01.3	08.9
B_c	02.4	04.0	02.0	04.0
B	03.6	05.8	03.9	07.7
ST_c	04.3	19.0	26.3	33.8
ST	02.2	05.6	17.9	28.7

The fact that the treatment ST (and the sub-treatment associated without fungicide and with the cultivar *Charger)* presents a high rate of contagion, should probably be got in touch with the presence of infectious residues of the crop corn precedent in the surface of the ground., host of some of the agents responsible for *Fusarium* head blight. In 2001, not any symptom of *Fusarium* on spikelets is observed. The nearness of results obtained on the direct drilling system with those of the bibliography (Krebs *et al*, 2000), confirms that it is a practices with risks for the contagion by toxin.

Table 2 - Content in mycotoxins in the grain of *Charger*, in the harvest (µg / kg)

Mycotoxins	zéaralénone		déoxynivalénol	
Parcelles	2000	2001	2000	2001
C	56.6	0	1233.3	60
Cof	141.6	0	490	30
I	41.6	0	526.6	78.3
B	0	18.7	373.3	1073.3
ST	452.5		4233.3	no measure

Obtained results show especially that except this system which accumulates factors favorable to the head blight (crop precedent, no work of the ground), it is difficult for lack of supplementary searches to classify *a priori* the crop systems. Finally, in the optics of an evaluation of the sanitary risk associated to various crop practices , the measure of the levels of infestation by diseases must be necessarily completed with an analysis of the rates of mycotoxins contained in grain (Fourbet *et al*, 2001).

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EFFECTS OF LEGUMINOUS PLANT COVERS ON SOIL FERTILITY AND OLIVE PRODUCTION IN AN OLIVE PLANTATION OF CONTINENTAL CLIMATE.

Hernández A J.[1], Prieto N.[2] & Pastor J.[2]

1 Dto. Interuniversitario de Ecología, Universidad de Alcalá. E.mail: anaj.hernandez@uah.es

2 Centro Ciencias Medioambientales, CSIC, Madrid. E-mail: j.pastor@ccma.es

Introduction

Appropriate soil management is essential to support less intensive and more environmentally sustainable production systems for ligneous crops. It is of widespread knowledge that traditional techniques for the management of olive crops are incapable of enhancing the water filtration rate when the soil is bare and contains scarce organic matter (0.45%) and nitrogen (0.016%). Further, in the semiarid setting of the Mediterranean basin, short bursts of intense rainfall lead to erosion forming fissures and ditches. To resolve these problems from a perspective of ecological agriculture, it was decided to implant or to propitiate the growth of plant covers, (Pastor *et al.*,2000) generally composed of gramineae and legumes, such as vetch, between rows of trees. Besides the use of vetch, we wanted to explore other options such as small, creeping, leguminous nitrogen fixing species including subclover. We also evaluated the possibility of managing the growth of weeds or "resident vegetation" (Ingels *et al.*,1994; Hernández *et al.*, 2001) which were carefully cut back such that the creeping species were able to seed and remain in the soil.

Materials and methods

Experimental trials were performed in a 7.5 ha olive plantation at the experimental farm "La Higueruela", CSIC (Toledo, Spain) over a 5 year-period. Plots (96 x 12 m) were prepared according to a statistical design that allowed the results of the live covers to be compared with those derived from the use of traditional management methods and non-tillage plus herbicides. The characteristics of the area and those of the starting soil for the trials are described in Hernández *et al.*, (1997). The following treatment designs were tested: (a) *Weed cover* - The ecological behaviour of this resident vegetation in the olive plantation was evaluated. (b) *Subclover cover* - This species was considered suitable for the soil properties. Seeds of cultivars of different biological cycle length were sown inoculated with *Rhizobium trifolii*. In this trial, weeds were left to grow alongside the subclover. (c) *Vetch cover* - *Vicia sativa* was grown from commercially available seeds in November. At the time of flowering, the vetch was mechanically trimmed , while the plant remnants were left on the soil until they were buried in mid-spring. (d) *Non-tillage plus herbicides* (glyphosate and simazine) - Plots subjected to conventional tillage were also included as controls.

Results and discussion

In semiarid continental zones, the lack of abundant rainfall and low winter temperatures hinder the installation of a plant cover. For this reason, knowledge of native species is of enormous interest in any evaluation of the sustainability of these systems. The coverage achieved by legumes in these plots during the experimental period is shown in Table 1.

% Coverage	1st year	2nd year	3rd year	4th year	5th year
Ornithopus compressus	+	6	16	61	33
Biserrula pelecinus	+	4	14	32	9
Trifolium arvense	+	5	4	5	2
Other legumes	2.5	8	17	13	2.5

Table 1. General balance of leguminous plant coverage (mean percentages) in plots in which the growth of resident vegetation ("weeds") was propitiated. + indicates presence only.

Legume coverage at spring reached values close to 50% in all the plots from the third year onwards. Total herbaceous coverage seemed highly satisfactory in terms of possible control of soil erosion, given that during most of the year, the proportion of bare soil never exceeded 50%. The implanted subclover persisted well and gave rise to an average coverage of 30% to 50% after the first year. Table 2 shows there were no significant differences in olive production according to treatment throughout the entire study period. Table 3 shows C and N contents and the C/N ratios at the end of the experiment. Final C and N contents were higher than starting values for the weed and subclover covers, yet showed no variation for the treatments vetch, non-tillage and control. The C/N ratio decreased for all the treatments throughout the experiment.

	1st year	3rd year	5th year
Weed cover	3039 a	1472 b	856 a
Subclover	2994 a	2228 a	636 a
Vetch	3217 a	2100 a	975 a
Tillage	3204 a	2193 a	1042 a
Non-tillage	2930 a	2197 a	731 a

Table 2: Olive production in kg/ha according to management treatment.

	Weed cover	Subclover	Vetch	Tillage	Non-tillage
C	0.33±0.13 a	0.34±0.16 a	0.18±0.02 b	0.19±0.04 b	0.17±0.04 b
N	0.025±0.012 ab	0.03±0.017 a	0.019±0.001 ab	0.02±0.001 ab	0.014±0.002 b
C/N	13.3±3.8 a	11±4.1 ab	9.13±1.1 b	9.6±2.3ab	12.6±3.9 ab

Table 3: Soil C and N and C/N ratio for the different treatments at the end of experimentation (5 years)

It may be observed in Table 4 that the biochemical variables at the end of the experiment, although low, were higher for the leguminous plant covers. Differences with respect to the tillage and non-tillage treatments were sometimes significant.

Management	Ind. Act.[1]	Basal Act.[2]	SOMM [2]	ATP [2]		CO_2/ATP [2]	
Weed cover	0.46 ±0.15 a	0.84 ±0.36 a	103 ±39.0 a	133.8	±86.0 a	4.15	±1.72 a
Subclover	0.35 ±0.03 ab	0.82 ±0.18 a	90.8 ±10.1 a	161.2	±34.4 a	2.79	±0.75 a
Vetch	0.45 ±0.30 a	0.54 ±0.03 ab	82.3 ±31.1 ab	134.0	±61.8 a	3.55	±1.66 a
Tillage	0.23 ±0.01 b	0.43 ±0.09 b	52.3 ±15.4 b	99.1	±32.0 a	2.53	±1.53 a
Non-tillage	0.20 ±0.05 b	0.09 ±0.03 c	26.3 ±4.2 c	11.9	±11.5 b	25.66	±14.84 b

[1] ($P<0.1$). [2] ($P<0.05$)

Table 4: Soil biochemical fertility for the different types of management after a 5 year field experiment.

Conclusions

Findings indicate a reduced incidence of erosion fissures in the plots with resident "weed" and subclover covers, compared to the tilled plots. Moreover, these covers were shown to provide efficient protection against erosion as early as from the first year. The presence of spontaneous legumes was favoured, with a notable abundance, in particular, of *Ornithopus compressus* and *Biserrula pelecinus* due to their creeping nature. So far, indications are that these herbaceous covers are capable of considerably mitigating erosion without substantially affecting olive production. Although low, a positive effect on soil fertility was noted in plots with weed and subclover covers, and in smaller measure, for the vetch covers, when compared with the effects of tillage and non-tillage.

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EFFECTS OF REPEATED SOD SEEDING OR MINIMUM TILLAGE AND NITROGEN FERTILISATION ON DURUM WHEAT GRAIN YIELD IN THE CLAY HILLS OF CENTRAL ITALY

Iezzi G., Roggero, P.P., Santilocchi, R., Seddaiu, G.

Dip. Biotecnologie Agrarie ed Ambientali, University of Ancona, Via S. Allende, 60131 Ancona

Introduction

Deep ploughing (40 cm) is conventionally used for seedbed preparation of durum wheat in the arable clay hills of central Italy. Durum wheat is grown in rotation with sugarbeet, sunflower or other spring-summer crops and the main purposes of cultivation are the incorporation of crop residuals into the soil, clearing from weeds and facilitate seedbed preparation. Recently, sod-seeding and herbicides are replacing soil cultivation, which is considered one of the main sources of soil fertility decline, erosion, sub-soil compaction, high energy requirements (Toderi & Bonari, 1986; Basso & Postiglione, 1994). However, it is not yet clear if repeated use of sod seeding or minimum tillage for a long time may have negative effects on soil fertility and hence on crop yield. This paper reports a synthesis of results on durum wheat yield from a seven years experiment on a durum wheat-sunflower biannual rotation, whose aim was to quantify the long term effects of repeated sod seeding and minimum tillage techniques combined with different nitrogen availability on soil physical and chemical properties, crop production and quality.

Methods

The experiment was established in 1994 at the farm "P. Rosati" of the University of Ancona in Agugliano (100 m a.s.l., 700 mm mean annual rainfall), in a hilly area (slope: 10-15%) with silt-clay soil type. A split-plot with two randomised blocks was designed to compare three tillage (T) techniques as main plot (P: conventional 40 cm deep ploughing; M: scarification at 25 cm; S: sod seeding with chemical desiccation and chopping) and three nitrogen fertilisation rates (N) as subplot (durum wheat: 0-90-180 Kg N ha^{-1}; sunflower: 0-45-90 Kg N ha^{-1}). N was applied in two rates during tillering (February) and before heading (March). Phosphorus (50 kg ha^{-1} P_2O_5) was applied before sowing. The main and sub-plot size was 1500 m^2 and 500 m^2 respectively. Wheat and sunflower were alternatively sown on two adjacent groups of 18 sub-plots (3T x 3N x 2rep), so that both crops were sown every year. T and N treatments were repeated for seven years on the same plots and sub-plots on both crops. Grain yield was measured with a plot combined harvester. Yield components were assessed on 3 random samples of 10 spikes (0.5 m^2 for head no. m^{-2}) collected from each sub-plot. Anova was performed on plot means, combining Year as a fixed sub-subplot factor, after verifying the homogeneity of variances.

Results and discussion

Results do not provide a clear evidence of negative effects of sod seeding or minimum tillage on durum wheat grain yield and yield components, but on average, S grain yield was lower than P grain yield of some 13% and the probability level for the effects of tillage on grain yield and heads m^{-2} was lower than 0.10, which could be considered significant as the error term for tillage variance had only 2 degrees of freedom (table 1). M grain yield was intermediate between P and S. The 7-years mean grain yield was 1.4, 3.2 and 3.6 t ha^{-1}, in the N0, N90 and N180, respectively, but with a high variation between years and a significant year x nitrogen interaction for all yield components (table 1). In five years out of seven (1996-2000), N180 yielded on average 0.7 t ha^{-1} and 2.5 t ha^{-1} more grain than N90 and N0, respectively, but differences between N180 and N90 were not significant in 1995 and 2001 (figure 1). This was attributed to the negative effects of intensive storms in spring 1995 and a week of frost in April 2001, whose direct and indirect (pathogens) damages were stronger on N180 than on N90 or N0. A significant linear correlation (r^2 =0,89; P =0,002) was found between the no. of heads m^{-2} and grain yield within N180, while this was not shown on N0 (r^2 = 0,05 n.s.) and at a lesser extent on N90 (r^2 =

0,46; P = 0,09). Therefore, tillering must have constrained N180 grain yield potential in some years. The no. of heads m^{-2} was slightly influenced by tillage treatments, but this aspect should be further investigated to clarify if tillering has been influenced by nitrogen nutrition, and hence by the mineralisation of organic matter, before the first application of N fertiliser. The highest grain yield was reached in 1997, thanks to a relatively mild winter, which favoured a high tillering, and to a relatively cool spring temperatures and abundant rainfall in April-June, corresponding to heading and ripening. The lowest grain yields were observed in 1996, 2000 and 2001, because of a prolonged drought in winter (1996) and spring (1996 and 2000) and a late frost in April 2001. As expected, production stability was inversely related to nitrogen nutrition availability. The grain hectoliter weight ranged from 74 to 85 kg hl^{-1} and was significantly lower in N180 in four years out of seven (figure 2).

Fig. 1 - Actual seed yield

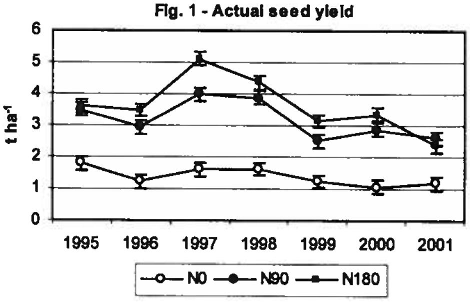

Fig. 2 - Hectoliter weight

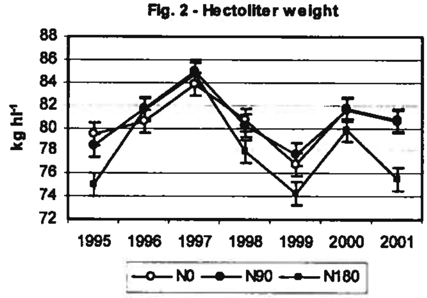

Table 1 – ANOVA results. Numbers in variable columns indicate F probability only when <0.1.

Sources of variation	df	Actual grain yield	Potential grain yield	straw yield	chaff yield	harvest index	no. of spikes m^{-2}	no. of spikelets per spike	no. of kernels per spike	kernels weight per spike	1000 kernel weight	hectoliter weight
Blocks	1											
Tillage tecniques (T)	2	0,09	0,09	0,04	0,01		0,09		0,02	0,02		
Error (a)	2											
Nitrogen fertilization (N)	2	0,00	0,00	0,00	0,00			0,00	0,00	0,00	0,00	0,00
T x N	4								0,07			
Error (b)	6											
Years (Y)	6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
T x Y	12									0,09		
N x Y	12	0,00	0,00	0,00	0,02	0,00	0,00	0,00	0,01	0,00	0,00	0,00
T x N x Y	24											
Error (c)	54											
Coefficient of Variation		15%	22%	23%	23%	6%	15%	9%	14%	15%	6%	2%

Conclusions

The permanent application of conservative tillage techniques, such as minimum tillage and sod-seeding, slightly reduced durum wheat grain yield, but nitrogen nutrition and weather were the most important sources of variation of yield components. Further investigations are required to clarify the mechanisms that constrained grain yield of durum wheat under non limiting nitrogen nutrition in spring, which may be corrected through an anticipation of N fertilisation in winter. The results also suggest that satisfactory and relatively stable durum wheat grain yield and quality can be obtained with low tillage and fertiliser inputs.

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THE EVALUATION OF CONVENTIONAL AND SOIL PROTECTION CROPPING FROM PRODUCTION, ECONOMIC AND ENERGETIC STANDPOINT IN CZECH CONDITIONS

Javurek M., Vach M., Strašil. Z.

Research Institute of Crop Production, Drnovská 507, 161 06 Prague–Ruzyn□ (Czech Republ.)

Introduction

An increasing interest in utilization of soil protection technologies of cropping both all over the world and in our country confirms their justified position in the systems of soil management. It turns out that they can effectively deal with some problems in farming practice, improve the cropping economy by decrease of costs per production unit and eliminate some unfavourable soil processes reducing its fertility. In the three-year cycle of long-term experiments we evaluated soil protection technology of cropping in comparison with conventional tillage from the standpoint of production, economy and energy.

Methods

Since 1997 field experiments were conducted at two different sites in sugar beet production type: in *Cáslav* (site1: Luvic Chernozem, clay loam soil) and in *Tišice* (site 2: Haplic Chernozem, loamy sand soil). The experiments were established as rotations of three crops (winter wheat, spring barley and soybean) which were grown under conventional technology (=CT, i.e. mouldboard ploughing to a depth of 0.20 m, seed bed preparation and sowing) and soil protection technology (=SPT, i.e. sowing with a drill machine J. D. 750 into no-tilled soil covered with mulch from soybean straw for winter wheat or from frost-killed biomass of catch crop mustard /*Sinapis alba L.*/ for spring crops). Catch crops are sown after shallow ploughing and regular seed bed preparation. A split-plot design with four replications is used. 100 $kg.^{-1}ha$ of nitrogen for winter wheat and 80 $kg.ha^{-1}$for spring barley was used. The newest pesticides were applied. There was also determined a specific energy consumption (energy output/energy input) per the unit of final production for individual crops and the whole crop rotations.

Results

The average yield results (Tab.1) from site 1 show significantly higher yields of both cereals in CT, on the contrary higher yields of soybean were found in SPT. At site 2, on light sand, soil yields of all crops were higher in SPT, yield of spring barley only insignificantly. From the above-said it follows that it is necessary to choose a way of cropping in view of the nature of the site. Economic evaluation proved that costs of agrochemicals make a substantial part (more than 50 %) of direct costs. It means that their price and number of applications can influence profitability of crop production very significantly. Yield level and selling price are the second important factor. The analysis proved that SPT essentially increased the profitability of cropping at the site 2 on light sand soil by increasing yields of growing crops. In dependence on the used farming practices, the highest demands of energy inputs in CT were shown for winter wheat, less for spring barley and soybean (Tab. 2). In SPT, the energy balance were unfavourably affected by increase of energy inputs in consequence of catch crop sowing. Therefore in SPT there are similar or higher values of energy inputs for barley and soybean in comparison with CT. In general, soil protection cropping demands lower energy inputs than the conventional one. It came out that winter wheat had got the best utilization of energy inputs both for the main product and for the total production. Spring barley and soybean had similar specific energy consumption with slightly higher values for the benefit of barley (Tab. 2). At site 1 higher values of specific energy consumption per unit of main product were found in CT, at site 2 it was in SPT.

Table 1: Economic evaluation of different ways of cropping

Crop site	Tech no logy	Average yield		Direct costs / € /	Total costs / € /	Main product price / € /	Total production price / € /	Cost-effective ness /%/
		Grain /t.ha^{-1}/	Straw /t.ha^{-1}/					
W.W. Site 1	CT	6.43	4.75	497.2	743.9	728.7	823.3	10.7
	SPT	5.57	3.83	412.2	658.3	633.3	716.7	8.9
W.W. Site 2	CT	5.53	4.41	497.2	743.9	626.5	708.0	-4.8
	SPT	6.03	4.92	412.2	658.3	683.2	772.0	17.3
S.B. Site 1	CT	5.42	3.65	451.3	683.0	650.0	728.0	6.6
	SPT	4.35	2.82	483.3	715.0	522.0	585.0	-18.2
S.B. Site 2	CT	4.60	3.49	451.3	683.0	552.0	618.2	-9.5
	SPT	4.75	3.60	483.3	715.0	570.0	638.4	-10.7
Soybean Site 1	CT	1.98	1.32	516.7	685.3	528.0	575.0	-16.0
	SPT	2.36	1.63	513.3	682.0	629.4	686.7	0.1
Soybean Site 2	CT	2.24	1.34	516.7	685.3	597.3	651.1	-5.0
	SPT	2.57	1.70	499.0	667.6	685.3	747.0	11.9

Notes: W.W.= winter wheat; S.B.=spring barley; Site 1=Luvic chernozem. clay-loam soil; Site 2=Haplic chernozem. loamy-sand soil; CT= conventional tillage; SPT=soil protection tillage

Tab. 2 Energetic balances of experimental crop rotations at different sites (GJ.ha^{-1}. year^{-1})

Site - tillage	Crop / crop rotation	Energetic outputs			Total energy input	Specific energy consumption	
		Energy of main product	Energy of secondary product	Total energy output		Main product	Total production
Site 1 CT	Winter wheat	99.77	72.25	172.02	25.07	3.98	6.86
	Spring barley	84.02	54.98	139	23.97	3.51	5.80
	Soybean	37.4	20.02	57.42	14.25	2.62	4.03
	Crop rotation total	221.19	147.25	368.44	63.29	3.49	5.82
Site 1 SPT	Winter wheat	86.43	58.25	144.68	21.83	3.96	6.63
	Spring barley	67.43	88.61	156.04	23.37	2.89	6.68
	Soybean	44.58	24.72	69.3	16.06	2.78	4.32
	Crop rotation total	198.44	171.58	370.02	61.26	3.24	6.04
Site 2 CT	Winter wheat	85.81	67.08	152.89	25.04	3.42	6.11
	Spring barley	71.31	52.57	123.88	23.9	2.98	5.18
	Soybean	42.32	20.32	62.64	14.27	2.97	4.39
	Crop rotation total	199.44	139.97	339.41	61.14	3.26	5.55
Site 2 SPT	Winter wheat	93.57	74.83	168.4	21.86	4.28	7.70
	Spring barley	73.63	54.23	127.86	23.39	3.15	5.47
	Soybean	48.55	25.78	74.33	16.07	3.02	4.63
	Crop rotation total	215.75	154.84	370.59	61.32	3.52	6.04

Conclusions

At the site on light sand soil SPT guarantee higher yield effect of tested crops than CT. SPT reduces total costs by simplified establishment of crop stands but later costs are increasing owing to a use of catch crops eventually use of higher doses of agrochemicals. Results show that, under given inputs, energy demands in CT on heavier soils are shown higher than in SPT; on light sand soils energy balances of both technologies are comparable.

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THE EFFECT OF CATCH CROPS ON THE WATER BUDGET OF THE FALLOW PERIOD AND THE SUCCEEDING MAIN CROP

Justes E. [1,2], Dorsainvil F. [1,3], Thiébeau P. [1] and Alexandre M. [2]
1 INRA, Unité d'Agronomie Laon-Reims-Mons, BP 224, 51686 Reims, Cedex 2, France
2 Present address: INRA, Unité d'Agronomie, BP 27, 31326 Castanet-Tolosan Cedex, France
3 Present address: Faculté d'Agronomie et de Médecine Vétérinaire, BP 1441, Port-au-Prince, Haïti

Introduction

In addition to constituting good N fertiliser management, the control of nitrogen in the soil during the fallow period between two main cash crops is necessary to reduce the nitrate concentration in the drained water in temperate climates. The efficiency of catch crops in preventing nitrate pollution has been widely demonstrated (e.g. Meisinger *et al.*, 1991). However, additional work is needed to optimise their management which aims at simultaneously minimising water transpiration, maximising temporary removal from the soil profile and maximising N release for the next crop. Using a soil-crop model seems to be the most efficient approach. STICS is a generic model initially developed for wheat and corn (Brisson *et al.*, 1998; 2002) and recently parameterised and validated for two catch crops, white mustard and Italian ryegrass (Dorsainvil, 2002). Moreover, it performs satisfactorily in bare soil (Justes *et al.*, 2001; Dorsainvil, 2002). Our objective was to optimise catch crop management practices under various French climatic conditions. In the present paper we focus on the simulation of various management practices scenarios and their impact i) on the water budget during the fallow period and ii) of the next main crop.

Methods

Various scenarios were simulated using the STICS model, in the case of a wheat-maize rotation with the maize sown 25/04. The objective was to compare water budgets obtained with a catch crop and with uncropped soil, for the fallow period and for the subsequent maize crop. Four pedoclimatic conditions representing the main French climates (other than Mediterranean) were tested (Table 1). The simulations were carried out for meteorological data of all the years of the three last decades.

The scenarios were built to investigate the effect on the water budget of two input variables i) date of emergence (01/08, 21/08 or 15/09) and ii) date of incorporation (01/11 or 15/12 for w. mustard and 15/03 or 20/04 for I. ryegrass, respectively). Two levels of mineral-N in soil at emergence of the catch crop were studied: 40 and 120 kg $N.ha^{-1}$, partitioned as 20 or 100 kg $N.ha^{-1}$ respectively for the 0-30 cm layer, and 10 kg $N.ha^{-1}$ for the two deeper layers of 30 cm depth each. All these factors may have an impact on dry matter production and therefore on plant transpiration.

Station (department)	Years	Latitude ° North	mean T °C	Rain mm	PET mm	Rain - PET mm	Catch crop simulated
Auzeville (31)	1971 to 2000	43.6	13.2	712	876	-164	w. mustard
La Jaillière (44)	1970 to 2001	47.5	11.9	664	745	-80	I. ryegrass
Quimper (29)	1970 to 2000	48.0	11.4	1230	675	555	I. ryegrass
Boigneville (91)	1975 to 2000	48.2	10.7	639	734	-95	w. mustard

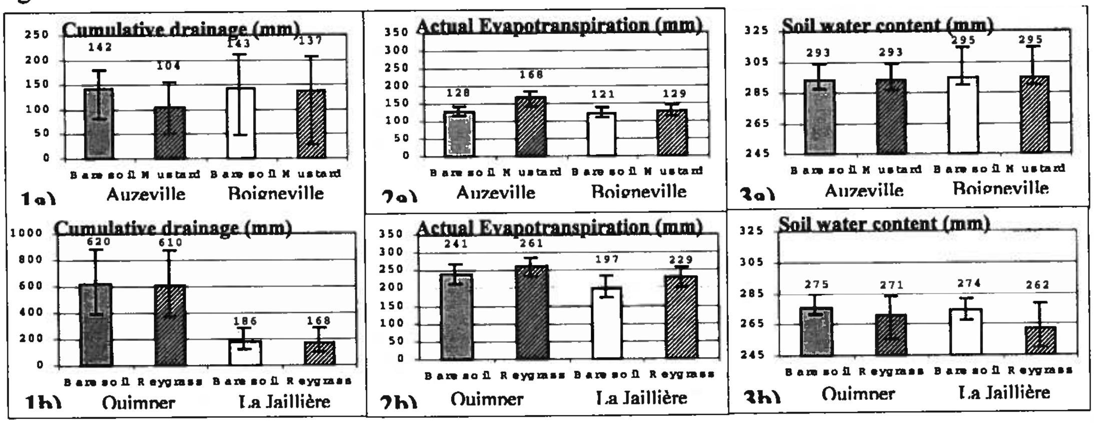
Table 1: Climatic conditions of the four French meteorological stations and catch crop tested.

Various output variables were considered. At the date of catch crop incorporation, dry matter, N uptake, plant transpiration and actual evapotranspiration (AET) and evaporation for bare soil were analysed. At the end of the drainage period (by default the 25 April), cumulative drainage under 90 cm depth, soil water content and soil moisture of the upper layer were compared between cropped and bare soils. Finally, the 30th of June, the indicator of water stress simulated by STICS and dry matter were analysed in order to evaluate the consequences on the next maize crop.

The results are expressed and shown in terms of median, first and fourth quintiles of the climatic series of each site and for all the scenarios simulated (bare soil and catch crops).

Results

The cumulative median drainage varied from 142 mm to 620 mm for bare soil (Figure 1a-b), indicating the great variability in French climatic conditions. The dry matter of the catch crop varied from 1 to 3 t.ha^{-1}. Transpiration varied from 21 to 110 mm and increased with *i)* the soil mineral-N availability and *ii)* the delay of the destruction date. The difference in drainage between bare soil and catch crops was only 6 to 38 mm (Figure 1a). The increase of AET for the catch crop was only 8 to 40 mm (Figure 2a-b). The soil water content on 25/04 was not significantly different between bare and cropped soils even for the spring date of incorporation (Figure 3a-b). However, for the site of La Jaillère and for ryegrass destroyed on 20/04, water content was lower by 12 mm than for the bare soil (Figure 3a), indicating a risk of soil drying in case of late spring destruction. No significant differences of dry matter were obtained for the next maize crop *i)* between cropped and bare soils, because no large water stress occurred, *ii)* between dates of destruction, although a significant increase of dry matter was simulated for higher initial soil mineral-N content.



Figures 1 to 3: Effect of catch crop and bare soil on soil water content, drainage and AET. Emergence 21/08 (40 kg N.ha^{-1}) destroyed 15/12 for mustard and 20/04 for ryegrass. Medians (bars), 1st and 4th quintiles.

Discussion and Conclusions

Surprisingly, catch cropping has a limited effect on water drainage, soil water content and then the succeeding spring crop, although it efficiently decreases the nitrate concentration in drained water. Crop transpiration does have an effect on the water budget, but its impact on AET is limited. This could be due to the reduction of soil evaporation under a catch crop compared to bare soil due to soil cover. This latter result is in good agreement with those obtained by Brisson and Perrier (1991).

Finally, the simulations indicated that an earlier date of emergence leads to greater cumulative evaporation and lower catch crop nitrate uptake efficiency per unit of water transpired. Thus in the French conditions tested, including the wet conditions of Quimper, to be efficient, the catch crop must not be sown too early (before 15/08) nor be destroyed too late (after 15/12) (Dorsainvil, 2002).

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YIELD AND INTERCROPPING ADVANTAGE AS AFFECTED BY MORPHOLOGICALLY AND PHYSIOLOGICALLY CONTRASTING MAIZE-PEA SOLE AND INTERCROPS

Kanton, R.A.L., Dennett, M.D.

School of Plant Sciences, The University of Reading, RG6 6AS Reading (UK)

Introduction

Intercrop combinations of particular crops are determined primarily by length of the growing season, the relative morphology of each species and the physiological adaptation to a particular environment (Azam-Ali *et al.*, 2002). The influence of plant type on competitiveness has been reported in maize-cowpeas (Wahua *et al.*, 1981) and maize-beans (Francis *et al.*, 1982). Wahua *et al.* (1981) demonstrated that the reduction of grain yield and attributes depended greatly on the associated maize cultivars. Hauggaard *et al.* (2001) reported 25 to 38 % more efficient use of growth factors by pea-barley intercrop than by the sole crops. Yadav *et al.* (2001) reported lower cluster beans yields when intercropped with pearl millet but the reduction was greater with tall and late-maturing pearl millet than with a medium and early-maturing pearl millet. This paper summarizes the results from studies on genotypes with the aim of identifying compatible and productive maize and pea genotypes for intercrop systems.

Methods

The experiment was conducted at the Field Unit of the School of Plant Sciences, Reading (lat 51° 25' N, long 0° 56'W 40 m asl) from June to October 2000. Peas were sown at a density of 71 plants m^{-2} and maize at a density of 6 plants m^{-2}. In the intercrops, maize rows were spaced at 0.75 m apart with a within row spacing of 0.30 m. Each maize row was alternated with 5 pea rows at 0.12 m apart with a within row spacing of about 0.07 m. The same maize and peas densities were adopted for their respective sole crops thus giving an additive design. The experimental treatments comprised of two morphologically contrasting maize cultivars, Nancis with erectophile leaves and Sophy with planophile leaves with two pea cultivars, Maro conventional leaved and Princess semi-leafless. These cultivars were sown in all possible combinations. The design was a factorial randomised complete block with three replications. Land Equivalent Ratios (LER) were calculated (Mead *et al.*, 1980):

LER = LERm + LERp = Ym/Sm + Yp/Sp

where LERm and LERp are the LERs for individual maize and peas and Ym and Yp are the intercrop yields of maize and pea respectively and Sm and Sp are their respective sole crop yields.

Results

Sole Nancis produced the highest kernel yield g m^{-2} 13% higher than sole Sophy (Table1). Intercropping peas with maize resulted in a significant ($P<0.05$) reduction in kernel yield m^{-2} but the reduction was greatest when both maize cultivars were intercropped with Maro (58%) compared to Princess (27%). Nancis in both sole and intercrops produced higher yields compared to Sophy (13%).

Table 1. Maize kernel yield (g m^{-2}) as affected by intercropping morphologically and physiologically contrasting maize-pea cultivars (2000). (LSD-141, cv-11.8).

2000	Maro	Princess	Sole	Mean
Nancis	435	546	712	564
Sophy	402	492	609	501
Mean	418	519	661	

Intercropping peas with maize resulted in a higher or comparable pea yields (g m^{-2}) compared to sole cropped peas but the reduction in seed yield was greatest when peas were intercropped with Sophy (11%) compared to Nancis (4%) (Table 2). Maro sole and intercrops produced a higher mean seed yield compared to their Princess counterparts (14%).

Table 2. Pea seed yield (g m^{-2}) as affected by morphologically and physiologically contrasting maize-pea sole and intercrops (2000). (LSD-86,CV-22.8).

	Nancis	Sophy	Sole	Mean
Maro	243	239	183	222
Princess	168	201	213	194
Mean	206	220	198	

All LER's were considerably greater than 1 when Sophy was intercropped, Maro and Nancis intercropped with Princess resulting in the lowest (Table 3). Intercropping maize with Maro resulted in higher (33%) LERs compared to when intercropped with Princess. Similarly intercropping Sophy with both pea cultivars gave higher LERs compared to Nancis (10%).

Table. 3. LER as affected by morphologically and physiologically contrasting maize/ pea intercropping (2000). (LSD-0.29, CV-9.58).

	Maro	Princess	Mean
Nancis	1.69	1.20	1.45
Sophy	1.79	1.41	1.60
Mean	1.74	1.31	

Conclusions.

- Intercropping reduced maize yields compared to sole cropping but the reduction was greatest when intercropped with Maro.
- Intercropping peas with maize caused a slight increase in pea yields compared to sole cropping but the increase was greatest when intercropped with Sophy.
- Calculation of LER showed that plant growth resources were used from 20 to 79% more efficiently by the intercrops than by the sole crops.

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THE EFFECT OF ORGANIC AND MINERAL FERTILISATION ON CROP YIELDS AND SOIL PROPERTIES IN THE POLYFACTORIAL FIELD EXPERIMENTS

Kubat J., Cerhanova D., Lipavsky J.

Research Institute of Crop Production, Drnovska 507, 161 06 Prague (Czech Republic)

Introduction

Development of site specific, highly productive and sustainable farming systems, that will meet requirements of growing human population on safe food and prevent environmental harms has been an important objective of the research in agronomy. A special attention has been paid to soil organic matter content and quality and to soil biota, its incidence and activities that belong among the important indicators of the soil productivity and sustainability of the farming systems.

Methods

The polyfactorial field experiments were founded on eight experimental stations of the Research Institute of Crop Production in 1979. The stations are located in different soil and climate conditions that originally formed a pedo and climate sequence representing arable soils in the Czech Republic. The experiments have been founded according to essentially the same experimental design that includes different fertilisation with farmyard manure (FYM) and/or with mineral fertilisers (N, P, K), liming and stand density, each in five levels with four replications. Altogether 56 variants in incomplete blocks (Cochran et al., 1957, Kubat and Lipavsky, 1994, Lipavsky et al., 1999).

Six variants of organic and mineral fertilisation in two experiments and time period 1996 to 2000 have been selected for this study. Some of the basic site characteristics are presented in Table 1.

Table 1: Site characteristics of the selected polyfactorial field experiments

Site	Altitude m	Latitude	Longi-tude	Average annual precipitation mm	Average annual temperature °C	Soil type	Texture class
Hnevceves	265	50°18′	15°43′	594	8.3	Orthic Luvisol	Clay-loam
Pernolec	530	49°46′	12°41′	572	6.6	Eutric Cambisol	Sandy-loam

Cultivated crops on Luvisol in Hnevceves included sugar beet, spring barley, spring barley and Lucerne, Lucerne, and winter wheat in 1996,1997, 1998, 1999, and 2000, respectively. On Cambisol in Pernolec, sugar beet was substituted with potatoes and Lucerne with clover. Organic and mineral fertilisation was the same on both sites. Non fertilised control (71) did not receive any fertilisers since 1979, FYM+PK plots (55) received farmyard manure ($40 t.ha^{-1}$ every four years under root crops) and mineral PK fertilisers every autumn. NPK variants (62) were fertilised with mineral fertilisers only, $50 kgN.ha^{-1}.a^{-1}$, on an average. FYM+NPK variant (68) received both farmyard manure and NPK in the same doses as previous two variants. Variants 63 and 56 received double doses of farmyard manure and mineral nitrogen, respectively.

Crop yields (main and second product), its dry matter and N content have been determined over the whole time of the experiments. During the time period 1996 to 2000, soil samples were taken twice a year, in the spring and autumn each year, from arable layer (0 - 20 cm) and passed through 2 mm sieve. Mineral nitrogen content, biomass C content, basal and potential respiration activities, ammonification and nitrification activity were determined in the fresh samples. Organic carbon, nitrogen and sulphur contents, hot water soluble carbon and humic substances C were determined in the air dried soil samples.

Results

Organic and mineral fertilisation increased the average dry matter yields of the main and second product on both sites (Tab. 2). Its effect was higher on the less fertile Cambisol in Pernolec than on Luvisol in Hnevceves. Similarly, average N uptake by the main and second product was about 20% to 40% higher on fertilised variants on Luvisol and 50% to 100% higher on Cambisol than on the unfertilised controls.

Table 2: Average values of the dry matter yields, N-uptake and soil organic matter characteristics in the polyfactorial field experiments over the time period 1996 to 2000

Sites and variants	Dry matter yields (t/ha)	N-uptake (kgN/ha)	Organic C in soil (%)	Total N in soil (%)	Hot water soluble C (mgC/g)	Humic acids C (mgC/g)
Hnevceves						
71(0+PK)	9.79	115.6	0.947	0.109	0.314	2.79
55(FYM+PK)	11.25	135.1	0.944	0.113	0.316	2.54
62(0+NPK)	10.84	134.8	0.962	0.113	0.323	2.63
68(FYM+NPK)	12.08	148.3	1.009	0.117	0.343	2.67
63(2FYM+NPK)	11.35	153.5	1.086	0.132	0.383	2.86
56(FYM+2NPK)	11.89	172.0	1.044	0.126	0.348	2.89
Pernolec						
71(0+PK)	5.16	71.9	1.174	0.113	0.466	2.14
55(FYM+PK)	7.36	109.2	1.354	0.131	0.518	2.58
62(0+NPK)	8.47	125.9	1.063	0.093	0.422	1.97
68(FYM+NPK)	9.24	145.4	1.451	0.151	0.564	2.85
63(2FYM+NPK)	9.24	148.0	1.465	0.135	0.599	2.93
56(FYM+2NPK)	10.55	170.0	1.527	0.150	0.598	3.02

Both organic and mineral fertilisation increased organic carbon and nitrogen content in soil. The effect of organic manuring was relatively higher than that of the mineral fertilisation. Hot water soluble carbon content in soil was higher on Cambisol and in the variants fertilised with mineral and especially organic fertilisers. Humic acids carbon content, on the contrary, was higher in the Luvisol than on the Cambisol. Organic and mineral fertilisation increased humic acids C content on both sites. Microbial biomass carbon content in soil and basal respiration activity of the soil samples were enhanced by manuring with farmyard manure. Potential respiration and ammonification activity was about 20% to 40% higher on the fertilised plots than on the non fertilised control. The most remarkable effect of organic and mineral fertilisation was, however, found for nitrification activity.

Acknowledgement

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MIXTURE SPRING CROPS IN SUSTAINABLE AGRICULTURE

Danuta Leszczynska[1], Kazimierz Noworolnik[1], Anna Nieróbca[2]

1 Institute of Soil Science and Plant Cultivation, Department of Cereal Crop Production, Czartoryskich St. 8, 24-100 Pulawy, (Poland)
2 Institute of Soil Science and Plant Cultivation, Department of Agrometeorology and Applied Informatics, Czartoryskich St. 8, 24-100 Pulawy, (Poland)

Introduction

Mixture crops seem to be more and more popular in Poland in recent years. An increase of cereals participation in the sowing structure as well as radical reduction of mineral fertilisation considerably encouraged this tendency. It is assumed that agrotechnical requirements of mixtures are less demanding than those of pure sowing crops (Rudnicki et al., 1994, Michalski et al., 1999). The more stable crops raised from mixtures, as compared to so called pure sowing, ensure stronger resistance to disease and falling over as well as better adaptation to changeable agrotechnical, climate and soil conditions (Noworolnik, 1995, Wanic, 1997). More stable crops, less costly cultivation and only slight environment pollution added to the growth of acreage under mixtures cultivation. Mixture crops are used for animal fodder. As mixtures do not require much chemical protection, they seem to be very suitable for ecological agriculture and, to some degree, for sustainable agriculture (Ku, 1999). In practice, there are mixtures of a number of corn varieties which makes it especially interesting to compare their crops according to the intensity of cultivation.

This experiment aimed at comparison of grain and protein yield of spring crops when relatively intense cultivation technology, as in sustainable agriculture, and low-cost technology (most often used in practice) were applied.

Methods

Experiments were conducted on two sites near Kalsk Agricultural Advice Centre between 1997-1999. Four kinds of mixtures of spring corn were used: barley +oat, barley + wheat, oat + wheat, barley + oat + wheat and pure barley sowing. Two levels of growing intensity were applied as well: relatively intense method (as used in sustainable agriculture) and low-cost method. First method required application of mineral fertilisers: 30-55 kg P_2O_5/ha, 35-75 kg K_2O/ha, 50-65 kg N/ha (maximum application doses for poor composition soil), herbicide and fungicide (for severe disease). The other technology used NPK doses reduced by half (as compared to first technology) and no pesticides. Experiments were conducted on soil complex good for wheat and another one very good for rye in a field after wheat. Components of sowing mixtures were applied in even ratio according to the optimum sowing rate of different varieties of corn in pure sowing (after IUNG).

The experiment allowed to determine the grain crop as well as total protein contents (after Kjeldahl method), protein crop, participation of individual corn varieties in the grain crop and the degree of falling over of plants. Final results underwent statistical variance analysis after Tukey method.

Results

The mixture of barley and oat cultivated with either relatively intensive or low-cost method, produced significantly higher crop, as compared to other mixtures. The above mentioned mixture appeared to give better results as it raised an even higher crop than barley in pure sowing while requiring less production input. Mixture of barley and wheat produced a lower crop by low-cost technology as compared to other mixtures and barley in pure sowing. This result confirmed that wheat has more demanding agrotechnical requirements than oat, even if combined with barley in mixtures.

The protein contents was only slightly different from one mixture to another. The only mixture with noteworthy higher protein contents was barley and wheat mixture, as compared to barley and oat mixture. However, it was the barley and oat mixture that was characterised by the highest protein yield. The only meaningful difference in fairly intense cultivation method appeared between the above mentioned mixture and the three-component one (barley + wheat + oat). Whereas barley and oat mixture cultivated extensively produced a seriously higher protein yield as compared to other kinds of mixtures and barley itself.

Barley prevailed over other mixtures in grain yield irrespective of cultivation intensity. Oat was characterised by the lowest participation in the crop, especially when cultivated relatively intensely. Mixtures under study did not show to be notably prone to disease or falling over. According to other authors, who carried out experiments with mixture of barley and oat, it also produced higher crop as compared to other mixtures, especially when grown in poor site and difficult agrotechnical conditions. However, limited use of oat for swine and poultry feed will limit cultivation of mixtures with its high contents once Poland joins European Union. This does not refer to varieties of oat in pure sowing and in mixtures that contain weeds. It seems mixtures of spring barley, wheat and wheat-rye as well as three-component mixtures with small participation of weeded oat and corn-legumes mixtures in particular will become more popular.

Specification	Cultivation technology	Mixtures				Barley	$LSD_{0,05}$
		barley+oats	Barley+wheat	Wheat+oats	Barley+wheat +oats		
Grain yield ($t\ ha^{-1}$)	I II	5.31 4.62	4.84 3.74	5.00 4.10	4.76 4.08	5.04 4.07	0.30 0.27
Protein content in grain (% d.m.)	I II	11.9 12.0	12.6 12.7	12.3 12.3	12.4 12.4	12.2 12.3	0.50 0.50
Protein yield ($kg\ ha^{-1}$)	I II	633 556	612 475	615 507	591 510	607 503	33 29

I -medium input technology
II- low input technology

Table 1. Yield of various cereal mixtures and barley depending on intensity of cultivation.

Conclusions

From all kinds of spring crop mixtures, the highest crop of grain and protein was produced by barley and oat mixture, especially when grown extensively. Worse results were achieved in case of fairly intense cultivation method used in sustainable agriculture. Barley turned out to be the dominant component as far as grain crop is concerned in mixtures with oat and wheat.

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SUNFLOWER SEED YIELD AND N UPTAKE AS AFFECTED BY RESIDUAL N AND TILLAGE METHOD IN A WHEAT ROTATION

López-Bellido, R.J.[1], López-Bellido, L.[2], López-Bellido, F.J.[3], Castillo, J.E.[2]

1 Departamento de Biología y Producción de los Vegetales. University of Extremadura, Ctra. de Cáceres s/n, 06071 Badajoz, Spain. E-mail: rlobellido@unex.es
2 Ciencias y Recursos Agrícolas y Forestales, University of Córdoba (Spain)
3 Departamento de Producción Vegetal y Tecnología Agraria, University of Castilla-La Mancha (Spain)

Introduction

In rainfed Mediterranean areas with better soil quality, farmers grow sunflower in rotation with wheat, and without applying fertilizer N to sunflower, since their own experience testifies to the lack of response when N is applied directly to sunflower. This approach is based on two major considerations: the uncertainty generated by rainfall variability, and the particular characteristics of the sunflower root system. Nevertheless, farmers frequently apply a greater amount of N to wheat, with a view to the following sunflower crop. This fertilization strategy would be more acceptable if N losses were negligible during the inter-crop season, and if the residual effect on the following crop were evident. Availability of N, and consequently response to fertilizer N rates, is closely linked to water availability (Connor and Hall, 1997). Use of the no-tillage system for sunflower has many advantages, including reduced soil erosion and increased rainfall infiltration and soil water storage (Halvorson *et al.* 1999). This should allow increased sunflower production in rainfed conditions, although some of the results obtained do not suggest a clear advantage of these tillage systems over conventional tillage (Halvorson *et al.* 1999).

Methods

Field experiments were conducted at Córdoba, southern Spain (37° 46' N and 4° 31' W, 280 m above sea level), on a Vertisol (Typic Haploxererts) typical of the Mediterranean region, where rainfed cropping is the standard practice. The study took place over a 5-year period (1995-96 to 1999-00) as part of a long-term experiment started in 1986. The experiment was designed as a randomized complete block with a split plot arrangement and four blocks. Sunflower (hybrid cv Sanbro) was grown in rotation with wheat (cv Cajeme), plots being duplicated in reverse order, so that data could be obtained for both crops every year. Main plots were tillage system [no tillage (NT) and conventional tillage (CT)]. Subplots were N fertilizer rates (0, 50, 100 and 150 kg N ha^{-1}) applied to wheat only. The N utilization efficiency (NU_tE) was calculated for each treatment as the ratio of seed yield to total plant N uptake (Lory *et al.*, 1995).

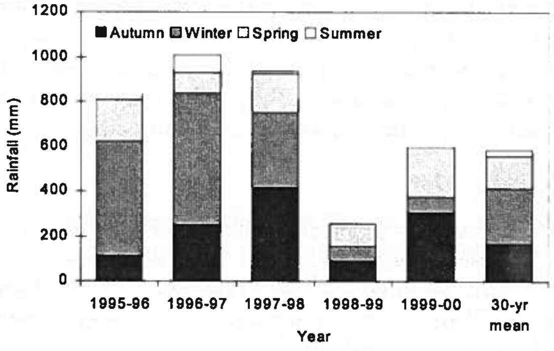

Fig. 1: Annual and seasonal rainfall for 5 yr at Córdoba (Spain).

Results

A sunflower harvest was obtained in only 4 of the 5 study years. Season 1998-99 was extremely dry, preventing sunflower growth as far as harvest (Fig. 1). All parameters studied were significantly influenced by year (Table 1). Mean yield for the four years was 2252 kg ha^{-1}. Significant differences were also recorded between all years for seed oil content, greater values being found in years with lower seed yield and lower values in years of greater seed yield. However, the correlation between yield and seed oil content was not significant. The highest value of NU_tE was recorded for 1997-98, the year with greatest seed yield. However, no clear relationship was observed between NU_tE and seed yield. The year of lowest yield recorded high value for NU_tE, whilst the lowest value was recorded for 1999-00, which displayed the second-highest yield. The tillage system did not significantly influence any of parameters studied (Table 1). The rate of fertilizer N applied to the preceding wheat crop exerted a significant effect on seed oil content, total N uptake and NU_tE (Table 1). Corbeels *et al.* (1998) suggest that deep-level N leaching below the sunflower root system between crops is unlikely to occur in semiarid conditions, due to low rainfall. However, the same cannot be said for the present study, since in three of the four study years rainfall was particularly high in the inter-crop period (Fig. 1). This may have strongly influenced results, due to leaching and possible denitrification under the anaerobic conditions caused by temporary winter waterlogging typical of Vertisols. Seed oil content was lower at 150 kg N ha^{-1}, and no significant differences were recorded at other N rates. According to Connor and Hall (1997), an increase in N rates reduces seed oil content. Total N uptake showed variations in response to changes in fertilizer N rates applied to wheat: rose with increased fertilizer N rates. These results suggest that the amount of residual N from the preceding wheat crop differs for each fertilizer N rate applied, however, these differences were not sufficient to influence yield. NU_tE decreased with rising fertilizer N rates.

Table 1 : Sunflower seed yield, seed oil content, total N uptake and NU_tE in continuos tillage-N rate experiment at Córdoba (Spain). Mean of 4 years.

Treatment	Seed yield (kg ha^{-1})	Seed oil content (%)	Total N uptake (kg ha^{-1})	NU_tE (kg kg^{-1})
Year				
1995-96	1560d	45.29b	88d	18.2b
1996-97	2224c	48.71a	148b	15.8c
1997-98	2743a	43.72c	111c	26.0a
1999-00	2479b	42.38d	209a	11.9d
Tillage				
No tillage	2224a	44.84a	137a	18.4a
Conventional tillage	2279a	45.21a	140a	17.6a
N rate (kg ha^{-1})				
0	2205a	45.1a	122b	20.3a
50	2230a	45.4a	132b	19.0a
100	2273a	45.1a	151a	16.4b
150	2298a	44.4b	152a	16.2b

* Within treatment means followed by the same letter are not significantly different at $P < 0.05$ according to LSD.

Conclusions

Under rainfed Mediterranean conditions, weather has a marked influence on sunflower seed yield. The tillage system did not exert a consistent influence on sunflower yield; continuous no-tillage may thus represent an economically and environmentally viable alternative to conventional tillage for sunflower production in rainfed Mediterranean conditions. Residual N had no influence on seed yield, therefore, overapplication of fertilizer N to wheat, a common practice amongst farmers in this area, designed to create a reserve of available N for the following sunflower crop, does not appear to be an advisable strategy. However, the unusual incidence of excessive rainfall over the study period suggests that further long-term studies are required to determine results under the dry conditions characteristic of this region.

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TILLAGE AND CROP RESIDUE MANAGEMENT FOR WIND EROSION CONTROL DURING FALLOW IN SEMIARID ARAGON

López M.V., Moret D., Gracia R., Arrúe J.L.

Estación Experimental de Aula Dei (CSIC), Avda. Montañana, 1005, 50059 Zaragoza (Spain)

Introduction

Maintaining residue cover on the soil surface is considered the most effective method to control wind erosion. However, in many rainfed farming regions, crop residue levels are too low to provide an adequate soil protection. In semiarid Central Aragon (NE Spain), residue production is limited by low and highly variable precipitation and inadequate agricultural practices. The most common cropping system is the cereal-fallow rotation with a long-fallow period of 16-18 months. This cropping system extends over 430.000 ha with an annual precipitation less than 400 mm. In these areas, where strong and dry WNW winds (*Cierzo*) are frequent all year round, fallow lands are prone to wind erosion due to insufficient crop residues on the surface and highly pulverised soils by multiple tillage operations. Although the adoption of conservation tillage has been encouraged as a fallow management alternative to attenuate wind erosion in those areas (López *et al.*, 1998, 2001), little information concerning the dynamics of crop residues during fallow is available. We report here results on the evolution of barley residue cover during two fallow periods under three tillage systems. Effects of specific tillage operations on the soil cover provided by residues and clods are also presented and discussed in relation to wind erosion control.

Methods

The study was conducted on the long-term conservation tillage plots established in 1989 at the experimental dryland farm of the Estación Experimental de Aula Dei (CSIC) in the Zaragoza province (41°44'N, 0°46'W, 270 m alt.). The soil is a loam (28% sand, 47% silt and 25% clay) and mean annual rainfall is 340 mm. The tillage treatments were conventional tillage (CT), reduced tillage (RT) and no-tillage (NT). The CT and RT treatments consisted of mouldboard ploughing (30-40 cm depth) and chiselling (25-30 cm depth), respectively, in winter, followed in both cases by secondary tillage (10-15 cm) with a cultivator in late spring. Prior to sowing in November-December, a pass of cultivator was implemented in both treatments for seedbed preparation. The NT plots were not tilled and kept weed-free with herbicides. The study was carried out during fallow after the harvest of the 1998-1999 and 1999-2000 growing seasons. Flat and standing residues were collected separately just after harvest and before and after any soil disturbing practice. In the same sampling dates, soil cover by flat residues (line-transect method) and silhouette area of standing residues (frontal area) were also estimated. These measurements were completed with the determination of frontal and basal areas of clods (aggregates >38 mm in diameter) produced by tillage.

Results

Average dry mass of barley residues at harvest was 1456 kg ha^{-1} in 1999 and 855 kg ha^{-1} in 2000. In both years, residue production was not significantly affected by tillage. However, as the fallow period progressed, differences in surface residues among tillage treatments increased. Primary tillage operation

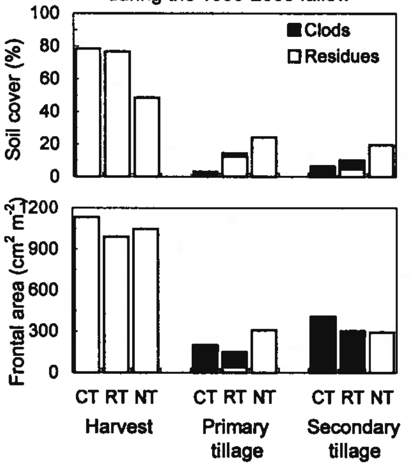
Tillage treatment	Percentage of cover reduction after: Primary tillage	Secondary tillage	Seedbed preparation	Sowing
CT	96-100	100†	-	-
RT	52-72	38-50	67-73	90-100†
NT	-	-	-	56-60

† Initial residue cover is null or negligible (<2%).

Table 1. Influence of tillage and sowing operations on barley residue cover under different tillage treatments.

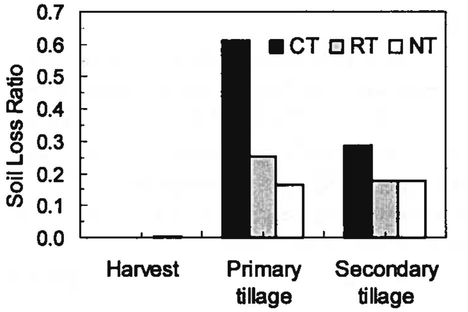
had the major influence on residue incorporation (Table 1) with reduction percentages of about 100% after mouldboard ploughing (CT) and 50-70% after chiselling (RT). At this date, NT and RT plots conserved a residue cover of 20% and 10%, respectively (Fig. 1). Standing residues represented at harvest 30-50% of total residue mass. In both years, 100% of these residues was flattened and buried by mouldboard ploughing and 90-95% by chiselling. Large clods (4-10 cm diameter) created by tillage were not, in general, enough to compensate for the loss of flat residues (in CT and RT vs. NT). Surface cover by clods was never >10%. In contrast, the frontal surface of these clods was, in general, similar and even higher than that provided by the standing residues under NT (Fig. 1).

Fig. 1. Soil surface conditions during the 1999-2000 fallow



The mathematical relationship established by Horning *et al.* (1998) allows to estimate the combined effect of residue cover and random roughness (standing residues and clods) on soil losses by wind erosion. Soil loss ratio (SLR) refers to the soil loss from a protected soil divided by the maximum soil loss (bare, smooth surface). In spite of the low amounts of residues after harvest, they were sufficient, in both years, for reducing effectively the potential soil loss in the three tillage treatments (SLR<0.01) (Fig. 2). Once the primary tillage was done, the risk of wind erosion was high in CT, being reduced after secondary tillage due to a higher presence of clods on the surface. Due to the combined effect of the residue cover retained after tillage and the roughness created by clods, RT maintained, in general, a soil erodibility condition comparable to that predicted for NT (SLR≈0.20).

Fig. 2. Soil loss ratio during the 1999-2000 fallow



Conclusions

The traditional fallow management system in semiarid Aragon seems to be ineffective for protecting the soil surface against wind erosion. Instead, conservation tillage practices must be adopted. The lack of residue-disturbing operations makes NT the best strategy for fallow management. In areas where residue production is very low, RT, through a combination of clods by tillage and residues, could be also a promising alternative. With this treatment, it would be advisable to delay primary tillage at least until early spring to extend the period of residue effectiveness to the most erosive months of fallowing (February-April).

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INTENSIVE FORAGE ROTATIONS IN GALICIA: EFFECT OF IRRIGATION AND TILLAGE SYSTEM

López-Cedrón F.X.[1], Ruíz-Nogueira B.[1], Piñeiro J.[1,2], Sau F.[1]

[1]Dep. de Producción Vexetal, EPS, Univ. de Santiago de Compostela- 27002 Lugo (Spain)
[2]Centro de Investigacións Agrarias de Mabegondo, Apdo. 10. - 15080 A Coruña (Spain)

Introduction

Agriculture in Galicia (north-west Spain) is largely dominated by small dairy farms. Their number has diminished sharply during the last twenty-five years. Nevertheless, the acreage of the remaining ones has increased less than their number of cows and milk production. In consequence, forage production systems should be intensified (Piñeiro, 1996). Although irrigation is not commonly practised in the area, it can allow a significant increase in yield if correctly implemented during the summer water-deficit period (Ruíz-Nogueira et al., 2001). On the other hand, no-tillage systems are increasingly used.
The objective of this work was to evaluate the mid-term effect of irrigation (irrigated-no water deficit (I), rainfed (R)) and tillage system (conventional (CT), direct drilling (DD)) on forage production of two crop rotations.

Methods

The study was conducted in Lugo (NW Spain, 43°04' N; 3°30' W; altitude 480 m) from September 1997 to September 2001. Two levels of water supply (I and R) were combined with three crop rotations-tillage systems (annual Italian ryegrass-maize (AIR-M; a two crops per year rotation) under two tillage systems (CT and DD), and biannual Italian ryegrass (BIR; a biannual rotation) under CT. The experimental design was a split-plot with four replications, being the water treatments (I and R) the main plots and the three crop rotations-tillage systems the subplots (AIR-M-CT; AIR-M-DD; BIR-CT). The plots were fertilised and managed to minimise limitations from nutrients, weeds and pests. The same management was maintained on the same plots from September 1997 till September 2001 and samples were taken in each subplot at 15-25 day intervals (0.25 m^2 for ryegrass; 0.50 m^2 for maize). The samples at harvest were larger (12 m^2 for ryegrass; 6 m^2 for maize).

Results

Total dry matter yield of the components of the different AIR-M treatments is shown in Table 1 for each of the four agricultural years (September to September). Annual yield of all the experimental treatments is presented in Table 2.

Table 1. Annual dry matter yields (Mg ha^{-1}) of the two components of the annual Italian ryegrass-maize rotation

	Sept. 97-Sept. 98		Oct. 98-Sept. 99		Oct. 99-Sept. 00		Oct. 00-Sept. 01	
Rotation	AIR	MAIZE	AIR	MAIZE	AIR	MAIZE	AIR	MAIZE
AIR-MAIZE CT[a]								
Irrigated	7.39	25.69	5.10	24.06	2.74	23.52	3.18	20.84
Rainfed	7.39	16.63	6.29	15.69	3.93	17.07	3.15	19.08
AIR-MAIZE DD[a]								
Irrigated	7.51	25.99	8.14	23.44	4.20	20.54	2.98	21.26
Rainfed	7.28	15.43	9.57	14.06	4.97	13.16	3.96	16.71
Significance of effects[b]								
Tillage (T)	NS	NS	***	*	**	**	NS	NS
Irrigation (I)	NS	***	NS	***	NS	**	NS	*
T×I	NS	NS	NS	NS	NS	NS	NS	*
CV (%)	4.34	6.40	11.16	4.72	16.32	7.21	16.61	5.76

[a]AIR: annual Italian ryegrass; CT: conventional tillage; DD: direct drilling.
[b]*, ** and *** indicate significance at 0.05, 0.01 and 0.001 levels, respectively. NS indicates differences were not significant at 0.05 level.

Table 2. Total annual dry matter yield (Mg ha^{-1})[a] of the different treatments

	S.[c] 97-S. 98	O.[c] 98-S. 99	O. 99-S 00	O. 00-S. 01
BIR				
Irrigated	20.45	15.10	15.84	12.01
Rainfed	15.74	0.00	7.50	6.51
AIR-MAIZE CT				
Irrigated	33.08	29.17	26.26	24.03
Rainfed	24.02	21.99	21.00	22.23
AIR-MAIZE DD				
Irrigated	33.50	31.59	24.74	24.24
Rainfed	22.71	23.64	18.13	20.68
Rotation-tillage means				
BIR CT	18.09 b	7.55 c	11.84 c	9.26 b
AIR-MAIZE CT	28.55 a	25.58 b	23.63 a	23.13 a
AIR-MAIZE DD	28.11 a	27.61 a	21.43 b	22.46 a
Irrigation level means				
Irrigated	29.01 a	25.28 a	22.27 a	20.09 a
Rainfed	20.82 b	15.21 b	15.66 b	16.47 b
Significance of effects[b]				
Rotation (R)	***	***	***	***
Irrigation (I)	***	***	***	*
R×I	***	***	NS	NS
CV (%)	4.34	5.61	7.34	10.12

[a] Two values followed by the same letter in the same column are not significantly different at the 0,05 level according to Duncan's Multiple Range Test.
[b] *, ** and *** indicate significance at 0.05, 0.01 and 0.001 levels, respectively. NS indicates differences were not significant at 0.05 level.
[c] September (S.), October (O.).

A severe water stress developed in the rainfed treatments during the 1998 summer that killed BIR plants. In consequence, the second year rainfed BIR forage production was null .

Discussion

Sowing two forage crops per year (AIR-MAIZE) instead of one every two years (BIR) allowed a significant increase in annual forage production, more than 61%, when water was not limiting, in each of the 4 experimental years. This increase can be attributed to the better adaptation of the maize crop to the high levels of temperature and solar radiation that prevail during summer in Galicia.

Although irrigation is not commonly practised in Galicia, because this region is within the wet area of Spain, it allowed an annual increase in forage production ranging from 30 to 111% for BIR, if the second experimental year is excluded because rainfed BIR yield was null, and from 8 to 48% for AIR-MAIZE. In this case, all the increment is due to maize irrigation because no rain deficit was detected during AIR growth and in consequence this crop was not irrigated. Finally, on average the tillage system had a minor and variable effect on AIR-MAIZE forage production and, when water was not limiting and the same management was maintained, dry matter yield tended to diminish with time.

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RELATIONSHIPS BETWEEN NITROGEN FERTILISATION, STUBBLE INCORPORATION AND YIELD IN MAIZE AND SUGARBEET

Lugato E., Berti A., Borin M. and Giardini L.

Dipartimento di Agronomia Ambientale e Produzioni Vegetali,
Agripolis, 35020 Legnaro (PD) – Italy

Introduction

The response of crop yield to nutrients is basic knowledge in the study of economics of fertilisation and for the identification of the optimal dose in site-specific applications, and the choice of an appropriate functional form is crucial because optimal input recommendations are drawn from these relationships (Llewelyn and Featherstone, 1997). The yield function can be affected by numerous environmental and agronomic factors. Among these, soil physico-chemical traits and residues management are particularly important because they can modify crop productivity both directly through the mineralisation of organic compounds and indirectly by affecting water retention, soil permeability and root growth. In this paper, the comparative effects of soil type and residues management on crop response to nitrogen have been studied with data from a long-term trial.

Methods

The data come from a trial underway since 1966 at the experimental farm of the University of Padova (NE Italy), covering 1999 and 2000, on 108 lysimeters (4 m^2 each). The treatments derive from a factorial combination of three soil types (sandy, silty and clay soils), two types of residues management (removal or burying) and six levels of mineral nitrogen supply. The crops were sugarbeet (1999) and maize (2000). The N-fertiliser levels for the two crops were 0, 37.5, 75, 150, 225, 300 Kg ha^{-1} for sugarbeet and 0, 50, 100, 200, 300, 400 Kg ha^{-1} for maize, while the same doses of P and K were applied on all the lysimeters (150 Kg ha^{-1} of P_2O_5 and 200 Kg ha^{-1} of K_2O).

The relationships between yield (grain d.m for maize and root f.w. for sugarbeet) and N supply were studied using the Mitscherlich model:

$$Y = Y_M \cdot \left(1 - 10^{-c \cdot (b+D)}\right)$$

where D is the applied dose of N fertiliser and YM, c and b are regression parameters. Interpolations were carried out separately for the three soils and two types of residues management.

Results

As expected, both crops showed a wide variation of average yields in the different soil types. In maize, there was a productivity gradient from the clay (av. 12.9 t ha^{-1} d.m.), to the silty (av. 9.6 t ha^{-1} d.m.) then to the sandy soil (av. 6.9 t ha^{-1} d.m.). The interpolation reflects this behaviour, but clearly indicates an important effect of stubble burying (table 1), which appears to be inversely proportional to soil fertility: while in the clay soil the effect is reduced, in the sandy soil stubble burying gives yields similar to those observed in silty soils.

The sugarbeet yield was similar in silty and clay soils (75.4 and 70.2 t ha^{-1} respectively), while crop growth in the sandy soil was very poor (av. yield 28.6 t ha^{-1}). In this latter situation crop growth was almost annihilated in the absence of N supply and the plots showed a non-homogeneous density, leading to a wide variation among replicates. The fitting of the Mitscherlich model was, for the sandy soil, unreliable, giving standard errors of the same order of magnitude as the parameters. In the other two soils, as for maize, the burying of residues caused an increase of the residual nutrient levels prior to fertilisation (parameter 'b').

Crop	Parameter	Soil					
		Sandy	Clay	Silty	Sandy-stubble	Clay-stubble	Silty-stubble
Maize	Y_M	13.8 ± 1.8	18.2 ± 0.5	17.3 ± 1.5	16.5 ± 1.5	18.9 ± 0.5	16.8 ± 0.8
	c	0.0015 ± 0.0004	0.0028 ± 0.0003	0.0017 ± 0.0004	0.0017 ± 0.0003	0.0027 ± 0.0003	0.0026 ± 0.0004
	b	23.6 ± 10.2	54.6 ± 6.2	38.3 ± 9.7	24.6 ± 7.9	79.4 ± 9.1	39.4 ± 7.9
Sugarbeet	Y_M	811.6 ± 606.6	834.0 ± 52.8	848.2 ± 23.9	750.5 ± 460.9	910.5 ± 58.4	975.8 ± 26
	c	0.0012 ± 0.0014	0.0067 ± 0.0028	0.0085 ± 0.0016	0.0014 ± 0.0016	0.006 ± 0.0024	0.0074 ± 0.0015
	b	17.0 ± 25.4	37.1 ± 19.1	25.3 ± 6.4	49.3 ± 41.3	41.7 ± 20.2	38.7 ± 9.2

Table 1 – Estimated parameters of the Mitscherlich model (± standard errors)

Discussion

Both crops showed an important response to N-fertilisation. However, sugarbeet appears to be more affected by variations of the physico-chemical traits of the different soils considered, while in maize N fertilisation can, at least partly, compensate for the lower fertility of sandy soils. Burying crop residues was proved always to be effective in increasing yields. This is due both to a direct effect on crop nutrition and to an improvement in the soil characteristics (water retention, permeability, penetrability, …).

Crop	Targeted Yield (t ha^{-1})	Amount of N fertiliser saved (kg ha^{-1})		
		Sandy soil	Clay soil	Silty soil
Maize	10	133	26	65
	12	255	28	87
	14	-	33	115
	16	-	48	138
Sugarbeet	400	38	5	15
	450	-	5	16
	500	-	6	16
	600	-	9	20

Table 2 – Amount of N fertiliser that can be saved by burying the stubble.
- = Yield level not achievable without stubble burying.

Even if the effect of this agronomic practice is complex, from the farmer's standpoint it gives a yield increase for a given amount of fertiliser input or a reduction of the required fertilisation for a given production level. From the curves obtained, it is possible to compute the savings in N fertilisation which can be achieved by adopting the burial of residues, in relation to the targeted yields (Table 2). The savings are higher in a low fertility situation and when the targeted yield increases. The two crops had anyway a different response, with maize being more able to exploit the improved growing conditions caused by stubble burying.

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COMPARISON OF TWO CULTIVATION TECHNIQUES IN OLIVE GROVES WITH UNTILLED SOIL, GREEN COVER AND ON SLOPES WITH INCLINATIONS GREATER THAN 25%

Martínez-Raya, A.[1], Ruiz, S.[1], Carceles, B.[1], Durán, V.H.[1], Francia, J.R[1], Arroyo, L.[1]
[1] Centro de Investigación y Formación Agraria de Granada. Apdo. 2027-18080 Granada (Spain)

Introduction

The olive groves located in our zones are characterized by an irregular distribution of rainfall as well as temperatures, which reach the highest points during the dry periods; thus dry farming is predominant in large areas of plantation. This augments the erosive effect of the rainfall, since the herbage covering the soil, in the majority of cases, is less than 35%. This situation is aggravated in the olive groves due to the fact that they are frequently located on marked slopes with excessively toiled soil, which increases the soil's vulnerability and its degradation. Therefore, it is necessary to adopt measures, which allow the risk of erosion and the volume of water run-off to be minimized to the greatest possible degree. The goal of this study is to compare different ways of dealing with the soil, and analyse their role in protecting it; ways of reducing or annulling the aggressive effects of rain; the most effective way to control water run-off, and thus avoid the structural degradation of the topsoil; and also to examine measures which may be alternatives to the traditional conservational practices.

Methods

The study undertaken centered upon dry, ligneous cultivational areas: olive groves (cv. Picual), in zones with slopes with an inclination of more than 25%. As a methodology of study, we used closed erosion plots of land, which allowed us to exactly quantify the loss of substances, such as the volume of water run-off.

Two treatments were compared:

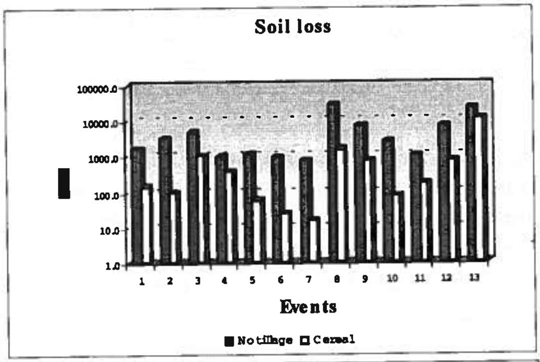
1. No tillage, but with the application of pre-emergence herbicides over the entire surface.
2. Areas covered with vegetal cereals, with the application of pre-emergence herbicides using strips of 3 metres, with the base of the tree in the center. Strips of vegetation, which had been transformed into mulch, were observed, due to the application of contact herbicide. In order to control pluviometric events, devices to measure the rainfall were installed along the lower border of the plot, in order to calculate the intensity of each rainfall. Samples were taken once each erosive event had ended. The sediments are calculated as the sum of those, which were gathered in the final collection, as well as those, which were suspended within the water accumulated in the sedimentation tanks.

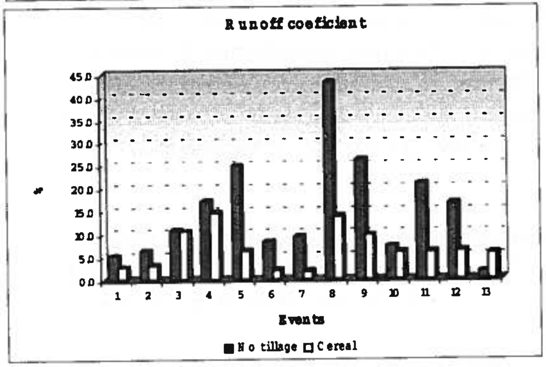
Tabla 1. Loss soil and runoff in the thirteen events.

Event	Rainfall (mm)	I30 ($cm\ h^{-1}$)	EI30	Soil loss ($kg\ ha^{-1}$)		Runoff coef. (%)	
				No tillage	Cereal	No tillage	Cereal
1	20.7	2.9	13.9	1685.5	141.2	5.3	2.8
2	31.6	1.6	10.0	3145.3	93.3	6.3	3.2
3	90.9	1.3	24.4	4905.8	1086.1	10.6	10.6
4	37.9	1.1	6.6	979.9	380.7	17.2	14.6
5	16.9	1.1	3.3	1167.2	57.3	24.9	6.2
6	42.2	0.6	4.2	966.3	24.1	8.3	2.0
7	58.3	0.9	9.2	737.3	15.1	9.3	1.8
8	22.7	4.1	24.4	28025.6	1557.6	43.2	13.8
9	33.3	2.4	16.0	7368.8	715.6	26.1	9.8
10	132.7	1.4	31.0	2653.6	75.7	7.2	6.0
11	45.6	0.8	6.1	1068.9	171.3	21.0	6.0
12	55.0	1.5	16.7	7553.2	715.8	16.6	6.3
13	60.3	2.1	23.7	21853.1	11632.7	1.6	5.6
Mean	49.9	1.7	14.6	6316.2	1282.0	15.2	6.8
Total	648.1	21.8	189.5	82110.5	16666.4	197.7	88.6

Results

The results were obtained from the years 1998 to 2001, during which a total of 30 erosive events were studied; these included precipitation, the maximum intensity of the rainfall in 30 minutes (I_{30}), and the EI_{30} of the USLE. In expressing the results, we have not taken into account those events, which caused small losses of soil (those inferior to 400 kg ha^{-1}); the study was thus reduced to 13 events. The data pertaining to these 13 events are shown in table 1.





When the plot of land with strips of cereal is used as a reference, the untilled plot had a sediment emission which was 4,9 times greater, and a water run-off which was 2,2 times that of the land with vegetal covering. The influence of the presence of vegetal covering on the soil over the entire surface of the slope leads to less water run-off, and minimizes the washing away of solid substances. The graphs show the development of the loss of soil and the water run-off according to the plot of land and significant event. In addition, the production of olives was studied, and a similar tendency was observed in the data. Since the water run-off was lower in the plots of land with cereal, the water was used more efficiently, and thus greater production was achieved. The average yield in the untilled plots was 29.8 kg per tree and year, while that of the cereal plots was 52.0 kg.

Conclusions

The results of this investigation, as well as those of previous studies, demonstrate that the use, within the olive groves, of strips of land containing cereal protects the soil, since it shortens the longitude of the slope and thus reduces the erosive effect of the impact of the raindrops. This demonstrates that the use of this type of soil management allows a greater utilization of water, since it facilitates its infiltration and therefore increases the amount of water available for cultivation, which naturally leads to greater production.

The use of cereal vegetal coverings can, for this reason, be a profitable solution for the olive farmer who, as an alternative to untilled land, utilizes steep slopes; in addition, this system serves to protect the soil from hydric erosion.

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EFFECT OF SOIL TILLAGE PRACTICES ON RUNOFF AND SOIL LOSS IN AN APRICOT PLANTATION.

Méndez[1], J., Domingo[2], R., Abrisqueta[3], J.M., Plana[3], V., Ruiz-Sánchez[3], M.C.
[1]Consejería de Agricultura, Agua y Medio Ambiente de la Región de Murcia.
[2]Dpto. Producción Agraria. ETSIA. Universidad Politécnica de Cartagena (UPCT).Cartagena.
[3]Dpto. Riego y Salinidad. CEBAS-CSIC. P.O. Box 4195, 30080 Murcia.

Introduction

Intensive agriculture implies the use of mechanical management practices, which cause soil compaction. The maintenance of vegetal cover reduces soil erosion and improves soil infiltration, but is not a sustainable option in semiarid areas with scarce water resources. In Mediterranean climates torrential storms occur one or twice a year, a situation which increases runoff in plantations located in steep slopes. Under these semiarid conditions, the soil of fruit tree plantations should be kept free of weeds with minimum tillage to prevent the loss of precious resources: water and soil. Soil management practices, which encourage increased water infiltration and rainfall retention, together with adequate irrigation scheduling, can contribute to saving irrigation water and to soil conservation in these areas.
The aim of this study was to evaluate the effect on water runoff and soil loss of different soil tillage practices, in order to increase rainfall and water use efficiency in an apricot plantation under semiarid conditions.

Methods

The experiment was performed from 1999 to 2002 in a 2 ha plot of a commercial orchard, located in Mula valley, Murcia (SE Spain), with a loam texture soil, classified as a Xeric Torriorthent, and 7 % slope. The volumetric water content was 26 % at field capacity and 11 % at wilting point The plant material consisted of twelve-year-old apricot trees (*Prunus armeniaca* L., cv. Búlida, on Real Fino apricot rootstock), spaced 8 x 8 m. Trees were drip irrigated using one drip irrigation line for each row, with seven emitters per tree, each with a flow rate of 4 $l\ h^{-1}$. The climate is semiarid Mediterranean with hot and dry summers, and a mean annual evaporation and rainfall of 1470 and 300 mm, respectively.
In summer of 1999 the plot was divided into three subplots, each with a different soil tillage practice applied between rows: in the first plot (control, C treatment), following the common practice in the area, weeds were cut back to ground level by a blade attached to a tractor, leading to high soil compaction; the second plot (P treatment) was mechanically perforated with an adapted-plough, which makes an imprint of 20 holes per m^2 of 10 cm depth, 130 cm^3 volume; and the third plot (M treatment) consisted of micro-catchments with low banks 20 cm heigh and 2 m long manually raised at 1 m intervals perpendicular to the line of emitters. No organic amendments were added to the soil.
An automated weather station installed nearby was used to collect meteorological data, the rainfall gauge stored data at 5-min intervals. Two runoff plots (8 x 22 m) on each soil treatment were isolated and equipped with a tank with two ten-slot divisors (Hudson, 1997). Runoff was calculated from measurements of water accumulated in the tank after each rainfall event, and soil loss from samples taken after stirring when draining the tank (four aliquots of 1 litre per tank).

Results

The annual rainfall recorded during the experimental period was 385, 190 and 327 mm in 1999, 2000, and 2001 respectively, of which more than 80 % caused runoff. Figure 1 shows data of the 52 rainfall events occurring during the experimental period and the runoff and soil losses registered in the 3 treatments. The rainfall varied between 3 and 117 mm, with a maximum 30-min rainfall intensity (I_{30}) of between 3 and 47 mm h^{-1}. In the control treatment runoff occurred when rainfall exceeded 10 mm and $I_{30} > 3$ mm h^{-1}, whereas in the treated soils (M and P treatments) runoff occurred for rainfall higher than 30 mm and $I_{30} > 20$ mm h^{-1}. The total runoff recorded in the control treatment was 255 mm (34 % of total rainfall), whereas it was reduced in both tillage treatments: 48 mm in M treatment and 57 mm in P treatment (6 and 8 %, of total rainfall, respectively). The M treatment was performed in an attempt to reduce the rainwater running down the slope, leaving the accumulated water near plant roots. The P treatment facilitated infiltration during rainfall.

Soil loss was also higher in the control treatment, with 1281 g m^{-2} being lost during the three years studied (Fig.1). Both tillage practices decreased soil losses, with a reduction of 73 % (M) and 67 % (P) compared to the control.

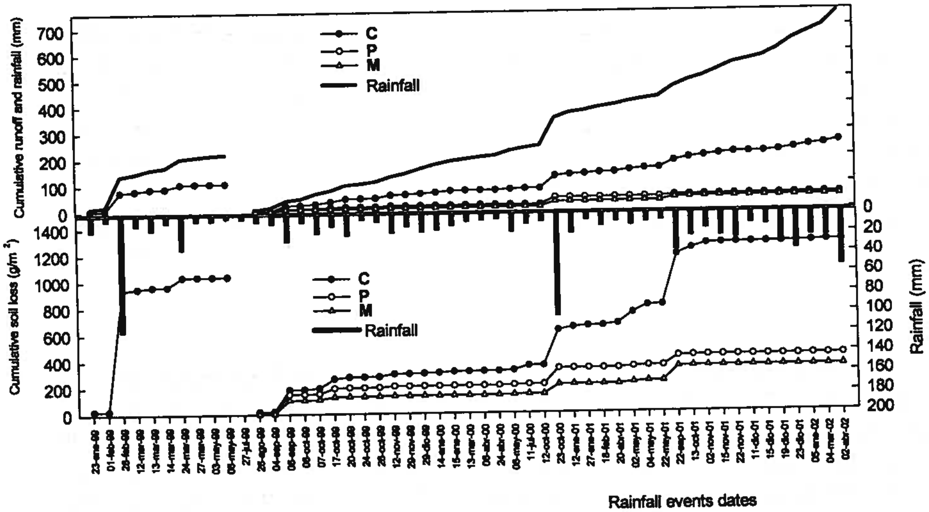

Figure 1.
Cumulative runoff (above) and soil loss (below) in the control (C), perforated (P) and micro-catchment (M) treatments, during the experimental period (1999-2002). Cumulative rainfall (above) and rainfall events (below).

Conclusions

In the three storms which occurred during the three-year-experimental period (typical of Mediterranean semiarid climates), 40 % of total runoff and 67 % of total soil loss were recorded. Total soil erosion was 23 t ha^{-1}, which involved a layer of 1.7 mm of soil loss. These facts indicate the potential risk of plantations in slope for soil conservation proposes.

In M and P treatments, total runoff decreased by about 80 % and soil loss by 70 % compared to the control treatment, similar to that found using mechanical tillage or addition of urban solid refuse in semiarid land (Albaladejo *et al.*, 2000). Both tillage treatments may be beneficial for water management, because almost all the rainfall is made available for plant water requirements, thus reducing by about 15 % the annual irrigation needs of adults apricot plantations (Domingo *et al.*, 2001).

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VALUE AND YIELD STABILITY OF TWO-YEAR CROP ROTATIONS WITH MAIZE

Mitov–Trifonova T.

National Centre for Agrarian Sciences, 30 Souhodolska str., 1373 Sofia (Bulgaria)

Introduction

Development of the theoretical bases of highly productive and sustainable agriculture is the main goal for scientists from many countries. The results obtained show that crop rotation and fertilization are important factors for crop yield and yield stability. Many authors reported that the more effective use of soil, climate and resources were observed when crops were grown in sequence compared with monoculture. The first long-term crop rotation experiments in Bulgaria started in several scientific units in the years 1911, 1919 and 1926 consecutively. At this time the work out of the experiments was difficult because of impossibility of efficient weed control in pesticide absence. For this reason, a periodic interruption of monocultures was done. After 1960 in 14 research institutes field experiments with different crop rotations, using same scheme, were set up. Results show that in large number of crops, yields in a monoculture are lower than those with sequences but effect of different crop rotations on the crop yield stability has not been studied extensively (Mitova T., 1997;1998).

Methods

The data from long-term experiment started in 1962 on Vertisol (Sofia region) were used. Vertisols cover 4.9% on the territory of Bulgaria (Boyadjiev, 1984). The plough horizon was clayey, with clay content over 60% and was characterized as follows: humus content 3.58-3.75%, total nitrogen content 0.165-0.174%, mobile potassium-38.4-40.4 mg $100g^{-1}$ and mobile phosphorus- 1.9-3.9 mg $100g^{-1}$.

The crop rotation experiment is a two – factorial split-plot with four replications. The main plots are the crop sequences and the subplots are the fertilizer treatments in a randomized design. The crop sequences are: (a_1) maize (*Zea mays L.*) monoculture; (a_2) winter wheat (*Triticum aestivum L.*)- maize-; (a_1) spring barley (*Hordeum vulgare* L.)- maize; (a_4) peas (*Pisum sativum)*- maize; (a_4) soybean (Glycine max L.)- maize; The subplots represent two different fertilisation treatments: (b_1) control (without fertilization); (b_2) with mineral fertilization ($N_{120}P_{80}K_{60}$ for maize and wheat; $N_{50}P_{80}K_{60}$- for peas and soybean; $N_{80}P_{80}K_{60}$ for spring barley). The stability analysis of the experimental treatments was conducted using the most important variance parameters: the coefficient of variation (CV%), the ecovalence (W^2) (Wricke, 1962) and the stability variance (σ^2) (Shukla, 1972) calculated by statistical programs. Different crop sequences of maize were compared with maize monoculture (a_1).

Results

1. Maize grain yield

The total precipitation for the study period (1984-1993) averaged 496.8 mm. In the dry years the average rainfall during the maize vegetation period (Apr.-Sept.) were 165.9 mm and the total annual rainfall 401.5 mm, compared to 402.5 mm and 730.0 mm, respectively, in the wet years. Differences in precipitation contributed to different yield responses, as show by the various year x treatment interaction. The maize grain yield varied from 3.041 to 6.863 t ha^{-1} in the sequences without fertilization and between 4.381 and 7.682 t ha^{-1} in fertilized treatments. The combined analysis of variance shows that for maize yield the greatest effect was recorded for fertilization, followed by the year effect and the crop sequence. The year x fertilization interaction was more important than the main effect of previous crop. The year x fertilization and fertilization x crop sequence interactions, as sources for the total variation, were very slight and significant at the 5% level.

2. Crop rotation productivity

The average grain yield from different two-year crop rotations with maize for the trial period and stability parameters calculated were presented in Table 1.

Crop sequences	Without fertilization				With fertilization			
	Yield t ha^{-1}	CV%	W^2	σ^2	Yield t ha^{-1}	CV%	W^2	σ^2
(a_1) M-M	8.465	14.2	28.79	9.95**	12.645	15.5	15.3	5.81**
(a_2) W-M	7.864	11.8	12.18	4.92**	12.286	7.2	3.46	1.19^{NS}
(a_3) B-M	7.482	13.2	8.82	2.65*	10.824	14.2	9.77	3.57*
(a_4) P-M	6.824	10.6	4.79	0.56^{NS}	8.480	8.6	6.87	0.92^{NS}
(a_5) S-M	6.952	12.4	9.95	3.19**	8.950	16.2	16.07	5.44**
$LSD_{1\%}$	0.256				0.320			

Table 1. Crop rotation productivity and stability parameters (^{NS}-Non-significant at P>0.05; *-Significant at $P\leq0.05$; **-Significant at $P\leq0.01$); W^2- ecovalence; σ^2- stability variance;

The results show that for the studied period the average yield from M-M plot in both variants of fertilization was higher compared to the other crop sequences. The total grain yield from crop rotations of the range 6.375-7.450 t ha^{-1} was the lowest in the "dry" 1987-year. In three years the yield of B-M sequences without fertilization was higher or equal to those received from W-M rotation. The coefficient of variation (CV%) and stability parameters showed that crop types, included in the studied rotations determined the temporal variation of their total productivity. The fluctuation of crop rotation productivity across years was lower in cases when winter cereal crops were included (CV=11.8–7.2%) compared to crop rotations with participation of spring crops (CV=12.4-16.2%). Participation of maize determined the high level of total productivity where crop diversity contributed the lower annual variation and the higher stability. The mineral fertilization lead to stable yields from M-M, W-M and P-M sequences and the coefficient of variation was significantly lower compared to cases without fertilization. The mineral fertilization has not influenced yield stability in S-M rotation, because of the stronger interaction between the fertilization effect and meteorological conditions. The CV% in this case was higher in comparison to variants without fertilization. The yield trend slope across years was highest and the total yield decreased most quickly in sequences formed by cereals only (from 0.26 till 0.38 t ha^{-1} yr^{-1}). Including a legume crop into crop sequences (P-M) lead to a smaller step decrease.

Conclusion

For the region of investigation and under non-irrigation, it is possible to create 2-year crop rotations with maize, which could be characterized as relatively stable in respect of the total productivity performance. Involving crops with different biological features (winter cereals and early spring crops) in rotation of maize is a prerequisite for higher stability of their total productivity and for the decreasing of yield risk. Mineral fertilization is a factor not only for the total productivity increase, but it is also an impact factor for yield stability. Yield stability at both levels of fertilization is highest in W-M and in P-M rotations.

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WHEAT-LEGUME INTERCROPPING FOR ALTERNATIVE CROPPING SYSTEMS IN MEDITERRANEAN ENVIRONMENTS : I. SUBTERRANEAN CLOVER AS LIVING MULCH AND GREEN MANURE.

Michele Monti, Giovanni Preiti and Monica Bacchi
Dipartimento di Agrochimica e Agrobiologia, Università *Mediterranea* di Reggio Calabria
Piazza S. Francesco da Sales, 4 89061 Reggio Calabria (I)

Introduction

In terms of land use, growing crops in mixed stand is regarded as more productive than growing them separately (Andrew et. al .,1976; Willey, 1979). Mixed cropping is performed traditionally in many parts of Africa, Asia and Latin America and consequently research in cereal-legume intercropping has been developed in temperate regions with warm climates. This may be due to some of the established and speculated advantages of intercropping systems especially higher grain yield, greater land use efficiency per unit area, and improvement of soil fertility through the addition by fixation and excretion from the component legume, keeping the fertilizer nitrogen requirement to a minimum. Considering intercropping of cereal-legume a tool for developing energy-efficient and sustainable agricultural system, one of the significant applications is overseeded wheat and subclover used as cover crop. Annual auto reseeding legume in mixture with durum wheat has been used as a living mulch and as a green manure for the subsequent summer crop defining alternative cropping system in Italy (Caporali e al. 1993; Pacucci e al., 2001). In this paper results of a five-year evaluation in Southern Italy of alternative management of durum wheat in rotation with summer vegetable crops are reported. The alternative system is based on the intercrop wheat-subclover and on the auto reseeding capacity of the legume acting as a winter cover crop (green manure) for the following vegetable crop.

Materials and methods

The research was carried out in five cropping seasons (1995/96 - 1999/00) at the experimental farm of Dept. of Agrochemistry and Agrobiology of UNIMED-RC (250 m; 39° 37' N; 16° 10' E) on Fluventic Xerochrepts soil. In the 2-year rotation (durum wheat-aubergine), two different managements of durum wheat were characterized by two cropping systems, conventional and alternative. In the first one (conventional), wheat was grown in a pure stand, according to the typical agronomical techniques for semiarid regions; in the second cropping system a vegetable crop was transplanted in spring (May), after winter fallow. The alternative system was defined by intercropping "durum wheat – subterranean clover" in which the cereal was sown at the same density (350 plants m^{-2}) than the conventional using a larger row distance (25 cm). Subclover was spreaded (30 kg ha^{-1}) immediately before the wheat sowing. Using subclover auto reseeding capacity a winter cover crop has been obtained during the subsequent cropping season that was incorporated into the soil (green manure) before eggplant planting.
Durum wheat in each of the two systems was evaluated at two different nitrogen input: typical amount for dry areas (90 kg ha^{-1} distributed in 50% in pre-sowing and 50% topdressed) and lower application (45 kg ha^{-1} topdressed only). In figure 1 the spatial arrangement of the experiment. is represented schematically.

Months	Nov	Ju	Sep	Ap	May	Sep-Oct
		harvesting		incorporation	transplanting	
Alternative system	Wheat + clover intercropping	Crop residues + seed of sub clover	subclover cover crop		eggplant	
Conventional system	Wheat sole crop	fallow			eggplant	

Fig. 1 Schematic representation of the two systems in the cropping season.

Results

Grain yield of durum wheat in the mixture was variable according to annual rain amount and distribution, but exceeding, in more favourable years, 4 t ha^{-1} . This confirmed the higher competitive pressure of this species towards clover that did not reach 1,5 t ha^{-1}. In the alternative system the effects on wheat average yield of N-low input management were negligible, but high interaction "year-cropping system" was observed; in fact three years out of five N45 over yielded the N90 treatment. Subclover showed less variability in biomass production during the period and the values in N45 was ever higher than N90 (tab.1).

Tab. 1- Grain yield of durum wheat (t ha^{-1}) and biomass production of subclover (t ha^{-1} d.m.) in mixture

Years	Durum wheat			Subterranean clover		
	N 45	N 90	Mean	N 45	N 90	Mean
1995/96	1,57	1,63	1,60	0,44	0,37	0,41
1996/97	4,10	3,89	4,00	1,00	1,08	1,04
1997/98	2,50	2,71	2,61	1,42	1,38	1,40
1998/99	4,31	4,15	4,23	1,39	1,28	1,34
1999/00	4,89	4,71	4,80	1,38	1,32	1,35
Mean	3,47	3,42	3,45	1,13	1,09	1,11

The high values of wheat relative grain yield demonstrated high competitive ability of this cereal in this specific intercropping, reaching 0,92 in the last year. On the contrary, sub clover suffered the competitive pressure of wheat and its annual RY values did not exceeded 0,26. The lower competitive ability of subclover allowed enough seed production for the natural sowing of the cover crop. The low N input determined an increment of competitive ability of durum wheat; in this conditions the yield disadvantage of the alternative system versus the conventional decreased to 8 %, reaching 2% in the last year (tab.2). Analysis of the LER, based on biomass, revealed the efficiency in term of land utilization of this alternative management of durum wheat and this advantage was observed also in low input condition.

Tab. 2- Relative yield of the two partners and Land Equivalent Ratio of the mixture

Years	Grain of wheat			Biomass of subclover.			LER		
	N 45	N 90	Mean	N 45	N 90	Mean	N 45	N 90	Mean
1995/96	0,80	0,81	0,81	0,11	0,10	0,10	1,05	0,98	1,01
1996/97	0,91	0,82	0,87	0,25	0,28	0,26	1,14	1,21	1,17
1997/98	0,94	0,76	0,85	0,23	0,22	0,22	1,10	1,17	1,13
1998/99	0,96	0,85	0,91	0,24	0,23	0,23	1,19	1,23	1,21
1999/00	0,98	0,85	0,92	0,23	0,22	0,22	1,08	1,13	1,10
Mean	0,92 a	0,82 b	0,87	0,21 a	0,21 a	0.21	1,11 a	1,14 a	1,13

Means following by the same letter are not significantly different for $P \leq 0,05$. Anova.

In order to evaluate the suitability of subclover as an auto reseeding crop acting as "green manure", biomass production of cover crop in the subsequent cropping season (fig.1) was evaluated in the alternative system as compared to the natural weed population covering the conventional system. The aerial biomass obtained from the subclover cover crop showed very high values every year and allowed a satisfactory control of the weed seed bank.

Tab. 3- Clover e weed biomass in the two systems (t ha^{-1} d.m.)

	Alternative		Conv
Years	Clover	Weed	Weed
1995/96	4,42	1,21	0,62
1996/97	4,80	1,14	0,64
1997/98	5,13	1,11	0,61
1998/99	5,00	0,95	0,37
1999/00	4,90	0,87	0,28
Mean	4,85	1,05 a	0,50 b

Means following by the same letter are not significantly different for $P \leq 0,05$. Anova.

Conclusion

The use of subclover intercropped with durum wheat, in a 2-year cereal-vegetables rotation, is an alternative management system based on green manure techniques. This could represent a suitable and energy-efficient cropping system to approach sustainability in Mediterranean regions.

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WHEAT-LEGUME INTERCROPPING FOR ALTERNATIVE CROPPING SYSTEMS IN MEDITERRANEAN ENVIRONMENTS: II. GENOTYPES SUITABILITY FOR SUSTAINABLE MANAGEMENT.

Michele Monti, Carmelo Santonoceto and Giuliana Ronzello
Dipartimento di Agrochimica e Agrobiologia, Università *Mediterranea* di Reggio Calabria
Piazza S. Francesco da Sales, 4 89061 Reggio Calabria (I)

Introduction

Many of the benefit from sustainable cropping practices derive from genetic interactions: between species in the crop mixture, between varieties and modified edaphic and aboveground environments due to an application of sustainable production systems.
In 1991 (1), C.A. Francis wrote "Crosses today are made to solve problems that will have priority after the year 2000" and he indicated some new plant breeding strategies to solve the constrains occurring in the transition from conventional (intensive) to sustainable cropping systems. Two of the most probable changes were identified in the *Greater use of multiple species systems, especially crop mixture and relay planting* and *Greater recognition of benefit of specific location and system adaptation of cultivars*. In the last ten years breeding programs for multiple cropping systems were carried out in and for the tropics where these systems are prevalent (Smith et al., 1991); in the semi-arid regions, particularly in European Mediterranean areas, the sustainability of agricultural systems in rainfed environments is approached don't taking into account the role the genotype x cropping system interaction. The alternative management of typical cereals-vegetables rotations, particularly based on Soil Organic Matter recovery, uses winter legume cover crop interseeded with cereal in the first year of rotation and ploughed in the second before summer crop establishment (Caporali et al.1993).

Material and Methods

Four durum wheat (*Triticum durum* Desf.) varieties were intercropped (additive series) with subterranean clover (*Trifolium subterraneum* ssp. *Brachicalicinum*) in an alternative cropping system and were grown as sole crops in a conventional system. For each system, in addition to typical N-fertilisation (90 kg ha^{-1}) for dry areas, the varieties were tested at a lower level of nitrogen (45 kg ha^{-1}). The four durum wheat varieties represented respectively the improved genotypes for intensive (Simeto) and low input (Valbelice) cereal systems of Mediterranean areas, an old variety (Cappelli) and a local landrace (collected in Calabria). Within the improved varieties, Simeto has a lower tillering and plant height than Valbelice, both varieties are early heading; Cappelli and local landraces are characterized by very high plant height and medium-late heading. Variety "Clare" of subterranean clover was used.
Experiments were carried out for five cropping seasons (1995/96-1999/00) in the experimental farm of University of Reggio Calabria. Specific information on experimental design and field management are reported in the Monti et al. (part I, this Proceedings).
Absolute yields for wheat and clover in the mixture and in the pure stand were recorded. For subclover we also analysed the aerial biomass of the winter cover crop obtained from reseeding clover after intercropping with each wheat variety. Mixture yields were analysed by computing the Relative Yield for the two partners in the mixture. The efficiency of intercropping was also estimated by the Land Equivalent Ratio.
Anova was performed for all productive and agronomical characters.

Results

Cropping system x variety interactions did not largely influence the absolute yield of durum wheat; the conventional system overyielded the alternative one, ranging from 10% (Simeto) to 16% (Landrace) (tab.1).

A large system x nitrogen x variety interaction was indeed observed; the values significantly decreased at N45 level only in the conventional system, showing the largest difference (-15%) in the improved variety Simeto and in the old variety Cappelli. On the contrary, in the alternative system three out of four varieties showed a better yield performance at low input (+1,7 – +7,9%); only Simeto (-2,8%) confirmed its good response to higher N-input. Aerial biomass production of the subterranean clover did not reached 2 t ha^{-1} but seed production, except in the first year, was sufficient for a good cover crop establishment (tab.2). Every year clover, in mixture with cv Simeto, had the highest seed yield, determining, in the next cropping season, the highest biomass production.

Tabella 1 Absolute grain yield of durum wheat varieties

System	Conventional			Alternative		
Nitrogen	N45	N90	Mean	N45	N90	Mean
Variety						
Simeto	4,29	4,96	4,63	4,14	4,26	4,20
Valbelice	4,32	4,71	4,52	3,79	3,70	3,75
Cappelli	3,01	3,49	3,25	2,96	2,91	2,94
Landrace	3,25	3,46	3,36	3,01	2,79	2,90
Mean	3,71	4,16	3,94	3,47	3,41	3,45

Tab. 2 Aerial biomass (t ha^{-1} d.m.) of subclover in mixture (A) and as cover crop (B).

Year	1995/96	1996/97		1997/98		1998/99		1999/00		Mean	
	A	A	B	A	B	A	B	A	B	A	B
Variety											
Simeto	0,61	1,56	5,98	1,96	5,89	1,77	5,74	1,77	5,42	1,53	5,68
Valbelice	0,31	0,45	3,71	1,05	4,53	1,13	4,18	1,08	3,85	0,80	3,93
Cappelli	0,37	1,01	5,02	1,31	5,19	1,28	5,24	1,33	5,36	1,06	5,04
Landrace	0,33	1,15	4,48	1,28	4,91	1,16	4,82	1,21	4,98	1,03	4,75
Mean	0,41	1,04	4,80	1,40	5,13	1,34	5,00	1,35	4,90	1,11	4,85

Referring to competitive ability of the partners in the mixture, expressed as relative yield, values revealed a very low competition of subterranean clover (tab.3); on the contrary, wheat varieties performed better at low N-input; in this conditions the yield gap between alternative and conventional systems was 8% .Simeto showed the best relative yield. The relative yield of s. clover was not influenced by nitrogen availability. The efficiency of intercropping in terms of land utilization, estimated by the Land Equivalent Ratio on biomass production, exceeded one (no profitability of intercropping versus sole crop), also at low input of nitrogen, demonstrating an advantage of 12% of land return (tab.4). Simeto and Cappelli determined the highest values of LER, due to biomass production; in mixture with Valbelice, LER fell below 1.

Tab. 3 Partial Relative yield in mixture at different N-inputs

	Durum wheat			Subterranean clover		
Nitrogen	N45	N90	Mean	N45	N90	Mean
Variety						
Simeto	0,96	0,85	0,90	0,31	0,30	0,30
Valbelice	0,87	0,79	0,83	0,14	0,14	0,14
Cappelli	0,95	0,82	0,89	0,20	0,19	0,20
Landrace	0,90	0,80	0,85	0,19	0,19	0,19
Mean	0,92	0,82	0,87	0,21	0,21	0,21

Tab.4 Land equivalent ratio of mixture at two N-levels.

Nitrogen	N45	N90	Mean
Variety			
Simeto	1,22	1,26	1,24
Valbelice	0,92	0,97	0,94
Cappelli	1,20	1,19	1,20
Landrace	1,10	1,15	1,13
Mean	1,11	1,14	1,12

Conclusions

The yield performance evaluation of wheat varieties intercropped with subterranean clover in semi arid conditions highlighted the role of wheat genotypes in defining specific alternative systems where the secondary crop represents a tool (cover crop) of sustainable management. Results, confirming the best performance of wheat-legume intercropping under low-input conditions, revealed that the low competitive ability of durum wheat varieties is an important character to consider for planning suitable techniques in sustainable cereal cropping systems.

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NITROGEN MINERALISATION, PASTURE PRODUCTION AND BOTANICAL COMPOSITION IN SYLVOPASTORAL SYSTEMS INSTALED IN VERY ACID SOILS

Mosquera-Losada M.R., Fernández-Sierra C., Rigueiro-Rodríguez A.
Departamento de Producción Vegetal. Escuela Politécnica Superior. Universidad de Santiago de Compostela. 27002-Lugo (Spain)

Introduction

Afforestation policy of the European Union (EU) contributed to the increment of the forest land of Galicia, where woody area was increased from 1 Million to 1,6 Million of hectares in the last decade (Rigueiro, 2000). Market demands high quality wood, which is obtained by using of low density of trees. This means that light reaches soil and therefore an important shrub biomass is developed, which unfortunately is directly related to fire risk. Fire prevention is encouragend by EU policy and is an important chapter of the budget of the region, and it is usually applied through the cut of these shrubs. Herbage development in forest areas is important as it means low vegetal fuel and high quality pasture, and it can be obtained through fertilisation and grazing, as this management gives advantage to herbage instead to shrub. On the other hand, sewage sludge disposal is an impotant problem that must be solved by UE, and the use of this as fertiliser in mountain areas can be a good management for this residue (Mosquera et al., 2001).

Methods

The experiment started on October of 1999 in Parga (Guitiriz, Lugo, NW of Spain). The design of the experiment was a randomised block with three replicates. Sward was established on 1999 and was sowing after clearing with 25 kg ha^{-1} *Lolium perenne* var Brigantia, 10 kg ha^{-1} Dactylis glomerata cv Artabro and 4 kg ha^{-1} *Trifolium repens* cv Huia.Thirteen treatments where applied after cut the above biomass of all experimental area, which come from a combination of liming applied in October (C), two sewage sludge doses (meaning 50 and 100 kg N ha^{-1} the low (L) and high (H) dose respectively) at three different dates: January (D1), February (D2) and March (D3). Finally a no fertilised treatment was also monitorized (NF). Treatments were NF, CLD1, CLD2 CLD3, CHD1, CHD2, CHD3, LD1, LD2, LD3, HD1, HD2 and HD3. Harvests were made in July and November of 2000, through cutting of four square samples (1 x 1 m) per plot. Two samples were handly separated into the different species and two were dried for determining dry matter production.

Soil samples were taken one month before cutting and in each harvest and ammonia ammonia was determined by extraction with ClK 2M (Bremmer, 1965), and measuring by use of TRACCS 800+.

Results

No effect was found of different doses of sewage sludge, the date of application and liming on pasture production (Figure 1). However, different treatments affected significantly botanical composition and ammonia content of soil (Figure and table 1).

	No liming	Liming	No liming
Date	No sludge	Sludge	Sludge
First sampling	34.80a	31.13ab	28.05b
First harvest	23.57	23.31	21.42
Second harvest	24.41a	15.08b	15.13c

Table 1: Ammonia ($N\text{-}NH_4$) content of soils one month before first harvest (first sampling) and in the first and second harvest.

The application of sewage sludge did not usually increase pasture production in the first year, as found Rigueiro et al (2001) with higher doses than used in this experiment (160 or 360 kg N/ha), but with succesive applications a positive effect on production is found, and herbaceous species increased its contribution to the pasture in the second harvest with respect to the first harvest. But, only limed treatments favoured sown species as ryegrass (*Lolium perenne*) and

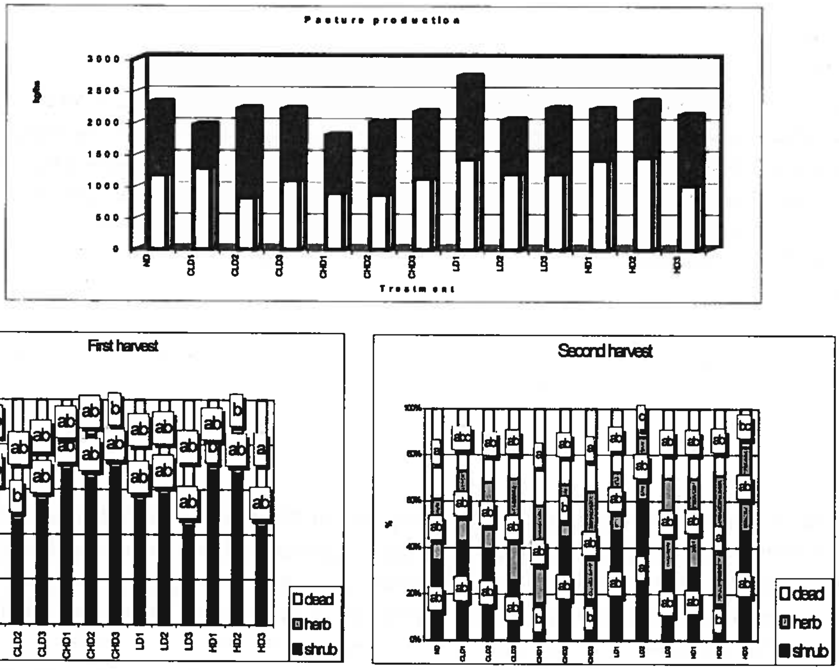

Figure 1: Pasture production (first harvest (black), second harvest (white) and botanical composition in the two harvests.

coocksfoot (*Dactylis glomerata*). The interaction date*liming was significant, showing that herbaceous species appeared in lowest proportion in plots not limed and fertilised with sewage sludge in the last date. Liming and sewage sludge inputs improve herbage proportion in pasture in acid soils, as found Mosquera et al. (2002). This could be explained because fertilisation and liming improved mineralisation, as ammonia content of soil is significantly reduced, and gives advantage to herbaceous component of pasture instead to shrubs.

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THE IMPACT OF STUBBLE TILLAGE AND COVER CROP ON NITROGEN-DYNAMICS AFTER GROWING OILSEED RAPE

Pekrun C., Kauter D., Claupein W.
Institute for Agronomy and Grassland, University of Hohenheim, 70593 Stuttgart, Germany

Introduction

After growing oilseed rape, soil mineral N-contents tend to be high, this implying a relatively high risk of nitrate leaching over winter. Omitting stubble tillage may be an option to minimise mineralisation of organic matter. Another well known option to reduce leaching is growing a cover crop to accumulate N within plant material. In this study two field experiments were set up to study the impact of both options on nitrogen dynamics and yields of the following crop.

Materials and Methods

Field experiments were set up at the Experimental Station Ihinger Hof of the University of Hohenheim (loamy soil, 690 mm, 7.9 °C) in July 1999 and in July 2000. The experiments were set up on a field where oilseed rape had been grown the preceding year. Immediately after combining the following treatments were applied (4 replicates):

1) immediate stubble tillage (dyna drive 6-8 cm), plough in autumn (20-22 cm), winter wheat (St, WW)
2) immediate stubble tillage (dyna drive 6-8 cm), cover crop (mixture of sunflowers, phacelia, annual raygrass), plough in autumn (20-22 cm), winter wheat (St, CC, WW)
3) no stubble tillage, plough in autumn (20-22 cm), winter wheat (no St, WW)
4) no stubble tillage, plough in spring (18-20 cm), spring wheat (no St, SW)
5) immediate stubble tillage (dyna drive 6-8 cm), cover crop (mixture of sunflowers, phacelia, annual raygrass), plough in spring (18-20 cm), spring wheat (St, CC, SW)

To assess nitrogen-dynamics NO_3-N contents were measured in 0-90 cm in monthly intervals from the beginning of the experiment on to harvest of the following wheat. In parallel, samples of the above growing crop respective volunteer stand were taken.

Results

N-dynamics were significantly affected by treatments (Fig. 1). Differences, however, appeared to be more an effect of the growing crop or volunteer stand than of soil tillage. There were no differences between plots sown into a cover crop and plots that remained in fallow until sowing wheat, as volunteer oilseed rape was the main component in either plots. Nitrate-measurements over winter reflected the poor sink capacity of the sown winter wheat in treatments 1) to 3) compared to treatments 4) and 5) where cover crop respectively volunteers still were alive and took up nitrogen from the soil. In spring the opposite situation was observed. As a result of a smaller sink capacity and a larger fraction of easily decomposable organic matter from the preceding cover crop respective volunteer population, nitrate-N contents were much higher in plots sown into spring wheat compared to plots sown into winter wheat.
Naturally, yields of spring wheat were significantly lower than yields of winter wheat (Table 1). Tillage and cover crop, however, had no impact within either crop.

Conclusion

These studies showed that the effect of stubble tillage and cover crop on nitrogen-dynamics can be largely masked by a volunteer population of the preceding crop. Sowing a cover crop was unnecessary with regard to nitrate leaching. In a practical farming situation, however, a cover crop needs to be assessed also for its phytosanitary value and weed suppression effect.

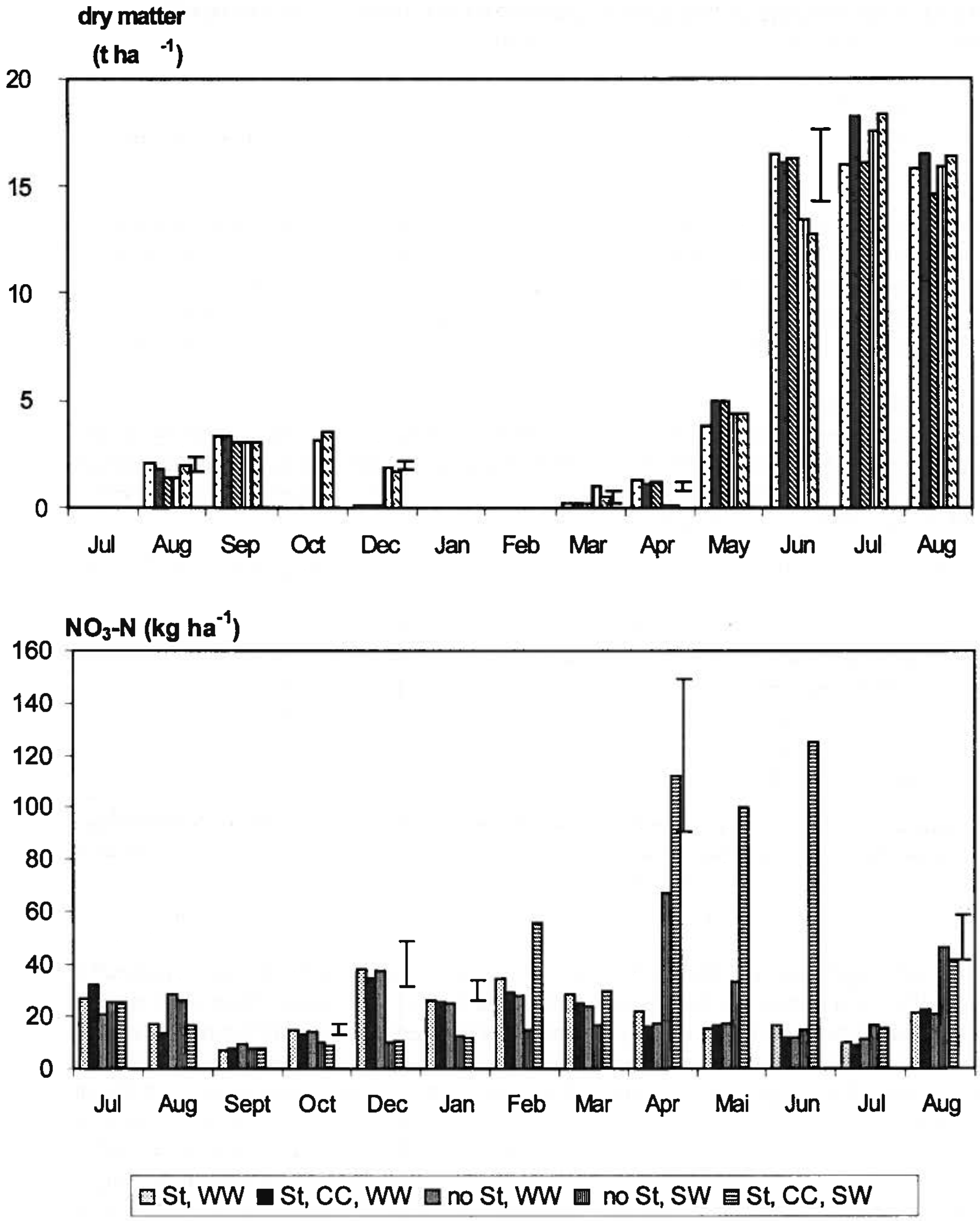

Fig. 1: Plant dry matter (dt ha^{-1}) of cover crop respective volunteers or wheat (upper graph) and nitrate-N contents (kg ha^{-1}) in 0-90 cm depth (lower graph) as a function of stubble tillage and cover crop after growing oilseed rape. Bars: least significant difference $_{Scheffé\ 0.05}$.

Table 1: Yields (t ha^{-1} dry matter) of spring and winter wheat as a function of stubble tillage and cover crop. Least significant Difference $(LSD)_{Scheffé}$ $\alpha = 0.05$. Treatment description in text.

Year	St, WW	St, CC, WW	no St, WW	no St, SW	St, CC, SW	LSD
1999	7.39	7.66	7.47	5.75	5.98	1.024
2000	8.14	7.19	8.18	6.17	6.13	1.461
mean	7.77	7.43	7.83	5.96	6.06	

EVOLUTION OF THE MECHANICAL RESISTANCE OF THE SOIL UNDER CONSERVATION TILLAGE AND RAINFED MEDITERRANEAN CONDITIONS

Perea, F.[1], González, P.[2], Gil, J.[3] y Giráldez, J.V.[2,4]

1 Universidad de Sevilla, Depto. Ciencias Agroforestales, Cra. Utrera km. 1, 41080 Sevilla
2 CIFA, Depto. Suelos y Riegos, Alameda del Obispo s/n, 14004 Córdoba
3 Universidad de Córdoba, Depto. Ingeniería Rural, Avda. Menéndez Pidal s/n, 14004 Córdoba
4 Universidad de Córdoba, Depto.Agronom ía, Avda. Menéndez Pidal s/n, 14004 Córdoba

Introduction

Soil compaction is a great problem in many soils, caused by the repeated traffic of tractors and agricultural machinery and excessive tillage. One effect of compaction is the resistance to root penetration, which is regularly assessed by the measurement of the resistance offered by the soil to the pass of one metallic bar, the penetrometer, through it. The penetrometer was developed in the early days of Soil mechanics, although its application to agricultural soils was no immediate. Authors like Farrell and Greacen (1966) have explored the relation between the resistance and relevant soil properties, while others as Weaich *et al.* (1992) have applied it to the study of several soil properties like the increase of seedbed strength under dry conditions in hardsetting soils. In some cases soil compaction is alleviated by tillage, but the widespread of conservation agriculture and minimum tillage techniques has reduced this possibility. In fact one shortcoming of conservation agriculture is the increased compaction of soils. The purpose of this report is the exposition of the combined effect or tillage practices and moisture content changes in the penetration resistance of heavy clay soils under rainfed cropping in the South of Spain.

Methods

The plots used in the study are located in the Tomejil Agricultural Experiment Station in Southern Spain, Northeast from Seville (37°25'N,5°35'W). The soils are clayey derived form Miocene Marl, Typic Haploxerert (USDA, 1999). Tillage treatments were conventional tillage, CT, where the straw is burnt after the harvest, and the soil inverted with the moldboard plough, and the clods refined with successive passes of other agricultural implements; minimum tillage, MT, where the stubble is incorporated into the soil after the first rains of the Fall, and there are no other tillage pass; and direct drilling or zero tillage, DD, where the stubble remains in the soil surface until its decay, and weeds are controlled by chemical herbicides. Common crops in the alternative are cereals, winter wheat, sunflower, and a legume. Average annual rainfall is 475 mm with a long dry summer period, and mean air temperature is 16.1C. The data for this report were taken with a ASAE standard penetrometer (S477 DEC98) developed at the Dept. of Agricultural Engineering of the University of Cordoba. The sampling period was may 1st, june 15th .

Results

Fig.1 shows the evolution of the penetration resistance for the CT treatment as average values in three depth intervals, and the recorded daily rainfall. The rain during this period kept the soil wet at the surface, and, consequently, the penetration resistance at low values until the last rainfall. Thereafter the surface soil dried up raising the resistance up to restrictive values, above 2.5 MPa. The resistance in the 0.40-0.50 m depth fluctuated according to the refreshment of the soil layer by the rainfall, until the last rain, that was the last one for the cropping period.

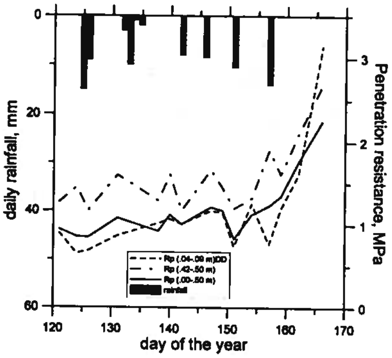

Fig. 1 Evolution of penetration resistance in the DD

As seen in fig. 2-a, there were no differences among the average values in the three treatments , for the whole depth interval, 0-0.50m , although surface values showed different behavior, fig 2-b, since the surface layer, 0.04-0.09 m, of DD was harder than the equivalent layers of the other

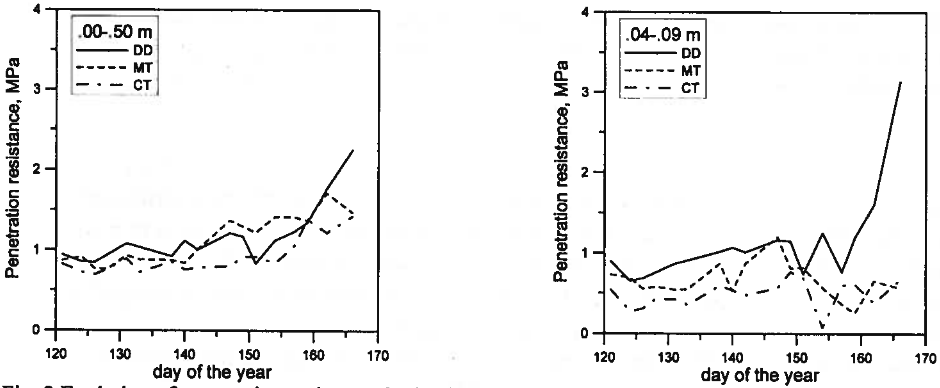

Fig. 2 Evolution of penetration resistance in the three treatments at indicated depths

treatments. The resistance fall detected in CT was due to a late tillage pass to remove weeds, day 154.

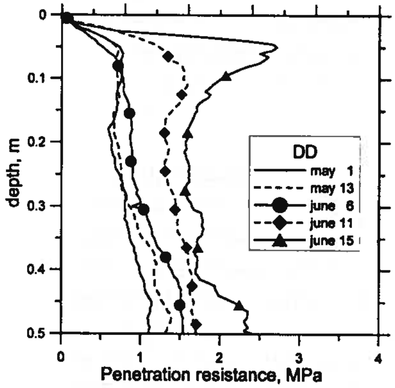

Fig. 3 Sequence of resistance profiles

Finally the sequence of soil hardening in the DD treatment is indicated in the fig. 3. The strong dependence of penetration resistance on the soil moisture content, and, subsidiarily, on the rainfall, is appreciated in the evolution of the resistance profiles of this soil.

Conservation agriculture maintains the soil and the water, but presents a surface compaction risk, that in some cases may refrain crop development. In any case moisture content appears as the main factor responsible for hardening of the rainfed clay soils of Southern Spain.

Acknowledgments
The authors acknowledge the support of Spanish CICYT in the project AGF99-327.

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DISTRIBUTION OF MAIZE ROOT SYSTEMS AS AFFECTED BY TILLAGE SYSTEMS AND BANDED STARTER FERTILIZER

Qin R.[1], Stamp P.[1] & Richner W.[2]

[1] ETH Zürich, Institute of Plant Sciences, ETH Zentrum, CH-8092 Zürich (Switzerland)
[2] Swiss Federal Research Station for Agroecology and Agriculture (FAL), Reckenholzstrasse 191, CH-8046 Zürich (Switzerland)

Introduction

No-tillage is an option to avoid the negative impacts of conventional tillage and to economize on fuel and labor (Lal et al., 1989, Logan et al., 1991). Under no tillage, however, crop yields may be reduced because of the lower temperature and the increased strength of the topsoil, especially in cool-temperate regions where evaporation is relatively low and precipitation is relatively high. Tillage-induced changes in the soil environment may affect root growth and, indirectly, shoot growth and crop yield. Therefore, knowledge of root growth is crucial for the successful adoption of no-tillage systems in such areas. However, information on tillage effects on maize root growth is quite limited, especially during later growth stage.
The application of banded N-P starter fertilizer may alleviate negative effects of cool and/or P-deficient soils to some extent and, thus, improve early growth of maize, especially in no-till systems. However, it is largely unknown how the localization of N and P fertilizer interacts with tillage-induced changes in soil conditions on maize root growth. In a previous study in the same project, we found that root length density (RLD) during the early growth of maize was increased in the zone enriched by the banded starter fertilizer, regardless of the tillage system (Chassot et al., 2001). However, it is largely unknown if such management-induced changes in early root growth persist until later stages of maize growth. Therefore, we studied the effects of tillage intensity and banded N-P starter fertilizer on the spatial patterns of maize root growth at anthesis.

Methods

Experimental design and treatments: A 5-yr field experiment was conducted at two sites in the Swiss midlands: Zollikofen (loamy silt) and Schafisheim (sandy loam). The average annual mean temperature and the average annual precipitation during the last 20 years were 8.7°C and 1075 mm at Zollikofen, and 9.2°C and 1047 mm at Schafisheim. The experiment was designed as a randomized complete block with three replicates. The crop rotation was winter wheat, oilseed rape, winter wheat, and maize. Two tillage systems were compared: a conventional moldboard-plow system (CT) and no-tillage (NT). The CT treatment was plowed to a depth of 0.25 m and rototilled to a depth of 0.10 m. The NT plots were sown without any prior tillage. The row distance of maize was 75 cm.
The broadcast basal fertilization applied before sowing included 35 kg P ha^{-1}, 133 kg K ha^{-1}, and 18 kg Mg ha^{-1}. The starter fertilizer, a mixture of diammonium phosphate and NH_4NO_3 (30 and 17 kg ha^{-1} of N and P, respectively), was banded at sowing 0.05 m to one side of each row and 0.05 m below the seeds. At the V4 growth stage, NH_4NO_3 fertilizer was sidedressed. The fertilizer rates applied with basal fertilization and starter fertilization, which were based on local recommendations, were the same for both tillage systems, whereas the N sidedressing was measured according to the soil N_{min} test (Wehrmann et al., 1979) on a per-plot-basis. Calculated sidedressing N rates did, on average, not differ among tillage systems; averaged across all years, sites, and tillage systems, 107 kg N ha^{-1} were applied.
Measurements and statistical analysis: Roots were sampled with the soil-core method at anthesis. There were three sampling locations per plot. At each sampling location, two positions at both sides of one maize plant were sampled, i.e. on the side with the fertilizer band and on the opposite side. This allowed to investigate the effects of fertilizer banding on root growth. The

Table 1: Maize root length density (RLD) as influenced by year, sites, tillage, fertilizer band, and soil depth

Main effect	RLD (cm cm^{-3})
Year	
1997	4.12 a*
1999	4.09 a
Sites	
Schafisheim	3.24 a
Zollikofen	4.97 b
Tillage	
NT	3.75 a
CT	4.47 b
Fertilizer banding	
Without banding	3.71 a
N-P banding	4.50 b
Soil depth (cm)	
0-5	5.57 a
5-10	5.20 a
10-15	4.03 b
15-20	3.17 c
20-25	2.56 d

** Main-factor levels followed by the same letter are not significantly different at P < 0.05 according to LSD.*

sampling positions were in one line perpendicular to the crop row, 10 cm away from the row, and the sampling depth was 25 cm.
The roots were washed from soil cores, scanned using a desktop scanner (600 dpi), and root length was determined using an image processing system (Chassot et al., 2001). RLD data was analyzed using an ANOVA model with the factors year, site, tillage system, fertilizer banding and soil depth.

Results

Year and site: The year had no significant impact on RLD (Table 1). In contrast, the effect of site was significant; RLD was on average higher at Zollikofen than at Schafisheim.
Tillage: RLD was, averaged across the other factors, greater under CT than under NT throughout the topsoil, but significant differences existed only below a depth of 10 cm (Fig. 1).
Fertilizer banding: As at the 6-leaf stage (Chassot et al., 2001), root growth at anthesis was affected by banding starter fertilizer (Table 1). Fertilizer banding generally increased RLD throughout the topsoil (Fig 1), most pronounced in NT (data not shown). The effect of fertilizer banding was greatest near the soil surface (0 to 10 cm), decreased with increasing soil depth, and disappeared below the 15-cm depth (data not shown).
Soil depth: From the soil surface to a depth of 25 cm, RLD decreased gradually, strongest below 10 cm (Fig. 1). From 5 to 25 cm soil depth, the difference between adjacent 5-cm soil layers was always strongly significant (P<0.01) (Table 1).

Conclusions

Site, N-P fertilizer banding, tillage and soil depth strongly affected RLD of maize at anthesis, whereas the effect of year was not significant. Differences in RLD among the tillage systems mainly existed below the 10-cm depth. RLD was significantly increased by fertilizer banding in both tillage systems, most pronounced near the soil surface. The banding effect decreased with increasing soil depth and disappeared below a depth of 15 cm.

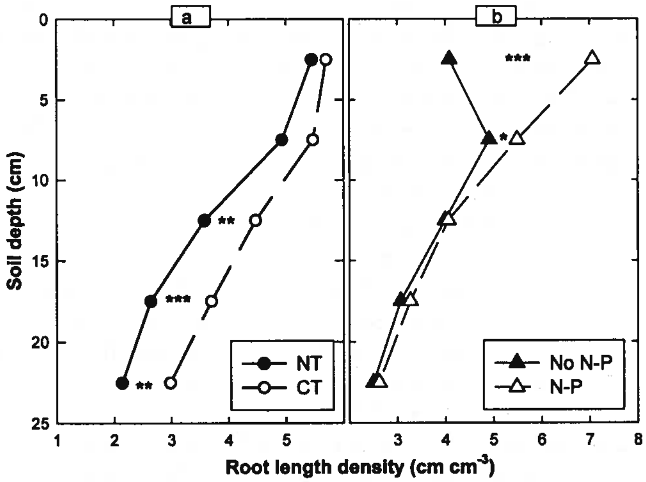

Figure 1: Root length density at the anthesis stage of maize as a function of *(a)* tillage and soil depth, and *(b)* NP-fertilizer banding and soil depth, averaged across the other factors. (*, **, *** significant at the á = 0.05, 0.01 and 0.001 level, respectively; blank is not significant).

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EFFECT OF TILLAGE AND NITROGEN ON YIELD IN IRRIGATED CORN

Santiveri F., Martín-Buil A.B., Lloveras J., Cantero Martinez, C.

Area de Conreus Extensius. Centre UdL-IRTA. Rovira Roure 191, 25198 Lleida (Spain)

Introduction

In the irrigated areas of the Ebro Valley, where up to 800 mm of water is normally applied during growing season, corn, alfalfa, and wheat are the main field crops and are part of the traditional crop rotation of the area. High rates of nitrogen fertilisation are usually applied in corn, reaching values up to 300 kg N/ha (Ballesta and Lloveras, 1996, Villar *et al.*, 2000). Conventional intensive tillage is mostly used. For these reasons, some of these areas have high risk of leaching specially the areas near Lleida. Therefore, nitrogen management and conservation tillage are techniques that could help to reach sustainability in these agricultural systems. The present study was established to evaluate the effect of tillage systems and N fertilisation on yield and on residual soil nitrogen.

Methods

Experimental design: The study was carried out in a wheat-maize rotation under Mediterranean irrigated conditions in Vilanova de Bellpuig (Lleida, north-east of Spain). This study presents the results obtained for corn in the 2000-growing season. Two adjacent trials were established in 1998 with the purpose of representing the two phases of the maize-wheat rotation. Each trial was designed as a split-plot with three replications. The main plots were nitrogen fertilisation (0, 100, 200 and 300 UF N/ha) and elemental plots the tillage systems (conventional tillage, minimum tillage and no-tillage). The size of the elemental plot was 8 x 21 m. Compa CB (FAO 800), a transgenic hybrid with resistance to corn borers, was sown 2^{th} of May, with a density of 80.000 plants per ha. Nitrogen fertilisation was fractionally applied, 40% at pre-sowing, 30% at three leaves stage, and 30% at six leaves stage. The crop was irrigated every 10-15 days. Weeds were controlled by chemical and mechanical treatments. Harvest was done the 19^{th} of October.
Measurements: Soil samples (0-25 cm, 25-50 cm, 50-75 cm) were taken before planting and after harvest to determine N-NO_3 from a solution of the soil after extraction with desionized water. Content of nitrate was obtained in lab by the readings done by colorimetric bands (Nitracheck). Yield was obtained by harvesting five rows of each plot.
Statistical analysis: ANOVA and mean separation tests were done using the GLM procedure of the SAS statistical package.

Results

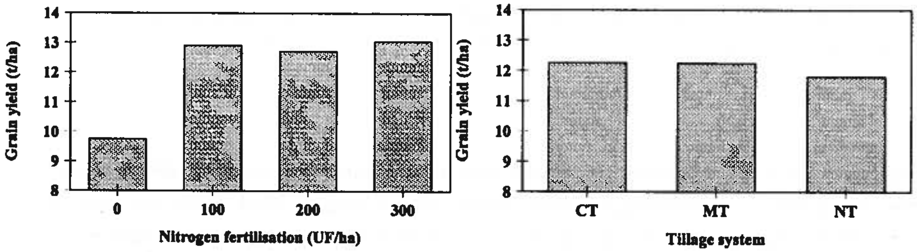
The average values of soil nitrate contents prior to sowing was 123 kg/ha and no differences were observed prior to the application of N treatments to corn. Such values are considered as high residual soil nitrogen contents. The final N contents after corn harvest were 29.7, 34.6, 64.6 and 125 kg N-NO_3/ha for the 0, 100, 200 and 300 Kg N/ha, respectively. This shows a clear decrease in the remaining soil nitrate content when the N rates were lower than 300 kg/ha. Tillage treatments did not affect significantly soil nitrate content after harvest, possibly because of the high CV of this parameter, although soil nitrate under conventional tillage (72 kg N /ha) almost double the nitrate content of the no-tillage (48 kg N/ha).
Lowest corn yield was obtained with zero N applied and no response to nitrogen fertilisation was detected above 100 kg N/ha (Fig. 1). Grain yield was statistically similar for the three tillage systems evaluated in this work (Fig. 1).

	Before sowing	After harvest

Nitrogen	0-25 cm	25-50 cm	50-75 cm	TOTAL	0-25 cm	25-50 cm	50-75 cm	TOTAL
0	62.8 a	44.0 a	26.8 a	133.6 a	16.7 a	8.7 b	4.2 c	29.7 c
100	64.0 a	29.3 a	22.0 a	116.3 a	16.4 a	11.5 b	7.3 bc	34.6 c
200	59.0 a	40.0 a	27.4 a	126.6 a	25.9 a	22.2 ab	16.6 ab	64.6 b
300	55.1 a	34.5 a	28.5 a	113.2 a	42.0 a	31.2 a	25.1 a	115.3 a
Tillage								
CT	85.2 a	57.4 a	36.4 a	180.5 a	29.4 a	17.7 a	12.7 a	72.0 a
MT	47.2 b	25.1 b	25.1 b	89.9 b	22.4 a	23.2 a	17.5 a	63.3 a
NT	47.5 b	26.8 b	26.8 b	95.5 b	24.1 a	14.3 a	9.6 a	48.0 a

Table 1- Mean values (kg/ha $N\text{-}NO_3$) and Duncan test for soil nitrate content by depth, depending on nitrogen fertilisation (0, 100, 200, 300 kg/ha) and tillage system (CT = conventional tillage, MT = minimum tillage, NT = no-tillage).

Figure 1. Effect of nitrogen fertilisation and tillage management (CT = conventional tillage, MT = minimum tillage, NT = no-tillage) on yield corn under irrigated conditions.



Discussion

Rates of nitrogen fertilisation higher than 100 kg N/ha did not increased grain yield, suggesting that even in high yielding areas such as those of Lleida under flooding irrigation condition, higher rates of N may not be needed when initial soil contents are high. Similar results have been obtained by other studies in similar area (Ballesta and Lloveras, 1996). Results also show the validity of the late spring test (Blackmer *et al.*, 1997) although the values should be adapted to the local growing conditions. The results obtained in U.S.A reported no yield increases when initial soil nitrate content was higher than 25 ppm, whereas in the experiment, some response was observed at the initial soil nitrate content of 62 kg /ha. Residual soil nitrogen ($N\text{-}NO_3$) after harvest was four times higher when nitrogen fertilisation increased from 100 kg N /ha to 300 kg N/ha. The results also suggest that rates of nitrogen fertilisation higher than 100 kg N/ha are not necessary for increasing grain yield leaving higher amounts of residual soil nitrogen ($N\text{-}NO_3$) susceptible to be leached.

The lack of statistical differences in grain yield among tillage systems also suggests that the conservation tillage systems (minimum tillage and no-tillage) could be alternative to conventional tillage for corn cultivated in irrigated areas.

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EFFECT OF TILLAGE AND RESIDUAL NITROGEN ON YIELD IN IRRIGATED WHEAT

Santiveri F., Berengué P., Lloveras J., Cantero-Martinez, C.

Area de Conreus Extensius. Centre UdL-IRTA. Rovira Roure 191, 25198 Lleida (Spain)

Introduction

Wheat is part of the crop rotation generally practised in the Ebro Valley's irrigated areas and it is normally seeded after corn. Thus, high fertilisation rates applied to the previous corn crop also can affect wheat production and can increase the risk of nitrate leaching. The present study has the objective of evaluating the effect of nitrogen fertilisation applied in corn on the subsequent wheat yield under three different tillage systems, also allowing a better adjustment of N fertilisation on wheat.

Methods

Experimental design: The study consisted in the evaluation of wheat-maize rotation under Mediterranean irrigated conditions in Vilanova de Bellpuig (Lleida, north-east of Spain). Two adjacent trials were established in 1998 with the purpose of representing the two phases of the rotation. This study presents the results for wheat in 1999-2000-growing season.

Each trial was designed as a split-plot with three replications, where the main plots were nitrogen fertilisation (0, 100, 200 and 300 Kg N/ha) and elemental plots corresponded to tillage management (conventional tillage, minimum tillage and no-tillage). The size of elemental plot was 8 x 21 m. Nitrogen fertilisation treatments were only applied for corn, evaluating the effect of residual nitrogen on wheat yield, sown after corn harvest.

Anza wheat was sown the 15th of December of 1999 at rate of 250 kg seeds/ha. Pre-planting wheat fertilisation consisted in 60 N - 70 P_2O_5 - 189 K_2O, and 120 kg/ha of nitrogen at the end of tillering. Wheat was irrigated four times during growing season. Trial was free of weeds by chemical and mechanical treatments. Harvest was carried out the 4th of July.

Measurements: Soil samples (0-25 cm, 25-50 cm, 50-75 cm) were taken before planting and after harvest to determine N-NO_3, from a solution of the soil after extraction with desionized water. Content of nitrate was obtained by the readings done by colorimetric bands (Nitracheck). Yield was obtained by harvesting the entire plot.

Statistical analysis: Anova analyses and mean separation tests were done using the GLM procedure of the SAS statistical package.

Results

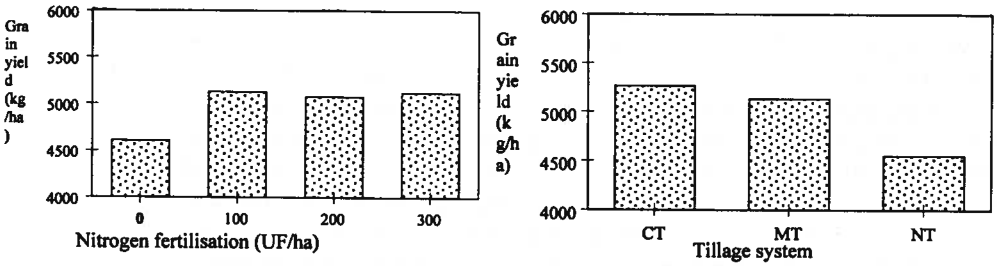
Differences for soil nitrate content prior to wheat sowing were due to nitrogen fertilisation treatments applied to the precedent corn. Total soil nitrate content previous to wheat was higher with the application of 200 and 300 kg N/ha on the precedent corn (Table 1). After the harvest of wheat, soil nitrate contents were similar for all nitrogen fertilisation treatments (Table 1). Tillage management affected soil nitrate content at sowing, and no-tillage showed lower nitrate content than minimum or conventional tillage (Table 1). After harvest, the content of soil N-NO_3 was similar than the values observed in the pre-sowing and differences between tillage systems were not detected (Table 1).

Lowest wheat yield was obtained with 0 kg N /ha and no effect of residual nitrogen fertilisation from corn was detected above 100 kg/ha (Fig. 1). No-tillage showed a grain yield lower than minimum or conventional tillage (Fig. 1).

Nitrogen kg/ha	Before sowing				After harvest			
	0-25 cm	25-50 cm	50-75 cm	TOTAL	0-25 cm	25-50 cm	50-75 cm	TOTAL
0	18.2 a	14.3 b	10.4 b	42.9 b	27.3 a	17.5 a	7.6 a	52.4 a
100	20.3 a	15.8 b	8.9 b	44.9 b	22.1 a	9.6 a	4.6 a	36.1 a
200	26.4 a	18.1 ab	18.3 a	62.8 a	31.2 a	16.7 a	13.0 a	61.6 a
300	25.4 a	22.9 a	23.3 a	71.6 a	34.5 a	14.7 a	8.4 a	57.7 a
Tillage								
CT	22.1 a	19.6 a	19.0 a	60.8 a	32.2 a	15.7 a	13.6 a	61.5 a
MT	24.2 a	18.5 a	18.7 a	61.4 a	27.1 a	14.1 a	6.1 a	47.4 a
NT	21.4 a	15.2 a	7.9 b	44.5 b	27.6 a	14.1 a	5.5 a	47.2 a

Table 1- Mean values (kg/ha $N\text{-}NO_3$) and Duncan test for soil nitrate content by depth, depending on nitrogen fertilisation on precedent corn and tillage system (CT = conventional tillage, MT = minimum tillage, NT = no-tillage), in wheat cultivated under irrigated conditions during 1999-2000 growth season.

Figure 1. Effect of previous nitrogen fertilisation on corn and tillage management (CT = conventional tillage, MT = minimum tillage, NT = no tillage) on following yield wheat under irrigated conditions during 1999-2000.



Discussion

Soil nitrate contents previous to wheat seeding were higher when nitrogen fertilisation applied to corn was 200 and 300 kg N/ha (Table 1), suggesting that corn did not use all nitrogen when N rates were higher than 100 kg/ha. Wheat yields and similar residual soil nitrate contents for the nitrogen treatments of corn, suggests that the amount of N applied to wheat may be sufficient. However, the lowest grain yield for wheat after 0 kg/N ha for corn suggested that N fertilisation applied to wheat in corn-wheat rotation, where the previous corn received no nitrogen might not be enough.

Grain yield was affected by tillage system (Figure 1). No-tillage gave the lowest grain yield, 4600 kg/ha, whereas minimum and conventional tillage did not differ between them (5134 and 5265 kg/ha, respectively). Some studies indicated a grain yield decrease when no-tillage is established, but, sometimes, after several years, grain yield increases and even exceeds the conventional tillage performance. Additionally, it has to be considered the beneficial aspects of no-tillage in soil physical, chemical and biological characteristics.

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EFFECTS OF TILLAGE SYSTEMS AND CROP ROTATIONS ON THE WEED POPULATION AND CEREAL YIELD IN A SEMIARID AREA.

A. Sombrero, A. de Benito, M. Nieto
SITA-Junta de Castilla y León, Apdo. 172, 47080 Valladolid, Spain.

Introduction

Conservation tillage plays an important role in sustainable agriculture because their ability to reduce soil erosion and increase soil water infiltration rate, soil organic matter content and nutrient availabity. Additionally, the conservation tillage system may have economic effects that are a direct result of various factors, environment, local climate conditions, cropping pattern, timing of management practices, and improve protection of environmental quality.
Weed infestation is one of the most important problems in adapting conservation tillage. Tillage and crop rotation are two important factors that affect weed population dynamics. Tillage can effectively control weeds, but this process increases labor as well as soil erosion when compared with other systems (Mannering et al, 1987). Crop rotations can also influence weed species as a result of diverse cultural practices, competitive ability, and herbicide use associated with different crops (Blackshaw et al, 1994).
The aim of this study was to evaluate the influence of tillage systems and crop rotations on weed community and yield in cereal cropping systems.

Methods

This study was carried out in a cereal producing area of Torrepadierne (Burgos) from 1999 to 2001. The soil formation is a Cacixerols Typic. Average annual rainfall is 530 mm.
The design of the experiment was a split plot replicated four times with conventional tillage (CT), minimum tillage (MT) and no tillage (NT) main plots and rotations subplots: cereal/cereal (C/C), cereal/fallow (C/F), and cereal/legume (C/L)). The CT plots were moldboard plowed followed by a second harrowing tillage, and the MT plots were cultivated with a chisel for seedbed preparation before sowing. The NT plots were sowed into undisturbed soil by a direct drill seeder, after spraying glyphosate at 36% (1l/ha + 1kg/ha ammonium sulfate). Cereals, legume and fallow were used because of their suitability for the climate conditions of this dry farming experimental site.
The sowing date for cereal and vetch were usually in early November. Cereal and vetch were sown at 180 and 160kg h^{-1} respectively. At sowing 400kg h^{-1} of NPK fertilizer (8:24:8) was applied to all plots, except to fallow. Ammonium sulfate was topdressed in the early spring (when plants were in the first stage of stem extension) at a rate of 300kg h^{-1}. Spring weed control was used in all cereal plots 2.5l/ha of Oxitril (Ioxinil 7,5% + Mecoproc 37,5% + Bromoxinil 7,5%) plus 1, 25 l/ha of Splendor (Tralkoxidin 25%).
Weeds were taken in heading cereal stage from four 0,25m^2 areas randomized within each plots in 1999, 2000 and 2001, when most of the weed species compete with crops. Weeds were identified, counted and biomass was determined. Cereal grain yield was determined from two 25m long rows mechanically harvested in July.

Results

Weed communities consisting of 26 common weed species were present throughout the study, however, seven of those species accounted for 90% of the whole weed population.
In the heading cereal stage, the relationship between weed density and tillage systems were consistent (Table1). Thus, in general, weed densities were significantly higher in MT than than CT. Although, the total weed number in NT was significantly lower than MT in 1999 and 2001, but not different in 2000. The biomass weed results followed the same pattern of those founded

in weed density. In conservation tillage, *Avena sterilis*, *Bromus sterilis* outnumber the rest of species, though *Poligonum aviculare*, *Poligonum convolvulus* and *Sinapis arvensis* were the most abundant in CT.

Crop rotations had a big influence in weed density and biomass. In C/C weed density and weed biomass were significantly higher than those in C/F in all three years. These parameters in C/L were significantly lower than C/C in 2000 and similar with data for the other years. In C/L rotation *Galium aparini* and *Lithospermum arvense* appeared the most abundant.

Table 1. Effects of tillage and crop rotations on total weed densities and biomass, at heading, along three years. CT, MT, NT, conventional, minimum and no tillage. C/F, cereal/fallow; C/C, cereal/cereal; C/L, cereal/legume.

YEARS	1998/1999		1999/2000		2000/2001	
	Weed dens. pl m^{-2}	Biomass gr.m^{-2}	Weed dens. pl m^{-2}	Biomass gr.m^{-2}	Weed dens. pl m^{-2}	Biomass gr.m^{-2}
CT	86 b	3.24 c	30 b	6.04 b	50 b	9.00 b
MT	144 a	97.84 a	95 a	51.06 a	226 a	72.99 a
NT	90 b	35.19 b	115 a	36.48 ab	167 b	57.27 a
C/F	48 b	38.17 b	40 b	6.40 b	51 b	15.07 b
C/C	131 a	79.65 a	137 a	50.27 a	212 a	80.58 a
C/L	139 a	18.45 b	64 b	36.85 a	179 a	43.62 ab
Tillage*ROT	ns	*	**	ns	*	*

Values with the same letter are not significantly differents (P<0.05)

Cereal yields varied with years and were related to rainfall and weed community (Table 2). Cereal yields were generally higher in 2000, when rainfall was high compared with rainfall in 2001. In general, no differences occurred among tillage systems in 1999 and 2000, though cereal yield was significantly lower in MT than CT and NT in 2001. The results of crop rotations showed that yield were significantly lower in C/C than C/F and C/L.

Table 2. Effects of tillage systems and crop rotations on cereal grains yield. CT, MT, NT, conventional, minimum and no tillage. C/F, cereal/fallow; C/C, cereal/cereal; C/L, cereal/legume.

YEARS	1998/1999	1999/2000	2000/2001
	Yield (kg ha^{-1})	Yield (kg ha^{-1})	Yield (kg ha^{-1})
CT	4.198 a	5.466 a	2.426 a
MT	3.708 a	4.933 a	1.867 b
NT	3.876 a	4.760 a	2.433 a
C/F	4.437 a	5.422 a	2.782 a
C/C	3.047 b	4.700 b	1.478 b
C/L	4.206 a	5.037 ab	2.467 a
Tillage*ROT.	ns	ns	*

Values with the same letter are not significantly differents (P<0.05)

Conclusiones

The tillage systems had a big influence on weed species. MT increased weed population and weed biomass, meanwhile CT decreased both. Monocotyledonous appeared in conservation tillage althougth dicotyledoneus were presented in CT. The rotation C/C had a negative effect on those parameters. The total weed number and biomass had an influence on cereal yields, thus, C/C had the highest infestation and the lowest yield.

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EFFECTS OF RESIDUAL NITROGEN FROM LUCERNE AND RED CLOVER ON MAIZE YIELD

Tabacco E., Borreani G., Grignani C.
Dipartimento di Agronomia, Selvicoltura e Gestione del Territorio - Università di Torino - via L. da Vinci, 44 –10095 Grugliasco (TO). E-mail: tabacco@agraria.unito.it

Introduction

Long-term experiments have demonstrated 10 to 17% greater yield for maize grown in rotation with other crops than when grown in monoculture (Riedell et al., 1998). Including forage legumes in a cropping sequence will generally improve soil fertility and increase yield of the subsequent non-legume crop (Hesterman et al., 1986). Legumes provide nitrogen (N) for the following crop (Groya and Sheaffer, 1985), improve soil structural stability, increase water efficiency and soil organic matter level, and reduce weed and disease infestations (Evans et al., 1991). Recently, increasing interest in more sustainable farming practices (i.e. organic farming techniques) and concerns about environment pollution have made forage legumes more attractive as less expensive sources of N in crop production. Most fertilizer recommendations base legume N credits on a fertilizer replacement value, which is the amount of inorganic N fertilizer required to produce a subsequent non-legume crop yield equivalent to that produced following a legume. This value takes into account the amount of N made directly available from legumes and the yield-enhancing effects that are not directly associated to the N contribution, which is referred to as the "rotation effect". For the U.S. environment, estimates of the fertilizer-N value of lucerne (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) to a following maize (*Zea mays* L.) crop have been as high as 180 kg ha^{-1} (Baldock and Musgrave, 1980) and 90 kg ha^{-1} (Bruulsema and Christie, 1987), respectively. In Italy few experimental data are available and a estimate of N that is made available from legumes during the first subsequent cropping year can help to improve fertilization efficiency of the following maize crop. The aim of the experiment was to determine, in the Po plain, the effects of the previous three year lucerne and red clover on the grain dry matter (DM) yield and N content of a subsequent maize crop.

Methods

The research was conducted during the year 2001 at the University Research Centre near Turin, Italy (44°50'N, 7°40'E) on a sandy–loam soil with a pH of 7.6. Maize crop hybrid (FAO 500) was sown on 12 April at 7.5 plants m^{-2} on plots of 7 x 3 m^2 (four maize rows) following three years of lucerne (L), red clover (RC) and Italian ryegrass (IR, *Lolium multiflorum* Lam.). At plowdown (15 March 2001), the legume DM (roots and crown) was sampled and analysed for total N content (data not shown). Prior to seeding 55 kg K_2O ha^{-1} and 40 kg P_2O_5 ha^{-1} were applied. Weeds were controlled by Metolachlor and Terbuthylazine (1.9 and 0.85 kg a.i. ha^{-1}). The experiment was arranged in a randomized complete block design with 3 replications. Plots previously grown with IR were fertilized with 0, 100, 200 and 400 kg N ha^{-1} as urea. Plots following RC and L received 0, 100, 200 and 0, 100 kg N ha^{-1}, respectively. Data from check plots with continuous maize (8 years) and fertilized with 0, 100, 200, 300 and 400 kg N ha^{-1} were also available in the same environment. Grain yield was taken on ten consecutive plants harvested from the centre two rows of each plot on 5 September, near maturity. The grain was oven-dried at 70°C till constant weight, ground in a mill to pass a 1 mm screen, and analysed to determine total N, according to the Kjeldahl procedure.

Results

The DM grain yield and grain N concentrations of maize crop following maize or IR, L and RC are reported in table 1. No differences were found between the grain yields and N content of maize following maize and IR, so the values of the two treatments were averaged in the table. The maize grain yield following L and RC were significantly greater than those following maize or IR, at the same level of N application. The maize grain with no N application yielded 4.3 t DM ha^{-1}. The maize grain yield following maize increased to 13.5 t DM ha^{-1} with increasing N application to 400 kg ha^{-1}. Maize following L with application of 0 and 100 kg N ha^{-1} yielded 9.8 and 11.5 t DM ha^{-1}, respectively. Yield of maize following RC increased from 6.9 to 12.2 t DM ha^{-1} with increasing N application from 0 to 200 kg ha^{-1}. Maize yield response to N fertilizer (kg ha^{-1}) on the check plots and following IR was described by a quadratic regression [yield (t DM ha^{-1}) = – 0.000094 N^2 + 0.0608 N + 4.24] with an R^2 of 0.83 (n = 55). The grain nitrogen concentration of maize responded similarly. The significant response of yield and N content of maize to N fertilizer was indicative of a limiting N supply from the soil; thus, at least a part of the contribution to the successive maize yield from L and RC was due to the enhanced N supply. The maize yields following L without mineral N were equivalent to those obtained by application of 120 kg N ha^{-1} on the check plots. Lucerne fertilized with 100 kg N ha^{-1} can contribute the equivalent of 75 kg ha^{-1} of mineral N. RC supported maize yields that were equivalent to those achieved with 55, 32 and 2 kg N ha^{-1}, with a N top dressing of 0, 100 and 200 kg ha^{-1}, respectively.

Conclusions

The results show that lucerne and red clover can provide large part of the N that is needed by a maize crop in the first subsequent year. Nitrogen contributions resulted to be equivalent to 120 and 55 kg ha^{-1} for lucerne and red clover, respectively. The N replacement value was reduced to 75 for lucerne and 32 kg ha^{-1} for red clover, when 100 kg ha^{-1} of urea N was top dress applied.

Table 1. DM yield and N content of maize grain in relation to the preceding crop and to different rates of mineral N top dress application.

Treatments †	Grain yield (t DM ha^{-1})	Grain N content g (kg DM)$^{-1}$
M or IR (0 N)	4.3	7.0
M or IR (100 kg N ha^{-1})	9.2	9.7
M or IR (200 kg N ha^{-1})	12.8	10.0
M or IR (400 kg N ha^{-1})	13.5	11.2
L (0 N)	9.8	9.5
L (100 kg N ha^{-1})	11.5	11.6
RC (no N)	6.9	8.8
RC (100 kg N ha^{-1})	10.4	9.8
RC (200 kg N ha^{-1})	12.2	10.6
LSD	*1.65*	*1.95*
treatment effect	***	***

*** Significant at the 0.01 level of probability.
† Maize following: M = maize, IR = Italian ryegrass, L = lucerne and RC = red clover.

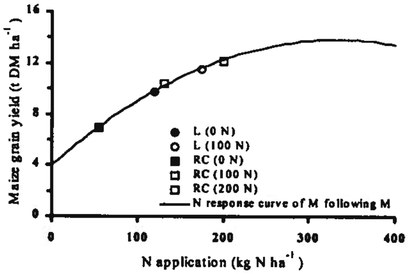

Figure 1. N response curve of maize grain yield following maize (n = 55) and N replacement value for lucerne and red clover at different N application rates (0, 100 and 200 kg ha^{-1}). Maize following: M = maize, L = lucerne and RC = red clover.

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EFFECT OF DIFFERENT TILLAGE SYSTEMS IN COLD SEMIARID SPAIN

Tenorio JL. [1], de Andrés EF. [1], Sánchez J. [2], Esteban E. [3], Catalán G. [1]

[1] INIA. Dpto. Medio Ambiente. Apdo. 1045. 28800 Alcalá de Henares. Madrid. España
[2] INIA. CRF. Apdo. 1045. 28800 Alcalá de Henares. Madrid. España[3] Dpto. de Química Agrícola. UAM. Crta Colmenar Km15. 28049 Cantoblanco. Madrid.

Introduction

The importance of preserving natural resources in competitive agricultural makes necessary the adoption of new cultivation techniques as well as diversifications of crop productions.
The main objectives of the present work are: to characterize the influence of tillage techniques on the soil water content in the top 90 cm and to determine the effect of the tillage system on growth, developement and yield of crops.

Methods

The trials started at INIA's experimental farm "La Canaleja" in central Spain (Alcala de Henares, Madrid) in 1994. Soil type is a *Calciorthidic Haploxeralf,* average annual rainfall is 470 mm and altitude reaches 610 m.a.s.l.
Three tillage treatments (CT: conventional tillage, MT: minimum tillage, NT: no tillage) and three crop rotations (BB: barley-barley, FB: fallow-barley, VF: vetch-barley) were tested.
At barley phenological stages of tillering, shooting, and earing, several measurements of growth and development of barley were taken. Soil water content was estimated with a neutron probe. Yield and its components were determined at harvest.
The data were analyzed using GLM procedures included in the SAS statistical package (SAS Institute Inc. 1988). Significant differences between means were estimated using Duncan's Multiple Range Test P = 5%. (Duncan. 1955)

Results and Discussion

Table 1. *Soil water content (mm) in the first 90 cm*

Tillage	SOWING [2]		TILLERING		SHOOTING		EARING		HARVESTING	
CT	94,47	b	122,71	a	98,21	a	110,37	ab	78,21	b
MT	95,21	b	118,82	b	95,12	b	106,97	b	74,21	c
NT	101,88	a	124,9	a	99,74	a	113,24	a	80,71	a
Rotation [1]										
BB	94,84	b	120,85	a	97,71	c	104,15	b	71,33	c
FB	101,75	a	122,95	a	92,71	d	103,01	b	76,63	b
BF	98,06	ab	124,24	a	104,95	a	141,21	a	92,64	a
VB	96,95	b	121,16	a	91,71	d	97,88	c	71,67	c
BV	94,98	b	121,51	a	101,36	b	104,72	b	76,28	b

Mean followed by the same letter are not significantly different at P< 0,05
[1] Last letter stands for present year crop
[2] Sowing data correspond to 1995, 1997, 2000, 2001 and 2002

Differences among tillage treatments and crop rotations, in the water content in the top 90 cm of soil, increase with time (table 1) but significant differences only appear in the last barley developmental stages. MT retains less water in the soil profile than the other two treatments and it shows significant differences in all the samplings. Also MT is less efficient than the other two treatments in the water use. NT retains more water in the soil profile than CT and MT (Giraldez *et al*, 1994; Chank *et al*, 1996; Lampurlanés *et al*, 2001; Tenorio *et al*, 2001) and the differences are significant from barley earing (table 1).

Fallow-barley crop rotation accumulates more water than the other two, differences are significant from barley shooting (table 1) probably for the accumulation of water in the fallow year (Tenorio *et al*, 2001). Continuous barley is less efficient than the other two crop rotations.

Figure 1: *Barley yields according to tillage treatment*

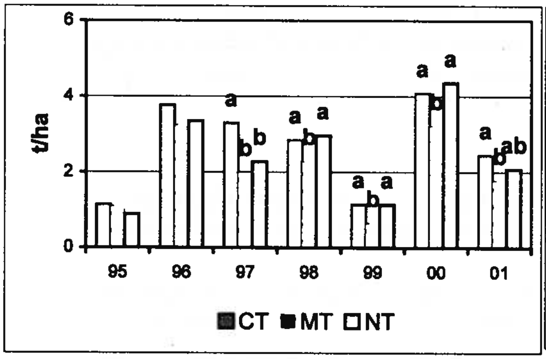
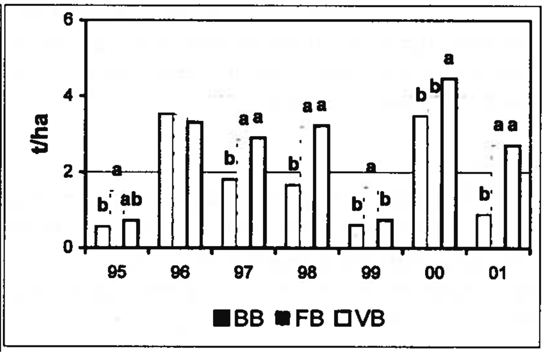


Figure 2: *Barley yields according to crop rotation*



Conventional (CT) and no tillage (NT) yields become nearly identical with time (Catalán *et al* 2001. Murillo *et al* 2001) (figure 1), on the other hand continuous barley yields from the second year are lower than those of the other two crop rotations (López-Bellido *et al.* 2001) (figure 2).

Acknowledgements
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EFFECTS OF ROW WIDTH ON WHEAT GRAIN YIELDS IN WINTER WHEAT/ WHITE CLOVER INTERCROPS

Thorsted, M. D.

Danish Institute of Agricultural Sciences, Dept. of Crop Physiology and Soil Science. P.O. Box 50, DK-8830 Tjele, Denmark

Introduction

White clover is known to compete with winter wheat when the species are intercropped, and wheat grain yields are often reduced compared to wheat in monoculture (Koefoed, 1996). White clover is intercropped with wheat to supply the wheat crop with nitrogen and reduce leaching of plant nutrients during autumn and early spring. The presence of white clover also reduces the risk of infection of some wheat diseases. To improve the competitive ability of wheat in an intercrop with white clover, changes in spatial distribution of wheat were suggested. Weiner *et al.* (2001) showed that increased homogeneity of the crop canopy increased the suppression of weeds. A similar effect was expected to occur with wheat and white clover, when wheat were allowed to explore more space an increase in the levels of resources available to wheat was expected.

Methods

A factorial plot experiment with intercropping of winter wheat and white clover was performed in Denmark in 2000 and 2001. Factors were: plant density of wheat (250 and 400 plants m^{-2}), rotatilled band width (7 and 14 cm) and seeding width of wheat within bands (3 and 6 cm). Not all combinations of the factors were present (Table 1). The wheat row distance was 25 cm. There were four replicates of each treatment, and the block effect was analysed as a random effect. Grain yields were measured by harvesting 13-14 m^2 pr. plot, and the dry mass of grains was determined after oven-drying at 80° C. Results were analysed statistically separately for each year with the MIXED procedure of SAS statistical analysis system (SAS Institute, 1999).

Rotatilled band width (cm)	Seeding width (cm)	Plant density (plant m^{-2})
7	3	400
7	3	250
14	3	400
14	6	400

Table 1. Combination of experimental factors.

Results

Grain yields were significantly higher ($p < 0.001$) in 2000 and ($p < 0.05$) in 2001 with the 14 cm band width compared with the 7 cm band width (Table 2). There was also a significant effect ($p < 0.05$) in 2000 and ($p < 0.001$) in 2001 of seeding width, with highest yields obtained with the 6 cm seeding width compared with 3 cm (Table 2). There were no significant differences in grain yields in 2000 and 2001 between treatments with different plant densities (Table 2).

	Grain yield (t ha^{-1})	
Factors	2000	2001
Seeding width		
3 cm	4.70	3.61
6 cm	5.39	4.56
S.E.* (9 D.F.)	0.125	0.208
Band width		
7 cm	4.49	3.48
14 cm	5.25	4.22
S.E.* (9 D.F.)	0.109	0.197
Plant density		
250 plants m^{-2}	4.49	3.47
400 plants m^{-2}	4.99	3.98
S.E.* (9 D.F.)	0.125	0.208

Table 2. Grain yields (85% dry matter).* Standard error of means.

Discussion and conclusion

The competition from clover was reduced and grain yields in winter wheat increased, when band width was increased due to a lower spatial proportion of white clover. Both inter and intra-specific competition, due to changed spatial distribution of wheat, was expected to be influenced by seeding width. An increase in distance between wheat plants was expected to improve wheat grain yields due to a higher possible resource exploration area on the level of individual plants. An increase in wheat plant density was also expected to increase the relative exploration for resources, but a suboptimal plant density may increase the competition between wheat plants in rows and counteract the effect. The increase in grain yields when seeding width increased and the lack of significant differences in grain yields when plant density increased, indicate that interspecific competition between spicies may be more important to grain yield development than intra-specific competition between wheat plants.

Winter wheat (*Triticum aestivum*) was intercropped with white clover (*Trifolium repens* L.). The wheat was sown in rotatilled bands in a stand of white clover. Wheat grain yields are often reduced in competition with white clover, and in the present experiment attempts were made to improve wheat competitive ability and grain yields by changing row geometry. In both 2000 and 2001 increased seeding width of wheat within the rotatilled band increased grain yields by changing row geometry. Additionally, increasing the rotatilled band width increased wheat grain yields.

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Agriculture-environment relationships

SOME METHODOLOGICAL ISSUES IN THE CONSTRUCTION OF ENVIRONMENTAL INDICATORS

Bockstaller C.[1,2]**, Girardin P.**[2]

[1] Association pour la Relance Agronomique en Alsace (ARAA)

[2] UMR INPL-ENSAIA-INRA Agronomie et Environnement Nancy-Colmar (France)

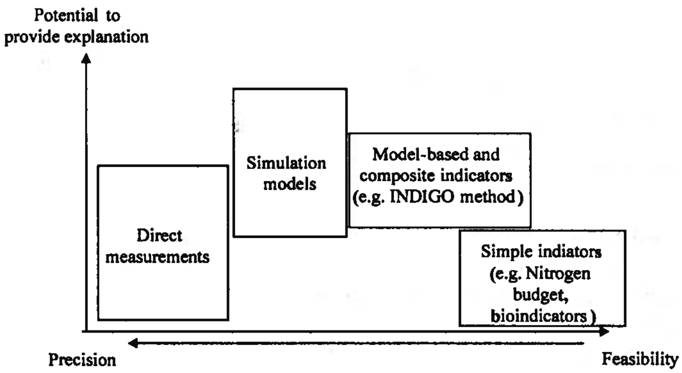
Introduction

An increasing interest for environmental indicators can be observed among environmentalists and agronomists during the last decade. The use of indicators is very relevant when direct measurements are impossible or too costly, when simulation models are not available or cannot be implemented outside a scientific context. That is especially true for some theoretical concepts like sustainability which absolutely needs assessment tools like indicators for its implementation (Rigby *et al.*, 2001). In any case, the construction and development of indicators should meet scientific standards. The purpose of this paper is to clarify some points of the methodology proposed by Girardin *et al.* (1999). Examples will be taken from our assessment method, INDIGO, which consists of a set of agro-ecological indicators (Bockstaller *et al.*, 1997).

Basic assumptions for the construction of environmental indicators

Every scientific approach is based on assumptions and choices which cannot be scientifically justified but have to be made transparent. It begins by the choice of a type of assessment tool and more specifically a type of indicator. This will determine the potential in the precision of the assessment given by the selected tool, its potential to provide a detailed information and explanation of the observed results, but also its weakness in the matter of feasibility for its implementation. Fig. 1 shows some examples. The indicators of the INDIGO method, as composite and model-based indicators, are placed between simple indicators and simulation models

Fig. 1 Potential and weakness of different assessment methods



The challenge of aggregation

Different type of aggregation are possible :

i) *Spatial* aggregation of an indicator obtained for spatial units (e.g. fields): A usual method is to calculate a weighted mean by the size of the units to obtain a value at a higher scale (e.g. a farm). However, this approach can be criticised in some situation as for a watershed where each field does not have the same importance. Similar problems may occur in *temporal* aggregation

ii) Aggregation of *simple indicators* into a *composite indicator* (Girardin *et al.*, 1999): A common approach is to sum up the scores of the different sub-indicators (Rigby *et al.*, 2001), or to calculate a weighted mean. However the use of the sum in both cases is open to criticism (the problem of summing apples-and-oranges). The weighting is also criticized for its subjectivity (Andreoli *et al.*, 1999). In the INDIGO method we try to avoid the pitfall of the sum by using other operators like the product or the minimum or by using expert systems and especially expert system based on fuzzy logic (Silvert, 2000).

iii) Aggregation into a *global and unique indicator*. We propose such an indicator (Bockstaller and Girardin, 2002b) to meet the need of having a synthetic view of a system, pointed out by some experts but criticised by others.

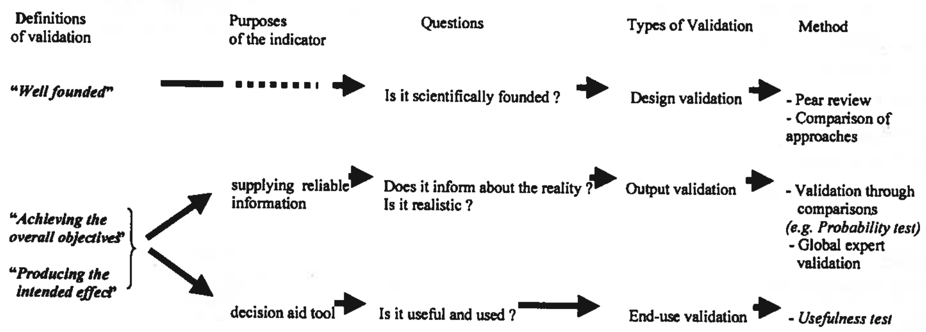
Determination of thresholds or references

Rather than providing a raw value of a indicator , it is relevant to define a target or recommended value, or, a threshold or a "minimal value" for an environmental indicator. This helps the user to know the importance of the risk and to decide whether he should change something in his system or not (Smith and McDonald, 1998). In INDIGO, this reference value is defined in different ways, depending on availability of data. It can be: i) an impact threshold or a norm defined by experts or by regulation ii) the precision degree of the measurement for the corresponding impact iii) a set of "good practices" inspired by the guidelines of Integrated Arable Farming Systems.

Validation of indicators

Although many indicator developers do not deal with the question, it is a requirement in a scientific approach. Because indicators differ in many cases from simulation, the procedure of validation will not be the same. We propose a general framework (Fig. 2). Comparison of indicator output may be carried out with: measured data, data from simulation models or expert knowledge by a *probability test*. It may also be done by comparison with other indicator outputs, or at least by direct submission to experts judgement (Bockstaller and Girardin, 2002a).

Fig. 2 Methodological framework for the validation of environmental indicators



Conclusions

The increasing need of different type of indicators for specific use requires in any case a scientific approach for their construction. Different solutions are proposed to solve some crucial problems which deserve more attention from indicator developers.

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A GLOBAL INDICATOR OF ENVIRONMENTAL SUSTAINABILITY (I_{GLO})

Bockstaller C.[1,2]**, Girardin P.**[2]

[1] Association pour la Relance Agronomique en Alsace (ARAA)
[2] UMR INPL-ENSAIA-INRA Agronomie et Environnement Nancy-Colmar (France)

Introduction

In spite of a multiplicity of definitions for sustainability, most experts agree with the need of developing assessment tools of sustainability at different scales for its three dimensions: ecological, economical and social. The approach generally consists of a set of indicators which is very relevant to identify strong and weak points of a system (Smith and McDonald, 1998). However, there is also a need of global indicators which provide a synthesis and help to compare systems. But such approach is often criticised because of methodological issues, like the use of the sum to add different scores, the subjectivity in the weighting of the different sub-indicators, and the compensation between indicators (Bockstaller and Girardin, 2002). Thus the following indicator (I_{GLO}) is an attempt to go further by avoiding those pitfalls.

Construction of the indicator

1st stage: Selection of the set of indicators.

I_{GLO} is based on the indicators from the INDIGO method . (Bockstaller *et al.*, 1997). Eight indicators are available: *crop diversity*, *crop sequence*, *organic matter*, *phosphorus*, *nitrogen*, *pesticide*, *irrigation*, and *energy*.

2nd stage: Weighting of the indicators

Four qualitative levels are defined: "critical", "high", "medium" and "low". This qualitative weighting is carried out according to guidelines. We defined these guidelines for each indicator to limit the subjectivity of this procedure, as recommended by Andreoli *et al.* (1999). The guidelines take into account the context of the farm (or the region) and the acuity of the different environmental problems. Tab.1 provides an example for the *nitrogen* indicator which assesses the risk of nitrate leaching.

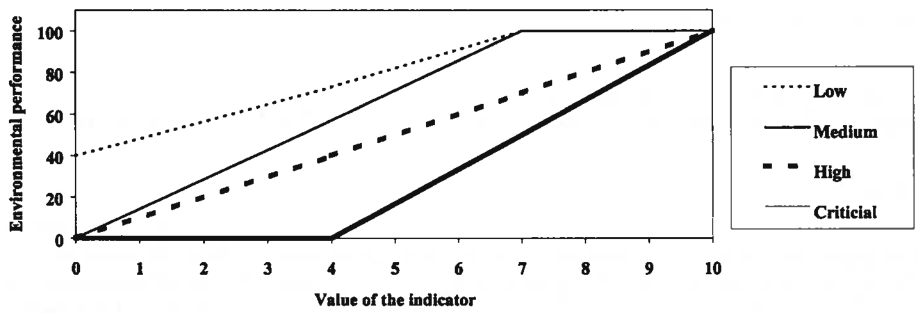
Tab. 1 Example of guidelines for the weighting of the *nitrogen* indicator

Weight class	Conditions for the weight attribution
Urgent	- Field located in a protection area of a well with nitrate pollution
Important	- Field in a protection area of a well without nitrate pollution - or Field in an area with polluted groundwater
Medium importance	- Field in an area with groundwater without pollution problem
Low importance	- Field in a area without groundwater

3rd stage: Definition of environmental performance functions

Functions of environmental performance are defined to avoid the problem of "adding apples-and-oranges". As shown in Fig.1, they transform the value of each indicator into a relative value between 0 and 100, expressing the degree of achievement of a environmental objective (e.g. preserving groundwater quality). They are inspired from the utility functions in multicriteria analysis (Foltz *et al.*, 1995).

Fig. 1 Function of environmental performance for the indicators (INDIGO method)



4[th] stage: Aggregation within each class of importance

If several indicators have the same weight, the *minimum* value of environmental performance for those indicators is selected (Phillis and Andriantiatsaholiniaina, 2001).

5[th] stage: Construction of an expert system with fuzzy logic to calculate Iglo

For each class of weight, the environmental performance is considered as "sustainable"or "favourable" (F) if its value equals 100 and "no sustainable" or "unfavourable" (U) if its value equals 0. For the extreme cases, the following expert system is proposed (Fig. 2). The values for I_{GLO} have been selected to avoid compensation between the weight classes.

Fig 2. Expert system giving the value of the global indicator I_{GLO} according to the environmental performance within each weight class for extreme cases (favourable (F) or unfavourable (U)) when each weight class is associated at least to one indicator

Weight class	Environmental performance of the indicator in each weight class															
Critical	F								U							
High	F				U				F				U			
Medium	F		U		F		U		F		U		F		U	
Low	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U
I_{GLO}	100	95	90	85	75	70	65	60	40	35	30	25	15	10	5	0

When the environmental performance is between 0 and 100, intermediate values are calculated according to fuzzy logic rules (Phillis and Andriantiatsaholiniaina, 2001).

Conclusions

The choices made for the construction of this global indicator I_{GLO} are open to discussion. However the framework of its construction is based on an approach avoiding some crucial problems in aggregating a set of indicators. It allows taking into account local conditions of a farm. The validation of such multi-criteria cannot be carried out with single comparison with measured data. The use of expert knowledge is required (Bockstaller and Girardin, 2002).

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TERRITORIAL INFORMATIVE SYSTEM FOR THE OIL WASTE WATER'S SHEDDING

Bonari E.[1] , Silvestri N.[2], Tonini M. [1], Sabbatini T. [1], Ceccarini L. [2]

[1] Sant'Anna Advanced School for University Studies and Doctoral Research, via Carducci 40 – 56127 Pisa (Italy); [2] Department of Agronomy and Agro-ecosystem Management of University of Pisa , via S. Michele degli Scalzi, 2 - 56124 Pisa (Italy)

Introduction

With the aim to improve the oil waste water's shedding on the agrarian land, a territorial informative system has been constituted. It evaluates the suitability of various areas to receive such waters, according to law constraints and environmental characteristics.

The Italian law (574/96), currently enforced, establishes: 1) the maximum amount of oil waste waters that is possible to shed on fields, 2) the categories of suitable lands for the distribution, and 3) the norms for water storage.

The optimization of the way of shedding oil waste water on the agrarian land is therefore a serious need. In particular, the definition of the site-specific conditions for distribution (amount, modes, timing, and the most suitable equipments) according to agronomic, pedological, orographic and climatic characteristics is required, thus avoiding the onset of either undesired (e.g., superficial sliding, limited drainage, smell emissions, etc.) or quite dangerous (e.g., groundwater pollution, superficial water bodies contamination, etc) phenomena.

Methods

A Territorial Informative System (T.I.S.) was constituted as a first step in the development of this research. T.I.S. is a system of organized and updatable information referring to the territory, and exploitable for planning and evaluation purposes.

The program is structured on three levels, progressively more detailed (and consequently characterized by a smaller scale of reference), corresponding respectively to the Tuscany region (1:250.000), the province of Pisa (1:100.000), and the local level (1:5000 scale) still to be examined. In particular, the factors considered at regional level were lithology, climatic types, catchment basins, oil waste water production, use of soil, hydrographical system. Other factors, such as cropping systems, climatic and pedological characteristics, slopes, hydro-geological vulnerability, and oil press location were examined at provincial level. The local level is still under study.

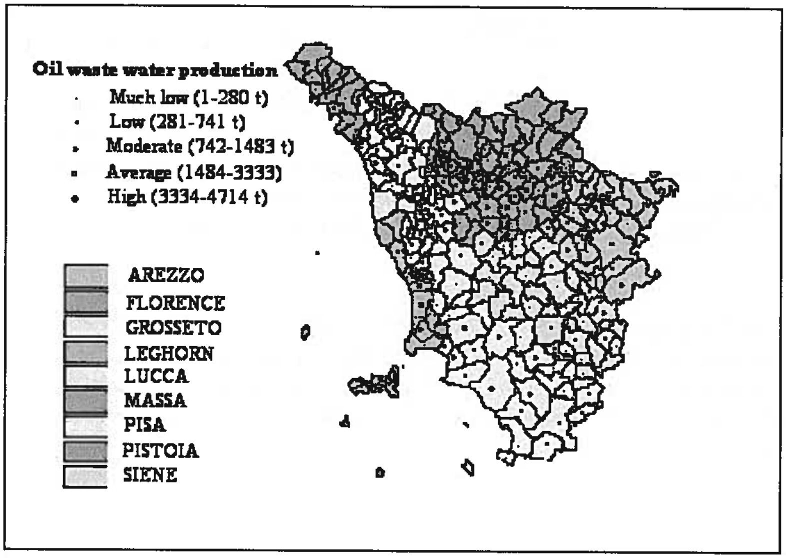

Fig 1. Production of oil waste water in the provinces of the Tuscany region.

Information has been organized in distinct layers referring to the same area. The operation of map overlaying allowed to classify the territory into different suitability areas for waste oil water shedding.
The oil waste water production for single oil press, summarized for each municipality of Tuscany region, is showed in Fig. 1. The legend includes five classes of rising intensity. The consultation of the IV Census of agriculture allowed to define, for each municipality, the size of agricultural area suitable to the shedding, corresponding to the useful agrarian surface minus the vegetable crops and grassland. The ratio between the oil waste water production and the respective surface useful for shedding determines the unit "charge" for each municipality and allowed to locate the area where the distribution of waste oil water can be dangerous, requesting more careful survey.

Results

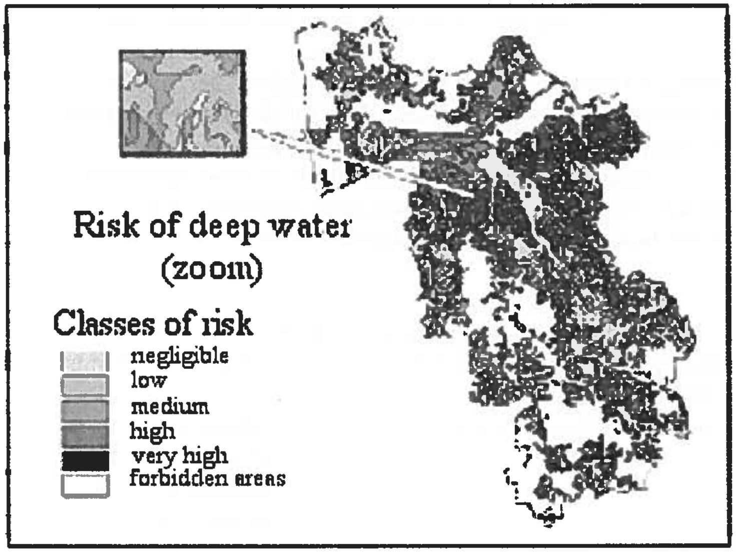

Fig. 2. Map of risk for deep waters.

Three maps of risk were defined, considering the shedding suitability at provincial level:

1) map of risk for deep waters (Fig. 2): it shows the pollution risk for the groundwater determined as a function of the total rain volumes in the months interested to the shedding, the soil permeability, and the water table depth;
2) map of risk for superficial waters: it points out the risk of run-off , based on the total rain volumes in the months interested to the shedding, the soil water retention capability, and the field slope;
3) map of accessibility in field, estimated as a function of the total of rainy days in the months interested to the shedding, the soil texture (drainability) and the field slope.

Conclusions

The setup of T.I.S. allowed to perform specific and sub-sequent procedural steps, characterized by different aims and quality of results. The regional level played the role of "screening"; the provincial level allowed an assessment of the vulnerability of territory, and the local level (still to be examined) will be aimed at optimizing the process of planning the oil waste water shedding in the area of pertinence for any oil press.

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RELATIONSHIPS BETWEEN TRANSFER SPEED AND DIURON CONCENTRATIONS IN THE DRAINAGE WATER. A LYSIMETER STUDY ON THE EFFECT OF SOIL CRUSTING.

Chapot J.Y.[1], Delphin J.E. [1], Schiavon M. [2]
1 INRA, UMR Vignes et Vins, Agric. et Environnement, BP 507, 68 021 Colmar, France
2 ENSAIA, Laboratoire Sols et Environnement, 54 505 Vandoeuvre-lès-Nancy, France

Introduction

The structure and porosity of the above soil layer and especially at the surface can be modified by the weather, cultural practices (irrigation etc) in interaction with the soil type. The infiltration rate of a soil is strongly dependent on the surface porosity. During rainfall whose rate temporarily exceeds the infiltration capacity of the soil, the pore state of the surface soil will determine a variable partitioning of the free water between rapid transport through preferential flow channels (macropores) and slow flow through fine pores (mesopores). The type of pores used by the water also varies according to the moisture content of the soil. The speed of drainage is related to the size of the pores through which the water flows. Different transfer speeds of solutions through the soil will, in the case of pesticide leaching, have an effect mainly on the duration and intensity of the adsorption process, on diffusion and to a lesser extent on degradation. We assume that they can have an effect on the concentrations in the drainage water (Shimojima E. et al. 1995). Using lysimeters, we compared the effect of two very distinct surface pore states, i.e. the presence or absence of a crust, on the kinetics of drainage and the pesticide concentrations in the drainage water under conditions of brief, high intensity irrigation whilst the soil was at field capacity.

Methods

Six large lysimeters (2*2*1m), were filled with a silty clay soil (loess), liable to crusting. Three were allowed to develop a surface crust, whilst the other three were tilled to a depth of 3 cm during the period of the study to break the crust. 1800g diuron/ha were applied on 2 May 2001; six irrigations of 20 mm (each composed of two 10 mm amounts in rapid succession) were applied between days 1 and 91 at an intensity of 90 mm/hour. Mean pesticide concentrations were measured in the drainage water from 0-48 hours after irrigation. The soil was brought back to field capacity before each of the six irrigations.

Results

1/ In a period of high pesticide availability at the surface, the pesticide concentrations in the drainage water were much higher in the presence of the crust (fig. 1). The pesticide concentrations at the surface, measured using porous cups, were comparable over time on the two treatments. The presence of a crust reduced the infiltration rate, measured with a T.R.I.M.S infiltrometer, encouraged the formation of puddles on the surface and the rapid transfer during the first few hours of part of the water via the macropores (fig. 2 and 4) In the absence of a crust, the area of puddles was less, they disappeared more quickly, the start of drainage was delayed by several hours and infiltration is assumed to take place via the mesopores. Slower transfer through finer pores encourages adsorption and diffusion, so the concentrations were lower. During the irrigation at 10 days, although the availability at the surface was high, the concentrations were greatly reduced on the crusting treatment. This result is explained by a soil moisture deficit at the surface which resulted in slow and little drainage, which was similar on both treatments during the first three hours, probably mainly through the mesopores (fig. 3).
2/ When the availability of pesticide at the surface fell to a low level, the concentrations in the drainage water were greatly reduced, but remained higher in the presence of the crust. That although the pesticide concentrations at the surface were similar on both treatments. In the

presence of the crust, during the phase of high pesticide availability at the surface, preferential transfer resulted in a greater proportion of pesticide at depth. During the next phase, the higher concentrations in the drainage water were linked to the desorption of the pesticide carried down to depth and facilitated by the low organic matter content (Moreau et al. 1997).
Similar results were obtained with the compounds studied: diuron, metolachlor and atrazine.

Conclusions

The results underline the importance of relationships between speed of transfers and concentrations in the drainage water. They show that the study of the fall in concentration through the soil should take account of the speed of water movement, the properties of the molecules and the organic matter contents of the layers. They enable the short and medium term risks to be assessed, following preferential transfer. In practical terms, the results show that it is possible to prevent the risk of leaching due to preferential transfer by tilling the surface soil (when possible), before applying pesticide and after application during the period of high availability. Under conditions of very rapid water flux, the risk of pesticide leaching, which is very high in the presence of a crust, is fairly small after a very superficial harrowing of the soil, which is enough to direct the water towards the mesopores. The level of risk increases with degradation of the surface soil structure, which depends on the weather and the structural stability of the soil.

Fig 1 Diuron concentrations µg L^{-1}

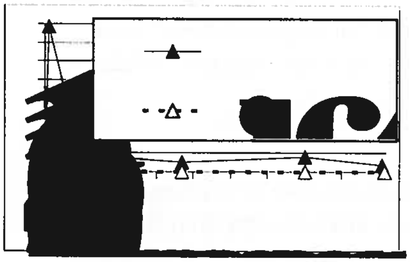
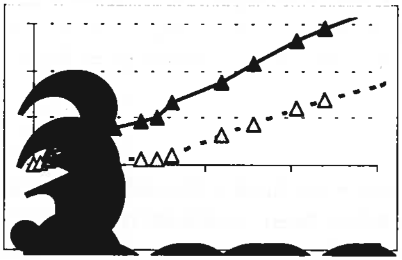


Fig 2 Drainage (mm) Irrigation 1



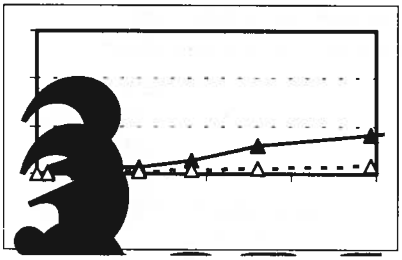


Fig 3 Drainage (mm) Irrigation 2

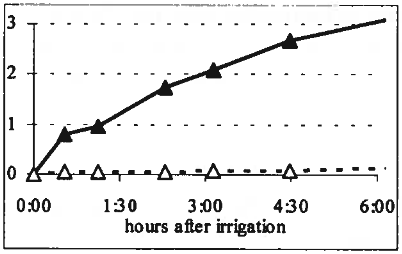


Fig 4 Drainage (mm) Irrigation 3

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RISK OF ATRAZINE LEACHING, A FIELD STUDY ON THE EFFECT OF THE INITIAL SOIL WATER CONTENT

J.E Delphin and J.Y. Chapot
Equipe Agriculture et Environnement UMR Vigne et Vins d'Alsace
INRA, 28 rue de herrlisheim, 68021 Colmar CEDEX, France

Introduction

Preferential flow is assumed to be one significant process affecting pesticide migration and the subsequent risk of groundwater contamination. Contradictory effects of initial soil water content on preferential transport of water and solutes have been found in field and column experiments (Flury et al. 1995, Delphin et al. 2001, Shipitalo, M.J. et al. 1990). One possible explanation could be that the effect of the initial soil water content is different according to whether it concerns the surface layer or the whole soil profile. The objective of the study presented here was to examine the effect of two initial water contents of a soil profile on the migration depth of atrazine applied to soil surfaces at the same water content.

Methods

The study was carried out in northeastern France at the INRA experimental field site on two plots (1.7 x 4 m) without crops. Each plot was equipped with porous cups at 50 cm, 100 cm and 150 cm depth. The cups were inserted horizontally into the undisturbed soil profile from a trench refilled after installation. At the end of April 2001, 35 mm irrigation was applied by sprinkling on the *wet plot* so that the soil reached field capacity. Three days later, the soil surface was dry and 1000 g ha^{-1} of atrazine was applied to both plots. A 20 min irrigation (90 mm h^{-1}) was applied two days later to both plots. Soil solution (varying from 100 mL to 1000 mL) was sampled from the porous cups with 6 replicates at each layer during the following year after each irrigation and major rain event. Water samples were extracted using SPE cartridges ; atrazine and DEA (desethylatrazine) in the extracts were analyzed by HPLC. The detection limit in the water for a 500 mL sample was 0.05 µg L^{-1}. The soil water content was measured with a neutron probe in two access tubes installed close to the plots.

Results

The 10 mm difference in the soil water content between the dry and wet plots after the first irrigation was mainly located in the 20-90 cm soil layer (fig 1). After the atrazine application, the amounts of water supplied during the following 15 days by the second irrigation and the rainfall (28 mm) eliminated the deficit.

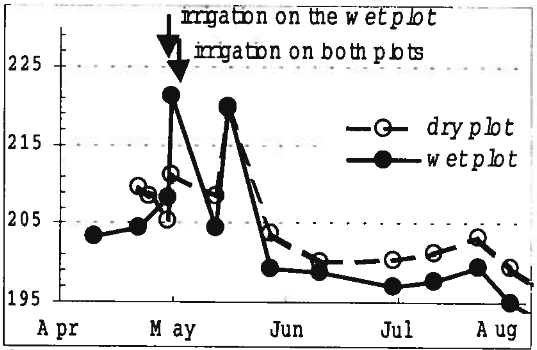

Figure 1 Water storage (mm) in the 20-90 cm soil layer

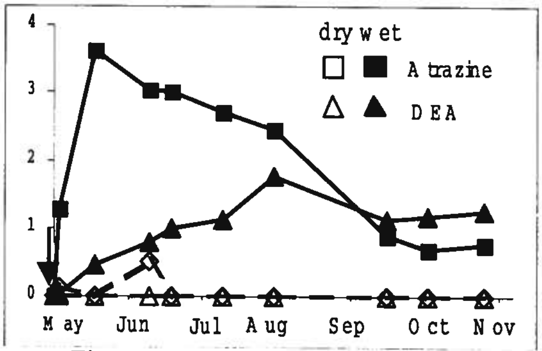

Figure 2 Atrazine and DEA in the soil solution at 50 cm depth (µg L^{-1}) (arrow : herbicide application)

In the *wet plot*, the atrazine concentration in the soil solution at 50 cm increased immediately after the irrigation. A maximum was reached 15 days later and was followed by a slow concentration decline. The DEA concentration increased slowly, reaching a maximum 3 months after the beginning of the experiment (fig 2).
Three porous cups out of six were affected by the atrazine increase; in the remaining three the atrazine concentrations were lower than the analytical detection limit. No atrazine or DEA was detected in the soil solution at 100 cm and 150 cm.
In the *dry plot*, the atrazine increase at 50 cm was only observed in one porous cup at two dates. The peaks were weak and did not persist. No DEA was detected in the soil solution after these peaks. No detectable concentrations of atrazine and DEA were measured in the soil solution at 100 cm and 150 cm over the course of the experiment.
The rapid increase in atrazine concentration in the soil solution at 50 cm may be explained as the consequence of preferential transport, since atrazine moved deeper than expected from the amount of water applied. The results obtained in our experimental conditions suggest that atrazine penetrated very unevenly down to 50 cm depth in the wet plot and that migration rarely reached this depth in the dry plot. The rapid transfer was firstly controlled by the intensity of the irrigation and rainfall occurring after the atrazine application. On the other hand, the migration of water and solute would be affected by the initial water content of the soil profile : water flowing in large pores was presumed to be laterally diverted into smaller ones along a dryness gradient. When the surrounding soil profile was dryer, preferential flow would penetrate less deeply with a lower intensity and would then be more rapidly dissipated.

Conclusion

As previously claimed by Flury et al. (1995), the possibility of solutions moving by preferential flow to migrate deeply into the soil is limited by the initial soil water content of the profile. In a dry profile, water and solutes penetrate less deeply and with a lower intensity into the soil. The soil water content seemed to be one significant factor controlling the depth of atrazine penetration by preferential transport and therefore the risk of groundwater contamination. The risk of atrazine leaching may therefore be influenced by the time of application and the nature of the treated crop.

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PHOSPHORUS LOSSES IN RUNOFF FROM A VERTISOL IN SOUTHERN SPAIN

Díaz, I.[1], del Campillo, M.C.[1], Barrón, V.[1] and Delgado, A.[2]
[1]Departamento de Ciencias y Recursos Agrícolas y Forestales, Universidad de Córdoba, Apdo. 3048, 14080 Córdoba, Spain, and
[2]Departamento de Ciencias Agroforestales, Universidad de Sevilla, Ctra. Utrera km 1, 41013 Sevilla, Spain. *e-mail: ef1cagam@uco.es*

Introduction

Phosphorus application is necessary in agricultural lands since it is an essential nutrient for plants. However, in the last decades, heavy fertilizer applications have been made in order to increase productivity of agricultural soils. In many cases, soils have received higher P rates than those necessary for crops. There is a profuse information reporting that P soil levels exceed those required for optimum crop yield in Western Europe, as well as in the USA. Phosphorus is readily fixed in soils through adsorption or precipitation processes, but the capacity of soil to bind P is limited and the upper soil layers can become saturated by P. Under these conditions, P can be lost through leaching processes. In calcareous soils from Mediterranean regions, saturation of surface horizons is almost impossible due to the high fixing capacity of soil. This determines that main P loses from soils are related to runoff processes, either in dissolved form or associated to soil particles (Sharpley et al., 1993). Increasing P concentration in water can accelerate the environmental problem of eutrophication (Sharpley et al., 1993). When P concentration in water reaches 0.01-0.07 mg P/l, considerable algal growth can occur for western European conditions (Golterman and Oude, 1991). The objective of this work was to study the effects of natural rainfall (from october to march) on runoff losses of P in a craking clay soil (Typic Haploxerert)that has been heavily fertilized with P during last 30 years.

Materials and Methods

The experimental site was a basin of 60 ha located in Córdoba (Spain). The basin included one of the most representative soil orders of the Mediterranean region (Vertisols) and the maximum slopes were about 10 %. Representative surface samples were taken and analyzed for texture, organic matter, carbonate and Olsen P. Experimental design consisted of four plots of 1 m^2 delimited by aluminum borders with a trough in the lower part to conduct runoff to 25 litres plastic bottles. P fertilization was done in early November before the rainy season, applying 45 kg P_2O_5 ha^{-1}. Rainfall and runoff was followed during the rainy season from october 2000 to march 2001. After each event, runoff volume was measured and bottles were shaken to take 1 L of representative sample. After that, runoff samples were stored at 25°C in the dark. A volume of each sample was centrifuged to separate soil sediment and solution. Sediment sample was dried and weighed to determine total soil loss. Total P in the separated sediment (particulate P, PP) was determined after nitric-perchloric acid digestion. Separated runoff water was analyzed for total P and inorganic P (molybdate reactive P). Organic P was estimated as the difference between total P and inorganic P.

Results

Soil had 10 g kg^{-1} organic carbon, 200 g kg^{-1} calcium carbonate, and a clayish texture (520 g kg^{-1} clay) in the top 25 cm. Olsen P levels ranged from 15 to 20 mg kg^{-1} soil which are above those considered as critical levels (8-10 mg kg^{-1}) for the most typical crops in these soils. The rainfall through the year was 552 l/m^2 (Fig 1a), slightly higher than the average (503 mm) in this area. The mean rainfall in the first seven events was 27 mm event and for the last three events was 120 mm per event, indicating an irregular rainfall distribution. The total runoff (45 mm) was approximately 8% of the accumulated rainfall (Fig 1b), although half of the total runoff corresponds to the last three events, due to the irregular distribution of the rainfall. At the end of the year the total eroded soil was 165 g m^{-2} (Fig 1c) but ca. 130 g m^{-2} were in the last four events due the wetness of the soil and the intensity of the rainfall.

In these experiments, total P (TP) lost during the season was ca. 0.6 g m^{-2}. Particulate P (PP) was higher than dissolved P (DP) (Fig 1d). In general, PP represented 80% of TP, being DP about the 20% of TP. This is consistent with previous studies in other regions (Sharpley et al., 1993) where it was described that 75-90 % of P transported in runoff from agricultural soils corresponds to PP. Before P fertilization (11 November), DP ranged from 0.015 to 0.06 mg L^{-1}, slightly above for significant algal growth (Golterman and Oude, 1991). Most of DP corresponded to molybdate reactive P (95 % of total DP). In the first event after P fertilization (15 November), the concentration of DP in runoff was 59 mg L^{-1}, revealing a high pollutant risk. Since P fertilization was four days before the rainfall most of P had no time to be dissolved and react with soil components. In this event, TP in runoff was about 10% of total P fertilizer applied. After the event of 15 November, DP was decreasing until reach a concentration of 0.4 mg L^{-1} (13 March). However PP was increasing with time and proportionally to eroded soil.

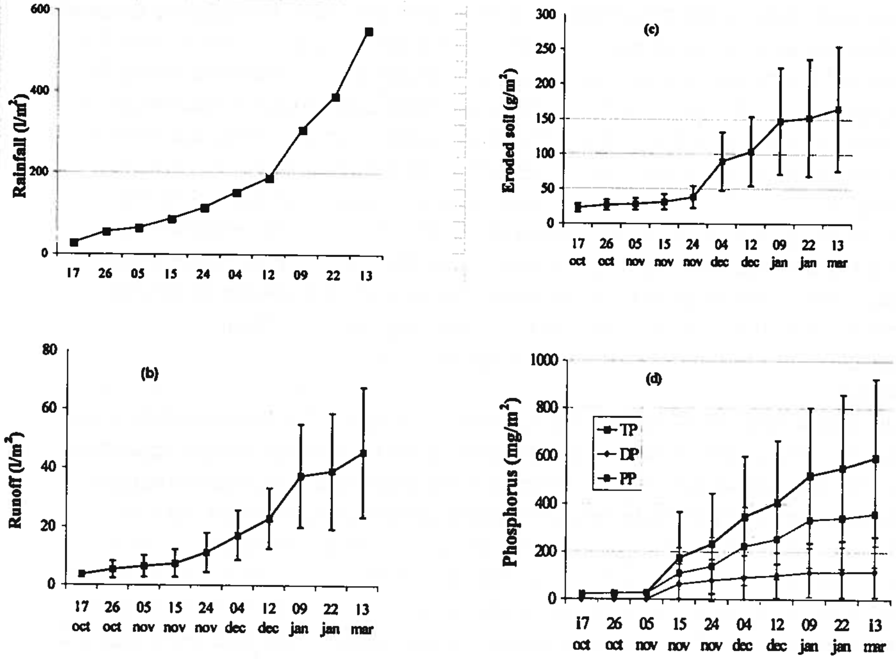

Figure 1. Rainfall (a), runoff (b), eroded soil (c) and phosphorus losses (d) in an area of vertisols.

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ARE ENVIRONMENTAL FRIENDLY FARM HOLDINGS DIFFERENT? THE CASE OF PORTUGAL

Maria de Lurdes Ferro Godinho (mgodinho@uevora.pt)*, Maria Leonor Macedo de Seabra Coelho (leonor.coelho@ine.pt)**
*Univ. de Évora, Dep. Gestão de Empresas, Largo dos Colegiais, 2, 7000-803 Évora – Portugal
** Instituto Nacional de Estatística – Direcção Regional do Alentejo

Introduction

In the past decades, it become evident that agricultural practices have major effects on the natural environment. These effects can be seen, on the one hand as negative external effects due to intensive farming practices and, on the other hand, as positive effects as landscape amenities. Thus, farmers are seen not only as food producers but also as countryside and landscape keepers and environment conservationists.

The Common Agricultural Policy (CAP), in 1992, shifted price support policies to farmers direct payments and launched the so-called accompanying-measures. The main objectives of these accompanying-measures were the protection of environment and the maintenance of the countryside. Each EU member state was obliged to establish and implement this regulation, however farmers' participation is voluntary.

Farmers' attitudes towards the use of environmental friendly practices have been studies by several authors. They found that the adoption of soil conservation practices was explained by education, and by their perception of the degree of the erosion problem. Other authors have shown that farmers will adopt environmental friendly practices as long as those practices also increase farm profitability. However, other studies have shown that environmental concerns are often more important than the 'financial' motives for same farmers who adopt organic farming (Offermann and Nieberg, 1999).

The objective of this paper is to find the difference between the farm holdings and the farmers who care for environment either by adopting environmental friendly practices, such as organic farming, or by conserving countryside landscape either participating or not in the agri-environmental schemes.

Methods

Farms level data was collected from the 1999 Agricultural General Census. The total universe of farm holdings was divided into 2 major groups according to their environmental and conservation attitude: the environmental unfriendly farm holdings which did not participate in the agri-environmental schemes, followed organic farming or used integrated crop protection practices; and the environmental friendly farm holdings which participated in the agri-environmental schemes or follow organic farming or use integrated crop protection practices. This later group of farm holdings was further divided into 2 sub-groups: the innovator holdings that used environmental friendly farming practices (organic farming or integrated crop protection with or without economic incentives);and those farms that only conserve the traditional farming systems. Finally, the innovator farms holdings were separated between those that had received economic incentives (participated in the agri-environmental schemes) and those that had not. A set of variables was selected to characterised the farmers and the farming systems for each sub-group (see Table 1). A statistical analysis was carried out to analyse whether these variables were different among the different groups.

Results

The results show that age is not an important distinction between the groups but younger farmers tend to adopt environmental friendly farming practices as shown in Table 1. More males and more educated farmers have a more environmental friendly attitude adopting farming practices even without economic incentives. Participation in short time courses in agriculture also distinguish these more innovator farmers.

Table 1 – Characteristics of Farm Holdings

	Farm Holdings	Environmental unfriendly holdings (without incentives)	Environmental friendly holdings (with and w/o incentives)	Environmental friendly holdings (with and w/o incentives)			
				Maintenance of traditional systems (with incentives)	Use of environmental friend practices (with and w/o incentives)	Use of environmental friend practices	
						With economic incentives	Without economic incentives
	Number	351 959	64 010	57 659	6 351	4 283	2 068
Farmer Characteristics	Sex-Male %	77,01	75,50	74,64	84,14	84,52	83,35
	Age	59,11	58,54	58,91	54,89	54,98	54,71
	Education	Only read and write	Basic – 4 years	Basic –4 years	Basic –6 years	Basic –6 years	Basic –9 years
	Agricultural Education	Field Training	Field Training	Field Training	Short time courses	Short time courses	Short time courses
	Part-time farming	< 50%	> 50%	> 50%	> 50%	> 50%	> 50%
[3] Farming Characteristics	UAA (ha)[1]	6,66	23,74	21,50	44,13	55,94	19,68
	Cereals [2]	17,58	15,61	16,67	6,00	5,83	6,27
	Vegetable[21]	4,41	0,77	0,70	1,42	0,84	2,62
	Olive Trees[2]	15,69	19,26	20,00	12,32	12,96	10,98
	Vineyards[2]	18,51	15,28	12,43	41,08	40,73	41,80
	Pastures [2]	10,30	21,45	19,95	6,39	7,42	4,24

Source: Agricultural Census, 1999

1. UAA - Utilised Agricultural Area; 2. In Percentage – Area of the Activity/ Utilised Agricultural Area*100;
3. The variable values represent the mean of each farm holding group

The results also show that farmers who spend more than 50% of their time in farming activities have an environmental friend attitude. For the environmental unfriendly holdings the average UAA is 6,66 ha whereas for the environmental friendly holdings this area is 23, 74 ha. Within this later main group a relevant position is shown by the holding using environmental friendly practices with economic incentives (55,94 ha). The most conservative holding groups, represented by both the environmental unfriendly and the environmental friendly holdings that follow the traditional farming systems, show a larger proportion of cereals (> 16%), vegetables and pastures areas (> 10%) in the total UAA. In contrast, in the holdings with more innovator farmers a large percentage of UAA is occupied by vineyards (> 40%).

Conclusions

The analysis of the characteristics of the Portuguese total universe of farm holdings show the environmental friendly holdings differ from the unfriendly ones. The main differences are in terms of education, agricultural education and age, the most educated, and the youngest are more environmental friend, which corroborated the findings of previous studies. This group also differ in terms of land use, occupying most of the UAA with vineyards. These results may be explained by the importance role played by the Wine Producers Associations in diffusion of information and technical assistance.

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FEASIBILITY OF SEWAGE SLUDGE AS AMENDMENT OF OLIVE ORCHARD SOILS

Pedro González F.[1], Rafaela Ordóñez F.[1] J. V. Giráldez C.[3], Manuel A. Aguilar T.[1],Rosario Miralles Imperial[2],Manuel Bigeriego M.[2], Mª del Mar Delgado A.[2], Miguel A. Porcel C.[2] and Eulalia Mª. Beltrán .[2]
1) CIFA-Alameda del Obispo, Córdoba. 2) INIA. Madrid. 3) ETSIAM Córdoba

Introduction

The adoption of Directive 91/271/EEC in Spain will generate, at the end of 2005, between 1,300,000 and 1,500,000 Mg of sewage sludge per annum (BOE, 2001). For municipal and environmental authorities, its application to the soil presents itself as being one of the most ideal solutions.

Methods

Field experiments were conducted between 1998 and 2001 to evaluate the agricultural value of sludge of a municipal origin characterized by Walter et al. (1989) and Delgado et al. (2000) on four olive orchards at Seseña, Aranjuez and Cordoba. The treatments applied were as follow: 1-Urea: 1 kg. de N/tree. 2-Mixed: 0.5 kg of N in the form of urea/tree + 8 Mg of sludge(dry matter)/ha, 3-sludge: 16 Mg/ha of sludge (dry matter). 4-Control: without both urea fertilizer and sludge.

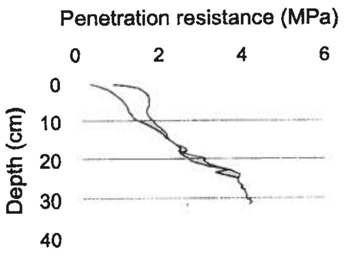
Results

A laboratory analysis of the sludge used showed that the levels of toxic metals were below the UE regulation limits. Cr was the most limiting metal.

The N mineralization rates and the proportion $N\text{-}NH_4^+/N\text{-}N0_3^-$ with values of 1.87 for the sludge of 1998 and 1.48 for that of 2000, among other measurements, indicate, according to Bernal et al. (1992), a lack of stability in most of the material used. The better composted 2001 sludge had a 0.01 relation.

Bioassays showed that the sludge used in 1998 and 2000 was highly phytotoxic in contrast with the 2001 sludge.

The land application of sewage sludge increased the phosphorus and soil organic matter content, which rose from 1.05-1.02 % in the control plots to1.91-2.57 % in the plots amended with sludge. The inorganic N also increased but only in the soils of Cordoba. It was found that sludge amendments improved the stability of soil aggregates. All these improvements had no effect on crop yields.



The plots treated with sludge showed a lesser resistance to penetration than in the control plots in the area between the tree rows; it was precisely on the horizon where significant differences in the content of organic matter were found. At lower depths, both curves were superposed (Fig. 1).

Figure 1. Average penetration resistance between the rows of olive trees. Red line: control plots. Blue line: sludge treated plots.

No other important or permanent soil parameter change was detected
An increase in the level of N in the olive leaf was detected in the most sandy soil whereas the sludge did not modify the rest of the nutrient contents except the Mn percentage, once, in Cordoba.
The levels of toxic metal (Cr, Ni, Cd, Hg y Pb) in the soil were always below detection limits.
In spite of the positive soil results leaf tip burning was detected in the treated trees. Additional research is needed to determine the causes.

Conclusions

It was confirmed that sewage sludge increases the organic matter in the soil, at the same time as improving some physical parameters in the first 10 cm of the soil. It also constitutes a valuable source of nitrogen and organic phosphorus, as well as of other nutrients. However, the appearance of some clear signs of phytotoxicity, - more intense in the olive orchards of Madrid than in those of Cordoba - which did not cause any apparent negative effects on production but obliges us to follow up the origin of this damage. Its long term incidence is unknown and at present prevents uncontrolled application of fresh sludge, especially raw (uncompleted ripen) sludge, as an amendment to olive orchard soils.

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UNITARY SYSTEM OF AGRICULTURE, FOREST AND WATER MANAGEMENT AS A FACTOR OF PROGRESSIVE DEVELOPMENT OF LAND AREA

K. Kudrna[1], M. Šindelálová[2], S. Kužel[3]

1. South Bohemian University, Faculty of Agriculture, Department of General PlantProduction.Studentská 13, 370 05 □eské Bud□jovice, Czech Republic. (External collaborator.)
2. South Bohemian University, Faculty of Agriculture, Department of General Plant Production. Studentská 13, 370 05 □eské Bud□jovice, Czech Republic.
E-mail: sindelar@zf.jcu.cz
3. South Bohemian University, Faculty of Agriculture, Department of General Plant Production. Studentská 13, 370 05 □eské Bud□jovice, Czech Republic.
E-mail: kuzel@zf.jcu.cz. Corresponding author.

Introduction

Increasing pressure on food, water and energy demand, caused by world demographic curve, signalizes necessity of demand of new technologies in agriculture. In presented information, we have tried to explain results of our research in this field briefly. It has been proved, that agriculture can't be solved as a separate factor acting in land area, but as a subsystem of a complicated complex formed by agriculture, forests and water management, and which we have called "Unitary System of Agriculture, Forest and Water Management" (USAFWM). USAFWM regulates all parts of water, carbon, mineral and energetic balance in land area, and thus it presents a command variable of a progressive development of land area. Disturbing of balanced state between runoff and groundwaters is the reason of present unfavourable state in water balance on the Earth. Solving of energetic, carbon and mineral balance in the own agricultural system (AS) in relation to intensity of production then is the second problem.

Methods

We have defined the complex of USAFWM as a dynamic system in state space, where flows of energy go. Catchment areas of two water streams of 1226.26 km^2 and a ten-year period have been chosen for analysis. Production acreage of 44716 ha then has been chosen for energetic balance, and production acreage of 2174 ha then for mineral balance evaluation. Analysis of water balance has been done according the block schema, in which the USAFWM is a command variable. The energetic balance has been evaluated according to the block scheme of energetically closed agricultural system, and the mineral balance then by conversion of harvest values to energetic units (GJ and kWh).

Results

Forest complexes have a crucial role in regulation of water balance in land area. Damage of their compaction involves ridge erosion, especially at their edges. In analyzed catchment areas it presents 2.87 % of area. Relation between runoff (hso) and groundwater reserves (hsp) is being disturbed. While hsp go down, hso goes up. The dependence is expressed by index of determination R^2 0.94. Thus, the function of forests as area regulators is limited. Analysis of changes of hsp in dependence on precipitation (hs) has proved that, in years with above-average hs, culmination was achieved at 150 mm, and in years with under-average hs, the hsp volume was growing up (R^2 0.72). The calculation according block schema then has proved that the water balance hso:hsp can be well-balanced at relation 19.31 % (144 mm) and runoff can be equalized, so that it would be 1.95 $m^3.s^{-1}$, while during the decade it fluctuated from 2.5÷5.0 $m^3.s^{-1}$. A period of three years has been found and analyzed, when it was so, and hsp:hso was quite well-balanced. In this respect, agricultural systems play an enormous role. Extensive farming and abandoned tracts of land cause enormous damages and disturbing of water balance. The necessity of rationalization of grass stands and increasing of cattle stock have been proved. It reflected then in volume of gross energy production and in energetic gain. Nearly a functional dependence has been achieved: with growing cattle stock per hectare, the total quantity of gross energy (R^2 0.991) and energetic gain (R^2 0.997) were growing. That is why a special structure of field, meadow and pasture farming has been suggested with possibility of biogas, ethanol, oil and electricity production in agricultural system. The mineral balance has proved arise of the deficit of mineral nutrients, because compensation feedbacks do not function, as a result of transport of produced matter across the boundary of agricultural system. Only high cattle stock as a transformer of carbon mass, based on perennial fodder crops, has then become a factor stabilizing the carbon and water balance.

Discussion

Lad area can develop progressively under precondition, that we achieve in it a well-balanced water, energetic, carbon and mineral balance. High biological intensity of production based on high cattle stock as a transformer of organic mass of fodder crops is a precondition of it.

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LONG TERM ASSESSMENT OF SOIL EROSION RATES IN VINEYARDS, AND ITS APPLICATION FOR *USLE* MODEL EVALUATION

Lorenzo L.[1], Casalí J.[1], Del Valle de Lersundi J.[2,3], López J.[1]

1 Univers. Pública de Navarra, Dep. de Proyectos e Ingeniería Rural-Campus de Arrosadía S/N-31006 Pamplona, Navarra, Spain
2 Gobierno de Navarra, Dep. Agricultura, Ganadería y Alimentación, Servicio de Estructuras Agrarias
3 Univers. Pública de Navarra, Dep. de Ciencias del Medio Natural

Introduction

Suitable assessment of the problem of soil erosion involves to know erosion rates referred to long periods of time and large areas. Such information can be obtained from field measurements and from simulation models, whose calibration and validation requires, in turn, field data. Accordingly, the main objectives of this paper are: 1) to present a method for long term assessment of soil erosion in vineyards, showing results from four vineyards in Navarre (Northern Spain); 2) to evaluate the applicability of *USLE* (Universal Soil Loss Equation, Wischmeier et al, 1978), the most widely used soil erosion model, to estimate the measured soil losses.

Methods

When a vine is planted, the graft is usually located at ground level. The graft enlarges with time, and it can be accepted (Badiola et al, 1992) that the enlarged graft, usually clearly visible at any time, tends to stay at the same position. If after a period of time the enlarged graft is located above the ground level, it can be considered that soil erosion occurred. The measurement of the vertical distance between the ground level and the enlarged graft, in a sufficient number of vines in a plot, allows for a suitable estimation of soil losses occurred from the moment of plantation. In this study, field measurements of such distances in four vineyards located in Central Navarre (Northern Spain) were made, and the corresponding soil erosion rates (t $ha^{-1}yr^{-1}$) were calculated, after careful determination of the vineyard age from land registry records. Climate in the study area can be considered as continental Mediterranean. Soils are moderately erodible, with estimated K_{USLE} values ranging between 0.32 and 0.40 t m^2 h ha^{-1} hJ^{-1} cm^{-1}. The selected plots were located just downstream from the watershed divide, and only sheet and rill erosion was detected. These vineyards can be considered as representative of Navarrese conditions. Average annual soil erosion rates can be determined with the well known *USLE* model. Estimations are based on the multiplication of six factors: rainfall erosivity (*R*), soil erodibility (*K*), slope length and slope steepness factor (*LS*), crop factor (*C*) and conservation practice factor (*P*). In this study, *USLE* was applied to the same vineyards where erosion was previously measured with the distance to the enlarged graft method. *R* was estimated from ICONA (1988), and *LS* and *K* from Wischmeier et al (1978), after field topographic surveys and soil analysis. *C* factor for vineyards was estimated from Moreira (1991), and *P* was assumed to be 1. This assumption is equivalent to accept that tilling was perpendicular to contour lines, a quite common practice in the area.

Results

On Table 1, soil erosion rates (t $ha^{-1}yr^{-1}$) from field measurements using the enlarged graft method, and from *USLE* estimations, at the four plots studied, are shown. Ranges in estimated values with *USLE* incorporate the uncertainty in *R* and *K* factors estimation.

Plot	Time after planting (yr)	Average slope (%)	Hillslope length (m)	Estimated (USLE) soil erosion rates (t ha^{-1} yr^{-1})	Measured soil erosion rates (t ha^{-1} yr^{-1})
Tafalla	80	11.8	56.3	18.5-24.0	22.0
Zabalza	25	32.1	25.0	87.5-113.5	44.1
Sansoain	50	6.7	110.5	15.8-20.4	19.6
Liédena	44	8.5	54.0	16.5-21.3	19.0

Table 1- soil erosion rates (t $ha^{-1}yr^{-1}$) from field measurements using the enlarged graft method, and from *USLE* estimations, at the four plots studied

Accepting that the enlarged graft method is precise enough, and that a more detailed analysis of such accuracy is required, it can be concluded that average annual soil losses after the study periods were high, even in quite short hillslopes. In Tafalla, Sansoain and Liédena plots, measured and estimated soil losses are very similar, whereas in Zabalza plot, estimated soil loss rates are around 125 % higher than measured erosion rates. It can be due to the steep slope at Zabalza plot, outside the scope of *USLE* model. On the other hand, Zabalza vineyard is the youngest, and measured erosion rates can be considered less representative. From these data, it can be stated that soil erosion rates estimations with *USLE* were very precise, in contrast with results from previous studies developed in the Iberic Peninsula (Azevedo et al, 1990).

Conclusions

The enlarged graft method arises as a promising tool for assessing long term erosion rates in areas cultivated with vineyards, providing data sets for model evaluations. Any way, before making time consuming and expensive new field surveys, the accuracy of the method should be definitively checked. Using such method, high erosion rates, above soil loss tolerances, have been observed in vineyards representative of Navarrese conditions. Assuming that the proposed enlarged graft method is accurate enough, it can be stated that erosion rates estimations with *USLE* were very precise, contradicting the widely accepted idea that *USLE* overestimates erosion rates in Mediterranean areas. The enlarged graft method and the excellent provisional results from *USLE* suggest a unique opportunity for assessing soil losses and evaluating erosion models in large Mediterranean areas.

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EVALUATION OF APPLICABILITY OF LIFE CYCLE ASSESSMENT AND ECO-INDICATOR 99 METHOD IN FIELD PLANT PRODUCTION IN PRACTICE

Ildiko Pechmann[1], Kovacs Elza[1], Janos Tamas[1] ,

1. University of Debrecen, Centre of Agricultural Sciences, Department of Water- and Environmental Management, Hungary H-4032

Introduction

To estimate the environmental burden of agriculture, objective and suitable methods to comprehend and assess the impact on natural resources are needed (Haas et al. 2000). By Life Cycle Assessment (LCA) methodology the environmental impact of agricultural production can be analysed (Morschner et al. 1998). This methodology is based on the ISO 14040-49 standard series (Andensam et al. 2000). According to the standard 14040 the first step of the LCA – after defining the aims of the assessment, the indicator time and the borders of the experimental area – was the environmental inventory of all resources and energies used and emissions released under the system investigation, resulting in all of the material and energy balances of the production processes. In the second part the inventory data were analysed and classified (Brentrup 2000). In the following part the damage categories were defined, and finally all data got one index (indicator value) representing its environmental burden. To define these indicator values the Eco-indicator 99 method was chosen.

Methods

The experimental field, with 880 ha can be found in Eastern Hungary, owned by Tedej Inc. During the indicator time (1999/2000) the produced plants were alfalfa, winter wheat, maize and sugar beat. The study began with the calculation of the material and energy balances by taking the following factors into consideration: all the operations, done in this area during the indicator time, all the wastes and emissions, evolved in the experimental fields, and all the starting materials, used in plant production. To simplify the plant production the experimental area is divided into cultivated units (tables).
The input and output values were summed by tables (table 1).

Material balance		Energy balance	
Starting material	Volume ha^{-1}	Activity	Diesel/ha
Organic manure – 95% horned cattle	-	Organic manure – cattering and conveying	-
Pesticide Acenit 50EC acetochlor Merlin Banvel 480 S dikamba	 1,00 l 500 g 0,12 l 0,37 l 167,05 g	Plant protection – cattering, conveying	5,23
Artificial manure N P K lime-fertilizer	 186,50 kg 187,20 kg 207,60kg -	Artificial manuring – cattering and conveying	6,31
Seeding Dante (30 ha) DK-557 (36 ha)	 67,47 emag 67,47 emag	Seeding	2,97
Irrigation	72,73 m^3	Tilling	72,77
Harvesting maize	 15,49 to	Harvesting	86,10
		Sum	173,38

Table 1 - Cumulative material and energy balances of experimental field P6

The data are based on field-plot card-index, technical descriptions, technical standards and personal interviews. To accomplish the material balance a questionary – in Access – was drawn up. To assess the logistical operation, a digital geographical information system – Arc View – was used.

Results

After drawing up the material and energy balances the inventory data were summed for each produced crop. Then eco-indicator values were added to give inventory values (Goedkoop 2000) and from these eco-indicator values the total environmental impact of production of each crop was calculated (e.g. maize presented in table 2).

Cultivation area: 265 ha

Harvested volume 1 5,59 t ha^{-1}

Raw materials, processes	Volume referring to 1t of harvested maize	Ecoindicator value	Result[10]
Diesel	6,9635 kg	7,26	50,55
Pesticides			
2,4D	0,002 g	9,90	0,003
Acenit 500- acetachlor	21,854 g	-	
Banvel 480S- dikamba	7,442 g	-	
Merlin WG – izoxaflutol	0,675 g	-	
Total			50,503

Table 2 - Cumulative table of life cycle and environmental impact of maize produced on area of 880 ha owned by Tedej Inc. from 1999 to 2000 with compared indicator values by Eco Indicator 99.

Conclusions

The results show, that the LCA methodology is basically objective and suitable to assess the environmental impact of agricultural production. The data of LCA's environmental inventory conform to Eco-indicator 99 model system and by the inventory indicator values can be calculated objectively. The total indicator value shows, that the emissions derived from the use of diesel are the most environmental polluting factors of the production (table 2). However, some important environmental issues are missing in the Eco-Indicator 99 method, e.g. the use of resources, land or pesticides.

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COMPARATIVE ECONOMIC AND ECOLOGICAL EVALUATION OF INTENSIVE, EXTENSIVE AND ORGANIC PRODUCTION OF MEAT AND DAIRY PRODUCTS

Pereira, M., Serrano, S., Simões, A., Domingos, T.
Instituto Superior Técnico, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal.

Introduction

Until now, it has been seen that most economic rewards and legal protection were given to the intensive resources exploring and pollutant activities. Nowadays, it is wise to reward activities that increase life quality level and preserve the environment. This makes sense in a world with limited resources.

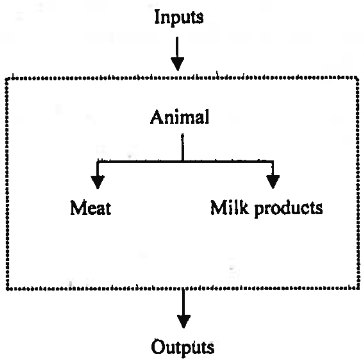
Agriculture has been directed and subsidised aiming only at high production and paying no attention to the processes that lead to its final goal, with consequences such as land and chemical over-use, water and food contamination, as well as economic disturbances caused by excessive production. The increasing knowledge about environmentally negative effects caused by incorrect agricultural practices developed other agricultural systems apparently more environment friendly. It is necessary to understand deeply how those systems work before taking any conclusion or decision about their sustainability. Anyway it is urgent to change thoughts and patterns in animal system production.

In this context, our study is searching for a sustainable production of meat and milk products by an evaluation of possible impacts of different system production, taking into account animal production, transportation, commercialisation, consumption, waste disposal.

Methods

The method adopted consists in the comparison between the three production systems. Such comparison will be possible by collecting data from the three production systems separately. Several approaches are made, namely economical, ecological, emergetic, energetic, life cycle analysis, which will provide indicators of sustainability, such as ecological footprint, emergy, economical and energetic ratios , enabling us with the desired comparison. In environmental terms, energetic issues will be considered (following the method in Serra *et al.* 1996), carbon, nitrogen, methane and calcium as well as hydrological balances and soil erosion. For impacts and services of difficult quantification, a qualitative analysis must be made.

Every production system has its inputs and its outputs, which will be considered in the various types of analysis. Schematically:



Economic analysis will be done considering cost flows in the system as work, capital, land and energy, fertilizers, water, animal feeding, including externalities. Cost - Benefit analysis, as described in Perman *et al*, 1996, will give us some indicators which enables the comparison between the three production systems.

As one can see in FAO's site (April, 2002) about one half of agricultural land is used for animal feeding and meat production per hectare of productive land is much lower than vegetable production. As an example:

Product	Bean	Apple	Carrot	Potato	Tomato	Meat
kg/ha	11 200	22 400	34 900	44 800	56 000	280

The ecological indicator, ecological footprint, is a measure of productive land necessary to produce goods or services, including necessary land to transform all residues produced (ARCA).

Activities in animal production consume high-energy quantities so, to reduce all unnecessary spent, an energetic analysis shall be done. Energetic analysis can be divided in two types of analysis, conventional energetic analysis and emergetic analysis. Energetic analysis based on inputs and outputs balance, measuring how much energy is embodied in goods and services (Stanhill, 1984). Emergetic analysis consists in a method of converting all inputs, flows and outputs in solar equivalent energy, by a conversion factor named transformity (ARCA).

Life cycle analysis (LCA) is defined in ISO 14040 as the study of all inputs, outputs and emissions produced in the whole system (Ferrão, 1998). In this study it will be considered 1 kg of meat and 1 kg of cheese as functional unity.

Results

The data available have not yet allowed results to be obtained. We expect to have obtained these results by June.

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FIELD AFFORESTATION AND ITS INFLUENCE ON WINTER WHEAT YIELD

Podolska G., Podolski B

Institute of Soil Science and Plant Cultivation, Czartoryskich 8, 24-100 Pulawy, Poland.

Introduction

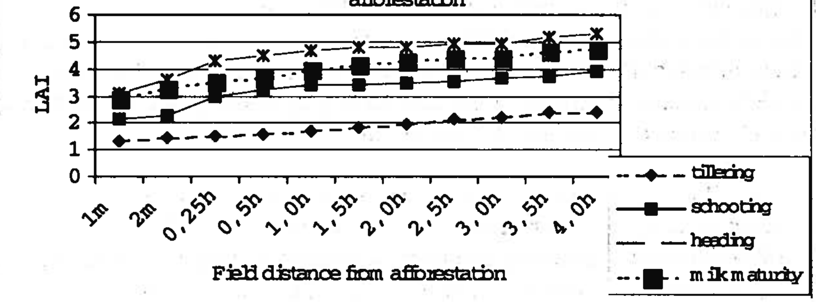
The forest and field afforestation play a positive role in creating microclimate for cultivate fields. In the direct proximity of trees productivity of cultivated plants is decreased. The aim of this research was to determine the affect of field afforestation on yield and yield components of winter wheat.

Methods

The field experiment was performed on alluvial soil considered to be good wheat soil complex in 1998-2000 at the experimental station - K□pa in Pulawy, Poland. The field on which the experiment was carried out was located around a field afforestation of 4,71 ha. Grain yield and yield components were examined depending on the distance from the field to the afforestation. The investigated factor was the distance between the field and the afforestation (1m, 2m, 0,25h, 0,5h, 1h, 2h, 3h, 3,5h, 4,0h). The plots were set at a distance from the trees as a multiple of the trees' height. The sowing date was optimal. The plot size for harvesting was 1,0 m^2. Sowing rate was 5,0 million seeds/ha, while the number of replications was 4. The phosphorus and potassium fertilisation was applied before sowing. The nitrogen fertilisation (80kg/ha) was divided in 2 parts - 50kg/ha at the beginning of spring vegetation and 30 kg/ha during shooting. The winter wheat was protected against weeds and diseases twice in vegetation period. The experiment was harvested at full maturity. Before harvest soil properties and Leaf area index (LAI) were examined. After harvest the yield and yield components were estimated. The LSD values were calculated using Tukey test at significance level 0,05.

Results

Fig 1 LAI of winter wheat depending on field distance from afforestation



The afforestation had affect on soil properties: Humidity and humus content decrease together with the increased distance between the forest and the field. There was no significant affect on soil mechanical fraction (tab.1). In direct contact with the trees (1-2 m) the grain yield was the lowest and increased together with increased distance from the field to the afforestation. The LAI (fig.1) and yield components (tab.2) mainly the number of plants, heads per area unit, number of seeds per head , grain yield per head, weight of 1000 grains were the lowest in the direct contact with forest.

Table 1. The affect of afforesttion on soil properties

Distance from afforestation	Mechanical fraction (mm) %			Humus content mg/100 g soil	Humidity %
	1-0,1	0,1-0,02	<0,02		
1 m	20	42	38	2,56	18,7
2 m	20	42	38	2,54	20,8
0,25 h	23	41	36	2,46	27,2
0,5 h	24	43	33	2,41	23,0
In further distance	23-24	42-43	31-33	2,28-2,36	24,9-29,1

Table 2 Yield and yield components of winter wheat depending on the distance from the field to afforestation

Distance from field to afforestation	Number of		Grain yield t/ha	Straw yield t/ha	Weight of 1000 grains	Grain yield per head	Number of seeds per ha	Productive Tillering
	plants/ m^2	heads/ m^2						
1 m	290	380	3,7	5,2	37,7	0,98	26,2	1,3
2 m	300	425	4,2	5,8	38,5	0,98	25,4	1,41
0,25h	303	491	5,2	6,1	39,6	1,06	26,7	1,61
0,5h	326	511	6,4	6,7	40,8	1,26	30,8	1,56
1,0h	348	520	6,6	6,9	41,3	1,27	30,7	1,49
1,5h	362	532	6,8	7,4	42,1	1,27	30,2	1,46
2,0h	369	539	6,7	7,6	42,6	1,25	29,3	1,45
2,5h	372	539	6,9	7,7	42,5	1,28	30,1	1,44
3,0h	377	550	7,1	7,8	42,1	1,28	30,3	1,45
3,5h	389	563	7,1	7,9	42,5	1,27	29,9	1,44
4,0h	390	605	7,6	8,5	42,8	1,26	29,4	1,54
LSD	14,2	105,0	1,14	1,59	3,13	0,318	2,81	0,322

Conclusions

The width of the field with significant decrease of grain yields and yield components depending on the height of the trees. Also (Orlik 1985,1996), (Podolski 1999), (Ta□a□aj 1999) in their research point at the negative affect of afforestation on grain yield and yield components. The biggest decrease in yield and yield structure was in winter wheat growing in direct neighbourhood of afforestation (1-2 m). The intensity of negative influence of field afforestation on grain yields and yield components depended on the distance between fields and trees' height. In this experiment the negative influence of the trees affected the field on its whole width extending to 1.5 of the trees' height. Reduction of grain yield results in decrease in the number of plants and heads per unit area, number of grains per plant and head and on weight of 1000 grains.

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PHOSPHORUS IN RUNOFF IN REPRESENTATIVE SOILS FROM THE MEDITERRANEAN AREA

Saavedra C. y Delgado A.

Dpto. Ciencias Agroforestales, EUITA, Universidad de Sevilla, Ctra Utrera Km 1, 41013 Sevilla, Spain

Introduction

High rates of P fertilizers contribute to increase the available P pool for plants in soils, but also determine an increased risk of P loss to continental water through drainage or runoff processes. In Mediterranean regions leaching water is usually limited and the main P loss in agricultural soils is related to runoff processes.

The environmental risk of P lost in runoff processes has been usually measured using P sinks in runoff samples (Sharpley, 1995) or soil samples (Delgado and Torrent, 2001). Bioavailable P for algae growth has been also estimated by these methods, using short term extractions (16 h, Sharpley, 1995). In this case, algae growth in incubations made at several weeks is related to the amount of P extracted using this sinks (paper strip impregnated with iron oxide). However, P release may be significant even at very long term (150 or 350 days, Delgado and Torrent, 1999) because of P release can be related to long term P reactions (reduction of sorbent surfaces, dissolution of precipitated phosphates). Thus, the environmental risk of lost P can be inaccurately estimated by using short term P extractions.

The main objective of this work is to compare the P loss potential of representative soils from the Mediterranean area by using simulated runoff and to study the different P forms in runoff samples and how are this forms related to original P forms in soil.

Material and methods

17 representative soils from Palma del Río (Córdoba, S Spain) were selected. Soils were classified as Inceptisols and Alfisols (Haploxeralfs, Palexeralfs and Aqualfs), differing widely in their properties. Clay content ranged from 16 to 41 %, Organic Matter content from 0.4 to 2 %, carbonates from 0 to 27 %, and pH from 7.7 to 8.1. Rainfall simulation was performed in each soil and soil samples were taken around the simulation site for soil characterization, including P status analysis (extractable P using 1:10 soil: 0.01 M $CaCl_2$ extracts, Olsen P and P fractions according to Olsen and Sommers, 1982). The day before to the simulation, soil surface was saturated by applying rainfall at 45 mm h^{-1} during 20 min. Rainfall was simulated and allowed to drain during 16 h. After that, rainfall was simulated for 20 m at 45 mm h^{-1}, which represents a storm event with 5-year (aprox) return period for the studied area using a single nozzle rainfall simulator based on that described by Miller (1987). Rainfall was applied on 2 x 2 m plots in which runoff isolation was made using metallic borders with a sampling pit. Slope was 2-3 %in the sample site. Runoff was sampling (measuring volumes) at 5 min intervals form the beginning of the runoff flow. Runoff caudal at each sample time was used to construct the caudal curve with time to calculate the total runoff volume. A flow-weighted composite sample was prepared in order to determine general properties of runoff samples, including molibdate reactive P in solution, total P (TP), and P fractions according to Olsen and Sommers (1982). In this fractionation scheme, the sum of fractions extracted by NaOH and citrate-bicarbonate (CB) can be considered the easily releasable P.

Results and discussion

Infiltration rate ranged widely between soils (from 0.39 to 0.98), being more sandy and calcareous soils the ones with lower infiltration rate. Dissolved molibdate reactive P in runoff was related to the concentration of more labile P forms in soils (Olsen and water extractable,

Figure 1), although the estimation value of water extractable P depend on the concentration on sediment in runoff. In this sense, Delgado and Torrent (1999) observed that the amount of P released from soil to water and the subsequent P concentration on water depends on the soil:water ratio. Olsen and WSP in soils are significantly and positively related to the saturation index (SI) of soils, defined as the NaOH-P to Fe related to poorly crystalline oxides ratio.

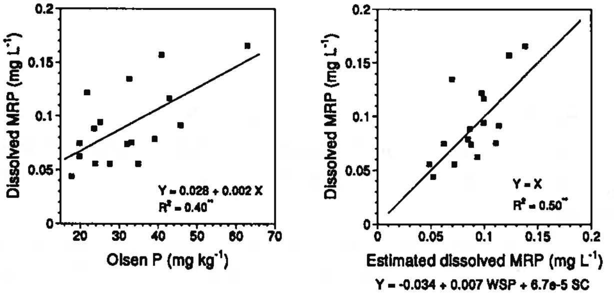
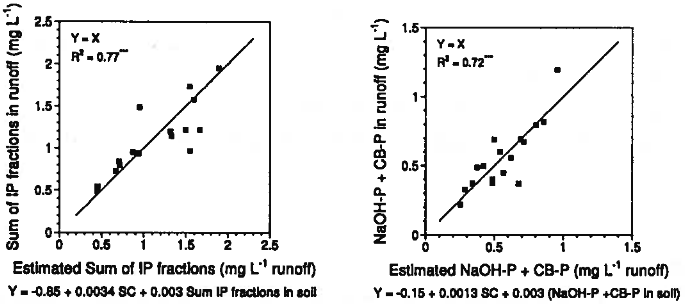


Figure 1. Dissolved molibdate reactive P in water runoff as a function of Olsen P and water extractable P (WSP) in original soil and sediment concentration (SC) in the runoff



Firgure 2. Estimation of the concentration of inorganic P fractions in runoff as function of sediment concentration and the sum of inorganic P fractions in soil, and estimation of the readily releaseble P (NaOH-P + CB-P in the Olsen and Sommers fractionation scheme) in runoff as a funcion of the sediment concentration in runoff and the readily releaseble P in soil

Inorganic P determined as the sum of P fractions according to the fractionation scheme by Olsen and Sommers (1982) and the more readily desorbable P estimated as the amount of P extracted by the two first steps in this scheme (NaOH and CB) are related not only to the sediment concentration in runoff, but also to the P status of the soil (estimated as sum of P fractions or NaOH-P + CB-P) (Figure 2). The sum of inorganic P fractions represents most of the P loss in runoff and it is mostly related to eroded soil particles (particulated P). Dissolved molibdate reactive P (Figure 1) represents in general terms less than 10 % of P loss in runoff.

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IS ALUMINIUM TREATMENT EFFECTIVE TO REDUCE PHOSPHORUS IN RUNFOFF FROM POULTRY LITTER AMENDED SOILS?

Saavedra C[1]., Sims J.T[2]., and Delgado A[1].

[1] Departamento de Ciencias Agroforestales, EUITA, Universidad de Sevilla, 41013 Sevilla, Spain
[2] Department of Plant and Soil Sciences, University of Delaware, Newark, DE 19717-1303

Introduction
Application of high rates of poultry litter to agricultural soils is a common practice in intensive chicken production areas. Poultry litter is used as fertilizer, although excessive application in agricultural lands contributes to environmental problems (eutrophication) related to N and P losses to water. The application of alum (aluminium sulfate; $Al_2(SO4)_3$) to poultry litter in the poultry houses has been shown to reduce P solubility by sorption and/or precipitation reactions and therefore decrease the potential for P losses by runoff and leaching (Moore et al., 2000). Alum also acidifies the highly alkaline litter, decreasing ammonia emissions which in turn can improve poultry health and reduce the impacts of poultry production operations on air and water quality. The Al added to litters in alum has an effect of P dynamics in soils where poultry litter is applied. Also it must be considered that an excessive application of Al to soils can become toxic for plants. The main objective of this work is to study P losses in simulated runoff from poultry litter amended soils, comparing the effects of Al amended poultry litter with non treated poultry litter on bioavailable P and total P in runoff from agricultural soils.

Materials and methods
Two representative acid soils from Delaware (USA) were selected and topsoil samples (0-10 cm) taken. General properties of soils, Mehlich3 P, Total P and oxalate extractable P, Al and Fe were determined. Experimental design involved 4 treatments and 3 replications. Soil treatments were: control (no P added), inorganic fertilizer (triple superphosphate), poultry litter (Al:P ratio = 0.04), and Al amended poultry litter (Al:P ratio > 0.8). Fertilizer or manure was applied at a rate that provided 150 kg Total P ha^{-1}. After mixing with the treatment, soil samples were packed in 7.5x20x150 cm boxes with a slope of 5 % at its bulk density and wet to its field capacity. Rainfall simulations were performed at 75 mm h^{-1} during 30 min at 1day (time 1) and 6 weeks (time 2) after the fertilizer/poultry application. All the runoff was collected. Between time 1 and 2, soil samples were maintained in the boxes at its field capacity by replacing lost water. Runoff samples were analysed for dissolved molybdate reactive P (Murphy and Riley, 1962), dissolved total P (DTP) (by ICP-AES), total P (TP) (acid digestion using microwave before ICP-AES determination), and bioavailable P by the paper strip impregnated with iron oxide (BAP) (Sharpley, 1995). Total P loss in the simulation was calculated as the product of P concentration by runoff volume. Statistical analysis involved analysis of variance (factorial with three factors: treatment, soil and time after treatment) and comparison of means.

Results and discussion
Soil properties are described in Table 1. Fertilization and poultry litter application significantly increased DPT loss (concentration and total loss) compared with the control (Table 2). No significant effect of treatments on TP loss was observed, although total BAP loss was significantly lower when P was applied as Al amended poultry litter. When TP concentration in runoff was considered, Al amended poultry litter promoted lower TP concentrations than other treatments in soil A only in the first simulation (1 day after treatment) (Table 3). This explains the effect of Al amended poultry litter decreasing BAP loss comparing to untreated poultry litter, fertilizer, or no P application to soil (Table 3). TP is mainly related to particulate P, since DTP represents about 5 % of TP in runoff samples (data not shown). This effect was not observed in

Soil B. This accounts for the significant interaction between treatment and soil (Table 2) on TP loss. On the other hand, in the second simulation (6 weeks after treatments) a significant reduction of BAP concentration in runoff was only observed in soil B when P was applied as Al treated poultry litter and this reduction was not related to a decrease in TP concentration (Table 3). Thus, it can be concluded that the effect in this case can be due to the increase in P adsorption on low crystalline Al-OH and Al-oxides formed in the litter as a consequence of the alum treatment. This adsorption determines a decrease in the estimated BAP for algae in the runoff. Also, the significant reduction of BAP/TP ratio when P is applied as Al-poultry litter (Table 2) can be also related to the increased P sorption due to alum amendment. The loss of all P forms was decreased as the time between fertilizer/poultry application and runoff increased (Table 2 and 3). A rainfall event after application (1day) determined a BAP loss 3 times higher than an event 6 weeks later.

Table 1. Soil properties[1]

Sample	pH	Organic Matter	Particle size Analysis Sand	Silt	Clay	Exchangeable K	Ca	Mg	Na	Acidity	CEC	Total P	Oxalate extractable Al	Fe	P	Mechlich P
		----------	$g\ kg^{-1}$	----------		----------		$cmol_c\ kg^{-1}$		----------		----------		$mg\ kg^{-1}$		----------
Soil A	5.4	16	487	340	173	0.4	1.8	0.6	0.1	0.2	3.0	702	625	634	206	96
Soil B	5.5	10	780	120	100	0.1	0.9	0.4	0.1	0.2	1.7	375	353	239	141	103

[1] CEC, cation echange capacity

Table 2. Analysis of variance summary of P losses runoff simulations[1]

Source	DF	DTP	TP	BAP	BAP/TP ratio
			Significance[2]		
Soil treatment (A)	3	***	NS	*	**
Soil (B)	1	NS	NS	NS	NS
Time (C)	1	***	***	***	NS
A x B	3	NS	*	NS	NS
A x C	3	***	NS	NS	NS
B x C	1	*	NS	NS	NS
A x B x C	3	NS	NS	NS	*
Residual	32				

[1] DTP, dissolved total P; TP, total P in runoff; BAP, extractable P using iron oxide impregnated paper strip. Time, time between treatment application and runoff simulation
[2] *,**,***, significant at probability levels of 0.05, 0.01, and 0.001 respectively; NS, not significant

Table 3. Comparison of means of P concentration (different P forms) in runoff for the different soil treatments (fertilizer or organic amendment)[1]

Treatment	Soil A Time 1 BAP	Soil A Time 1 TP	Soil A Time 2 BAP	Soil A Time 2 TP	Soil B Time 1 BAP	Soil B Time 1 TP	Soil B Time 2 BAP	Soil B Time 2 TP
				$mg\ L^{-1}$				
Control	0.34a	3.52 a	0.10 ab	0.52 b	0.28 a	1.65 a	0.09 ab	0.71 a
Inorganic Fertilizer	0.36a	3.08 ab	0.15 a	0.56 ab	0.38 a	1.92 a	0.13 a	0.83 a
Poultry	0.48a	3.05 ab	0.08 a	1.17 a	0.41 a	2.33 a	0.09 ab	0.50 a
Poultry + Al	0.30b	2.17 b	0.07 a	1.00 ab	0.35 a	3.04 a	0.06 b	1.33 a

[1] Analysis of variance and comparison of means made separately for each soil and time after application; means separated by the same letter are not significantly different according to the LSD test ($P > 0.05$)

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ECOLOGICAL ECONOMIC ANALYSIS OF AGRICULTURE: A METHODOLOGICAL DEVELOPMENT AND A CASE STUDY

Serra L.[2], Canaveira P.[3], Domingos T.[1], Domingos J.[1], Simões A.[1]

1 Instituto Superior Técnico, Av. Rovisco Pais, 1, 1049 – 001 Lisboa (Portugal).
2 PROET – Projectos, Engenharia e Tecnologia, S.A., Av. Estados Unidos da América, 55 – 2°, 1700 – 165 Lisboa (Portugal).
3 CELPA - Associação da Indústria Papeleira Portuguesa, R. Marquês de Sá da Bandeira, 74 – 2° Dto., 1069-076 Lisboa (Portugal).

Introduction

One of the great problems in environmental systems analysis is the quantification of the environmental costs and benefits and its relation to economic costs and benefits.
We have created an integrated method that allows the analysis of the economic and environmental performance of agricultural systems. This method aims to solve the problem of the inexistence of general data due to the inexistence of a standardisation (Palonen et al., 1992) in the existing studies (Leach 1976, Stanhill 1984, Cary 1985, Pellizzi et al. 1988, Palonen et al., 1992).
We have started from the conventional production systems analysis of Bousted et al. (1978), then we have used the simplifications for agricultural systems (Leach, 1976), in one general accounting system that quantifies all the agricultural process, eliminating qualitative descriptions.

Methods

The ecological and economic accounting of the agricultural system is made through crop accounts, organised in groups of costs and revenues (economic analysis) and inputs and outputs (energetic analysis). The unit considered in the crop accounts is a rectangular lot, with an area of 1 ha, 200 m of length, and at a distance of 1 km from the farm centre.
The necessary machinery operations, the necessary quantities of production factors, and the expected production quantities are recorded. The quantitative values are multiplied by the economic and energetic unitary values, to obtain the balances and the indicators used in the analysis.
The unitary values used were obtained through the database, where we have, for each point, the economic value (at current prices for 1994/1995 campaign) and the direct, indirect and total energy values. The values obtained through references were: seeds, straws and hay (Jarrige, 1981); steel, scrap, tyre, diesel oil and oil (Bousted et al., 1978) and manure and crop protection chemicals (Leach, 1976). For the labour costs we have considered the values of the campaign of 1994/1995 for Cova da Beira, Portugal.
For the accounting of energy flows we have used energy systems analysis techniques, analysing the way energy sources are used to provide useful functions (Bousted et al., 1978). We have just considered the upstream productive chain, using mainly a first order energy analysis.
The energy inputs are the total energy associated with each operation, the direct energy associated with the seeds and the total energy (direct and indirect) associated with the chemicals used. We have not considered solar energy and human labour as energy inputs. The energy outputs correspond to the direct energy of the marketable products.

Crop	Computed	Leach (1976)
Hay	6.57	-
Oat	3.45	2.4
Rye	3.29	-
Wheat	3.12	4.87
Maize	3.37	2.34

Table 1 – Comparison between the computed energetic coefficients with the reference.

Results

We present in Table 1 the energy coefficients computed by us with those obtained by Leach (1976) results (Table 1), and the economic and energetic computed indicators (Table 2).

COMPUTED INDICATORS		Oat	Hay	Rye	Maize	Wheat
Costs / kg of produced biomass		15.66	13.04	18.09	25.25	22.63
Revenues / kg of produced biomass		26.17	29.00	31.79	53.28	51.56
Costs / Revenues	(PTE/PTE)	0.60	0.45	0.57	0.47	0.44
Revenues / Costs	(PTE/PTE)	1.67	2.22	1.76	2.11	2.28
Costs / Outputs	(PTE/MJ)	1.00	0.89	1.16	1.54	1.39
Revenues / Inputs	(PTE/MJ)	1.67	1.99	2.04	3.26	3.18
Financial Profit	(PTE)	31 530	63 834	32 872	210 228	130 170
Inputs / kg of produced biomass		4.55	2.22	4.74	4.85	5.20
Outputs / kg of produced biomass		15.69	14.60	15.61	16.34	16.24
Inputs / Outputs	(MJ/MJ)	0.29	0.15	0.30	0.30	0.32
Outputs / Inputs	(MJ/MJ)	3.45	6.57	3.29	3.37	3.12
Inputs / Revenues	(MJ/PTE)	0.17	0.08	0.15	0.09	0.10
Outputs / Costs	(MJ/PTE)	1.00	1.12	0.86	0.65	0.72
Energy Balance	(MJ)	33 404	49 520	26 087	86 195	49 641

Table 2 – Economic and energetic indicators.

Discussion

There is a consistent relation between the computed values for the energy consumption of the crops and the values in the references. We consider that the computed values are more rigorous than the values in the references, as they were obtained using physical variables, in coherence with thermodynamic laws (see Table 1). The values obtained for the energy coefficients allow us to classify the crops in the range of half to total industrial crops (Leach, 1976).

There exists a one-way correspondence between the energy analysis values and the economic analysis values. We have noticed a positive linear correspondence between economic costs and revenues and between the energy inputs and outputs, a result that brings into energy analysis the economic concept of growing gains with growing investment. We have noticed a positive linear relation between economic and energetic balance, which means that the maximisation of economic profits leads to growing energy consumption. The relative revenues (associated with the relative production value) increase with the degree of intensification of the crop, a tendency also followed by relative costs.

Through the identification of these relations we can now study different cultural systems and technologies, evaluating the ones that allow the decrease of the energetic *inputs* without compromising the economic profitability.

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RESOURCE USE AND SUSTAINABLE CEREAL PRODUCTION

Hubert J. Spiertz
Department of Plant Sciences – Crop and Weed Ecology, Department of Plant Sciences
Wageningen UR, PO Box 430, 6700 AK Wageningen, The Netherlands

Introduction

Agronomically, farmers should aim at the minimum input of each production resource required to allow maximum utilisation of all other resources (de Wit, 1992). Consequently, above a certain minimum, higher inputs of yield-increasing factors such as water and nutrients result in higher yields per unit area and are associated with higher efficiencies of other resources.

The management options for ecological and economical sustainable agriculture are maintaining soil health and fertility, site- and time- specific nutrient and water management, fine-tuning in dose and timing of crop protection measures and the choice of adapted crops and high-yielding cultivars.

Nitrogen cycling and utilization

Today, the agronomic and economic requirements of nitrogen management remain central, but in addition we must consider the potential impact of nitrogen on the environment (Cassman et al., 2002). Improved efficiency of N-use at a field and farm scale, both aiming at increasing crop yield and quality and reducing losses, is dependent upon the magnitude of matching N-supply and -demand of the crop (Lloveras et al., 2001). Nitrogen is mobile in the soil-plant-animal system and with the required N-inputs for a high crop yield and protein content of the grain the risk on N-losses increases. Traditionally, nutrient management has been concerned with optimising the economic return from nutrients used for crop production. The main emphasis is on the expected crop response from adding nutrients to the soil. However, in practice nutrients are not always applied in such a way that plant nutrient use is optimized because of agronomic or labor constraints. Such practice or the improper or untimely application of manure and fertilizer may release nutrients into the air and water; this represents an unsustainable use of natural resources. Today, the agronomic and economic requirements of nutrient management remain central, but in addition we must consider the potential impact of these nutrients on environmental quality. Leaching is the major route by which nitrate enters the ground and surface waters, while denitrification and nitrification are significant sources of N_2O, an important greenhouse gas. Improved efficiency of N-use at a field and farm sçale, both increasing crop yield and quality and reducing losses, is dependent upon dynamic optimisation to match supply of N and the N requirements of the crop at a field scale. The optimisation requires measurement and prediction of soil-N supply, crop uptake and their variability (Stockdale E.A. et al., 1997). These procedures are in line with the results of nitrogen split-dressing experiments in winter wheat in Europe some 25 to 30 years ago (Dilz et al., 1982). However, the demand of the grains in high-yielding wheat crops is much higher than the post-floral uptake of nitrogen by the crop; relocation of nitrogen from the vegetative to the generative parts becomes very important for high-yielding crops (Spiertz & de Vos, 1983). To maintain a prolonged activity of leaves as a source of assimilates - carbohydrate and nitrogen – the canopy must have ample nitrogen reserves and stay healthy. Future crop research should aim at combining improved quality traits with an optimum acclimation of wheat cultivars to climatic variability during grain filling (Spiertz & Schapendonk, 2001).

The problems with nutrient pollution are not generally the result of mismanagement by farmers, but are a result of how agricultural systems have evolved with no direct costs associated with environmental quality and conservation of natural resources. Beegle et al. (2000) concluded that nutrient management strategies would not be the same for all farms. They classified farms on nutrient balance basis in three groups:

- *Nutrient-deficient farms*; nutrient imports are less than exports. Thus, additional nutrients in the form of purchased fertiliser or other sources are required for achieving optimum crop yields.
- *Nutrient-balanced farms*; nutrient imports are approximately equal to exports. Because these farms are often at the upper limit of being able to safely handle all the nutrients in the production system, nutrient management planning may offer potential environmental benefit.
- *Nutrient- surplus farms*; nutrient imports significantly exceed exports. The nutrients in the manure generally exceed those required for crop production on the farm. Decision-making related to a nutrient management planning occurs at the strategic, tactical and operational levels of management.

In the Netherlands, there exists regulations set by the government to protect the environmental compartments - soil, water and air – against nutrient losses from agro-production. The Dutch government imposed a policy that will lead to a balanced application of manure and fertiliser. This is to be brought about by the introduction of the Minerals Accounting System (MINAS). Under this system farmers are to keep records of the exact amount of minerals they use, the quantities that leave the farm and the quantities lost to the environment. With a balanced application of nutrient inputs the EU Nitrate Directive's objectives can be met and nitrate levels in groundwater will not exceed the standard of 50 mg nitrate per litre. A more environmentally sensitive nutrient management on the field and farm level can reduce nitrogen losses to a level that meets the standards of a clean environment.

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ADAPTATION OF A PESTICIDE INDICATOR TO THE WATERSHED SCALE

Thiollet M., Bockstaller C., Girardin P., Morvan G.,
UMR INRA-ESAIA, 28 rue de Herrlisheim, 68000 Colmar, FRANCE
thiollet@colmar.inra.fr

Introduction

Vineyards are highly sensitive to disease and require a large degree of protection. Important quantities of pesticides are used for the protection of vineyards, which usually leads to extensive long-term environmental damages. Environmental regulatory bodies require appropriate tools for environmental impact assessment of vineyard practices, especially for water quality. Indicators (among them a pesticide indicator I-PHY) were developed on the field scale using the INDIGO method at INRA, Colmar (Girardin *et al.*, 1999). serve as a diagnostic or a decision aid tool, in order to adapt winegrowers' cultivation practices to the requirements of sustainable viticulture. However problem of water quality are often studied at the scale of a watershed. The extensive use of the indicators of the INDIGO method requires some modifications before it may be applied on a larger scale as a watershed.
In this paper, we intend to present results of I-PHY values calculated from fields of an experimental watershed and results of analysis of pesticide content in surface water . Results from this comparison will be used to propose I-PHY modifications and to adapt it to an use at watershed scale (I-PHYw).

Materials and Methods

I-PHY values were calculated for most of the fields of an experimental watershed, located in Bourgogne, France and which covers 192 ha, (and divided into 820 fields).
Values were calculated for only 140 cultivated ha (divided into 556 fields), following which I-PHY values were compared to results of surface water analysis. Sixty-one active pesticide compounds (APC's) have been spread over the watershed. The remaining fields were not included in the study as some winemakers declined to participate in the research program. At the same time, surface water analysis of pesticide concentrations was carried out. Water from the outlet was analyzed after primary rainfalls in 2000 (27/4, 30/5, 4/7, 24/7) and was analyzed for more than 260 APC's.
Indicators are expressed on a scale varying from 0 (strong impact) to 10 (weak impact) and are calculated with the data available on the vineyard (cultivation practices, soil analyses and permanent characteristics such as field size, slope). I-PHY (Van Der Werf *et al.*, 1998; Chégard *et al.*, 2000; Thiollet *et al.*, 2001) is based on a system of fuzzy logic built on five modules; rate of application of the pesticide, risk for; groundwater, surface water; air and beneficial organisms. The value of I-PHY is only of interest when related to a reference (set at 7/10). An I-PHY value of 7/10 corresponds to a soft pesticide application program.

Results

Value of I-PHY	Number of fields	Frequency (%)
I-PHY >7	29	5.2
I-PHY = [4 - 7]	113	20.3
I-PHY < 4	414*	74.5

Table 1 : Repartition (Classification) of watershed fields according to I-PHY value (* in this group, 115 fields have I-PHY=0).

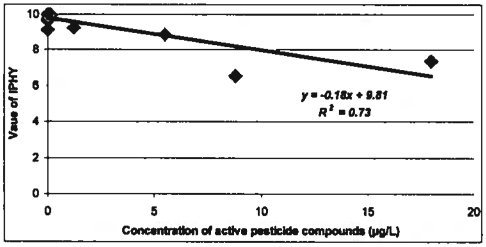

Figure 1 : Correlation between I- values PHY and APC concentrations in surface water analysis for first primary rainfall (27/04/00).

Results presented in this paper are of I-PHY values calculated at the field level from a vineyard watershed Eastern of France (Duchenes, 2002; Allier, 2001), (Tab. 1).

The majority of the fields have high rates of pesticide application and only a small number of fields have cover crop. Herbicides are widely used over the vineyard and 20 of the 61 APC's detected in water analysis are herbicides. For the first period of rainfall , we observed a good correlation (R^2 = 0.73) between water analysis and I-PHY (only modules of groundwater and surface water quality) (Fig. 1), as well for the second primary rainfall (data not shown) For the following periods, significant discrepancies were noticed. This may be explained by i)the lake of data for some fields, ii) accumulation of APC's resulting from increased pesticide application in July, iii)the incomplete adaptation of I-PHY to the watershed scale.

Discussion and conclusion

The water analysis can only reflect potential non-point source pollution of surface water, water normally resulting from runoff. In contrast I-PHY considers potential non-point source pollution of groundwater, surface water and air. Generally, results of surface water analysis includes freshly applied pesticides and few previously applied pesticides which have been carried away by rainstorm.

It is proposed to build I-PHYw containing only water modules reflecting the risk (as a ratio) for ground and surface water. This aggregated module reflects hydrological characteristics of the watershed. Preferential circulation of water which passes though the watershed needs to be evaluated before evaluating the risk of non-point source pollution.

Furthermore, there is no homogeneity in the contribution of each field to the distribution of polluted water. It is planed to identify the field(s) responsible for runoff, sub-surface infiltration and leaching.

We therefore decided to select different factors for the assessment of the environmental impact of pesticides linked with geology, pedology, typology and cover crop of the field.

To validate the indicator, input parameters are submitted to hydraulic experts and results compared to those obtained experimentally.

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FARM EXPLORER: DESIGNING SUSTAINABLE ARABLE FARMING SYSTEMS

G.W.J. van de Ven[1], W.A.H. Rossing[2], M.K. van Ittersum[1], H. Boekhoud[3], F.K. van Evert[4], PA.C.M. van de Sanden[4] and R.F Mauritz[5]
[1]Plant Production Systems, Wageningen-UR, P.O. Box 430, 6700 AK Wageningen; [2]Biological Farming Systems, W-UR; [3]Van Hall Institute; [4]Plant Research International, W-UR, [5]CAH-Dronten

Introduction

Legislation on environmental and health issues and price developments force farmers to continuously adapt their farming systems towards a more sustainable way of farming. However, re-designing farming systems may provide better perspectives for farm continuation than gradual fine-tuning. Quantification of promising hypothetical crop rotations offers the opportunity to compare and evaluate various farming systems before putting them into práctice. We have developed an instrument, Farm Explorer, using recent research data, to re-design farming systems in a consistent way.

Model description

Farm Explorer is a future oriented instrument that integrates knowledge on components in arable farming. The effect of newly designed crop rotations on economic, technical and environmental objectives and constraints at the whole-farm scale can be evaluated. The farming system is defined by the strategy, the biophysical and socio-economic characteristics of the farm and the crop rotation (Table 1). The goals refer to the outputs of the farm (Table 1), can be expressed in a target value, e.g. nutrient management expressed in a maximum permitted N surplus in kg ha^{-1} yr^{-1}, and are evaluated at the end. The rotation is composed of a set of crops cultivated in different sequences, with various production technologies and with mutual interaction.

Table 1. Inputs and outputs of Farm Explorer.

	INPUTS	OUTPUTS
Farm strategy	Various goals at farm level	Physical crop yield
Farm definition	soil *	Economic results
	Buildings and machinery	Nutrient flows and balances
	Labour availability	Energy use
	Capital availability	Labour requirements per 2 weeks
Rotation definition	Crop	Heavy metals balance
	Production orientation**	Organic matter balance
	Target yield	
	Crop protection measures***	
	Fertiliser application***	

* choice between sand and clay; soil-borne pathogens are specified
** choice between good agricultural practice, integrated agriculture, organic agriculture or bio-dynamic agriculture
*** choice between a standard packages based on the production orientation and composing a package

For each of these inputs various choices are possible. The user can specify a target yield for each crop and indicate fertiliser use and pest, disease and weed management. Yields reductions due to crop sequence, crop frequency and pests and diseases are derived from a database. The program checks on a sufficient supply of nutrients. For the relations used for the underlying calculations we refer to Boekhoud et al. (2001). For each farm various rotations can be designed, tested and compared and also various farms can be defined and compared.
Farm Explorer uses a database consisting of three parts. The basis is CAPS (Crop and Animal Production Systems; Van Evert et al., 2001), a relational database serving as a central point for collection of new data from agricultural research. The relevant part of CAPS is adhered to Farm Explorer and can easily be replaced by updated versions. The second database is the

Environmental Pressure Indicator for crop protection agents (CLM, 2001). For data not available from those two databases, a separate database is constructed containing data from literature and expert knowledge.

Results

The results comprise the outputs in Table 1. They are presented in tables and flow diagrams depending. An example of a flow diagram on nitrogen for potatoes is given in the Figure. By clicking on the numbers in the flow diagram the underlying equations and parameter values become visible. One can see which measures can be taken to improve goal achievement Evaluation of the results with respect to the targets may lead to changes in the design of the rotation and new results can be generated. This process of evaluation and adaptation of the design is repeated until the targets are satisfied or, if the targets cannot be achieved in an acceptable way, they have to be adapted themselves. It is the responsibility of the user to carry out this procedure in a sensible way.

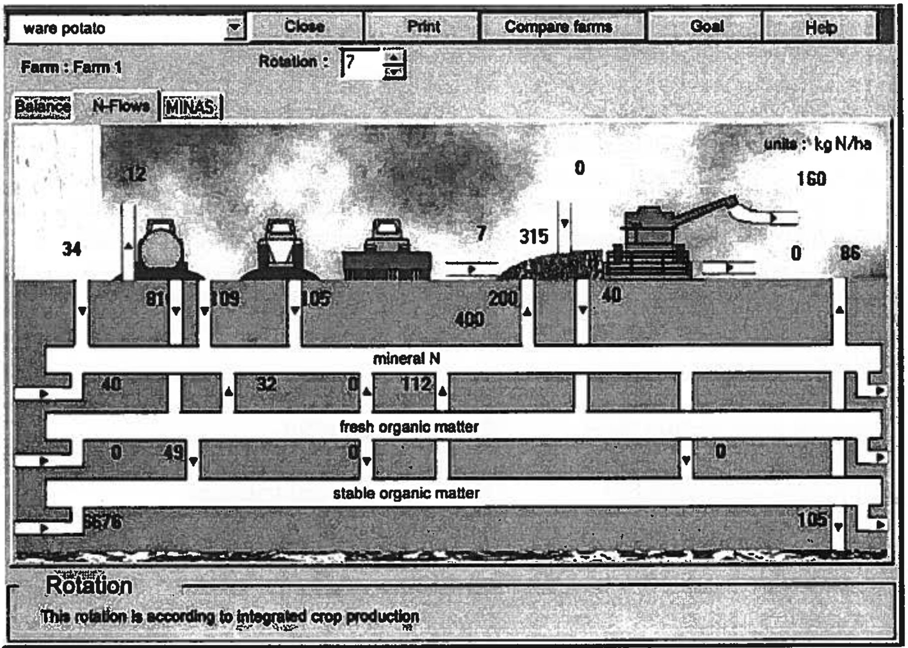

Figure 1. N flows for ware potato on farm 1 and in rotation 7 (kg N ha^{-1})

Perspectives

This model provides a useful instrument in designing crop rotations and evaluating their economic, environmental and technical performance related to targets defined in advance. It provides an opportunity to compare the performance of various rotations and farms. Farm Explorer can be used in farming systems research and the user friendly interface, makes it also suitable for educational purpose.

The model is built in such a way that it can easily be extended with livestock and mixed systems.

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BEHAVIOR OF PRETILACHLOR IN PADDY SURFACE WATER AND SEDIMENT

Vidotto F[1]., Barbero L.[1], Busi R.[1], Ferrero A.[1], Bertoia O.[1]

1 Dipartimento di Agronomia, Selvicoltura e Gestione del Territorio. Via L. da Vinci, 44. 10095 Grugliasco (Italy)

Introduction

Pretilachlor is a herbicide that belongs to the chloroacetanilide family which is effective against a large spectrum of grasses, broad-leaved weeds and sedges in rice. Due to the low selectivity towards rice, pretilachlor is used on its own alone in pre-seeding (or pre-transplanting) of the crop, or in mixture with the safer fenclorim in post-emergence. Pretilachlor has been widely used in Italy, since 1998, for pre-seeding applications, primarily to control weedy rice (*Oryza sativa* L.). Application of the product is currently performed when the paddy field is flooded. After the spraying, the inlet and outlet floodgates of the field are usually kept closed for about 30 days. The dissipation of pretilachlor from water is mainly due to the high adsorption of the soil, especially by the organic fraction (Fajardo *et al.*, 2000; Wang *et al.*, 1999). The aim of this study, carried out in 2001, was to investigate the behaviour of pretilachlor in surface water and sediment in rice paddies.

Methods

The study was conducted in the East Sesia zone (municipality of Barengo; lat. 45° 33' 30", long. 8° 31' 15"), the most northern rice cultivation area in Italy, in a test paddy of 1.74 ha, located within a series of connected fields. No other pretilachlor-treated paddies were present uphill or up-gradient. Pretilachlor was applied over the two previous years in the selected area. Pretilachlor was applied at 1370 g a.i. ha^{-1}, as the commercial herbicide Rifit® (49.75% a.i.), in pre-seeding to fields flooded with 20 cm of water. After the treatment, water circulation in the test paddy was stopped for 23 days. Samples of water were taken in the eastern, central and western parts of the paddy before and immediately after treatment and at 2, 8, 15, 21, 29, 36, 44, 57, and 74 days after treatment (DAT). samples of sediment (top 1 cm of soil) were collected in the same points, before and immediately after treatment and at 2, 6, 29, 36, 44, 57, 85, and 110 DAT. All the samples were stored at –18 °C until they were analysed.
Extraction of pretilachlor from water samples was carried out by liquid-liquid separation with dichloromethane, evaporation and re-solubilisation in esane. The extraction from the sediment samples was performed in the same way, after a first treatment with 95:5 v/v dichloromethane : methanol solution on samples dried at 50% (w/w) water. Analytical determination was carried out using a Perkin Elmer 8500 Gas Chromatograph equipped with a JW DB-23 column operating at a temperature of 240°C and an ECD detector. The carrier gas was He and the pretilachlor retention time was 8.69 min in these analytical conditions.

Results

No pretilachlor was present in the paddy water before treatment except for the west point, where traces of herbicide were found. This was most likely due to desorption of the herbicide applied during the previous year from the soil. A concentration of pretilachlor of about 2.6 □g L^{-1} was in fact observed in the sediment at the same date and position. In the western and central point of the paddy the maximum concentration of pretilachlor in water was recorded the same day as the treatment (375.57 and 347.55 g L^{-1}, respectively), while, in the eastern point, the maximum value was reached 2 DAT (312.46 g L^{-1}). After the reaching the peak, the pretilachlor dissipated from water according to an exponential decay model (Fig. 1). Despite the differences in concentration between the 3 positions found immediately and in the first days after treatment, the time required for 50% of active ingredient disappearance (DT_{50}) was quite similar for the different points, ranging from 6.0 (centre) to 6.7 (east) days. The period in which the water circulation was stopped (23 days), was roughly correspondent to the time required for a 90% disappearance of pretilachlor (DT_{90}). The calculated DT_{90} was in fact ranging from 20 (east) to 24 (centre) days.

In the days following the opening of the floodgates, the amount of pretilachlor in the water of the test paddy quickly fell from levels of about 27 g L^{-1} to levels below 0.50 g L^{-1} and remained almost unchanged until the last sampling date (74 DAT). After the treatment, the herbicide was quickly adsorbed by the sediment, as the pretilachlor concentration in the sediment showed a fast increase until 6 DAT, when values ranging from 105.3 g L^{-1} (west) to 247.4 g L^{-1} (east) were observed. After this time, the herbicide gradually disappeared from the sediment following a pattern similar to that observed for water (Fig. 2). The calculated DT_{50} varied from position to position, ranging from 20.4 days (east) to 24.8 days (centre).

Fig. 1 - Pretilachlor concentration in the paddy water

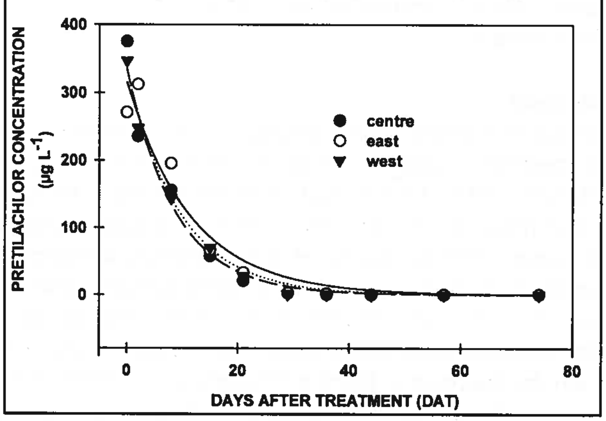
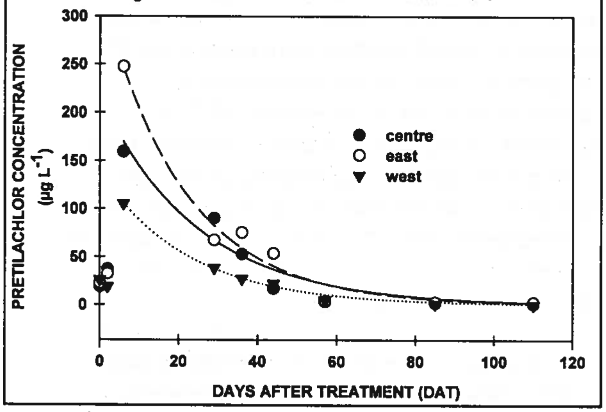


Fig. 2 - Pretilachlor concentration in the sediment



Average DT_{90} was 63.7 days, with no relevant differences between the positions in the test paddy. The concentration was quite stable until the last sampling date (110 DAT), when an average value of 1.4 g L^{-1} was observed.

Conclusions

The concentration of the herbicide pretilachlor in paddy surface water decreased relatively fast after treatment, reaching 50% and 10% of the initial value after about 6 and 20 days, respectively. The disappearance of herbicide from water was primarily due to adsorption by the soil, in which the concentration increased over the first 6 days after the treatment. Residues of the herbicide were still detectable at 74 DAT in the surface paddy water and 110 DAT in the soil sediment.

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COMPARATIVE ECOLOGICAL ECONOMIC EVALUATION OF EUCALYPTUS AND INDUSTRIAL HEMP PAPERS

R.F. Vieira[1], T. Domingos[1], P. Canaveira[2], A. Simões[1]

1 Instituto Superior Técnico, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal.
3 CELPA - Associação da Indústria Papeleira Portuguesa, R. Marquês de Sá da Bandeira, 74 – 2° Dto., 1069-076 Lisboa, Portugal.

Introduction

Paper industry is a very important sector in Portugal that has a high representation in the international market of pulp industries (Portugal is the third largest exporter of eucalyptus pulp [2]). This fact is due to the high quality of Portuguese pulp. However, there exists increasing competition from similar quality pulp papers from countries that are becoming increasingly important in the international market (e.g. Brazil, Chile and New Zeeland [5]).
There is also the problem of increasing costs of human labour, land and transportation. The latter is due to migration to littoral areas, which pushes forests more and more to the interior, leading to a greater distance between factories (littoral) and forests (interior).
Environmental problems are pollution generated by this kind of industries and the fact that the high quality of Portuguese pulp paper is due to the use of eucalyptus (*Eucalyptus globulus*) monocultures [5]. For example, in 2000, in Portugal, 84% of pulp production came from eucalyptus [2]. This leads to an increased area of exploration of eucalyptus, with a proportional increase in the environmental impacts associated with it.
The existence of non-wood alternatives to eucalyptus pulp paper, like industrial hemp (*Cannabis sativa*), that may have some environmental, economic and social advantages and also produce a high quality paper (due to a long fibre structure), leads to the goal of this study.
This study's main goal was to compare the sustainability of eucalyptus and industrial hemp papers by determining the carbon, nitrogen, phosphorus, potassium, calcium and hydrological balances, energy balance, environmental impacts, and economic balance and calculating aggregate indicators like the ecological footprint and emergy. Based on this analysis, this study analyses the policy measures to promote the best solution.

Methods

The method adopted for this study was the life cycle analysis of one ton (1 t) of paper. Therefore two life cycles were determined: one for eucalyptus paper and the other for industrial hemp paper. The life cycle analysis comprised the quantification of mass and energy fluxes and of costs associated to each process in the life cycle. The life cycle included the following steps: cultivation, pulp production, paper production and waste disposal.
Because eucalyptus and industrial hemp can be produced both on dry lands and irrigated lands, four alternatives were compared:

1. eucalyptus cultivation vs. industrial hemp crops on irrigated lands;
2. eucalyptus cultivation on irrigated lands vs. industrial hemp alternating with corn crops, also on irrigated lands;
3. eucalyptus cultivation on dry lands vs. industrial hemp cultivation on dry lands;
4. industrial hemp alternating with corn crops on irrigated lands vs. eucalyptus cultivation on dry lands.

The mass and energy fluxes were based on values from pulp and paper industries and from existing systems of eucalyptus and hemp.
The ecological footprint of 1 t of paper was determined based on the estimation of the area needed to support physically the activities and the area needed to produce the resources and assimilate the wastes generated.

The emergies [4] were determined based on the transformaty values and the values of energy of the life cycles obtained on this study.

Results

At the moment the study is in the data acquisition phase. We expect to have results by mid June.

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PHOSPHORUS TRANSPORT AND EROSION FROM AN INTENSIVELY CULTIVATED PLAIN AREA IN NW ITALY

L. Zavattaro[1], E. Barberis[2], D. Sacco[1], M. Bassanino[1]
[1]Dip. Agronomia, Selvicoltura e Gestione del Territorio; [2]DIVAPRA Chimica Agraria. Università di Torino. via L. da Vinci, 44 - 10095 Grugliasco - Italy. e-mail: zavattaro@agraria.unito.it

Introduction

The Po Plain is a large area with slight slopes but intensive agriculture which may contribute to non-point source pollution. Contrarily to Italian hilly areas, there is a lack of information regarding soil and P losses due to surface runoff in the plain. The study presented here is aimed to evaluate the environmental impact of cropping systems at the catchment scale in a plain area, and is part of the DESPRAL EU Project. The objective of this paper is to describe the particular conditions of the study area and the first results.

Methods

The study is being carried out in Fossano, in the western Po plain (Piemonte, Italy). The region is highly representative of the NW Italy conditions. The selected area is 1152 ha wide, and lies in an alluvial plain which is intensively cultivated. The average slope is 0.61%. The climate is subhumid and the average rainfall is 778 mm, with two peaks in spring and autumn. The maximum groundwater depth is 4.4 m. The phreatic surface is a regular plain and has a slope of 0.57% in the same direction as the field slope. The groundwater plane intersects the field plane in the central part of the area, where in fact some springs are present. A complex channel net exists, which supplies fields with irrigation during summer, and removes the excess during the rest of the year. The study area conditions are very particular if compared with other runoff studies because 1) the slope is slight, 2) the area has no morphological boundaries to water flow, 3) the canalization drains the groundwater.
Uphill and downhill boundaries of the area were identified along some ditches which had no or scarce connections with the others. Two ditches serve as outlets from the area (S. Michele and S. Ciriaco), and one is an inlet (Mellea). Three automatic stations composed by a doppler sensor gauge (to record water flow) and an automatic sampler were installed at these three points. Sheet steel was used to have a regular section of the natural ditches. Flow data are being recorded every 15 minutes. The sampling strategy is based on flow. A 1-litre sample is collected every 20000 m^3 at each site. When the flow is low (base flow), 2-3 litres are composed for one analysis. When the flow is higher (peak flow), 1-litre samples are analysed separately. This strategy is rough but efficient and flexible to study both base and peak flow, where no historical data are available. About 100 analyses are expected to characterize the base flow, while about another 100 analyses will be devoted to peak flow, at each site and every year. Samples are analyzed for the dry residue, total P on unfiltered water (TP), total P and molibdate-reactive P (MRP) on 0.45-µm filtered water. Rainfall is also automatically and continuously measured at S. Michele, and manually measured and sampled for analysis every week at S. Michele and Mellea.

Results

There are three different soil types in the area: two are Inceptisols and one is a Mollisol. In all cases, texture of the topsoil ranges from loam to silt loam. The most widespread crop is maize (62%), followed by winter cereals 14%. Permanent or rotational meadows cover all year round 17% of the surface. A large number of animals are present, for a total of 3.0 pigs ha^{-1} and 2.2 heads ha^{-1} among dairy cows and beefs. If we calculate a P balance at the field scale, we obtain a P surplus of about 60 kg ha^{-1}, on average. Olsen P in the topsoil is in fact high, ranging from 3 to 132 mg kg^{-1} (avg. 35 mg kg^{-1}, n=289). Such characteristics suggest that unless for the slight slope, there is a very high risk of erosion and P transport in the area.

Fig. 1. Water balance in a 10-days time step.

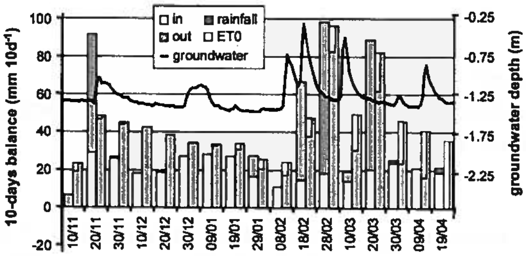


Fig. 2. Forms of P in canal waters.

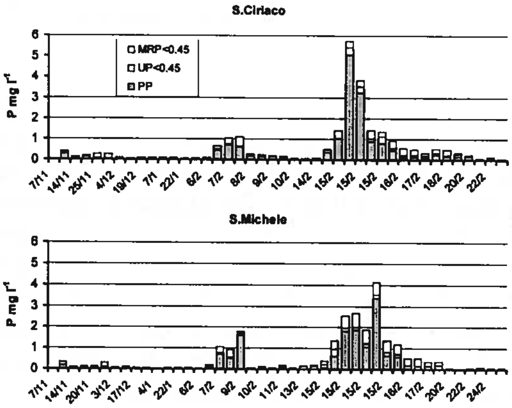
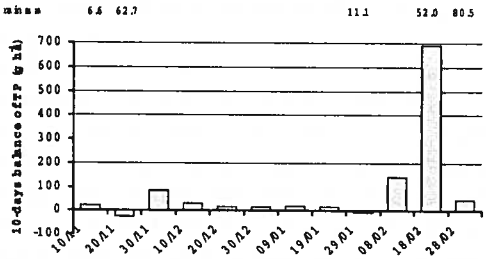


Fig. 3. Total P balance in the catchment area.



Measurements and sampling of water in ditches started in November 2001. First results show that the amount of outgoing water really exceeds that entering the area, because of the contribution of the groundwater to outflow (Fig. 1). Such contribution is also demonstrated by a significant inverse relation between the water table depth and the excess of outgoing water. Intense rainfall may increase outflow 1) through surface and subsurface runoff, and 2) through rising the water table level. Figure 1 shows that after 50-100 mm of rain, 30-40 days are needed to drain water from fields and return to base flow, while 15-20 days are sufficient to lower the phreatic surface to its normal value.

Total P concentrations in canal water ranged from 0.01 to 5.74 mg l^{-1} (Fig. 2). Concentrations in the inlet canal were never greater than 0.14 mg l^{-1}, therefore inputs were low (1.3 g ha^{-1} d^{-1}, on average). Most of P in outgoing water was bond to particles (PP), both during base flow and peak flow (49% of TP on average), while MRP was 15% of TP during base flow and 38% of TP during peak flow. However, no clear relation was found between P fractions and TP. On a daily basis, concentrations were linearly correlated with flow only during very intense events (total outflow >10 mm ha^{-1} d^{-1}, velocity >1.7 m s^{-1}). The contribution of the groundwater to P transported in ditches was low, as its average concentration was 0.05 mg l^{-1}.

If we calculate a balance also including P in rain (Fig. 3), in the period 1/11/01 to 25/2/02 the amount of P removed from the area was 1048 g ha^{-1}, 28% of which was as MRP. Molibdate-reactive P is directly available to algae, hence it may severely contribute to eutrophication. In the same period, 1866 kg ha^{-1} of soil were eroded. If extrapolated to the whole year, these results are smaller than those reported by Acutis *et al.* (1992), who found 2.4 kg of TP and 0.9 t ha^{-1} of soil erosion in 1000-m^2-experimental fields with very similar conditions of soil, slope, land use and climate. In that case also, most of erosion was concentrated in few big events.

Conclusions

First results suggest that erosion losses of soil and P can be remarkable also in plain sites. Therefore, in order to establish a correct protection policy, monitoring studies are needed, although difficulties are greater than in hilly areas.

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Seed science and technology

SELECTION OF HIGH QUALITY SEEDS BY X-RAY ANALYSIS

Martien P.M. Caspers[1], Erwin van Zwet[2], Karin Sierat[1], Mieke van Zeijl[1], Jolanda Heistek[1] and Bert van Duijn[1].
[1]Department of Applied Plant Sciences, TNO Nutrition and Food, Wassenaarseweg 64, 2333 AL Leiden, The Netherlands, tel: +31.71.527.4914, fax: +31.71.527.4863, email: caspers@voeding.tno.nl
[2]Optical Instrumentation Division, TNO Institute of Applied Physics, Stieltjesweg 1, Postbus 155, 2600 AD Delft, The Netherlands, email: vzwet@tpd.tno.nl

Summary
We have developed a device for making high-resolution X-ray images of individual seeds. Because X-ray detectable internal seed structures can be correlated with quality of seed germination and/or plant quality of the seedling, our device can in principle be used for upgrading of seed batches by high throughput seed selection.
A model study shows that X-ray detectable cucumber seed morphology highly correlates with plantlet quality and that seed selection on the basis of computer image analysis, results in seed batches giving increased percentages of good plants. Currently, seed transport and image processing are further optimized and we are studying other crops.
In the lecture different examples of relationships between internal morphology of individual seeds and the plantlet quality will be demonstrated.

MALTING QUALITY OF BARLEY CULTIVARS IN TERMS OF GENE EXPRESSION

M. Caspers[1], E. Potokina[2], B. van der Vat[3], N. Sreenivasulu, A. Graner[2] and M. Wang[1]*

[1] Department of Applied Plant Sciences, TNO Nutrition and Food, Wassenaarseweg 64, 2333 AL Leiden, The Netherlands, Phone: +31-71.527.4914, Telefax: +31-71.527.4863, email: wang@voeding.tno.nl, * Corresponding author.
[2] Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben, Germany
[3] TNO Nutrition and Food, Zeist, The Netherlands

Introduction

Variability of barley quality is a major obstacle in achieving and maintaining product quality at a constant level in industrial beer brewing. Current analytical methods in barley-breeding, malting en brewing aim to find an optimal balance between raw material quality and production tolerancy. However, the current set of quality methods for (malted) barley seed is limited, the applied technologies numerous and the correlation with quality not always clearly valorized. New developments in molecular and nanotechnologies provide opportunities to expand the number of quality parameters, to assess them rapidly with one high-throughput technology and to developed new, more accurate sets of quality parameters for various stages during seed development and germination (Potokina, 2002a). The high potential of these analytical tools for large-scale rapid quality typing and process monitoring is expected to change quality control in the sector of barley breeding, malting and brewing in the coming decade.
Here we present an initial study for the identification of quality related gene-expression during seed germination (Bewley and Black, 1994). This pilot project is focussed at a collection of cDNA arrays representing approx.1400 barley clones, which were used to screen mRNA levels of a set of 10 selected barley varieties of extreme (both positive and negative) malting quality. The first results of this transcriptomics strategy indicate that indeed correlation between malting quality (based on conventional malting parameters) and gene expression patterns can be found (Potokina, 2002b).

Methods

Barley cultivars were grown on one location. Malting quality of micro-malted seeds (140 hrs germinated) of 10 selected cultivars was determined by measuring 12 conventional malting parameters (e.g. protein in seed and malt, soluble nitrogen and Kolbach, friability, homogeneity, ß-amylase, milling energy, extract yield and fermentability). Gene expression analysis was performed with (polyA+)RNA isolated from total RNA from total seeds, taken after 69 hrs micro-malting. ^{33}P-labelled cDNA fragments were generated with Reverse Transcriptase on the polyA+RNA and hybridised to barley cDNA arrays (membranes) spotted with 1400 different, sequenced PCR fragments (each representing a unique barley gene: Michalek, 2002 and Potokina, 2002a). RNA isolation and hybridisation were performed in duplo for each cultivar. Expression data found for the most dynamic genes among the 10 cultivars (Max>2xMin) were normalised (Max/Min represent the extreme expression levels per gene among the 10 cultivars). Both malt-quality- and gene-expression-data were analysed with multivariant data-analysis techniques such as: (i) Principle Component Analysis (PCA) and/or (ii) Principle Component Discriminant Analysis (PCDA) (Thormod and Næs, 1989) using MATLAB software and focussing on grouping the analysed cultivars in pre-assigned good, middle (med) and bad malting cultivars.

Results

10 selected barley cultivars (c.v.'s) were classified in 3 groups (4 good, 4 middle and 2 bad c.v.'s) based on significant individual differences of their determined classical malt parameters. Principle Component Analysis (PCA) of the malt quality data independently confirmed the malt

quality classification because PCA resulted in 3 rather distinct clusters of the pre-assigned good, middle and bad cultivars (Figure A).
Also the most dynamic gene-expression data among the ten cultivars were analysed with PCA (approx. 210 of 1400genes showing expression dynamics: Max > 2x Min). This did not directly lead to a clustering of the good, middle and bad malt cultivars, indicating that not simply the principle components of the expression data correlated with malting quality. However, by applying Principle Component Discriminant Analysis (PCDA) the cultivars could be grouped in the 3 pre-assigned malt-quality clusters (Good, Middle and Bad, Figure B). Based on this PCDA clustering, various subsets of the most differentially expressed genes can be identified that each seem to be correlated with a preferred malt quality (data not shown).

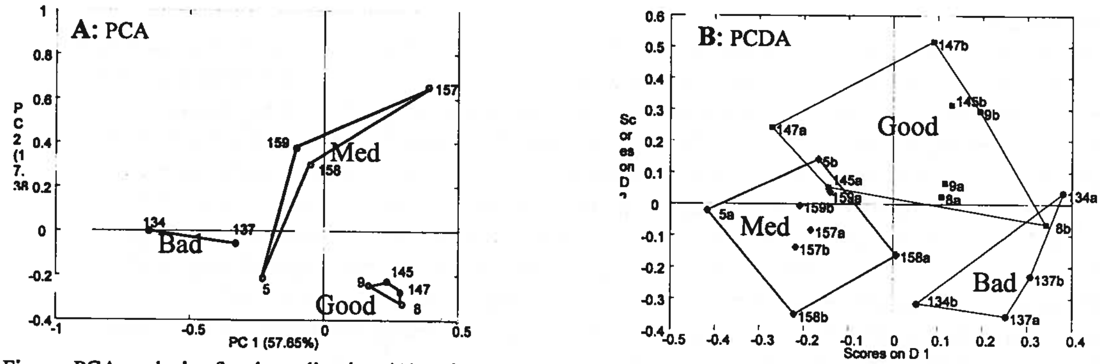

Figure: PCA analysis of malt quality data (A) and PCDA analysis of gene-expression data (B) of 10 barley varieties (nr 5, 8, 9, 134, 137, 145, 147, 157, 158, 159; a and b indicate duplo RNA isolations/hybridisations). Cultivar clusters of Good, Med and Bad malting quality are indicated.

Conclusions

This pilot study indicates that correlation between conventional malting quality parameters and half-way malting (69h) gene expression in germinating barley seeds can be made by applying array-based transcriptomics technology and multivariant data analysis techniques.
In further studies we will try to confirm these results and extend the amount of screened cDNA's and barley cultivars in order to improve the amount of candidate quality genes and statistical quality of the found correlations.

The authors thank the company Cebeco-Seeds for the supply of micro-malted barley cultivars and the corresponding malt quality data.

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THE USE OF CYTOPLASMIC MALE-STERILITY IN MAIZE SEED PRODUCTION

Voichita Has, I.Has, C.Grecu
Agricultural Research Station, Turda, Romania

Introduction

The use of cytoplasmic male sterility (cms) in maize hybrid seed production is of economic importance and it is also advantageous for genetic purity of seeds (Duvick et al., 1978; Josephson et al., 1978; Sarca et al., 1982; Cabulea et al., 1987, Has et al., 1989; Has et al., 2001). Three types of male sterile cytoplasms in maize are used as *cms* maternal parents to produce hybrids: *cms-C, cms-S, cms-T.* The concern that in a few years all maize might again be in C, or S cytoplasms (Tai-Chen Qin, 1990) gave way to ideas as to how to prevent this narrowing of the cytoplasmic gene base.Thus, a new technique of producing hybrids was proposed, using *multiplasm*, respectively a blend of several kinds of male sterile cytoplasms (Cabulea et al., 1987; Duvick et al., 1978; Has et al 2001).The aim of this investigation is: 1) to detect the presence of dominant Rf alleles genes in more than 600 inbred lines in crossing with diferent types of *cms*:C, ES, M, T; 2) to compare some registered "TURDA" hybrids developed with normal and *cms* /or Rf parental forms, in different environmental conditions, for three agronomic traits.

Methods

Restoration reactions of 600 inbreds lines on the *cms*:C, ES, M and T were scored using Josephson's scale (Josephson et al., 1978). The observation were performed at the Agricultural Research Station-Turda, between 1995-2001. Nine registered "Turda" hybrids carring both fertile and sterile cytoplasms were grown in two years at five locations.

Results

When using *cms* in maize breeding programmes it is as necessary as it is difficult to identify the inbred lines by their composition of Rf alleles genes. Identifying restorers to *cms C* and *cms ES* becomes much more complicated, due both to the involvement of at least two-three complementary Rf4, Rf5, Rf6 genes and to certain modifying factors, probably quantitative ones which, in some specific environmental conditions act in the absence of Rf gene, influencing the reactions of lines by the "late-breack" phenomenon (Kheyr-Pour et al., 1981). The percentage of non-restorer genotypes was 40% both to *cms-C* and to *cms-ES* (Table 1).

Table 1 The distribution of inbred lines according to their reaction in crosses to four *cms* types

cms types	No *cms* tester lines	No Studied Lines	% inbred lines			Different reactions
			Non restores	Restorers		
				partialy	fully	
cms-C	5	198	34	4	55	7
cms-ES	3	94	35	5	51	9
cms-M	2	121	20	33	20	27
cms-T	7	223	74	1	16	9
Total-studied lines		636				

121 inbred lines have been tested with *cms-M,* only 20% of them being identified as Rf3 Rf3. This confirms the results published by Ciobanu et al. (1998). The inbred lines which partially restore fertility or have a variable reaction according to the environmental conditions represent 27% of the inbred lines tested to *cms-M.* This instability is also mentioned in the specialized literature by Duvick et al. (1978), Kheyr-Pour et al., (1981).Because the *cms-T* is only used in areas less favorable to the disease caused by "Helminthosporium maydis" T-race, research on the use of this *cms* type is limited. Table 2 presents the synthetic results of the comparison between the cytoplasmic (N or cms) effects on certain agronomic traits of registered hybrids developed at the Agricultural Research Station, Turda. Trial conditions (years,locations) have emphasized a

series of significant differences between two cytoplasms as far as grain yield is concerned.These differences are greatly determined by nuclear-cytoplasmic interaction or by hybrid x local conditions interaction.

Table 2. Cytoplasmic male sterility effect for some traits at 9 registered "TURDA" hybrids

Hybrid	Cytoplasms	Grain yield q/ha	Dry matter of grain %	Erect plants at harvest %	Synthetic relativ index %
1	2	3	4	5	6
Turda-SU 182	N	98.6	76.6	85.4	100
	cmsC	95.0	77.1	79.3	90
	(%)cms/N	96	101	93	-
Turda-Mold 188	N	101.1	77.7	79.0	100
	cmsC	97.3	77.9	81.8	100
	(%)cms/N	96	100	103	-
Turda Super	N	85.1	75.3	81.6	100
	cmsC	86.7	76.0	78.2	98
	(%)cms/N	102	101	96	-
Saturn	N	78.2	73.2	78.0	100
	cmsC	92.1	75.1	83.2	129
	(%)cms/N	118**	102**	107	-
Turda 215	N	97.5	76.0	73.5	100
	cmsT	86.2	74.4	70.0	82
	(%)cms/N	88^{0}	98^{00}	95	-
Turda-SU 210	N	84.9	76.0	73.6	100
	cmsC	89.2	77.0	75.8	110
	(%)cms/N	105	101	103	-
Turda Favorit	N	93.3	75.8	80.7	100
	cmsC	104.5	74.7	74.3	102
	(%)cms/N	112*	99	92	-
Turda 198	N	102.1	76.8	76.1	100
	cmsES	101.2	76.5	75.5	98
	(%)cms/N	99	100	99	-
Turda 160	N	90.0	77.9	78.7	100
	cmsC	87.8	77.1	81.2	97
	(%)cms/N	97	99	100	-
Trial	N	92.3	76.1	78.5	100
mean	cms	93.4	76.1	77.7	100
	(%)cms/N	101	100	99	-

*** Significant at 5% and 1%, respectively

*Si%= {col.3x4x5(cms) / col.3x4x5(N)}. 100

Conclusions

1) The fertility restoration reaction of the inbred lines influenced by *cms*-source, the cms versions of several inbred backgrounds, nuclear-cytoplasmic interactions and environmental conditions.2) The fertility restoration data clearly show close relationship between the two representatives of the C group (*cms*-C and *cms*-ES). 3) The nine hybrids carrying *cms* did not differ generally from their counterparts with fertile cytoplasm (N) for yield and for two other traits.

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THE CONTENT OF NET ENERGY AND ANATOMICAL STRUCTURE OF GRAINS AS CHARACTERISTICS OF THE SEED-STOCK QUALITY.

F.Hnilicka[1], L.Bláha[2], V. Novák[1]
1 Czech University of Agriculture in Prague, Prague 6 – Suchdol, Kamýcká 987, Czech Republic
2 Research Institute for Plant Production,16106, Drnovská 507, Prague - Ruzync, Czech Republic

Introduction

Stress abiotic factors (drought, high temperature, low level of nutrients,…) affect the seed quality, seed morphological, physiological and biochemical traits and performance of progeny generations. Drought, high temperature and other abiotic stresses have a large influence on the basic metabolic processes, anatomy and morphology of seeds, yielding traits and traits of seed technological quality. For those reasons it is necessary to find out and cultivate more resistant cultivars. From a biological point of view it is also needed to study the anatomical structure of the stressed seeds of plants, especially in case of seed stock - the changes are visible on the outer layers of caryopsis.There are evident differences in the thickness of pericarp and seedcase and in content of net energy.
The seed contains energy in chemical compounds – sacharides, lipids and proteins, which are formed during photosynthesis of green plants. Besides the influence of photosynthetic intensity, the energetic value of biomass is also influenced by environment effect, i.e.by radiation intensity, photoperiod, nutrient uptake, soil type etc. (Golley, 1961).

Methods

The analysis of the energy content in grains and anatomical changes of grains of winter wheat cultivars (Astella, Estica, Ilona, Samanta and Zdar) from different stress conditions was performed. The plants were cultivated in Mitcherlich's pot experiments with homogenised soil and with standard level of nutrients. The average temperature was 23° C by day and 15° C by night. The lights intensity was 700 $mol.m^{-2}.s^{-1}$.The water potential of the soil was -0,12 MPa with pH 7,0 The second variant of the experiment included three types of stresses and their combination (low pH, high temperature and drought).
The analysis of net energy ($kJ \cdot g^{-1}$ of dry matter, by SN ISO 1928,) was provided with the automatic dry combustion calorimeter MS 10 A of the German firm Laget. The sections were taken in the middle part of the caryopsis, then evaluated and photographed with the help of a light microscope Nikon Eclipse E 600.

Results

The best tolerant cultivar to abiotic stresses is cultivar Astella, the less tolerant is Ilona. The significant anatomical changes of the cells construction after influence of abiotic stresses were obtained (fig.2), above all in the area of the pericarp, where more differently shaped cells of epidermis are formed, having a thinner wall than control grains (fig. 1). Another changes are observed in the aleuronic layer. These changes are connected with the change of chemical composition of grains (content of proteins, sacharides and lipids) and with the content of rich-in-energy matter accumulated in the grain.

There was found a considerably negative influence of stress factors combination upon the amount of net energy of representative cultivars of winter wheat, where this amount was decreased for 6.24 %, compared to the control variant. Besides the unsuitable outer environment conditions, the amount of energy accumulated into grain was influenced by genotype of the cultivar, where the sensitivity or tolerance towards unsuitable environmental conditions shows up. For example Astella cultivar of the control variant had an average combustion heat value 15.97 $kJ.g^{-1}$, then at the stressed variant occurred the decrease of net energy to 13.04 $kJ.g^{-1}$. In cultivar Zdar we have found at the control variant content of rich in energy matters 14.30 $kJ.g^{-1}$, and at stressed plants it was 13.86 $kJ.g^{-1}$. It can be stated, that abiotic stresses influence not only the basical metabolic processes, but also the final quality of grains. The anatomical structure of grains of the cultural crops and the content of rich-in-energy matter could help as one of the determining characters of the seed - stock quality and of plants adaptation to unsuitable conditions of outer environment.

Fig. 1: Control grains

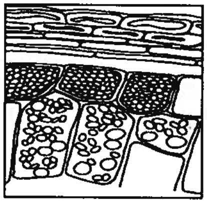
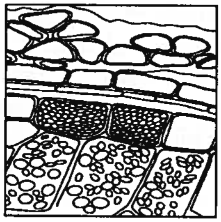


Fig. 2: Grains of stresses



Discussion

Our results are very similar to results of Hansen and Diepenbrock (1994) and to our own results (Hnilitka et al., 2000) with plants stressed by drought, low pH and high temperature. Particular cultivars react differently to unsuitable conditions of environment, i.e. stress tolerance is under genetic control as it is shown in the works of Golley (1961), Hansen and Diepenbrock (1994), Hnililka et al. (2000).

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ASSESSMENT OF PHYSIOLOGICAL VIGOUR OF NEW POLISH POTATO CULTIVARS

Rykaczewska K.

Plant Breeding and Acclimatization Institute, Branch in Jadwisin, 05-140 Serock, POLAND

Introduction

The fundamental element of potato production technology is a choice of suitable cultivar and an adaptation of the physiological age of seed tubers to the rate of their physiological ageing. The results of earlier experiments show a different reaction of cultivars to the identical conditions of environment (Reust et al., 2001; Rykaczewska, 1993). Accordingly, the way of storage and pre-sprouting of seeds ought to be adapted to cultivar. The aim of the experiment was to determine the influence of physiological age of mother tubers of new Polish cultivars on their ability to yielding and the elaboration of a method of seed tubers vigour assessment.

Methods

The field experiment was done in three year cycles during the period 1995-1999, in Jadwisin (Central Poland). The tested potato cultivars were as following: Albina, Bila, Sumak – early; Baszta, Glada, Ikar, Irga, Oda – middle early; Vistula – middle late and Dunajec, Hinga – late. The physiological age of tubers was regulated in a way of pre-sprouting. Five treatments were obtained and among them two extreme: the treatment A with tubers physiologically youngest, stored from autumn to planting at the temperature about 2-3°C and the treatment E with tubers physiologically oldest, stored at the same time at the temperature about 18°C, in darkness. The treatment B, C and D represented average physiological age: pre-sprouting in light by 4, 10 weeks and from autumn. The date of planting was always the same for all treatments, cultivars and years – about 20 April. During growing period the influence of physiological age of mother tubers on plant structure and canopy architecture were determined, and also the yield and tubers size in three dates of harvest. Finally the method of assessment of physiological vigour of several potato cultivars was elaborated.

Results

The significant influence of physiological age of mother tubers on all tested elements of plant structure was confirmed. Earlier development of tubers in over-soil environment caused the acceleration of plant phenological stages, particularly at early cultivars Albina and middle early cultivars Irga and Oda. At the end of May and beginning of June the phases of emergence and blooming were observed at the same time, at the same cultivar. The range of modification of other elements of canopy structure are shown in Figure 1.

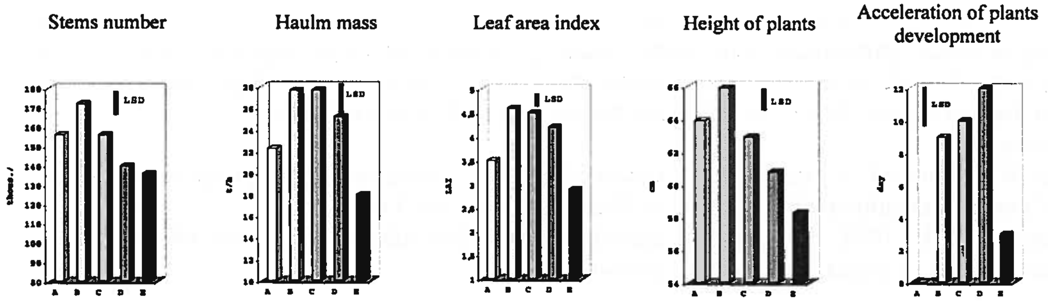

Fig. 1. The influence of mother tubers physiological age on some elements of potato canopy architecture – mean value for 11 tested cultivars.

The physiological age of seeds significantly influenced the yield in three dates of harvest – at 60, 75 days after planting and at maturity. The strong negative effect of darkness on tuber vigour in relation to light under the same temperature conditions was confirmed (fig.2).

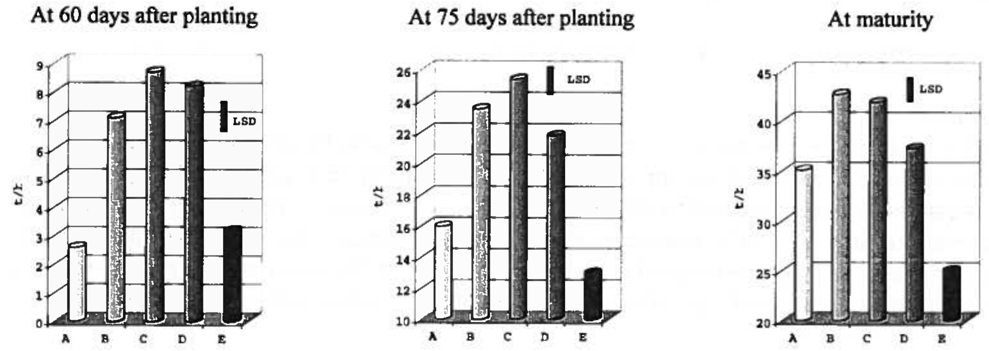

Fig. 2. The influence of physiological age of mother tubers on the yield at 60 and 75 days after planting and at maturity – mean values for 11 tested cultivars.

The rate of physiological ageing of several cultivars was estimated as a decreasing of the yield in treatment D or E in relation to treatment B and expressed in per cent and in 1-9 degree scale (fig. 3).

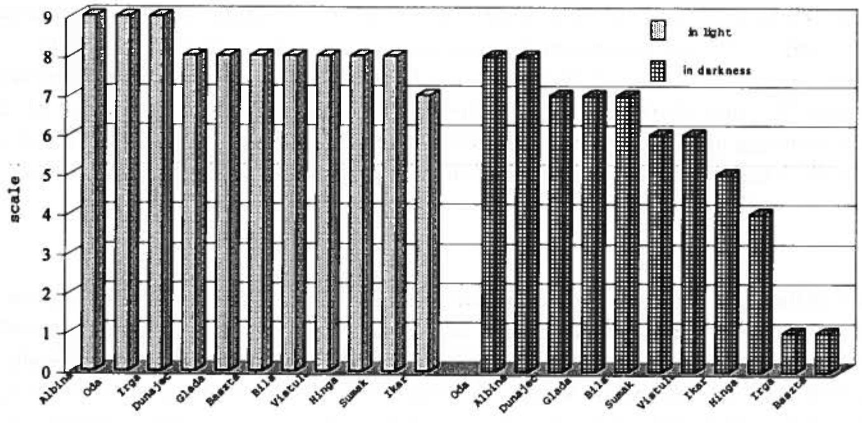

Fig. 3. Ordering of tested potato cultivars according to the rate of physiological ageing in light and in darkness.

Conclusions

The majority the cultivars tested in this experiment are characterised by slow physiological ageing of tubers, particularly under light conditions. It indicates a high degree of their tolerance to a way of seeds treatment in the period from autumn to planting, a high degree of their physiological vigour. This is an important success of Polish potato breeding.

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SPATIAL AND TEMPORAL EXPRESSION BETWEEN 14-3-3 ISOFORMS IN GERMINATING BARLEY EMBRYOS

Christa Testerink and Mei Wang
Department of Applied Plant Sciences, Center for Phytotechnology UL/TNO, Wassenaarseweg 64, 2333 AL Leiden, The Netherlands, e-mail: Wang@voeding.tno.nl

Introduction

We were interested in the role of 14-3-3 proteins in seed germination, as there are good indications that 14-3-3 proteins are involved in the signal transduction pathways that play a role in the germination process. First, FC, which binds to the 14-3-3-H^+-ATPase complex, can break seed dormancy and is a potent stimulator of seed germination (Marrè, 1979). In barley grains, it can promote germination without altering the endogenous level of the germination inhibitor abscisic acid (ABA) (Wang et al., 1998). ABA is an important factor in the induction and maintenance of dormancy during seed development (Wang et al., 1995; Bewley, 1997). Second, the transcriptional complexes associated with the G-box element in the promoters of several ABA-regulated genes (*osmotin, Adh, and Em*) contain 14-3-3 proteins (Liu et al., 1995; Lu et al., 1992; Schultz et al., 1998). The *Em*-promoter-associated GF14 (14-3-3) was shown to bind VP1, which is one of the effectors of ABA-induced maintenance of dormancy. This apparent involvement of 14-3-3 proteins in binding of FC and in ABA signal transduction prompted us to study the role of 14-3-3 in the germination of barley grains.To study the roles of these different barley 14-3-3 isoforms in the physiological process of germination, it was necessary to first establish which of the isoforms are expressed in the embryo. Using specific probes and antibodies that each detects one of the barley 14-3-3A, B, or C isoforms, we demonstrated the presence of all three isoforms in barley embryos. In addition, we investigated the spatial expression of the three different 14-3-3 isoforms in the barley embryo. These results reinforce the idea that 14-3-3 isoforms are differentially regulated, and provide a starting point for elucidating the role of the different 14-3-3 isoforms in the germination process.

Methods

RNA Isolation and Northern Analysis. Embryos were dissected from the grain and ground in liquid nitrogen. Total RNA was isolated (Wang et al., 1998), separated on a glyoxal/DMSO/1% (w/v) agarose gel and blotted to nylon membranes (Genescreen, DuPont). Blots were hybridized to the 14-3-3A, B and C probes as described by Testerink et al., 1999. Production of Isoform-Specific Anti-14-3-3Antibodies, Western Analysis and In situ Immunolocalization Studies Antibodies production and analytic methods used are described by Testerink et al., 1999.

Results

We studied the expression of 14-3-3 mRNA and protein in barley (*Hordeum distichum* L.) embryos during germination. With the use of specific cDNA probes and antibodies, we could detect individual expression of three 14-3-3 isoforms, 14-3-3A, 14-3-3B, and 14-3-3 C. Each homologue was found to be expressed in barley embryos. Whereas protein levels of all three isoforms were constant during germination, mRNA expression was found to be induced upon imbibition of the grains. The induction of *14-3-3A* gene expression during germination was different from that of *14-3-3B* and *C. In situ* immunolocalization analysis showed similar spatial expression for 14-3-3A and B, while 14-3-3C expression was markedly different. Whereas 14-3-3A and B were expressed throughout the embryo, 14-3-3C expression was tissue specific, with the strongest expression observed in the scutellum and the L2 layer of the shoot apical meristem. These results show that 14-3-3 homologues are differently regulated in barley embryos, and provide a first step in acquiring more knowledge about the role of 14-3-3 proteins in the germination process.

Conclusion:
The expression of 14-3-3 isoforms in barley embryos is differentially regulated, which might reflect a difference in function of the individual isoforms in the germination process. Since a possible role of 14-3-3 in control of germination is likely to be connected with its binding of FC (Marrè et al., 1979; Wang et al., 1998), it will be interesting to investigate where in the embryo FC is bound.

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NON-INVASIVE AUTOMATED OXYGEN CONSUMPTION MEASUREMENT ON SINGLE SEEDS AS A NOVEL TOOL IN SEED RESEARCH

Bert Van Duijn, Wessel Holtman, Mieke van Zeijl, Hans König

TNO Department of Applied Plant Sciences, Wassenaarseweg 64, 2333 AL Leiden, The Netherlands.
TNO Department of Sensor Technology, TNO Voeding, Zeist, The Netherlands.
e-mail: b.vanduijn@voeding.tno.nl

Introduction

Most of conventional agriculture is engaged in growing plants from seeds. Plant breeding programs are dependent on the germination of the seeds obtained. Therefore the slow or no germination of seeds has a major impact on food production and research. The research on dormancy or environmental factors influencing the germination needs a simple method to monitor the germination process. In addition, the value of seeds can be largely increased by seed treatments such as priming. The control of priming needs very accurate determination of the development of the seeds. The metabolism of seeds is an important indicator of the status of the seed during the germination process. Hence, a non-invasive automated method to measure oxygen consumption on single seeds will be a valuable tool in seed sciences.

Method

One or more seeds are brought into a small container, along with some water to induce the germination process. The container is a hermetically closed, confined space. Due to the germination, at a certain point in time the seed(s) will start to consume oxygen. Because the container is hermetically closed, the oxygen concentration will drop from the moment the germination starts. This can be monitored with a special oxygen sensitive coating on the inside of an optically transparent part of the confined space. The main advantage of optical oxygen determination is the fact that the coating itself does not consume any oxygen. In this way the seed metabolism can be monitored accurately.
Figure 1 shows the set-up in an automated system allowing automated seed metabolism measurements on 96 single seeds simultaneously.

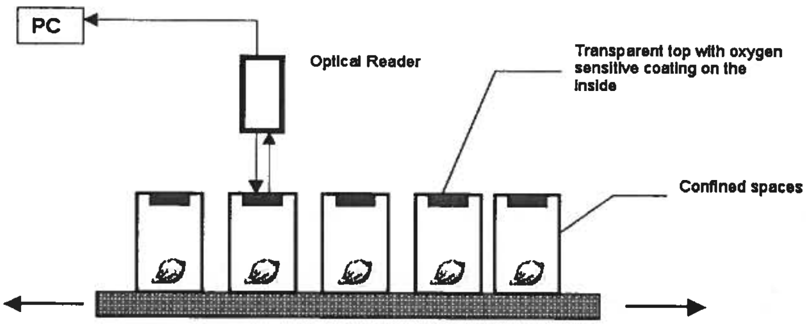

Figure 1 *Optical reader with seeds in small containers as a confined space*

Results

We tested the metabolism of different types of seeds after imbibition. As an example figure 2 shows the oxygen consumption of a single lettuce seed and a single barley grain. The linear extrapolation of the oxygen levels shows the point where the metabolism of the imbibed seeds starts.

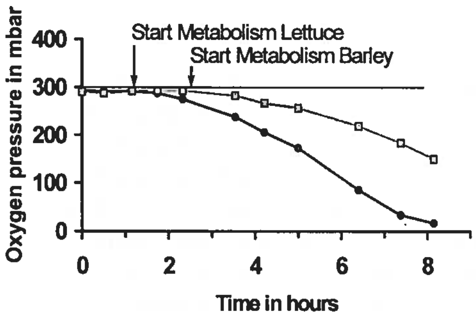

Figure 2: oxygen levels in closed containers with an imbibed lettuce seed and an imbibed barley grain.

Conclusions

With this method it is possible to examine the effect of all kind of environmental influences on the germination process. It also gives an opportunity to influence the germination process in an early stage. This method is a simple and powerful tool in germination research and in the priming of seeds.

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Special session on precision agriculture

SOIL MOISTURE VARIATION IN SPACE AND TIME IN MAIZE IRRIGATED FIELDS

Acutis M., Fagnano M., Zarone S., Quaglietta Chiarandà F.

DIAAT, via Università 100, Portici (Na), Italy

Introduction

Variability in space and time of soil moisture highly affect uniformity of yield in the field, leaching and solute transport. Irrigation is a key factor in regulating soil moisture for maize in Mediterranean environments and a correct management must avoid excessive drainage and insufficient water supply. Besides, effective modelling of transport at field scale requires the definition of the spatial-temporal continuum of soil water related variables (Feddes et al., 1993; Wendroth et al., 1999) and the knowledge of the correlation length is needed to develop appropriate sampling strategies.

Materials and methods

This study was carried out in 2 clay-loam soils, in 2 years. (figure 1).

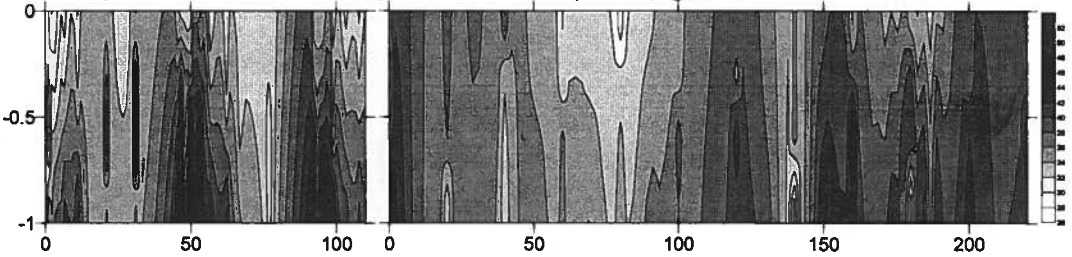

Figure 1 Contours of clay content (% mass) in 1999 (left) and 2000 (right)

The soil water content (SWC) was determined using the gravimetric method for the 0-0.15 m layer (for each sampling point, the bulk density was determined to convert SWC per unit mass to volumetric SWC), and using a neutron probe for readings at 0.15-.045, 0.45-0.75 and 0.75-1.05 m of depth. In 1999 measurements were performed along a 110 m transect in 29 places, using a nested design (the shortest distance between 2 points was 1 meter, the longest 10 m); in 2000 a transect of 220 m was sampled, using 2 m and 20 m as minimum and maximum distance between two sampling points, respectively. The irrigation was scheduled to maintain the SWC between the 100% and the 60% of available water and applied with a traveling big gun system. To identify the spatial structure we used a geostatistical approach, based on spherical function for variograms.

Results

Soil water content in the 2 years was similar and lower in the first soil layer, as expected because the irrigation scheduling. In 1999, rainfalls generated percolation and not an increase in SWC. (figure 2). All variograms were well defined, with few exception, and gave similar geostatistical parameters with different choices of lag distance. Nugget/sill ratios were only 0.13 on the average, indicating the presence of a strong spatial structure. In 1999 ranges, for the 0.15-0.30 m layer was close to the maximum allowed lag distance and therefore, in 2000 we sampled a longer transect. Range was shorter for the surface layer, with an average of 31 m and 69 m respectively in 1999 and 2000; in the 0.15-0.45 layer the average range was respectively 53 and 170 m in the two years. No relation between range, sill and average SWC was found. Joint analysis of range, sill and nugget indicates that there is not a clear effect of irrigation on the spatial structure, because after an irrigation in some cases there is an increment of variability of soil moisture, and

in other a reduction, indicating that probably the temporal changes of range, sill and nugget are due to irregularity typical to the irrigation system used.
In any case, no dry or wet spots are generated. In this irrigated maize field, water content variability was much lower than that reported by Famiglietti et al. (1998) in natural conditions.

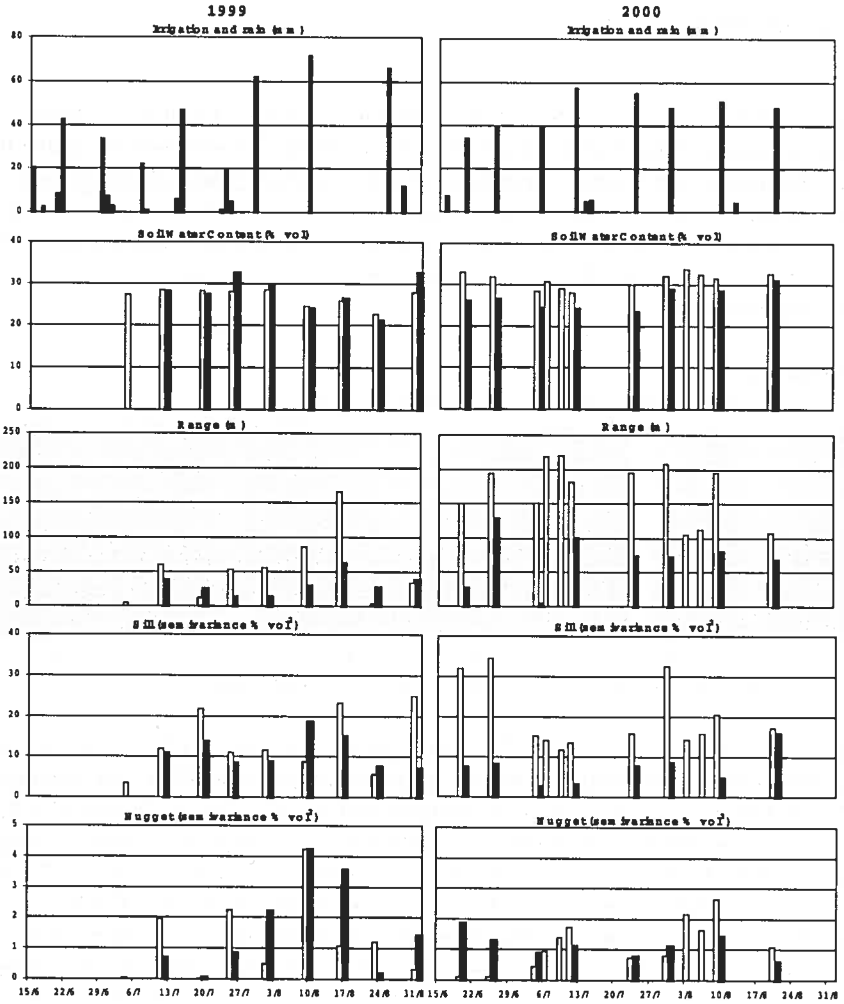

Figure 2. Water supply, soil water content and geostatistical indices in 2 years. In black data for the 0-0.15 m layer, in white for the 0.15-0.45 m layer

Conclusion

The spatial structures indicates a correlation distance between 10 and 200 m; ranges are greater for the sub-surface horizon. Irrigation scheduling seems to be effective in creating and maintaining uniform condition of soil moisture even in large size fields.

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SPATIAL STABILITY OF WILD OAT POPULATIONS UNDER ANNUAL USE OF LOW RATES OF HERBICIDES

Barroso, J., Ruiz, D., Fernandez-Quintanilla, C.

Centro de Ciencias Medioambientales, CSIC, Serrano 115 B, 28006 Madrid (Spain)

Introduction

Weeds are generally aggregated in patches within a field. This fact is important from the point of view of weed management. Various studies have shown that herbicide use could be substantially reduced by spraying only those patches with densities above a given threshold (Goudy et al., 2001) or by adjusting herbicide rate to the actual densities of weeds in each area of the field (Heisel et al., 1999). The economic feasibility of using weed maps to plan herbicide treatments is heavily conditioned by patch stability. If weed patches are consistent in density and location over years or have slow dynamics, maps from one year could be used to direct sampling and herbicide application plans in subsequent years. However, if infestation patches are not stable, maps have to be built year after year, requiring a big sampling effort and overburdening the decision-making process. The present study was designed to investigate the long-term effects of using annual treatments with imazametabenz at half rates on stability of patches of wild oats (*Avena sterilis* ssp. *ludoviciana*) under continuos cropping of winter barley.

Methods

A field experiment was conducted from 1999 to 2002 at La Poveda Research Station, Arganda del Rey, Madrid, Spain. The field was 0.5 ha in size and was sampled using a 10-m grid (50 samples per field; 100 samples ha^{-1}). The cropping system was based on a winter barley monoculture with minimum tillage practices. Imazamethabenz (Assert®) was applied at 0.6 L ha^{-1} (recommended rate) in 1999 and at 0.3 L ha^{-1} all the other years. All the treatments were conducted when barley was in the early tillering stage. Sampling was performed two days prior to herbicide application. At each grid point, a 0.1 m^2 quadrat frame was used to count the seedlings emerged. Data were converted in seedlings m^{-2} for analysis, using kriging to generate spatial distribution maps of *A. ludoviciana* seedlings in each year of observation. The contour maps for weed density estimates obtained with kriging were made with Surfer v 6.0 (Golden-Software Inc.). In order to determine the persistence (consistency in location) of *A. ludoviciana* patches, we used the statistical test proposed by Syrjala (1996) to detect whether the spatial distribution of the population has changed over time. This test is specifically designed to be insensitive to differences in the total abundances in the study area but sensitive to differences in the distributions given the respective sizes of the two populations. In order to study the stability of the population, individual data from each grid point throughout all the experimental period were log transformed and analysed by linear regression techniques. Three data sets were considered independently: those from the high, medium and low density patches.

Results

The initial distribution of *A. ludoviciana* was moderately heterogeneous, with an important patch located in the east-west diagonal of the field and an area relatively free of this weed (seedling densities < 10 plants m^{-2}) in the southern corner. (Fig. 1). Due to the high weed densities in most of the field, imazamethabenz was sprayed at the recommended rate (0.6 L ha^{-1}) under favourable environmental conditions, resulting in an excellent control (>95%) of the weed. In the second season, seedling densities were substantially reduced in comparison with those from the previous year. However, patch location remained very similar (Fig. 1). Considering that a high proportion of the field was with moderate infestation levels, imazamethabenz was applied at half the recommended rate (0.3 L ha^{-1}). Apparent control of the weed was also excellent. In 2001 weed population levels ranged from 10 to 100 plants m^{-2} in all the east-west diagonal and were close to zero in the remaining areas. After herbicide application (at half rate), a significant rainfall occurred within 24 hours of herbicide application. This factor may have caused some herbicide being washed off. Seedling populations the following year remained quite stable, with even some population increase in the west corner of the field (Fig. 1).

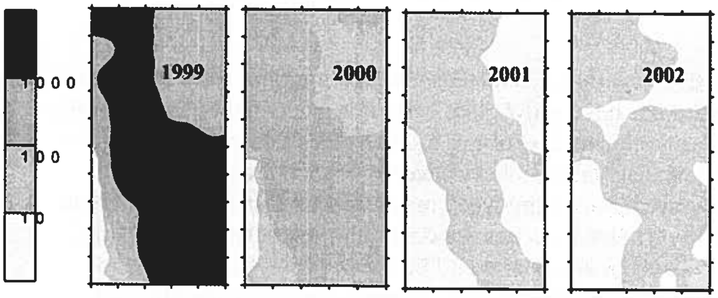

Fig. 1. Spatial maps of *A. ludoviciana* from 1999 to 2002. Kriged estimates from 50 sampling units

Using the procedure devised by Syrjala (1996), we can conclude (with a significance level of 1%) that the location of the patches was stable throughout the four-year period (Table 2). When we compared the stability of *A. ludoviciana* populations in areas of the field with different initial densities, we observed a logarithmic decrease in all cases (Fig. 2). However, the rates of population reduction (the slopes of the lines) seem to be higher when initial populations were very high or high than when the populations were lower. This indicates than in the center of the patch the population declined annually about ten times whereas in the border areas this reduction was less pronounced.

Table 2. Syrjala´s test statistic (Ψ) and its level of significance (P) for the differences in the spatial distributions of populations of *Avena ludoviciana* in various years

	2000		2001		2002	
	Ψ	P	Ψ	P	Ψ	P
1999	0.082	0.175	0.426	0.012	0.414	0.085
2000	-	-	0.202	0.138	0.313	0.174
2001			-		0.274	0.535

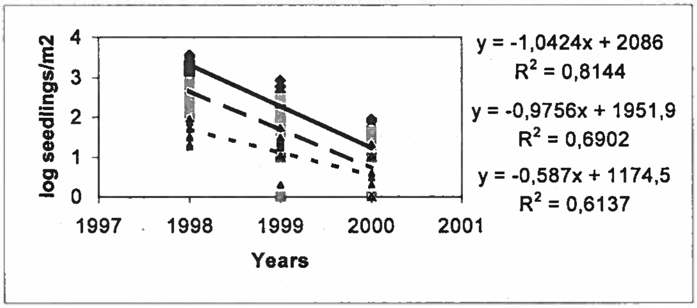

Fig. 2. Regression lines of the reduction of the population of *A. ludoviciana* from 1999 to 2002 in three areas of the field:
—— patch center
– – medium density
······ patch border

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ESTIMATION OF SOIL PROPERTIES WITH NEAR INFRA-RED SPECTROSCOPY: APPLICATION AT FARM SCALE FOR PRECISION FARMING

L. Bechini, P. Marino Gallina, G. Cabassi

Department of Crop Science, Section of Agronomy, University of Milano, Via Celoria 2, 20133 Milano, Italy

Introduction

NIR (Near Infra-Red) spectroscopy is a low-cost, fast and non-destructive analytical technology, currently used for agricultural products. Approaches with NIR technology to analyse soils were presented in the early nineties and are now increasingly used with improved estimation performances (e.g. Reeves et al., 1999). At the same time, technologies were developed for managing spatially variable yield-determining factors (precision farming). However, a limiting factor in the development of site-specific fertilisation is the high cost of soil analyses. The aim of this work was to explore advantages of site-specific fertilisation based on NIR analyses compared to conventional approach.

Methods

Soil samples were collected, air-dried and sieved at 2 mm in 1999 over the entire area (55 ha) of the experimental farm "A. Menozzi" of the University of Milano (Landriano, Pavia, Italy). The sampling was carried out on a regular grid (50 m × 50 m). The samples were analysed for organic carbon, total nitrogen and available phosphorous by using official reference methods (RM). Analyses were replicated two or more times until coefficient of variation was less than 5%. On the same samples sieved at 1 mm, NIR spectra were collected with a FOSS NIRSystem 6500 in the interval 1100-2500 nm at the resolution of 2 nm. Both multiplicative scattering correction and second derivative (SG 2,17) were performed on the spectra. C, N and P were estimated through a PLS regression with 100 samples for calibration/cross-validation and 133 samples for independent validation. The optimal number of loading factors for each variable was determined by leave-one-out cross-validation. We used Matlab 6.0 (Matworks, Inc.) with PLS_Toolbox 2.1 (Eigenvector Research, Inc.). A software and a database were designed and implemented to calculate the amounts of cattle slurry to be applied at each single field (or at each grid node) by comparing three different approaches:

1. ordinary field management based on one average datum per field (ORD);
2. site-specific management based on RM results at each grid node (REF);
3. site-specific management based on NIR cross-validated and validated results at each grid node (NIR).

The third approach is a practical possibility of precision farming, while the second is merely a research step due to its high costs. The software determines the amount of slurry-N to be applied by considering a simplified N budget (inputs: mineralization of soil organic N, residues and slurry; output: crop N uptake). N from mineral fertilisers ("mineral N") can be applied to integrate slurry-N. Slurry-P applied is derived by considering slurry N:P ratio. No slurry was applied when available P soil content was above 115 ppm, full dose (based on N budget) was applied below 85 ppm and intermediate amounts between.

Results

Statistics of RM and NIR results are reported in Table 1. NIR results for N and C are comparable with RM for agronomic purposes (standard error less than 10% of the population average). The performance of the method for P is semi-quantitative, but acceptable for discriminating samples in few classes of P availability.

Table 1 - Results of conventional analyses and NIR predictions

Variable	Reference methods			NIR-PLS			
	Mean	Min	Max	Cross-validation (n=100)		Independent validation (n=133)	
				R^2	SECV	R^2	SEP
C (g/100 g)	1.130	0.3	2.410	0.939	0.079	0.89	0.088
N (g/kg)	1.219	0.5	2.220	0.908	0.088	0.89	0.079
P (ppm)	74	10	170	0.779	16	0.770	15

SECV and SEP are standard errors for cross-validation and independent validation, respectively.

Results of fertilisation plans are shown in Table 2. Total amount of N and P applied is very similar for REF and NIR. Traditional approach (ORD) generates greater application of slurry and lower application of mineral fertilisers because field averages of available soil P are always lower than the threshold of 115 ppm.

Table 2 - N and P applied with slurry and mineral fertilisers for the entire farm

Approaches	Slurry N (kg N)	Mineral N (kg N)	Slurry P (kg P_2O_5)	Mineral P (kg P_2O_5)
ORD	7557	2776	4580	0
REF	6773	3442	4105	0
NIR	6877	3317	4168	5

In Figures 1 and 2 the spatial variability of the amount of slurry-N applied is represented for each field: the differences between REF and NIR approaches are not relevant.

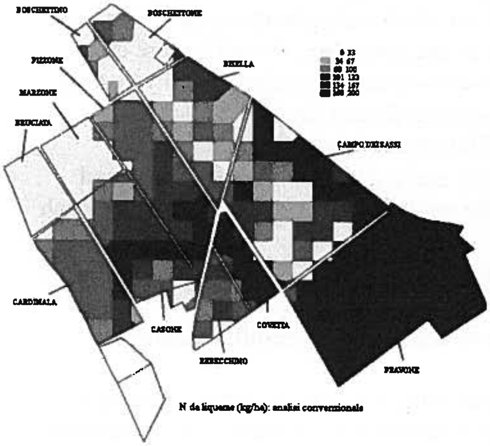

Figure 1 – Slurry-N applied, kg N/ha (REF)

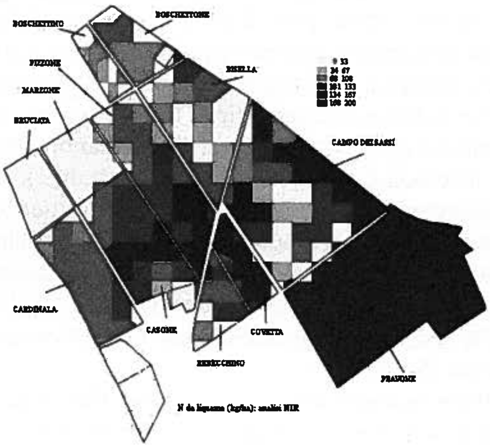

Figure 2 – Slurry-N applied, kg N/ha (NIR)

Conclusions

NIR might be a reliable analytical technique for N management in precision farming, provided that robustness of calibrations can be maintained through a sufficient number of years to reach economic competitiveness.

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CROP MODELS CAN EXPLAIN SPATIAL VARIABILITY OF CORN YIELD

Ricardo Braga [a,b] and James W. Jones [a]

[a] Agric. Biol. Eng. Dpt., Univ. of Florida, Gainesville, Florida, USA
[b] Current address: Escola Sup. Agrária de Elvas, Apartado 254, 7351 Elvas, Portugal

Introduction

Predicting within field spatial variability of grain yield should be considered as a major objective in Site-Specific Management (SSM). Having a tool that relates resource availability to yield allows for testing of management prescriptions and for correct assessment of agronomic and economic outcomes (Sudduth et al., 1996).
Most of the algorithms used to estimate yield from environmental factors can be divided into empirical and process-based tools. The basic difference between the two approaches is that the process-based algorithms attempt to predict final grain yield by describing the most important physical/chemical/biological processes responsible for yield formation. An example of this approach is a crop simulation model.

Methods

A field experiment was carried out for corn (Zea mays L.) in a 3.6 ha farm field located in Michigan, USA (42° 50'N, 83° 58'W) during the crop seasons of 1997 and 1998. The field experiment had no imposed levels of any kind of inputs. The experiment consisted of observing variables of interest in a uniformly managed field. The farmer managed the field exactly the same as he has been doing for over 10 years. The field was chosen from among others for its characteristic spatial variability of final grain yield according to the farmer. The farmer planted the crop on April 29 (DOY 119) in 1997 and on May 11 (DOY 131) in 1998. The sites for observing soil and crop variables (total of 43) were spatially distributed in a grid of approximately 30.4-m (100-ft). Effective soil depth was determined by the depth of an existing hard clay layer thorough direct observation using a probe. Soil particle size analysis was carried out for each 15 cm increment layer up to the constraining clay layer. All existing combinations of point values of sand and clay classified the textures as loam, sandy-loam and silt-loam types. Plant weight and leaf area index were determined at anthesis (DOY 211 in 1997 and 207 in 1998) for three individual plants in each of the 43 sites. The limited size of the sample was due to farmer constraints. The area of the leaves of each individual plant was measured using a LICOR leaf area meter instrument. Grain yield and its components were determined at maturity (DOY 289 in 1997 and 288 in 1998) on 3 x 2 m^2 in all 43 sites. The crop simulation model used for this study was CERES-Maize V 3.5 (Hoogenboom et al., 1994).
The values of LL, DUL, SAT and SRGF for each layer up to effective soil depth and SSKS of the deepest layer were estimated using an estimation procedure described in (Braga, 2000) using the observed time series of soil-water content as the objective function variable.

Results

The average RMSEP of grain yield for both years was 501 kg/ha, which is an exceptionally low value. The proportions of yield variability explained by the model were 88% and 76% for 1997 and 1998, respectively. The better performance of the model in 1997 compared to 1998 makes sense if we consider that 1997 was a dry year. The remaining variability was not explained by the model because either the model is not perfect or we did not take all the spatially variable inputs into account.

Although the RMSEP values for grain yield were quite low, in 1997 the model showed tendency to under estimate higher yields (>10000 kg/ha) and in 1998 the model showed a tendency to over estimate yield for the whole range of observed values.

The model performed very well in predicting yield components and growth variables as well. The model only performed poorly in predicting LAI at anthesis for 1998. There was a clear lack of sensitivity of the model because lower values were over estimated and higher values under estimated. Nevertheless, this error did not affect the over all performance of the model because all observed LAI were above 3.5, which intercepts most of the incoming solar radiation.

The fact that the model was able to predict grain yield as well as yield components and growth in a very satisfactorily way increases the confidence in its performance. A model that is able to predict yield but does a poor job in all other variables may have questionable validity. Since a crop simulation model is a mechanistic tool, all intermediate variables should be correctly predicted. Only in this case can we be sure that the model works appropriately.

The maximum possible error (RMSEP) had similar magnitude in both years and was below 1000 kg/ha. The model performed slightly better in 1998 than in 1997 when we consider the prediction of spatial yield pattern. The reason for this bias was related to the tendency for underestimation of higher yields (> 10000 kg/ha) which occurred in the southern part of the field. As for the variability among sites, the model predicted the spatial pattern of grain yield in a very satisfactory way.

Conclusions

CERES-Maize V3.5 accurately predicted the spatial variability of corn growth and yield for two years of independent data when accurate inputs were provided for soil properties and plant population. The average root mean square error of prediction of the model was 501 kg/ha. The model accounted for more than 80% of total observed yield variability. The model also performed very well in predicting most of the yield components and growth variables as well.

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MODELLING BLACK-GRASS (*ALOPECURUS MYOSUROIDES* Huds.) GERMINATION AND EMERGENCE, DEPENDING ON SEED CHARACTERISTICS, SEED MOVEMENTS AND SOIL CLIMATE

N. Colbach[1], C. Dürr[2], B. Chauvel[1] and J.M. Meynard[3]

1 Unité de Malherbologie et Agronomie, INRA, BP 86510, 21065 Dijon Cedex (France)
2 Unité d'Agronomie, INRA, rue Fernand Christ, 02007 Laon Cedex (France)
3 UMR d'Agronomie, INRA INA P-G, BP 01, 78850 Thiverval-Grignon (France)

Introduction

Black-grass (*Alopecurus myosuroides* Huds.) is a common annual grass-weed in autumn-sown crops of Western Europe. It has become increasingly resistant to herbicides, but can be controlled by adapting cultural practices. A model describing the effect of cropping systems on seedling emergence would greatly improve this control.

Input and output variables

The input variables are (a) the initial seed bank, *i.e.* number of black-grass seeds per m² in each of the 30 one-cm-thick layers and their characteristics (seed production conditions, weight, age); (b) soil mean temperature and water potential for each layer at daily intervals, either measured or calculated by other models; (c) crop management variables, *i.e.* tillage dates, modes (mouldboard plough, skim-coulter, chisel, superficial tillage) and characteristics (depth, width) as well as sowing and harvest dates. The output variables are the number per m² of viable un-germinated and germinated seeds in each layer of the seed bank and of emerged seedlings, for each day from seed maturity (July 1) to next harvest date.

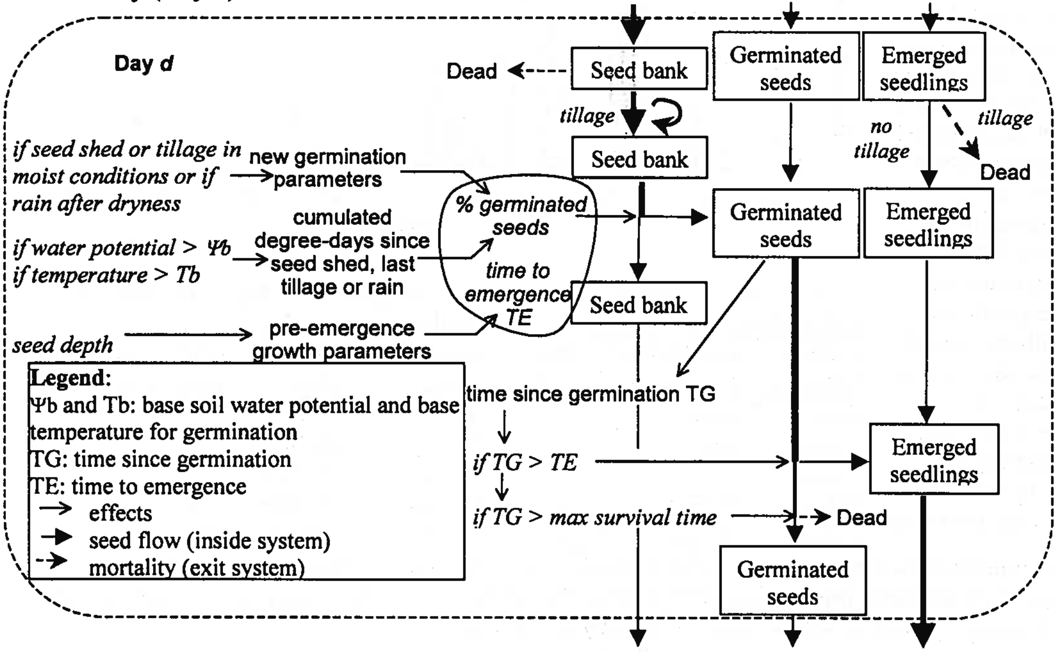

Figure 1. Organisation of the germination and emergence model for black-grass

Model structure

Each day, a series of events are repeated (Fig. 1) and modelled according to previous work (Lonchamp *et al.*, 1984; Colbach *et al.*, 2000; Roger-Estrade *et al.*, 2001; Colbach *et al.*, 2002a, 2002b; Colbach and Dürr, 2002). Seeds die because of age. If the soil is tilled, un-germinated seeds are moved among layers; germinated seeds and emerged seedlings are destroyed. Seed shed or tillage in moist conditions and rain on dry soil set off germination and germination proportion and rate are calculated as a function of seed characteristics. Conditions unfavourable to dormancy loss such as darkness (vs. prior exposition to light in moist conditions) or continuous moisture (vs. alternating moist/dry periods), or those inducing secondary dormancy such as prolonged moist darkness or long dryness after initial moisture decrease both germination proportion and rate. If soil moisture and temperature are above base values determined for black-grass germination (–1.5MPa and 0°C, respectively), the proportion of seeds germinating during the day is calculated using the germination parameters and the hydro-thermal time (°C MPa days) cumulated since germination set-off. It is then multiplied by the number of seeds in the seed bank to obtain the number of germinated seeds, which are deduced from the seed bank. For these seeds, the time TE necessary for the shoot to reach soil surface is calculated, depending on seed characteristics and depth. For seeds germinated during the previous days, the hydro-thermal time TG since germination is calculated; if it exceeds the time necessary to reach soil surface, the seeds are added to the number of emerged seedlings; if it exceeds the maximum time a germinated seed can survive before emergence, the seeds are declared dead.

Simulations

Simulated emergence starts later if the soil was tilled vs. left undisturbed (Fig. 2), because buried seeds germinate in darkness (and therefore later and more slowly) and their shoots take longer to reach soil surface. Buried seeds emerge continuously over time because the deeper layers do not dry during autumn. Most seedlings emerge before late October. If the sowing could be delayed until then, most plants would already have emerge and could be destroyed at sowing, thus leaving less plants to emergence in the crop (see also Table). Stubble breaking and superficial tillage also decrease black-grass density in the crop because they stimulate pre-sowing germination. Ploughing, especially if deep and combined with a skim-coulter, buries seeds too deep for successful emergence.

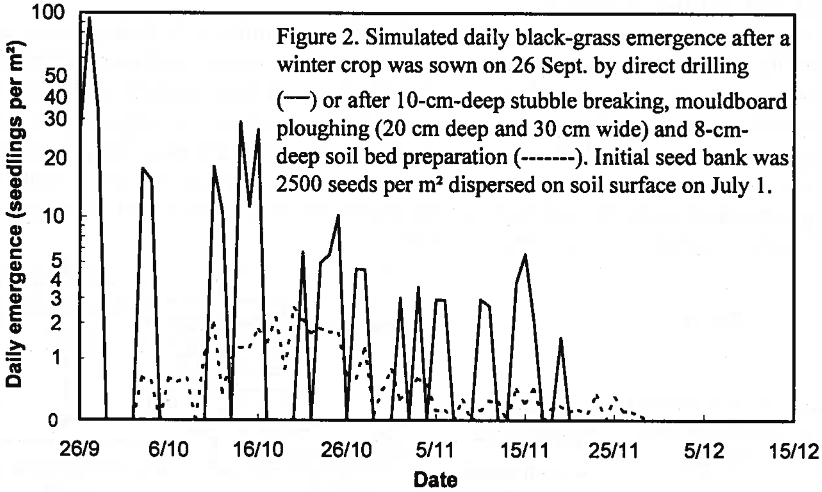

Figure 2. Simulated daily black-grass emergence after a winter crop was sown on 26 Sept. by direct drilling (—) or after 10-cm-deep stubble breaking, mouldboard ploughing (20 cm deep and 30 cm wide) and 8-cm-deep soil bed preparation (-------). Initial seed bank was 2500 seeds per m² dispersed on soil surface on July 1.

Table. Effect of tillage on black-grass emergence in a field with seeds on soil surface, from sowing to 31 December

stubble breaking	mouldboard ploughing	skim-coulter	superficial tillage	sowing date	relative black-grass density
none	none		none	26 Sept.	1.00
7 Aug.	none		26 Sept.	26 Sept.	0.23
7 Aug.	16 Sept.	no	26 Sept.	26 Sept.	0.12
7 Aug.	16 Sept.	yes	26 Sept.	26 Sept.	0.08
7 Aug.	16 Sept.	yes	21 Oct.	21 Oct.	0.06

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BLACKGRASS SPATIAL PATTERNS : INFLUENCE OF THE CULTURAL PRACTICES

F. Dessaint, B. Chauvel, M. Sester

INRA, Unité de Malherbologie et Agronomie, BP 86510, F-21065 Dijon Cedex(France)

Introduction

Studies have shown that in most agricultural sites, weeds are not uniformly or randomly distributed, but their distribution across the field present spatial dependence. In such a situation, sites with high weed densities are often surrounded by high weed densities, while sites with low densities are bordered by low weed densities. Implications of the non uniformity of weeds have become more evident as weed management models have increased in complexity. Simulations of weed control decisions have shown that assuming a uniform distribution for aggregated populations could be costly over a wide range of weed density. Therefore, quantifying the spatial structure of the weeds is an important aspect of developing management strategies for sustainable use.

This study was realised in a field with a high initial density of a single weed due to herbicide resistance development (Chauvel *et al.*, 2001). In the present paper we describe an initial attempt to understand the role of various weed control systems (crop rotation, tillage) on the spatial structuring of *Alopecurus myosuroides* Huds. plants (blackgrass).

Methods

The experiment was performed over a uniform 2 ha field infested with resistant blackgrass at Lux, Burgundy (47° 29' N, 5° 12' E) during six years (1996-2002). In 1996, the field was divided into 7 permanent plots of 110 m x 20 m and a different cropping systems was used for each plot (see Chauvel *et al.* (2001) for a more detailed description of the experiment). Only three plots are presented in the present paper. Plot CV1 was managed according to local practices which comprised intensive herbicide use, low tillage (chisel and harrow), early sowing, and winter crops (barley / wheat / wheat / rape / wheat / barley). Plot CV3 was managed following a low-input strategy aimed reducing at black-grass infestations and consisted of low tillage, delayed seeding, and low nitrogen fertiliser levels and the same winter crops as CV1. Plot NW3 presented a low-input strategy similar to CV3 but with a new rotation comprising spring crops and winter crops (spring barley / spring pea / winter wheat / spring barley / winter rape / winter wheat). For CV3 and NW3, herbicide spraying was limited to a single application whenever possible. Blackgrass density was assessed by counting seedlings just after emergence in 0.04 m^2 quadrats distributed on a systematic 5 m x 5 m grid consisting of four 23-quadrat rows (92 quadrats per plot). The coordinates, (x_c,y_c), of the centroid of the counts provide a simple measure of central location and are the spatial analogue of an aritmethic mean. Another particular useful statistic which characterises a particular pattern is δ, the distance between the centroid of the counts and the centroid of the sample units (Perry and Klukowski, 1997). Whilst necessarily limited in interpretation, this provides a simple measure of overall displacement of the population from the centre of the sample area towards an edge.

Results

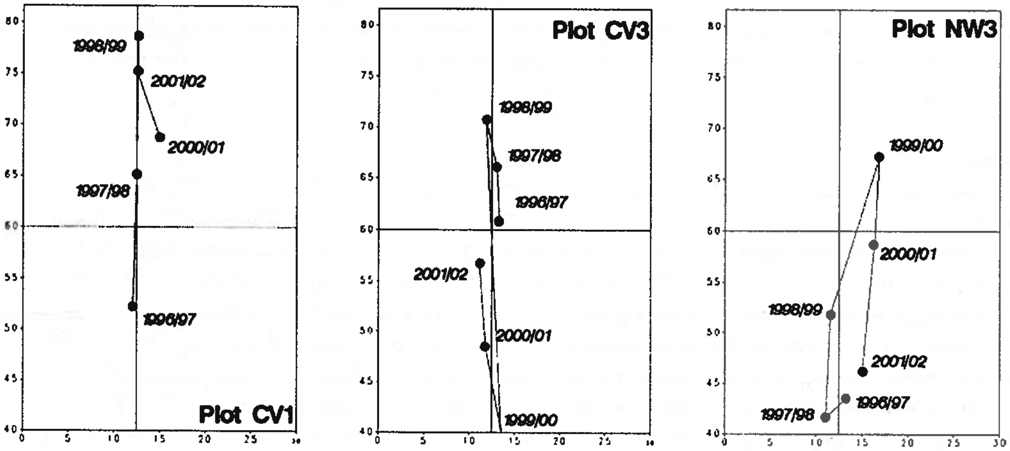
The nature of this study is largely descriptive but it suggests that the spatial pattern and scale of plants variability can differ markedly among different weed control strategies. Globally, in all the plots, the centroid of counts moved to the top (the 3 first years), and then returned to 1996/97 position (Figure 1). This movement is accompanied by a decrease in density with a minimum in 1999/2000. In the conventional cropping system (CV1), blackgrass density decreased during the first four years. Despite the absence of changes in the practices, the plant number increased again during the last 2 years with a high density in 2001/02 due to low herbicide efficiency (Table 1).

Plots	1996/97		1997/98		1998/99		1999/00		2000/01		2001/02	
	d	δ	d	δ	d	δ	d	δ	d	δ	d	δ
CV1	391	7.8	97	5.2	9	18.7	0	6	2	9.1	33	15.2
CV2	239	1.1	46	6.1	29	10.8	1	38.4	5	11.5	73	3.5
NW3	17	16.4	15	18.4	10	8.2	3	8.5	2	3.9	16	14.0

Table 1: Effect of cropping system on blackgrass density (d, plants m^{-2}) and distance δ

In the low-input system (CV3), blackgrass population decreased more slowly due to limited number of herbicide treatments and increased again very fast the last two years with the highest density for the same reasons as (CV1). In the new system (NW3), introduction of spring rotation was more efficient in reducing blackgrass density. Despite lower herbicide pressure, blackgrass density remained lower than in (CV1).

Figure 1: Centroids of counts of blackgrass on each of the 6 sample years for the different plots



Discussion

As blackgrass seeds have a low survival rate in soil (Barralis *et al.*, 1988), the seed bank has no long term effects for this species. Effects of non chemical practices on weed density were already discussed (Chauvel *et al*, 2001) The introduction of spring crops despite the reduction of herbicide treatment allows a better control of blackgrass which is a preferentially winter weed. The reduced tillage carried out on the three plots is know to favour blackgrass in case of poor herbicide efficiency (Dessaint *et al.*, 1993). The centroids movements parallel to the movements of agricultural implements could be mostly explained by the tillage operations. But the observed trend to the top of the plots cannot be only related to tillage the machines moved alternatively "up" and down" the plots.

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DEVELOPMENT AND DELINEATION OF PRODUCTION LEVEL NUTRIENT MANAGEMENT ZONES IN THE GREAT PLAINS REGION OF THE UNITED STATES

Gangloff W.[1], Westfall D.[1], Khosla R.[1], Shaver T.[1], Fleming K.[1], Heermann D.[2]

1 Colorado State University, Department of Soil and Crop Sciences, Fort Collins, CO, (USA) 80523-1170
2 USDA-ARS Water Management Unit, Fort Collins, CO (USA) 80523

Introduction

Farmers have historically observed that yields from different areas of a field are variable. This variability is primarily due to the inherent spatial variability common to most fields. It is only recently that we have developed technology to quantify and record grain yield from all areas of a field using yield monitors and global positioning systems (GPS). In traditional farming systems in the Great Plains region of the United States, producers apply inputs at uniform rates across the field. This results in various areas of the field receiving greater input than necessary while other areas will receive less inputs than necessary. The significance of this is two-fold: 1) extra inputs are costly and do not result in a return, and 2) excess input can have negative environmental impacts such as runoff and leaching.

In 1997 we initiated a precision agriculture study in Colorado which includes four research sites and three crops: corn, onions, and potatoes. The research team is multidisciplinary and includes 22 individuals working in a variety of areas including nutrient, irrigation, weed, disease, insect management, etc. The primary objective for our research group is to identify in-field production level management zones. For our purposes, a production level management zone is defined as a sub-region of a field that expresses a homogenous combination of yield limiting factors.

Materials and Methods

A preliminary study identified management zones using bare soil imagery and farmer experience. Once delineated, each management zone was fertilized with nitrogen (N) according to standard recommendation procedures based on soil test results. Additional treatments included uniform application based on soil test results as well as uniform application plus 20 kg N ha^{-1} and minus 20 kg N ha^{-1}(i.e. above or below standard recommendation). Overall, the management zone approach showed no yield differences when compared with uniform application treatment. In addition, the management zone approach required less fertilizer than the uniform application approach. Based on the results of this study we concluded a management zone approach to N management was feasible.

In the current study, all sites are irrigated (i.e. center pivot or furrow). Fields range in size from 25 to 65 ha. Onions and potatoes are found in some rotations, however, corn is the primary crop for investigative purposes. Four techniques for management zone delineation were selected and are currently being tested. The techniques range from simple to technical with respect to implementation.

Results

Technique I. Management zones are delineated by using only soil apparent electrical conductivity (ECa) as a layer (simplest technique; data collected with a Veris conductivity cart).

Technique II. Management zones are delineated by using topography, and bare soil imagery layers combined with farmer experience.

Technique III. Management zones are delineated by using topography, bare soil imagery, organic matter, texture, and cation exchange capacity (CEC) layers combined with a yield map from the previous year.

Technique IV. Management zones are delineated by using remote sensing, an alternative soil sampling procedure (i.e. not a grid sampling approach) combined with organic matter, nitrogen, ECa, and pH layers (most difficult technique).

Conclusions

This project is enhancing the farming communities' capacity to integrate site specific technologies into farming systems. The use of management zone systems to better manage the inherent variability of farm fields should reduce environmentally sensitive agricultural inputs, maintain or increase grain production, increase net profit, and enhance efficiency of agricultural inputs. Economic and environmental cost benefit analysis of precision farming will provide greater incentive to farmers for adoption of precision technologies into their farming operations.

IDENTIFICATION OF SITE-SPECIFIC MANAGEMENT ZONES TO TARGET NITROGEN APPLICATION

Graeff S.[1], Claupein, W.[1]

1 Institute of crop farming and grassland research, University of Hohenheim, Fruwirthstr. 23 – 70567 Stuttgart (Germany)

Introduction

Site-specific soil and crop management implies the concept of using information about variability in site to manage specific sites within a field with best practices. Site-specific N management practices offer the potential to increase yields, improve N use efficiency by crops, and minimize NO_3-N leaching. Yet, because tillage practices, climatic variability, and the dynamics of crop growth all influence various components of the N cycle, predicting site-specific N fertilizer requirements with great accuracy is difficult. Up to now soil must be sampled each year to determine the variation in soil N. The expense and the time to sample is high and cost prohibitive. In the last few year remote sensing techniques have become readily available and may be helpful to determine management zones differing in N availability. The objectives of our field studies were to test the use of reflectance measurements to identify N status of corn plants.

Methods

Field trials were conducted at the experimental station Ihinger Hof, of the University of Hohenheim, Stuttgart, Germany. Two trial sites were chosen, representing different soil types and different crop rotations. Site 1 "Talacker" was a sandy loam, with a three-year grassland as previous crop. Site 2 "Hohler Markstein" was a loamy sand, with summer barley as previous crop. Corn [*Zea mays* L. cv. Tassilo] was sown on 02 May 2001. In order to determine the natural variability of soil nitrogen, no additional fertilizers were applied. Corn was harvested at mid of September 2001.

Reflectance measurements were conducted during the growing season (May – July) to document spatial variability of corn N status. Reflectance measurements were carried out every 2 m along a transect of 50 m at each trial site. Reflectance measurements were performed with a digital, light-sensitive (ISO 200 – 2400), high spatial resolution LEICA S1 PRO camera (5140*5140 pixel) in conjunction with a light source (HMI 21 W/D ~10 W m^{-2}, Sachtler, Germany) of total daylight spectrum to ensure controlled light conditions. Reflectance spectra were taken from the 4th leaves without removing the leaf from the plant. A leaf area of 4.5 cm² was scanned roughly at a point one-quarter of the way from the base to the tip, once a week.

Total daylight spectrum was split into various wavelength ranges using long-pass filters (Maier Photonics, Manchester, USA), active at wavelengths longer than 380 nm, 390 nm, 430 nm, 470 nm, 490 nm, 510 nm, 516 nm, 540 nm, 600 nm, 715 nm, and 740 nm, respectively. Scans were carried out with the software SILVERFAST V. 4.1.4 (LaserSoft GmbH, Germany) and later on analyzed with the Software ADOBE® Photoshop 5.0 in the L*a*b*-color system (CIE, 1976).

Results

Figure 1 shows the reflectance data for the trial site "Hoher Markstein". The nitrogen concentration in leaf dry matter changed significantly over a transect of 50 m. Changes in plant nitrogen status lead to reflectance changes in the wavelength range 516-1300 nm. According to the value of the b* parameter nitrogen deficient locations in a field could be determined. Similar results were obtained also at the trial site "Talacker".

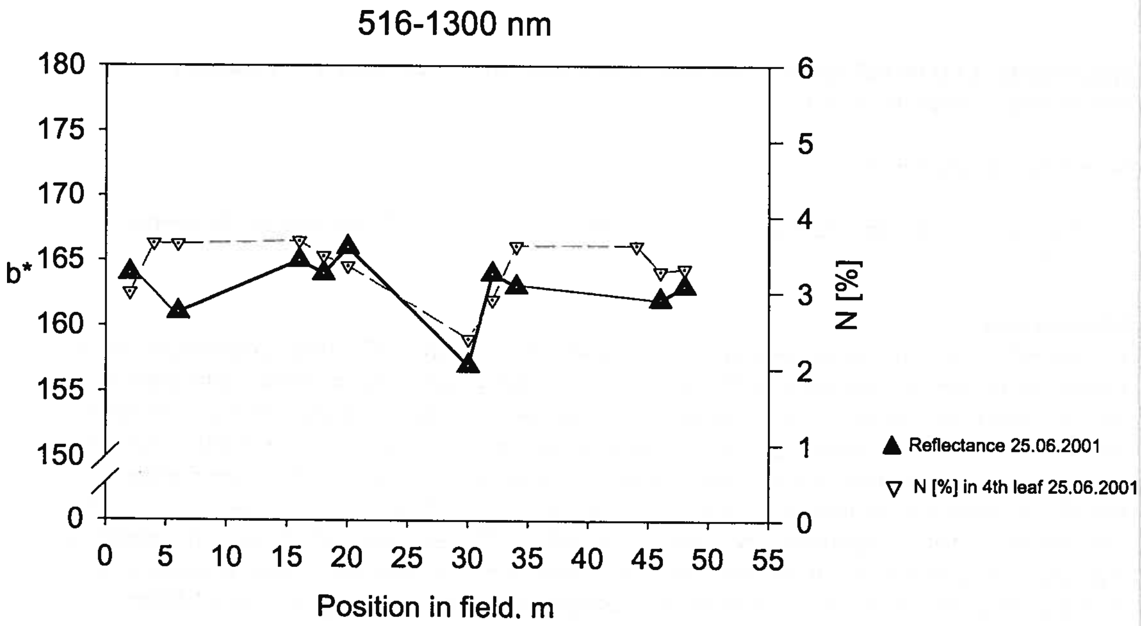

Fig. 1. Leaf reflectance (b* parameter) of corn plants over a transect of 50 m at the trial site Hoher Markstein.

Figure 2 shows the results of the N variability at the trial sites Hoher Markstein and Talacker. The N supply of the corn plants was higher at the trial site "Talacker" were a three year grassland was the previous crop. Up to a nitrogen concentration of 3 % in leaf dry matter, the b* value showed no significant differences between the two trial sites. The b* parameter decreased signify-cantly in the wavelength range 516-1300 nm at the time the nitrogen concentration in leaf dry matter was lower than 3 %.

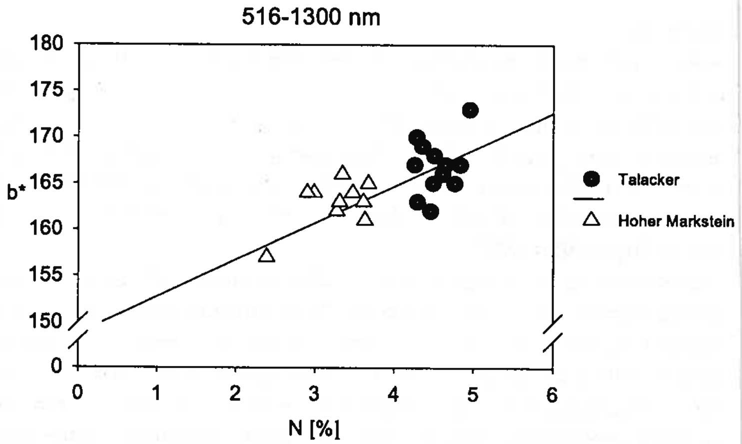

Fig 2. Natural variability in N supply of corn plants at the trial sites "Talacker" and "Hoher Markstein" representing different soil types and different previous crops.

Conclusions

These results show that reflectance measurements indicate the nutrient status of a corn plant quite well during a growing season. Crop nitrogen status varies along a transect of 50 m depending on the soil type and the crop rotation. Nitrogen deficient zones in a field could be detected. Therefore, reflectance measurements might be a useful tool for the estimation and optimisation of fertilizer requirements of corn plants during a growing season. Plant surveys could be used in conjunction with soil surveys to identify management zones and to optimise fertilizer applications.

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SMALL-SCALE VARIATION OF YIELD AND GRAIN PROTEIN IN WINTER WHEAT AS AFFECTED BY N FERTILIZATION AND TILLAGE INTENSITY

R. Hausherr[1], S.V. Garibay[1], P. Stamp[1] & W. Richner[2]
[1] ETH Zürich, Institute of Plant Sciences, ETH Zentrum, CH-8092 Zürich (Switzerland); [2] Swiss Federal Research Station for Agroecology and Agriculture, CH-8046 Zürich (Switzerland)

Introduction

The typical procedure of applying a fixed rate of fertilizer N for an entire crop field often leads to areas of over- and underapplication because the spatial variation of soil and microenvironmental characteristics influences crop yield potential and, thus, N requirements on the one hand and mineralization and losses of N on the other. Spatially-variable N fertilizer application may reduce the risk of environmental pollution and increase the economic return of N fertilization (Fiez et al., 1995), but it requires knowledge about the site-specific N requirements of crops. However, the spatial variation of crop yield, N requirement, and soil N supply was mostly investigated at large scales (Sadler et al., 1998); very few studies have been done in small fields. The spatial patterns of yield and N status of crops may vary not only due to natural soil variability, but also as a result of cropping practices (e.g., tillage intensity), which influence many N-related soil and plant processes.
The objectives of this experiment were (i) to assess the small-scale variability of soil mineral nitrogen (N_{min}), grain yield (GY) and grain protein concentration (GPC) in winter wheat (*Triticum aestivum* L.), and (ii) to investigate if the spatial variability of these traits was modified by nitrogen fertilization and tillage intensity.

Materials and methods

Site and experimental design: Investigations were conducted in a 2-ha field in the Swiss midlands in 1999 and 2000. The soil was a sandy loam with 3.3 % organic matter content. The average annual precipitation at the site is 1047 mm and the average annual mean temperature 9.2°C. Using a split-plot design with three replications, crop as the main-plot factor, and tillage system as the subplot factor, the effects of different tillage systems on crop productivity and nitrogen efficiency had been studied since 1997.
Treatments: The investigations shown in this paper were done in the wheat crop following maize. The tillage systems studied were conventional tillage (CT) and no-tillage (NT). The maize straw in the CT plots was plowed in to a depth of 0.25 m, whereas the NT wheat was sown without soil disturbance into the maize residues. At four positions within each tillage subplot (420 m^2), N fertilizer rates of 0, 50, 100, 150, 200, and, only in 2000, 250 kg N ha^{-1} were applied at random to a group of adjacent microplots (2.25 m^2), split into four applications of NH_4NO_3. Thus, 12 groups of N-fertilizer-rate microplots were created for each tillage system.
Soil and plant sampling: N_{min} samples were taken to a depth of 90 cm at the beginning of the vegetation period in the center of each microplot. GY was determined on 1 m^2 in the center of every microplot. The N content of grains was analyzed and, by multiplying the grain N content by 5.7, GPC was calculated.
Statistical Analysis: ANOVAs were calculated with the factors year, tillage system, N-fertilization rate and their interactions. The factor 'within-plot position' (= microplot group) was considered as nested within replication and tillage system.

Results

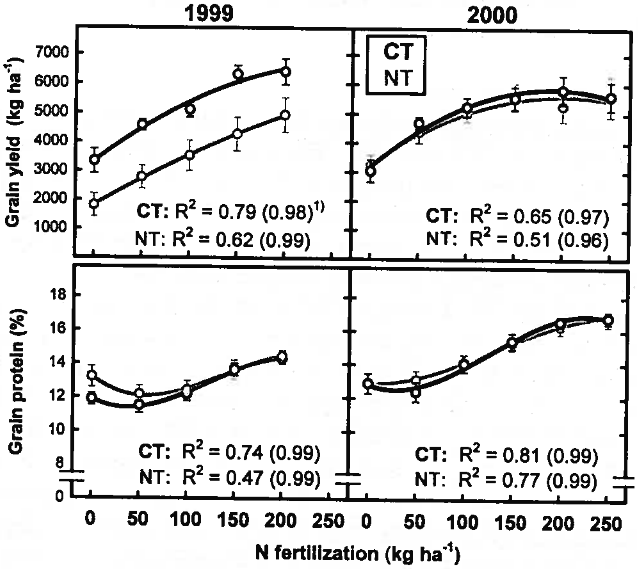
Tillage effects (Table 1): Soil N_{min} contents in spring were similar in both tillage systems, but varied stronger across within-plot positions in NT than in CT plots in 2000. In 2000, N_{min} contents differed significantly (p □ 0.001) within plots in CT and NT, in 1999 only in NT.

GY was significantly lower in NT compared with CT in 1999, due to a strongly reduced plant density, especially in NT, after a severe winter (data not shown), whereas there were no significant yield differences between tillage systems in 2000. GPC was remarkably greater in NT compared with CT in 1999, possibly due to the strongly reduced GY in NT in this year; in 2000, GPC was similar in both tillage systems. In 2000, GY varied significantly (p □ 0.001) among within-plot positions in both tillage systems, in 1999 only in NT. Accordingly, the range and the coefficient of variation (CV) of GY across the 12 within-plot positions were generally greater in NT compared with CT, most pronounced in 1999. The within-plot variation of GPC was much smaller than the yield variation, and the range and CV of this trait were greater in NT compared with CT only in 1999.

Table 1. Means, ranges, and coefficients of variation (CV) across 12 within-plot positions for grain yield, grain protein concentration and N_{min} at the beginning of the vegetation period in conventionally tilled (CT) and non-tilled (NT) winter wheat in two years.

Tillage system	Yield (kg ha^{-1})			Grain protein (%)			N_{min} (kg ha^{-1})		
	mean	range	CV (%)	mean	range	CV (%)	mean	range	CV (%)
1999									
CT	5145	764	5.8	12.7	1.4	3.7	27.8	16.9	20.9
NT	3465	2317	21.4	13.2	2.2	5.7	35.6	24.5	18.5
2000									
CT	4999	2080	10.8	14.7	1.7	3.8	71.6	28.2	11.8
NT	4852	2488	13.5	14.8	1.7	3.7	74.8	70.2	25.9

<u>Nitrogen effects (Fig. 1)</u>: In 2000, the N-response curves of yield were similar for CT and NT, whereas in 1999 the almost linear N-response curve was shifted towards lower GYs in NT compared with CT, due to the suboptimum ear density in NT in this year (data not shown). In both years, the N-response functions of GY (quadratic response) and GPC (cubic response) explained a greater part of the variance of the dependent variable in CT compared with NT, when fitted for the individual values of the 12 within-plot positions. Functions fitted for means of these 12 values had uniformly high coefficients of determination in both tillage systems. This suggests a greater within-plot variability of the N-response of these two traits in NT.



Conclusions

The N response of GY and GPC was modified by tillage intensity. Generally lower GYs in NT compared with CT at individual N-fertilization levels indicated that differences among tillage systems existed in N use efficiency (data not shown). Our results suggest that there is small-scale variation in GY and GPC and their response to N in wheat fields. This spatial variability tends to be greater on untilled soil.

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SENSITIVITY OF A CROP MODEL TO PEDOTRANSFER FUNCTIONS AT THE FIELD SCALE

Houlès V.[1], Nicoullaud B.[2], Beaudoin N.[1], Mary B.[1]
[1] I.N.R.A. Unité d'Agronomie rue Fernand Christ F-02007 LAON Cedex
[2] I.N.R.A. Unité de Science du Sol BP 20619 Ardon F-45166 OLIVET Cedex

Introduction

This study is part of a project on precision agriculture which aims at defining a site-specific nitrogen fertilisation method within a field using a crop model associated with soil and remote sensing information (Guérif *et al.*, 2001). Our strategy consists first in running simulations with the crop model STICS (Brisson *et al.*, 1998) on the basis on the available pedological information, and then recalibrating the model outputs using remote sensing observations. We have characterised in great detail the soil and rooting properties of an agricultural wheat field (Beaudoin *et al.*, 2001). This information was used to establish a pedologic map and pedotransfer functions concerning 4 important input parameters of STICS: water content at field capacity (*WFC*), water content at wilting point (*WWP*) and bulk density (*BD*) of each pedological layer, and maximum rooting depth (*MRD*) of each pedological zone. In this paper, we compare the sensitivity of the model to three types of soil inputs:

T1. all parameters estimated from a simplified map, established before this study ("carte des sols de l'Aisne", scale 1:25000; Jamagne *et al.*, 1964)
T2. all parameters estimated from the detailed map established in this study (scale 1:2500)
T3. same as T2, except for *WFC* which were forced to be the water contents measured in winter.

Methods

The soil variability was assessed on soil cores taken over 0-150 cm depth on a regular grid of 81 nodes. The characteristics recorded for each pedologic layer were: depth, type of material and textural class; $CaCO_3$, stone and gravel contents. Additional soil profiles (37) were realised to complete the map. The detailed pedologic map thus obtained includes 48 polygons (Figure 1). It was used to constitute the inputs of the pedotransfer functions.

WFC was assumed to correspond to the water content measured at each of the 81 nodes, on the cores taken in February 2000 and 2002. The two measurements were well correlated and gave similar values. Each core was 30 cm thick. The cores which were not entirely included into a single pedologic layer were excluded from the data base used to build the pedotransfer functions.

A pedotranfer function was then built to calculate *WFC*. 26 classes were defined by combining the previously defined pedological criteria.

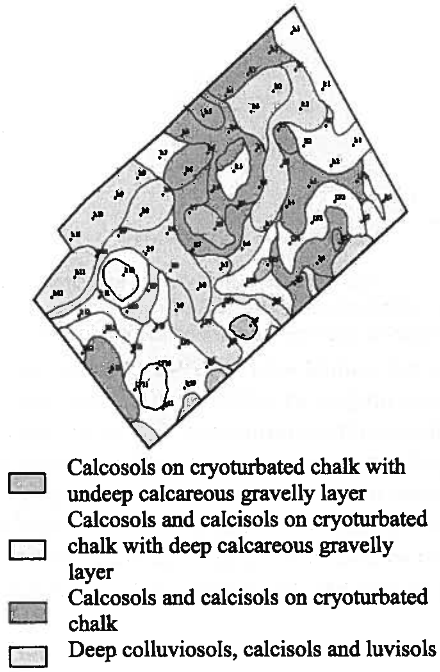

Figure 1: Pedologic map of the 10 ha field with the regular sampling grid.

WWP and *BD* were determined after digging trenches on 4 sites, representative of the main soil materials. They were measured on soil samples at laboratory. These parameters were thus

assessed with less accuracy than *WFC*. The *WWP* and *BD* pedotranfer functions were established for the same 26 classes.
The rooting characteristics were also determined on the same trenches, and were used to elaborate a *MRD* pedotranfer function for rooting properties : some materials are supposed to stop roots, while others result in a progressive reduction in root density.

Results and discussion

We first evaluated the *WFC* and *BD* pedotransfer functions on the heterogeneous soil cores which had not been included in the data base. The predicted *WFC* in the heterogeneous soil cores compared favourably with the values measured in February (Figure 2). However, there remained a bias which indicates that the pedotransfer function could not reproduce the whole variability. The quality of prediction was acceptable : RMSE = 0.016 g water g^{-1} soil.
We then evaluated the effect of pedotransfer functions on STICS outputs by comparing simulations obtained with soil inputs types T1, T2 and T3 on the nodes of the grid. The grain protein content was better predicted with T2 and T3 than with T1 inputs (Figure 3): the RMSE were 0.78, 0.84 and 1.24% grain, respectively. However T1 inputs gave better results for other output variables, such as grain yield and soil mineral nitrogen.

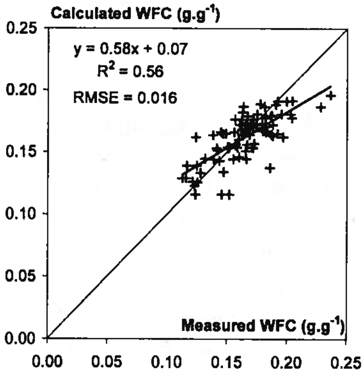

Figure 2: Comparison between observed and predicted estimates of *WFC* in February 2000 and 2002 in heterogeneous cores.

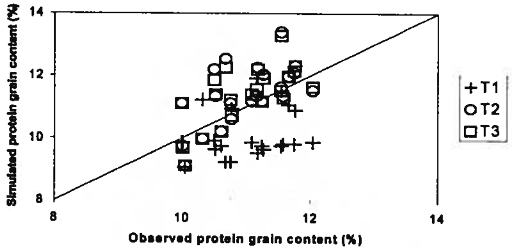

Figure 3: Comparison between observed and simulated nitrogen grain content for the real climatic year. T1 to T3 are the types of soil inputs described in introduction.

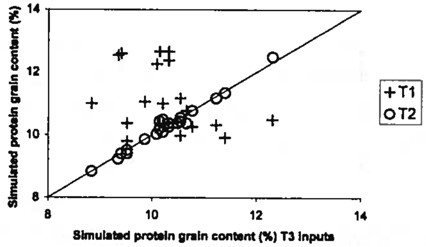

Figure 4: Comparison between simulated nitrogen grain content for a typical climatic year with the different types of soil inputs described in introduction.

In fact, the studied year (1999-2000) was particularly rainy and two hail events occurred, so that soil water properties (*WFP* or *WWP*) did not exert a great influence on model outputs. Therefore we ran simulations for a more typical year, i.e. a less rainy year. The prediction of grain protein content was very different with T1 than with T2 or T3 inputs (Figure 4), showing the sensitivity of the model to soil water properties and to the scale of the pedological map. Conversely, the very small differences found with T2 and T3 inputs for both climatic years (Fig. 3 and 4) show that *WFC* pedotransfer function established at high resolution scale was quite relevant to pursue the evaluation of the model at field scale.

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YIELD FORMATION AND NITROGEN UPTAKE OF MAIZE ON HETEROGENOUS GROWING SITES - SPECTROSCOPIC DETECTION OF THE NUTRITION STATUS

Huber G., Maidl F.-X.

Chair of Agromomy and Plant Breeding, Technical University Munich – 85350 Freising

Introduction

Heterogenous Fields are caracterised by a spatial variability in water supply and nitrogen mineralisation. Site specific cropping takes care of these parameters. The knowlegde about biomass development and nutrient uptake of maize, grown on various locations with different cropping capacities, does not suffice yet for stating instructions for a site-specific cultivation (Kitchen et al., 1995). A vital approach for a variable cultivation can be the adaptation of nitrogen application and plant density to the characteristics of the soil in different fieldparts. A variation of the seed density is naturally bound to mapping systems that include historic information such as former yields or field capacity, whereas variable fertilisation could be realised according to the current biomass production and nitrogen uptake. Non destructive methods for detecting the biomass and nutrition status of crop stands have to be developed.

Methods

Field trials were performed in the year 2000 and 2001 on heterogenous fields near Freising in the Upper Bavarian Tertiärhügelland. Similar test plots were placed on two sites that differ clearly in cropping capacity and water supply. Table 1 shows the two plant densities that were combined with four levels of nitrogen fertilisation.

	N 1		N 2		N 3		N 4	
Nitrogen amount [kg N/ha]	0		70		120		170	
Plant density [grains/m²]	8	12	8	12	8	12	8	12

Table 1 – Plant density and nitrogen fertiliser treatment

The variety was Banguy. In the period between early June and the middle of August, when the vegetative growth took place, intermediate harvests of the whole plant were made at six dates, every two weeks. The dry matter yield and the nitrogen concentration of every biomass sample was detected. At dough stage (Sept. 12th) and at the time of physiological maturity (Oct. 15th) the cob and the rest of the plant were harvested and analysed seperately.
An additional field test with the factors nitrogen amount, application date and cultivar was conducted on a uniform site. Four varieties that differ clearly in terms of colour and leaf orientation were grown and detected periodically using a reflection spectrometer. The recorded reflection signature was transformed into the vegetation index Red Edge Inflection Point (Reusch, 1997).

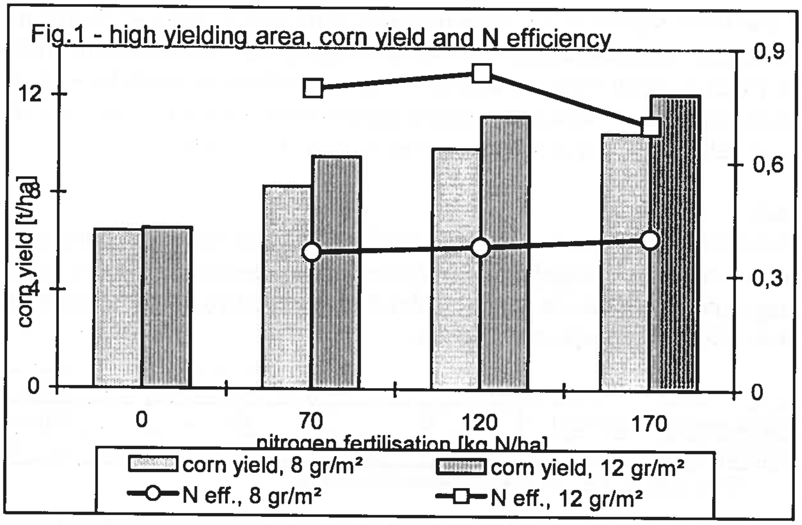
Results

Four weeks after the emergence of the plants (June 26th) the spectrometer detection was still affected by the soil background. A reliable relation between the REIP and the applied amount of

	Detection date			
Variety	June 26th	July 3rd	July 24th	Aug. 24th
Attribut	0.81	0.82	0.69	0.91
Banguy	0.52	0.59	0.65	0.91
Magister	0.65	0.83	0.83	0.90
Major	0.70	0.72	0.71	0.87
All varieties	0.58	0.70	0.67	0.79

Table 2 – Coefficiants of determination (r^2) of the linear regression between the red edge inflection point and the applied nitrogen amount

nitrogen could be found for only one variety (Tab.2). After one week of continuing growth, the plant canopy covered the ground much better and the coefficients of determination got clearly higher. The reaction of the cultivar Banguy is remarkable. Due to its restrained and slow vegetative development, the fertilisation of this variety could not be detected securely by spectroscopy at this early growth stage. On July 24th, at the time of flowering, the measurements were affected by tassels and anthers. After flowering, when the development of the stem was fully completed, the REIP values showed the fertilisation very well for all varieties. The r^2 values of the regression, pooled across all varieties, are lower than those calculated separately for the varieties Attribut, Magister and Major. Thus it appears that a specific calibration for every variety is required. As shown in Fig.1, the maximum corn yield in the high yielding area was achieved by the highest fertilisation with 170 kg N/ha. That reaction could be noticed in combination with every tested seed density and, less explicit, also in the low yielding fieldpart. The best nitrogen utilisation was achieved with 120 kg N/ha. Under every fertilisation level and on both locations a raised plant density caused increased corn yields. The consequence was an increased N uptake under constant fertilisation and a higher nitrogen efficiency.



Discussion

High amounts of applied nitrogen result in high corn yields but however exeed the range of optimized nitrogen efficiency. Under constant fertilisation doses, a raised plant density results in higher corn yields and in better fertiliser utilisation. Provided that the plant density is high enough, moderate nitrogen doses can lead to very high utilisation rates.

The results show that the used spectroscopic method is suitable for the non-destructive detection of the nutrition status of maize. The differences concerning leaf colour and leaf orientation require a variety-specific calibration of the sensor. There are restrictions at early stages of growth, when the soil background is not yet covered enough. A practical approach for a site specific fertilisation could be constructed on the basis of nitrogen uptake targets for every fieldpart. After a uniform start application of a small nitrogen rate a supplementary fertilisation would be added. This could occur as soon as the online detection works reliably, which is usally ensured from the time when the fifth leaf has unfolded. The difference between the actual N uptake and the target would determine the supplementary rate.

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PRECISION FARMING STRATEGIES TO OPTIMIZE THE USE OF AGROCHEMICALS UNDER MEDITERRANEAN CONDITIONS. PART II: DEVELOPMENT OF SITE-SPECIFIC HERBICIDE APPLICATION MAPS.

Jurado-Expósito M[1]., López-Granados F[1]., García-Ferrer A[2]., García-Torres L[1].
1 Institute for Sustainable Agriculture, CSIC, Apdo. 4084 – 14080 Córdoba (Spain)
2 University of Córdoba. Dep. of Remote Sensing. Av. Menendez Pidal. 14004-Córdoba, (Spain)

Introduction

Field observations clearly show that weeds are not uniformly distributed, but rather tend to appear in patches, so that it is rare for a crop to be infested with a single weed species, but rather a multi-species population is present in the field and, often, the need for weed control varies within fields. A goal of site-specific weed control is to apply herbicide only in areas where weed density exceeds an economic threshold. Further, a selective application strategy could be based on a weed map. Mapping is the way to design a selective herbicide application strategy only in areas where weed density is above the economic threshold procedures. The research reported in this paper is a first step towards developing and evaluating a site-specific weed control program in sunflower under a precision farming strategy, which includes mapping, spraying patches, and evaluating these patches to determine if a site-specific weed control can reduce herbicide use and environmental impact in our Mediterranean conditions.

Methods

Weed surveys were carried out on two 240 m x 240 m sunflower fields (Monclova and Cabello) located at a typical agricultural area in Andalusia, Southern Spain, on regular 7 m x 7 m grid. At each grid-node, an infestation severity (IS) index value was assessed for each individual weed species identified in a square sampling area of 4 m^2. The position of each node was georeferenced using a Differential Global Positioning System (DGPS). Data were statistically and geostatiscally analysed. Geostatistical techniques were used to describe and map the multi-species weed spatial distribution and to design intermittent spraying strategies.

Spherical, exponential or gaussian models were fitted to the experimental semivariograms. (Isaaks and Srivastava 1989). The spatial distribution of individual and multi-species weed infestation was classified as random, moderate and strong patchy distribution according to its semivariogram nugget coefficient (nugget/sill ratio, > 75%, 26% to 75%, and 0% to 25%, respectively) (Cambardella et al. 1994). Once cross validated, the semivariogram models were used to map the IS of each single weed and of overall infestation by kriging. Site-specific herbicide application maps were then drawn based on the multi-species weed map and the estimated economic threshold (ET, was estimated at IS ≥ 2) (Jurado-Expósito et al. 2002)

Results

The summary statistical data of IS index, spatial distribution characteristics and cross validation parameters are listed in Table 1. Weed species, the individual weed IS index and the spatial distribution varied considerably with the location. Semivariogram parameters strongly varied between species and locations. All the weed species generally showed moderate to strong patchy distribution in the surveyed fields, regardless of their infestation severity.

Kriged estimates were used to draw contour maps of each weed species (Fig. 1a) and site-specific herbicide application maps based on the overall infestation severity index (Fig. 1b).

Conclusions

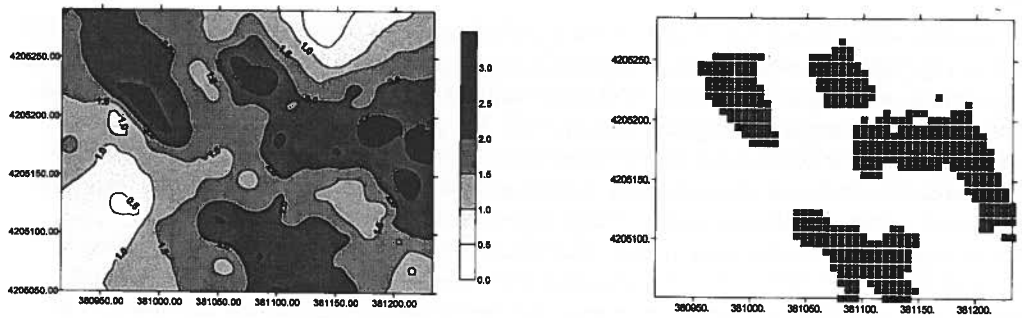
The results of this work indicate that the geostatistical procedure becomes useful for describing multi-species weed infestation maps, which could be used to design intermittent spraying strategies.

Table 1. Main weeds species, statistical data of infestation severity index (IS), spatial distribution characteristics and cross validation statistics.

Location	Weed	IS				Semivariogram parameters						Cross validation		
		Mean	Median	SD	Skew	Model	Range (m)	Nugget	Sill	Nugget /sill (%)	Spatial dependence	MEE	MSE	SM
Monclova	*Amaranthus albus*	1.48	1.5	0.98	0.01	Exponential	30.4	0.35	1.06	33.0	Moderate	0.001	0.56	1.0
(n[1]=511)	*Chenopodium album*	2.30	2.5	0.81	-1.00	Exponential	8.0	0.19	0.75	25.2	Strong	0.0	0.62	1.0
	Heliotropium europaeum	0.43	0	0.78	0.82	Exponential	36.7	0.18	0.70	25.7	Strong	0.0	0.31	1.0
	Orobanche cumana	0.46	0.5	0.52	0.87	Spherical	110.0	0.13	0.26	50.0	Moderate	0.0	0.17	1.0
	Picris echioides	0.06	0	0.37	0.64	Gaussian	43.5	0.08	0.15	53.3	Moderate	0.0	0.10	1.0
	Polygonum aviculare	0.40	0	0.75	0.89	Gaussian	71.9	0.25	0.98	25.5	Strong	0.002	0.24	0.9
	Vaccaria hispanica	0.44	0	0.72	0.79	Spherical	106.7	0.16	0.63	25.3	Strong	0.0	0.27	1.1
	Overall infestation	2.60	3.0	0.57	0.63	Spherical	55.8	0.28	0.32	87.5	Random	0.0	0.29	0.9
Cabello	*Brassica napus*	0.35	0	0.85	0.25	Spherical	20.4	0.39	0.74	52.7	Moderate	0.04	0.74	1.1
(n[1]=264)	*Chenopodium album*	0.21	0	0.46	0.30	Exponential	26.0	0.05	0.23	21.7	Strong	0.14	0.23	0.8
	Convolvulus arvensis	0.09	0	0.44	0.15	Spherical	75.9	0.02	0.22	9.1	Strong	0.0	0.19	1.7
	Galium aparine	1.02	1.0	0.92	0.50	Exponential	31.7	0.31	0.88	35.2	Moderate	0.02	0.84	0.5
	Phalaris paradoxa	0.34	0	0.86	0.39	Exponential	21.0	0	0.71	0	Strong	0.05	0.39	1.0
	Polygonum aviculare	0.18	0	0.62	0.43	Spherical	39.0	0.17	0.42	40.5	Moderate	0.05	0.41	1.0
	Ridolfia segetum	0.79	0.5	0.77	0.85	Exponential	17.0	0.25	0.62	40.3	Moderate	0.0	0.50	0.9
	Sinapis arvensis	0.53	0.5	0.60	1.09	Spherical	126	0.09	0.43	20.9	Strong	0.0	0.28	1.32
	Overall infestation	1.79	2.0	0.88	0.29	Exponential	19.1	0.34	0.73	46.6	Moderate	0.0	0.52	0.85

[1] n: number of georeferenced counting units

Figure 1. At Cabello: a) Isoline map of global weed IS index and b) site-specific application maps obtained for overall infestation (threshold value IS≥ 2, marked blank)



If a selective herbicide were applied just to the areas exceeding the economic threshold a significant herbicide saving could be accomplished in Cabello and Monclova.
Therefore, is necessary to determine multi-species infestation for implementing precision farming in sunflower weed control under Mediterranean conditions. Furthermore, a multi-species spatial analysis offers the opportunity to improve the planning of differential herbicide treatments. For example at Monclova, the detection of parasitic *O. cumana* patches could lead to specific herbicide treatments to prevent any further spread of this species. Similarly, the detection of hard-to-control weeds at Cabello, such as *C. arvensis* and *Ridolfia segetum* would facilitate spatial herbicide treatments targeted to these patches even though infestation severity was below the established economic threshold.

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ASSIMILATING REMOTE SENSING DATA INTO A CROP MODEL IMPROVES THE YIELD ESTIMATES ON A REGIONAL SCALE.

Launay M. and Guérif M.

INRA, Unité Climat Sol et Environnement, Site Agroparc, 84914 Avignon cedex 9, France

Introduction

Agronomic or environmental diagnosis on a regional scale, as well as yield estimate constitute major issues for crop models application. However, the use of such models on a regional scale is made difficult because of the lack of spatialized information on some of their input variables or initial conditions. Remote sensing measurements in visible and near infrared wavelength give estimates of the "true" status of the crop growth that can be assimilated into the crop model for re-estimating the missing information and thus provide a better spatial estimate of crop growth and yield. Such a method was developed on a local scale (Guérif et al, 1998) and the conditions of its extension to a regional scale was therefore analyzed (Guérif et al, 2000). The present paper presents the development and application of a method for estimating sugarbeet yields for 48 fields in two sugar factory basins (Launay, 2002).

Data, models and methods

Yields were recorded on 48 fields belonging to 2 factory basins of Picardie (North of France). According to the basin, 2 or 3 SPOT images and 2 to 3 airborne images (from a SPOT simulation sensor) were acquired. Meteorological data were obtained from 3 weather stations of Meteo France. A very detailed soil map (1/10000) provided the soil description. A sugarbeet version of Sucros model including water stress effects was used, after modifications done to better simulate water stress effects on LAI behavior (Launay et al, 2002). This model was coupled with a radiative transfer model, SAIL, in order to simulate reflectance and the vegetation index TSAVI (Fig.1). This TSAVI was compared to the measured TSAVI obtained from images after corrections of atmospheric perturbations thanks to the SMAC model inversion (Launay et al, 1999), and a minimization algorithm allowed to re-estimate some chosen input variables. These variables consisted in those characterizing the crop establishment phase (time from sowing to emergence and number of plants emerged) and some (growth rate and maximum depth of roots) that allowed to correct for bad soil characterization (depth or water retention capacity).

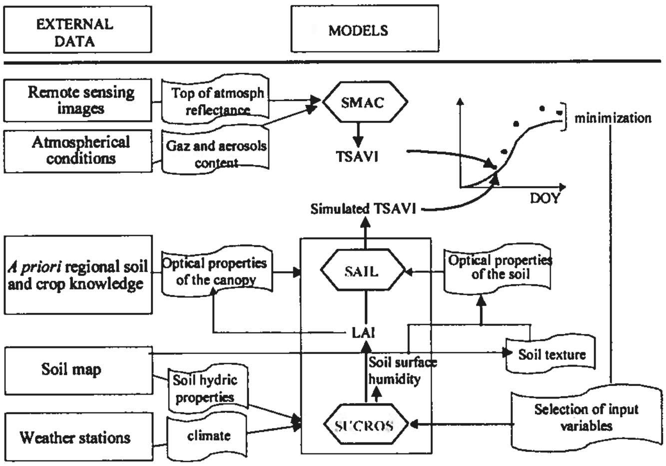

Figure 1. Models and data used in the assimilation procedure

Results

Figure 2 illustrates for one specific field how the assimilation procedure does work. The initial guess for the 4 input variables produced a TSAVI simulation that was far from the observed values. The assimilation of these observed values led to a re-estimation of the 4 variable values and a best fit of the simulated LAI, and hence yield (43.3 t/ha instead of 53.6 with the initial guess, and 48.3 for the measured value). The thermal time between sowing and emergence was

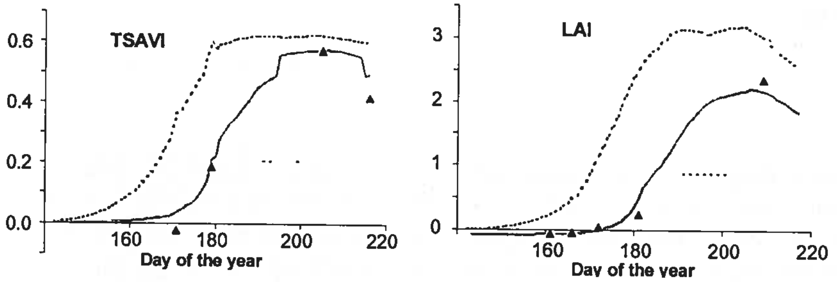

Fig. 2 : Measured ▲ and simulated LAI & TSAVI for one field before ▪▪▪▪▪ and after —— remote sensing data assimilation.

increased (re-estimated 138 °C.day instead of 120 °C.day with the initial guess, and 148 °C.day for the measured value) allowing a better fit of the early LAI, and the root growth rate was reduced (re-estimated 0.008 m.day^{-1} instead of 0.012 m.day^{-1}) allowing a better LAI drop under moisture stress during the summer period. When considering the whole fields (Fig.3), it became obvious that the procedure allowed to improve the quality of the yield estimation (the relative RMSE dropped from 18% before assimilation to 12% after). The results in terms of re-estimated input variables (not shown here) provided information on the fields context (soil reservoir characteristics) and behavior (crop emergence conditions) which may be useful for a diagnosis approach.

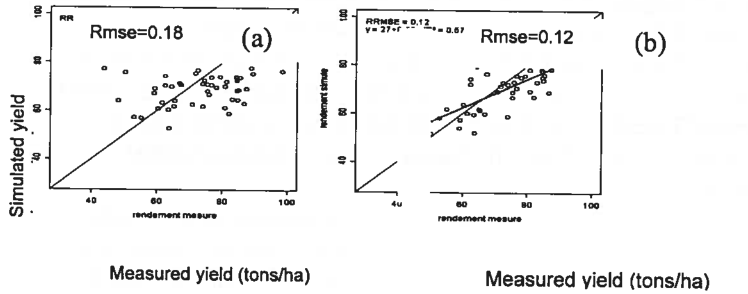

Fig. 3 : Estimated compared to observed yields (a) before and (b) after remote sensing data assimilation .

Discussion

This method was able to estimate the input values of the crop model, which could be spatially variable and to which the model is very sensitive. However the accuracy of estimate depended on the number and position in the crop growing period of available remote sensing data, especially for the variable characterizing the results of the establishment phase. The method was also efficient to provide site specific yield estimation, but was limited in case of severe and sudden moisture stress, because of the crop model inability to simulate the LAI behavior in this context. Further improvements in modelling water stress effects would benefit the method. Remote sensing data assimilation into crop models as applied in real field conditions on a regional scale appeared as an interesting way of both performing a spatial adjustment of the crop model and retrieving information on the crop context (initial conditions or soil characteristics). Its performance still depends on the remote sensing data availability and should rise with the future development of earth observation satellites.

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SPATIAL VARIABILITY OF NUTRIENTS CONTENT IN SOIL AND WINTER WHEAT PLANTS

Lipavský J., Slejška A., Kroulík, M., Haberle, J., Baierová, V.

Research Institute of Crop Production (RICP), Drnovská 507, 161 06, Prague (Czech Republic)

Introduction

Three years ago the research in the field of precision agriculture began in RICP. Most of the experiments are made on the fields near RICP. The field is monitored from a lot of aspects. Content of nutrients in soil and plants are analysed from samples taken from localised sites. Digital photographs used for canopy evaluation are made on the sites. Weeds and pests are counted on the sites. The yield is measured by a yield monitor. A camera carried by a model of a helicopter screens canopy. The resistance of soil against processing of the soil and fuel consumption is measured during stubble breaking, tillage and soil preparation. All obtained data are put in GIS and evaluated by standard statistical methods and by geostatistical methods.

Methods

The soil samples were collected from 60 specified points after harvest of winter wheat on 19 ha field in Prague - Ruzyne. The sampling depth was 0-30 cm. The samples were analyzed for pH, moisture, N, P, K, Mg and Ca content. From the same points the samples of plants in the growth stage 31 DC and 41 DC were collected (DC = decimal code according to Zadoks et al. 1974). The samples were analysed for dry matter, N, P, K, Mg and Ca content.

Results

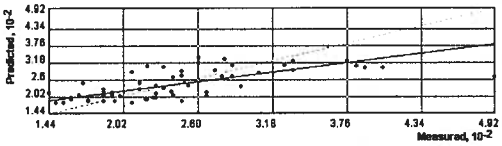
Contents of phosphorus and potassium in soil correlated between years 2000 and 2001 on the level of significance 0.01 (bold-type) and contents of nitrogen on the level of significance 0.05 (italic).

Nutrients in soil	N	P	K
Corr.2000x2001	*0.2526*	**0.7981**	**0.7587**

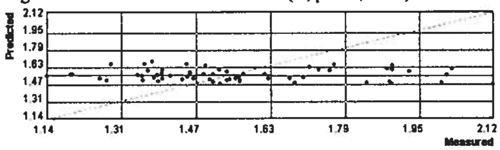
Contents of nutrients in plants correlated less than contents of nutrients in soil. Also during geostatistical analysis data from plants evaluation showed higher variability. This was the reason for impossibility to make maps showing real contents of nutrients in plants. The quality of prediction of geostatistical model can be demonstrated by regression functions of cross validation of predicted values.

Nutrients in plants	N	P	K
Corr.2000DC41x2001DC31	-0.0226	*0.2532*	0.0128
Corr.2000DC41x2001DC41	0.1762	0.0813	0.4394
Corr.2001DC31x2001DC41	*0.2656*	0.3695	*0.2916*

Regression function: 0.526*x + 112.683 (K, soil, 2001)

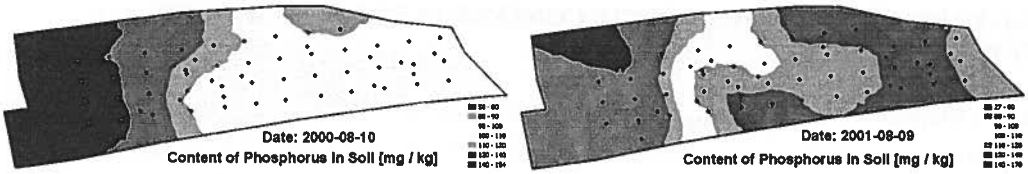


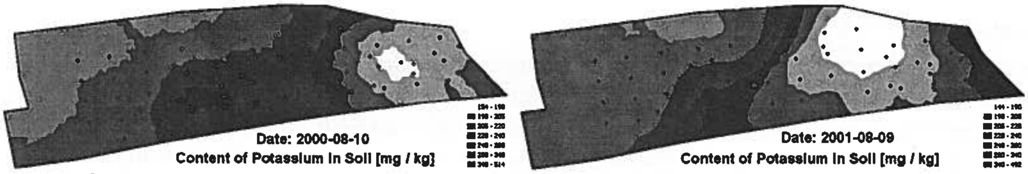
Regression function: -0.011*x + 1.554 (N, plants, 2000)



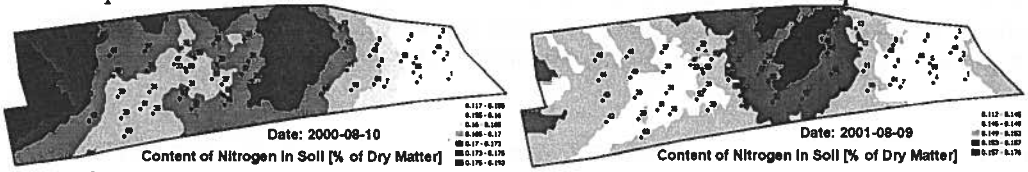
First item of regr. func.		N	P	K
Soil	2000	0.102	0.359	0.317
	2001	0.039	0.431	0.526
Plants	2000DC41	-0.011	0.167	0.027
	2001DC31	0.175	-0.002	0.098
	2001DC41	0.088	-0.006	0.051

Only from the data of phosporus and potassium contents in soil the maps with the same categories of contents of the nutrients could be made.

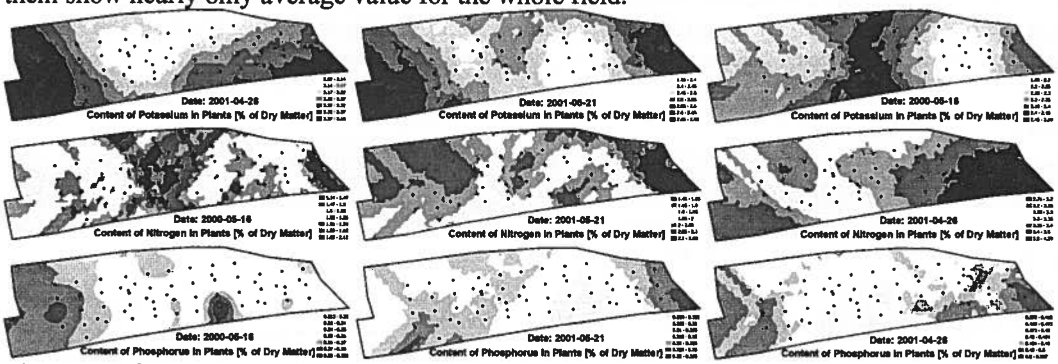




Maps of contents of nitrogen in soil show similar regions with higher and lower values but they do not express the real situation in the soil. More measurements would be required.



Maps of contents of nutrients in plants can not be used for site specific fertilisation. Most of them show nearly only average value for the whole field.



The maps of contents of nutrients in plants can not be used for site specific fertilisation. Due to high soil nutrient contents the measured values of plant samples exhibited mostly average contents through the whole field.

Discussion

Approx. 3 sampling points per ha represent the minimum sampling density for estimation of soil nutrient contents. Therefore, some improvement of geostatistical prediction could be reached by incresing the density of smapling points. Brodský et al. 2001 reported recently significantly better prediction model when sampling grid 40x40 m (approx. 6.5 sample/ ha) was used. Nutrient contents of plants can not be predicted by geostatistical analyses with sampling grid used in our research. One possibility for making good spatial prediction of nutrient contents in plants could be cokrigging with data from indirect measurement methods.

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ASSESSMENT OF SOIL USES IN OLIVE GROVES FROM AERIAL PHOTOGRAPHS

F. López-Granados[1], J.M. Peña-Barragán[1], M. Jurado-Expósito[1], M. Sánchez de la Orden[2], A. García-Ferrer[2] and L. García-Torres[1]

[1] Institute of Sustainable Agriculture, CSIC, Apartado 4084, 14080- Córdoba, Spain; cs9logrf@uco.es.
[2] Córdoba University, Dept. of Remote Sensing, Apartado 3048, 14080- Córdoba, Spain;

Introduction

Olive crop is very important in the Mediterranean basin. Generally, olive trees are separated 10 to 12 m each other and soil management for weed control is mainly based on plough-, disk- and harrow- tillage operations, which drastically alter the natural soil profile. Therefore, soil vegetative coverage in olive groves used to be scarce throughout the year and soil erosion very pronounced. To overcome this environmentally unacceptable situation a drastic change in the soil management of olive groves has been developed, globally named as conservation agriculture. This mainly consists of altering as little as possible the natural soil profile in order to protect the soil permanently with cover crop or crop residues (García-Torres, 2001). Cover crops are about 4 to 6 m wide and are placed in between tree rows. Generally, they consist of grassy species sown in September, grown throughout autumn and winter and usually terminated in early spring by applying a non-residual systemic herbicide which completely desiccated the cover crop.

Recently, EU and National Governments has developed administrative regulations to subsidy the implementation of cover crops in olive groves (EU Directive 1999; Spanish RD 4/ 2001). Estimation of cover crop soil coverage on the ground is time consuming, and consequently not feasible economically. Therefore, this study aims to establish a rapid, accurate and profitable methodology to assess cover crops in olive groves at a farm and regional level using remote sensing techniques.

Methods

Color (0.4 –0.7 μm) and color-infrared (0.5- 1.1 μm) aerial photographs were taken in spring and summer on three olive farms of over 75 ha each, namely La Cubana, Cortijo del Rey and Matallana, all located in Southern Spain. Cover crop species composition was predominantly made of *Hordeum murinum* and *Lolium rigidum*; *Avena sativa;* and *Hordeum sativum* and *Avena sativa,* respectively. Photographs were taken from a plane provided with a camera WILD RC-10/ film AGFA AVIPHOT COLOR H-100 PE-1 (flight height 1,525 m. and scale 1:10,000).

The selected farms were visited near when photographs were taking in order to determine the cover crop vegetative development and odd land uses that could be clearly distinguished in the images. Each farm were georeferenced on the ground (DGPS TRIMBLE).

Photographic prints were digitized using the Hewlett Packard Scan Jet 4C scanner taking 635 points per inch (PPI), resulting pixels of 40 cm. ILWIS 2.2 software was used for analyzing the airborne images. Each pixel was characterized by its reflectance digital values DL or DV (from 0 to 255) or by values assigned through diverse algorithms (indexes) in order to enhance the discrimination in between soil uses (olive- tree, the cover crop and the bare soil). In color photographs, fourteen vegetation indexes were calculated: B, G, R, G/B, R/G, R/B, $B/(G+R)$, $G/(B+R)$, $R/(B+G)$, $B/(B+G+R)$, $G/(B+G+R)$, $R/(B+G+R)$, $(B+G+R)/3$ and $(G-R)/(G+R)$; where B, G and R are the blue, green and red reflectivity values, respectively. Similarly, in color-infrared photographs the following vegetation indexes were calculated: G, R, I, I/R, I/G, R/G, $I/(G+R)$, $R/(G+I)$, $G/(R+I)$, $I/(G+R+I)$, $R/(G+R+I)$, $G/(G+R+I)$, $(G+R+I)/3$ and $(I-R)/(I+R)$, where I is the near- infrared reflectivity value.

The selection of vegetative indexes consisted of: a) Visual pre-selection at 500 x 500 pixels training plots established by image cutting in representative zones; and b) Numerical comparison (confusion matrix and overall accuracy expressed as percentage of coincidences between the pixels classified as olive trees, cover crop and bare soil by every vegetation index and by the Groung Truth Map, GTM, Chuvieco, 1996) of visually selected vegetative index images in 100 x 100 pixels training subplots (TS).

Results

In *color photographs taken in summer* 5 vegetation indexes out of a total of 14 were selected for having discriminated at least one soil use in the three tested farms. The vegetation indexes *R/B*, *B/(G+R)(Figure 1a)* and *R/(B+G+R)* were visually pre-selected and accepted to discriminate cover crop from the other soil uses. The index *B/(G+R)* showed slightly higher discrimination power for cover crop than the indexes *R/B* and *R/(B+G+R)*. Overall accuracy of *B/(G+R)* for cover crop discrimination was 79.9%, 91.8% and 83.1% for La Cubana, Cortijo del Rey and Matallana, respectively. Similarly, the indexes *R/(B+G)* and *R/(B+G+R)* discriminated olive trees from the others soil uses with a overall accuracy in between 90% to 95% in each farm. However, none of the 14 indexes tested was appropriate for bare soil discrimination. It should be pointed out that vegetation indexes made up blue band as dividend, generally, are the most suitable for cover crop discrimination whereas those which the dividend is red band discriminated well olive- tree. In Figure 1b is shown an unacceptable index *(R/B)* due to an unsatisfactory discrimination.

In *color photographs taken in spring*, the indexes *B, R* and *(B+G+R)/3* were selected for bare soil discrimination, with an overall accuracy of 84%, 90% and 88% in the three tested farms.

In *color-infrared photographs taken in summer* none of the 14 tested vegetation indexes improved the discrimination of the previously mentioned indexes in the color photograph.

Conclusions and final comments

These results can be considered acceptable for the following up of the cover crop program in olive groves by the administrations (Peña-Barragán *et al.*, 2002). Color photograph was more profitable (cheaper) material to discriminate the mentioned soil uses than color-infrared photograph. Work is in progress using IKONOS and QuickBird satellite images.

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Figure 1. *)* Cortijo del Rey farm: Classification made in the 500 x 500 pixels training plots by: a) the index *B/(G+R)*, and b) index *R/B*

a) b)

PRECISION FARMING STRATEGIES TO OPTIMIZE THE USE OF AGROCHEMICALS UNDER MEDITERRANEAN CONDITIONS. PART I: SPATIAL VARIABILITY OF SOIL PARAMETERS USING GEOSTATISTICAL ANALYSIS.

F. López-Granados[1], M. Jurado-Expósito[1], A. García-Ferrer [2], M. Sánchez de la Orden[2], and L. García-Torres[1]

[1]Institute of Sustainable Agriculture, Apdo. 4084, 14080-Córdoba (Spain)
[2] University of Córdoba, Department of Remote Sensing, Apdo. 3048, 14080-Córdoba (Spain)

Introduction

Precision farming is a new crop management system wherein inputs are limited where needed, which reduces the use of agrochemicals, costs and environmental pressure. Developing accurate application maps for site-specific fertiliser applications requires a deep and precise knowledge of the variability of soil factors. Most of the studies on soil nutrient status variability have been carried out in Northern conditions (Blackmore *et al.*, 1998). The aim of this research was to examine the spatial variability of soil variables of two fields under different long-term management histories (conventional and no tillage cropping systems) in order to determine the profitability of a precision management under Mediterranean conditions.

Materials and methods

Spatial variability of 7 soil parameters (soil organic matter content, nutrient status: P, K, NO_3, NO_2, and NH_4) was determined in two locations (Cabello and Monclova) of Andalusia, Southern Spain, under no tillage and conventional tillage systems. Sampling was on a 35 m by 35 m grid over an area of approximately 7 ha. There were a total of 89 and 96 georeferenced (DGPS-Trimble) sampling points at Cabello and Monclova, respectively. Sunflower yield data were also recorded with a precision georeferenced harvester (Field-Star, Massey Fergusson). Data were statistically and geostatistically analysed. The spatial distribution of each soil property was classified as random, if the variogram was pure nugget, moderately or strongly spatially structured based on the nugget/ sill ratio, 26% to 75%, and 0% to 25 %, respectively (López-Granados *et al.*, 2002). Soil property maps were based on the kriged estimates. Site specific fertiliser applications map can be developed from those maps.

Results

The summary statistics for soil variables and sunflower yields are given in Table 1. Experimental variograms showed that soil variables and sunflower yield spatial structure can be described by spherical, exponential or Gaussian models. The variograms suggested that soil variables and yield varied in a patchy way resulting in some areas with small values and other areas with large ones. The geostatistical analyses showed different degrees of spatial dependence for the two field locations. The field under the no tillage system had moderate to strong spatial dependence for the most important nutrients, P, K NO_3, NO_2 and NH_4 compare with the conventionally tillage field. Kriged maps for some soil properties are shown in Figure 1 for Cabello. Generally, all maps indicated uneven patchy distribution, as expected from the variogram functions.

The clearly patchy distribution of P and K in the two locations together with the low temporal component of variability that P and K uses to show, indicated the feasibility for developing a strategy for a site-specific application of P and K at least under the more representative farming management practices of Southern Spain.

Conclusion

In our Southern conditions, number of farmer who are involved with the direct sowing and conservation agriculture technology is increasing because government policies for reducing erosion. This together with the high trends to a patchy distribution of soil parameters at the location under no till (Cabello), indicated the profitability for developing precision farming techniques in our Andalusian conditions.

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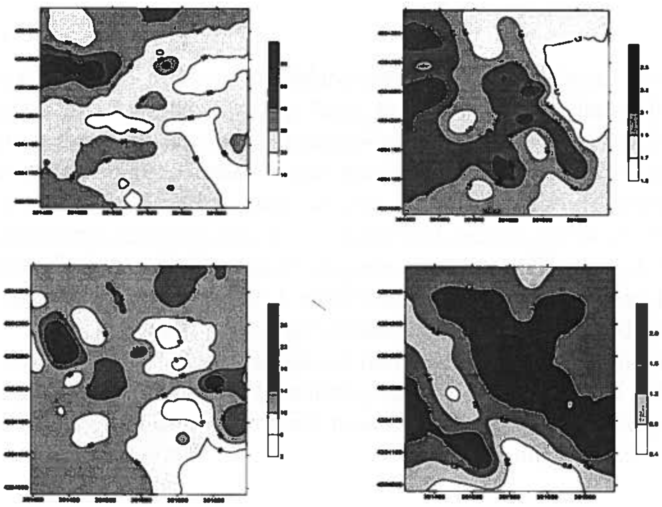
TABLE 1. Geostatistical and Statistical overview of soil parameters at Cabello and Monclova

Location	Parameter	Mean	Median	SD	CV %	Model	Range	Nugget	Sill	Nugget / sill	Spatial dependence
Cabello	O.M. %	1.75	1.75	0.14	8.0	Gaussian	54	0.005	0.022	22.7	Strong
	P ppm	27.6	27	12.4	44.9	Exponential	35	0	142.4	0	Strong
	K meq/100g	1.9	1.9	0.3	15.8	Spherical	57	0.02	0.099	20.2	Strong
	NO_3 ppm	10.8	10	4.8	44.4	Spherical	55	0	22.8	0	Strong
	NO_2 ppm	0.9	0.9	0.6	66.7	Exponential	32	0	0.39	0	Strong
	NH_4 ppm	2.2	2.0	1.2	54.5	Exponential	21	0.31	1.36	22.7	Strong
	Yield Tm/ha	1.5	1.6	0.4	27.5	Spherical	108	0	0.20	0	Strong
Monclova	O.M. %	1.59	1.5	0.14	8.8	Nugget effect	-	0.021	-	-	Random
	P ppm	15.5	15	4.4	28.4	Exponential	27	0.60	19.2	3.1	Strong
	K meq/100g	1.2	1.2	0.3	25	Exponential	34	0	0.09	0	Strong
	NO_3 ppm	7.1	6	5.3	74.6	Nugget effect	-	27.2	-	-	Random
	NO_2 ppm	1.9	2.0	1.1	57.9	Gaussian	36	0.26	1.10	23.6	Strong
	NH_4 ppm	1.9	1.9	0.7	36.8	Nugget effect	-	0.53	-	-	Random
	Yield Tm/ha	2.0	2.1	0.3	16.7	Exponential	61	0.02	0.13	15.4	Strong

FIGURE 1. Maps of kriged estimates for P (10-60 ppm), K (1.5-2.5 meq/100g), NO_3 (2-26 ppm) and sunflower yield (0.4-2 Tm/ha) at Cabello

P

K



NO_3

Sunflower yield

SAMPLING-SCALE FACTORS MAY AFFECT THE EVALUATION OF CROPPING-SYSTEM MODELS

R. Marchetti[1], F. Castelli[2], G. Ponzoni[1]
[1] Istituto Sperimentale Agronomico, Viale Caduti in Guerra 134, 41100 Modena, Italy
[2] Istituto Sperimentale per il Tabacco, Via Canton 14, 37051 Bovolone (Verona), Italy

Introduction

In the field of agricultural research, the standard approach for the measurement of crop economic yield, when, for example, comparing different treatment effects, is to measure the whole experimental plot crop yield. For the purpose of plot sampling, each plot is considered a population. The measurement of other plant features, especially when repeated time measurements are needed, is carried out, for obvious operational constraints, by sampling a fraction of the whole plot, which is the sampling unit. The difference between the sample value and the plot value constitutes the sampling error (Gomez and Gomez, 1984). Parameters needed for cropping-system models to simulate crop growth are usually determined by measurements at sampling scale (SS). Parameterised models are then applied to compare crop yields for varying climate, soil and management scenarios, at field and at farm scale. The model evaluation in this case is based on plot scale (PS)-measured crop yields. The aim of this study was to show the possible consequences of these sampling-scale differences on model evaluation for application purposes. The case study here considered concerns tobacco crop simulation.

Materials and methods

Field measurements were carried out in 1998 and 1999, at the Experimental Tobacco Institute, Bovolone (Verona, Italy), on flue-cured tobacco, cv. K326. In this experiment, fertilised (4 N levels) and unfertilised plots, with 2 replications (10 plots in all) were compared.
Each plot measured 200 m^2 and hosted approximately 460 plants. All the plots were divided into two sections. In one of them, 2 contiguous plants per plot were collected weekly at random positions, to determine the above-ground biomass (AGB) accumulation and partition, and the leaf area index curves. All the growth and morphology parameter values (that is, radiation-use efficiency, water-use efficiency, specific leaf area, etc.) were deducted using these basic measurements sets. The final value of the accumulated AGB curve is identified as SS-AGB (AGB at sampling scale). In the central area of the same plot a plant row (second section of the main plot), including 50 individuals, was used to measure intermediate and final tobacco-leaf harvest amounts (4 harvests, in all), as well as the inflorescence amount removed from the tobacco plant at the topping time and the final plant-residue amount. The accumulated plant biomass removed is identified as PS-AGB (AGB at plot scale). Soil samples for the soil water (SW) content measurements were collected at 4 soil depths: 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8 m, at the same time and place where the SS plant samples were collected. *Model simulations* were carried out using the CropSyst model (Stöckle and Nelson, 1996).

Results

The mean SS-AGB was equal to 9 412 kg ha^{-1}, in 1998, and to 8 637 kg ha^{-1}, in 1999. The mean PS-AGB was equal to 6 752 kg ha^{-1}, in 1998, and to 5 870 kg ha^{-1}, in 1999. The AGB underestimation, in the PS measurement, was confirmed by the relationship between the 2-year, SS- and PS-AGB, temporal measurements (PS-AGB, kg ha^{-1} = 0.669 * SS-AGB + 86.3; R^2=0.81, n= 120). In the simulation of AGB accumulation, two cases may occur: 1) the obtained parameter values are used in the model exactly as they are, since the simulated AGB fits the SS-AGB measurements; 2) empirical calibration steps must be introduced because parameter values do not allow an adequate simulation to be obtained. When the model is applied at field and at farm scale for the prediction of tobacco crop yields, the following consequences may be expected. In the first case the model, having been calibrated by means of parameter values obtained on a SS-AGB basis, will probably overpredict the crop yield, which is PS-based (or even field-based). In the second case, since empirical parameter definition is based on the matching of the simulated final AGB values to the measured ones, what kind of measurement should be taken into account as the reference, that obtained from the SS measurements, or the PS one? Given the interest in the economic yield simulation for practical model application purposes, the PS-AGB measurements as reference values for the calibration could be chosen instead of the SS- ones. Since soil water depletion, when removing 9-t plant biomass, is presumably higher than when removing 6.5-t biomass, the model efficiency in simulating soil water content is influenced by the way we simulated the crop. Here below we report the model efficiency in simulating water content in the soil profile explored by the tobacco roots, down to 0.8 m depth, throughout the crop growth season.

Model efficiency in simulating soil water content (cascade submodel), as influenced by the above-ground-biomass (AGB) values chosen as the reference for the empirical calibration process. SS-AGB: sampling-scale based AGB measurements; PS-AGB: plot-scale based AGB measurements. RMSE, root means square error; MD, mean difference; n, number of data pairs (24 or 23 sampling dates x 4 sampling depths; each value is the mean of the 10 plot values).

Condition	Year	MEAN (m^3 m^{-3})		RMSE	MD	R^2	n
		Observed	predicted		(m^3 m^{-3})		
SS-AGB	1998	0.234	0.218	13.5	0.017	0.73	96
	1999	0.246	0.268	14.2	-0.022	0.68	92
PS-AGB	1998	0.234	0.227	12.6	0.007	0.67	96
	1999	0.246	0.277	17.2	-0.031	0.59	92

Model efficiency in simulating soil water content was, on the whole, higher for the SS-AGB condition, probably due to the fact that soil samples for SW measurements were collected close to the SS plant samples. The following factors could have determined the observed differences between SS- and PS-AGB measurements: the accuracy of the SS-plant sampling (that is, the careful recovering of all plant tissues) is much higher than that allowed by the sampling of a larger number of plants; the procedure applied for the dry-matter weight determination is different when dealing with a few plant individuals rather than large biomass amounts; a misinterpretation of the "representative" plant sample may actually occur. Workers collecting plant samples, while rationally thinking that they are following random criteria, may in fact unconsciously exclude stunted plants, considering them unrepresentative of the population.

Conclusions

We have described a case study, which is of recent interest to us. Other cases of sampling-scale dependent differences in the measured accumulated plant AGB could be mentioned, deriving from experimental data not presented here. The model evaluation process should therefore include criteria to accommodate these contrasting measurement results.

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Acknowledgements

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SPATIAL VARIABILITY OF SPRING MALTING BARLEY GRAIN YIELD AND QUALITY. PART I. SUMMARY STATISTICS

Alicja Pecio
Institute of Soil Science and Plant Cultivation, Czartoryskich 8, 24-100 Pu□awy, Poland

Introduction

There are two main goals in production of malting barley; high grain yield and proper malting quality. The most important parameter of the quality is protein content in grain which should be in the range of 10,5-11,5%. Brewery needs to be provided in big homogeneous grain parcels. It is often very difficult for farmers due to soil variability of their fields. It was found before that both grain yield and its quality is influenced by soil quality and nitrogen availabity [Hector et al, 1996; Muller, 1998]. The object of the study presented in 3 parts was the spatial variability analysis of malting barley grain yield and quality on field scale accomplished with traditional statistics and geostatistical methods.

Methods

The experiments with spring malting barley were set up in Experimental Station Baborówko, Poland, in 1998 (cv. Maresi) and 1999 (cv. Brenda) on production fields, covering 7,43 ha and 8,79 ha, respectively. On the area of the fields five complexes of agricultural suitability: good wheat complex, very good rye complex, good rye complex and weak rye complex were found. Soil samples for mineral nitrogen content were collected early spring before barley sowings in joints of 24 x 24 m geostatistical grid. Grain samples for spatial variability of yield and protein content were collected at maturity of barley from the area of 1m^2 in joints of the grid.

Results

In the field of 1998 there was much bigger variability in grain yield and protein content than in 1999 (tab.1). In 59% of sampling points yield of 401-500, 27% - >500, 12% - 300-400 and only 2% <300 g m^{-2} was found. In the other year 35%, 31% and 19% points yielded in the ranges 401-500, 300-400 and <300, respectively, 10% showed yield bigger than 500 g m^{-2}. Only 29% of grain samples in 1998 showed protein content acceptable for brewery. The most of them (52%) included more and 19% less than the norm. In 1999 only 14% samples fulfilled the norm and 85% had not enough protein.

Table 1. Number of samples with different grain yield and protein content

Grain yield g m^{-2}	Count		Grain protein content %	Count	
	1998	1999		1998	1999
>500	35	11	>11,5	67	-
401-500	77	37	10,5-11,5	38	15
300-400	16	33	<11,5	25	91
<300	2	25			

Barley grain yields in 1998 were higher than in 1999 (tab.2). Both grain yield and protein content were differentiated by soil quality in terms of soil complex and mineral nitrogen content (tab.2, 3). However it should be considered that the averages in tables were related to number of samples.

In 1998 42% grain samples were picked up from the good wheat soil complex and 25% and 26% on good and very good rye complexes, 7% from weak rye complex (tab.2). The soils in the field in 1999 were poorer: only 6 % was covered by soil of good wheat complex, 42% by very good rye complex, 25% and 24% by good and weak rye complexes, 6% by very weak rye complex. The best yields were found on good wheat, very good rye and good rye soil complexes. Low average yield on good wheat complex in 1999 was probably due to small number of samples. Protein content only in 1998 fulfilled the brewery norm. The averages on good wheat and very good rye complexes were the most adequate.

Table 2. Grain yield and protein content as influenced by soil complex of agricultural suitability

Soil complex	Count		Grain yield (g m^{-2})		Protein content (%)	
	1998	1999	1998	1999	1998	1999
Good wheat	55	6	478,1 a	289,7 cd	11,6 b	10,1 a
Very good rye	33	44	482,9 a	414,1 a	11,5 b	10,0 a
Good rye	34	26	452,4 ab	382,7 ab	12,1 ab	9,9 a
Weak rye	8	25	406,3 b	356,6 bc	12,8 a	9,8 a
Very weak rye	-	5	-	258,1 d		9,9 a
Average			468,2 A	378,4 B	11,8 A	9,9 B

The nitrogen content in most of the soils (56% in 1998 and 60% in 1999) was in the range 50-99,9 kg N ha^{-1}, 39% and 23% in the following years was in the range 100-150 kg N ha^{-1}; 3% of the soils contained more than 150 kg N ha^{-1} in both years and 2% and 8% included less than 50 kg N ha^{-1}.

Soil nitrogen content influenced mainly grain protein content (tab.3). There was no statistically proved relationship between barley grain yield, protein content and soil Nmin content found (tab.3). It resulted rather from the frequency of sampling points than from real values of studied characteristics. However, differentiation of grain protein averages, especially in 1998, indicates its relation with Nmin content in the soil. The most adequate for malt production were samples taken in points with middle Nmin content.

Table 3. Grain yield and protein content depending on soil nitrogen content

Soil N content kg N ha^{-1}	Count		Grain yield (g m^{-2})		Protein content (%)	
	1998	1998	1998	1999	1998	1999
>150	4	3	408,8 a	292,9 ab	12,4 a	10,3 a
100-150	51	30	482,2 a	395,5 a	11,8 a	10,0 a
50-99,9	73	64	461,9 a	385,3 a	11,7 a	9,9 a
<50	2	9	457,5 a	301,3 b	13,2 a	9,6 a
Average			468,2 A	378,4 B	11,8 A	9,9 B

Conclusions

Spring barley grain yield and protein content were differentiated by soil conditions on the area of the fields. Geostatistical analysis of spatial variability is needed for determining of field parts with high yield potential and proper malting quality.

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SPATIAL VARIABILITY OF SPRING MALTING BARLEY GRAIN YIELD AND QUALITY. PART II. GEOSTATISTICAL ANALYSIS OF GRAIN YIELD

Alicja Pecio
Institute of Soil Science and Plant Cultivation, Czartoryskich 8, 24-100 Puławy, Poland

Introduction

It is characteristic of each production field that there is a variability of chemical and physical traits, which determine variability of cereal grain yield. Knowledge of spatial variability of grain yield on the area of the field enables, by interpolation processes, its visualization in form of map [Faber 1998]. Passing through these procedures is possible with using of geostatistical tools. Geostatistical methods enable determination of spatial variability of studied characteristics and accomplish an interpolation of the characteristics values in points, where samples weren't taken.

Methods

The experiments conducted in 1998 - 1999 were set up on the fields characterized with soils of five complexes of agricultural suitability: good wheat complex, very good rye complex, good rye complex, weak rye complex and very weak rye complex. Mineral nitrogen content in the soil profile 0-60 cm ranged from 39,7 to 177,8 kg ha^{-1}in 1998 and from 36,5 to 156 kg ha^{-1} in 1999. Grain samples (130 in 1998 and 106 in 1999) for spatial variability study were collected at maturity of spring barley from the area of $1m^2$ in joints of 24 x 24 m geostatistical grid on the whole area of the fields. The points were described with geographical coordinates determined by GPS satellite receiver, according to WGS-84 system. For analytical purposes the values were recalculated to metric system.
Spatial dependence among grain yield data was characterized by semovariograms, calculated using geostatistical software package, GS+ (Gamma Design Software). Exponential models were fitted to semivariance values calculated by the program. Semivariograms plot lag distance between sample pairs at each lag distance. The semivariance is calculated as $\gamma(h)=[1/2N(h)]\Sigma[z_i-z_{i+h}]^2$, where h is the lag distance. The semivariance is expected to increase out to a distance, where spatial dependence ceases to be detectable. The main parameters of the semivariograms are nugget, sill and range. The nugget (C_o), when present, is interpreted as variability due to experimental error and other random effects. Presence of nugget suggests variability on a spatial scale smaller than that sampling distance. The range is the lag distance, beyond which samples are considered independent. The corresponding value of the semivariance at this point is termed the sill and is equivalent to the combination of the nugget effect and variability (C), attributable to spatial dependence.
The model of the semivariogram was selected on the base of determination coefficient (R^2) and minimal Residual Sum of Squares (RSS). The parameters of the semivariograms were used for the interpolation of grain yield with point kriging method, which enables visual presentation of spatial distribution of grain yield in the form of isoline map.

Results

The average spring barley grain yield in 1998 was 468,2 g m^{-2} and ranged from 215,0 to 750,0 g m^{-2}, in 1999 - 378,4 g m^{-2} ranging from 182,1 to 621,3 g m^{-2}. The coefficients of variability equaled 17,6 and 25,3 respectively.
Analysis of semivariance showed linear relationship between semivariance of barley grain yield and the lag distance in both fields (fig.1). Obtained semivariograms were characterized with R^2=0,74 and RSS=1,299E+10 in 1998 and R^2=0,89 and RSS=2,568E+11 in 1999.

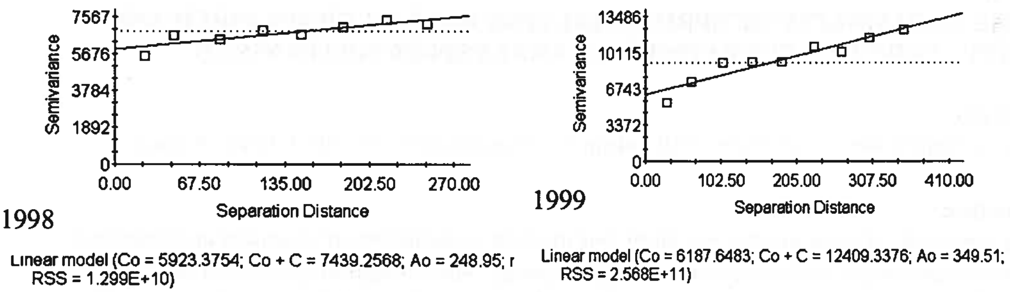

Figure 1. Isotropic semivariograms for grain yield (linear models)

Spatial variability of spring barley grain yield in 1998 was influenced mainly by nugget effect Co=5923,4 and spatial dependence C/(Co+C)=0,20. In 1999 the variation was explained partially by both nugget effect and spatial dependence of the observations: Co=6187,6 and C/(Co+C)=0,50. The results indicate big variability of barley grain yield on the distance smaller than probing interval of 24 m in 1998 and moderate variability in 1999. It might be a result of big variability of soil physical or chemical traits in both fields and close relation with barley grain yield. Błaszczyk [2001] obtained nugget ratio value 34% for grain yield of winter wheat.

The range of spatial dependence of barley grain yield equaled 249,0 m (1998) and 349,5 m (1999).

Described above parameters of linear semivariograms were used for estimation of grain yield in points, where samples weren't taken, with method of point kriging. Applied cross-validation method showed high conformity of interpolated grain yield values with measured ones and allowed to present the distribution of barley grain yield on the maps (fig.2).

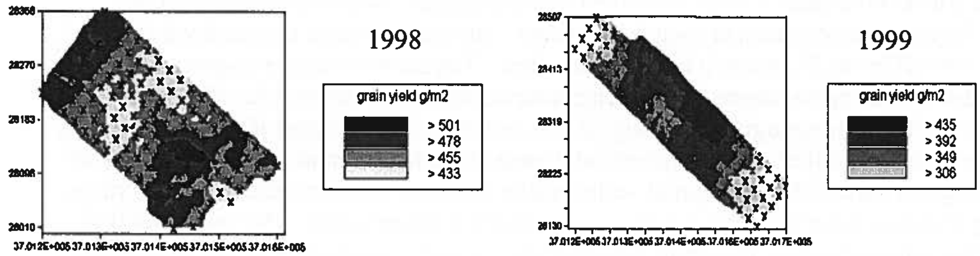

Figure 2. Maps of spring malting barley grain yield (g m^{-2}) in study years

Conclusions

Spatial distribution of spring barley of grain yield on the area of fields was found. The results indicate close dependence of spring barley grain yield on soil characteristics.

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SPATIAL VARIABILITY OF SPRING MALTING BARLEY GRAIN YIELD AND QUALITY. PART III. GEOSTATISTICAL ANALYSIS OF PROTEIN CONTENT

Alicja Pecio
Institute of Soil Science and Plant Cultivation, Czartoryskich 8, 24-100 Pu□awy, Poland

Introduction

Protein content in malting barley grain is the most important indicator of grain quality due to its effects on other malt and wort parameters. For the best results it should be in the range between 10, 5 and 11,5%. Higher values decrease the malt extractability and reduce beer quality. Grain of protein content smaller than 9% is not useful for brewery at all. Quality of barley grain is close related to soil type and nitrogen content [Timmer 1993, Muller 1988]. Distributions of grain protein content are considered heterogeneous as the result of soil variability. Knowledge of spatial variability of grain protein content may enable estimation of big field parcels of acceptable for malt production grain quality.

Methods

The experiments with spring barley conducted in 1998 - 1999 were set up on the fields characterized with soils of five different complexes of agricultural suitability. Mineral nitrogen content in the soil profile 0-60 cm ranged from 39,7 to 177,8 kg ha^{-1}in 1998 and from 36,5 to 156 kg ha^{-1} in 1999. Grain samples (130 in 1998 and 106 in 1999) for spatial variability study were collected at maturity of spring barley from the area of $1m^2$ in joints of 24 x 24 m of geostatistical grid on the whole area of the fields. The points were described with geographical coordinates determined by GPS satellite receiver, according to WGS-84 system. For analytical purposes the values were recalculated to metric system.

The analysis of barley grain protein content was done with methods of isotropic semivariance, which describes spatial variability dependence on the distance, but independent on direction variability (anisotropy). The semivariance was presented in graphical form of isotropic semivariograms, separately for each field. The models of the semivariogram were selected on the base of determination coefficient (R^2) and minimal Residual Sum of Squares (RSS). The parameters of the semivariograms (nugget, sill, range) were used for the interpolation of grain yield with point kriging method, which enables visual presentation of spatial distribution of grain yield in the form of isoline map. Interpolated values of studied characteristics were compared with actual ones using cross-validation methods.

Results

The average spring barley grain protein content in 1998 was 11,8% and ranged from 8,5% to 15,2%, in 1999 – 9,94% ranging from 8,60% to 11,0%. The coefficients of variability equaled 12,49 and 4,75, respectively.

Analysis of semivariance showed linear relationship between semivariance of barley grain protein content and the lag distance in both fields (fig.1). Obtained semivariograms were characterized with R^2=0,64 and RSS=1,12 in 1998 and R^2=0,63 and RSS=7,775E-03 in 1999 showed big meaning of nugget variance in total spatial variability of protein content.

Spatial variability of spring barley grain protein content in both years was influenced mainly by nugget effect. In 1998 Co=1,80 and C/(Co+C)=0,26, in 1999 Co=0,209 and C/(Co+C)=0,20. The results indicate big variability of barley grain yield on the distance smaller than probing interval of 24 m. It might be a result of big variability of soil physical or chemical traits and close relationship between barley grain protein content and soil properties.

The range of spatial dependence of barley grain yield equaled 215,9 m in1998 and 265,1 m in 1999. Longer semivariogram range causes wider area of interpolated values belonging to the classes separated by isolines on the map. On the obtained linear semivariograms the parameter was estimated arbitrarily on the base of distance to last class (lag). The values outside of the obtained range are determined with accidental variability and they equal statistical variance s^2.

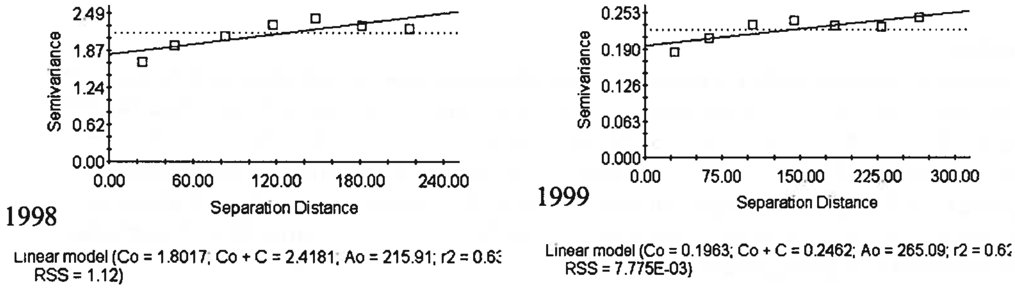

Figure 1. Isotropic semivariograms for grain protein content (linear models)

Described above parameters of linear semivariograms were used for estimation of grain yield in points, where samples weren't taken, with method of point kriging. Applied cross-validation method showed high conformity of interpolated grain yield values with measured ones and allowed to present the distribution of barley grain yield on the maps (fig.2).

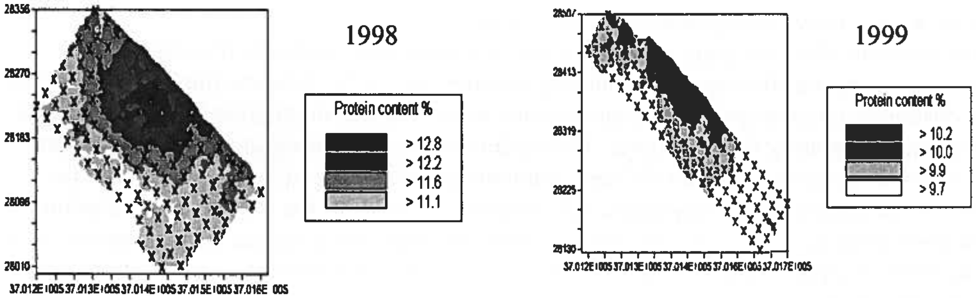

Figure 2. Maps of spring barley grain protein content (%) in study years

Conclusions

Using geostatistical methods makes possible to determine the spatial distribution of barley grain protein content. It enables to estimate the field parcels with adequate grain quality for brewery.

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MULTIDISCIPLINARY PRECISION FARMING STRATEGIES TO INCREASE PROFITABILITY AND SUSTAINABILITY IN WESTERN GREAT PLAINS IRRIGATED AGRICULTURE OF THE UNITED STATES.

Shaver T.M., Khosla R., Westfall D.G., and Gangloff W.G.

Colorado State University, Department of Soil and Crop Sciences, Fort Collins

CO. (USA) 80523-1170.

Introduction

The Western Great Plains region of the United States is among the leaders in the nation's crop production. The average corn grain yield of this region usually exceeds the national average. However, such high grain yield production comes at a cost of applying significant quantities of various agricultural inputs, i.e. irrigation, nutrients, and pesticides. Corn (*Zea mays L.)*, a major crop in this region is grown in rotation with high value crops such as onions (*Allium cepa*). These crops require a high level of inputs. In traditional farming systems, producers attempt to apply these inputs at a uniform rate across a given field. However, due to inherent spatial variability in the field, not all areas require the same amount of inputs. Intuition suggests that precision agriculture and site-specific management of crop production inputs to match the variability that occurs in the field will solve many of the problems cited above. The overall goal of this multi-site and crop, multi-disciplinary, multi-agency research and technology transfer project is to increase farm profitability while enhancing environmental protection by developing precision agriculture strategies that are compatible with farming practices in the irrigated western Great Plains region of the United States.

Materials and Methods

Several different disciplines are conducting projects that combined make up this Precision Agriculture Project. The Soil and Crop Sciences unit is studying the management zone approach as a decision/support tool for variable rate application of nitrogen (N) fertilizer. This approach may maintain and/or improve crop yields, and potentially reduce leaching of nitrates to the groundwater. Four approaches of defining production level management zones within farmer's fields are currently being developed and compared. The Pest Management unit is determining if treatment decisions for locally important fungal pathogen and arthropod pests of irrigated crops on a management zone basis will improve pest management benefits relative to treatment decisions made on a whole-field basis. The Weed Management unit is studying if site specific weed management based on management zones reduces herbicide use while maintaining weed control comparable to uniform weed management treatments. They are also investigating the potential use of new, high-resolution multi-spectral imagery to distinguish weed populations to support post emergence weed management decisions. The USDA-ARS unit is determining if remote-sensing technology can be used to monitor in-season crop nitrogen stress to synchronize N application when and where needed by an irrigated crop within a given field. The USDA-ARS unit is also working on improving water use efficiency by scheduling irrigation with crop and soil water temporal needs in production management zones. There is also an effort to provide training in the design, implementation, and analysis of field scale farm trials using precision farming technology. Promoting models and templates for data sharing, and demonstrating the applicability of precision farming technologies is a primary concern of this project.

Results

A preliminary study was conducted in 1998 and 1999 by a multi-disciplinary and multi-agency precision agriculture team made up of scientists, extension specialists, and growers. The preliminary study investigated if management zone maps based on soil color from aerial photographs, topography, and the farmers' management experiences can be an effective alternative to grid soil sampling in developing variable rate fertilizer maps for N application for irrigated corn. The study revealed that there was no significant difference in corn yields between the treatments, indicating management zone based variable rate application is as effective as grid based. However, the cost of implementing the management zone based variable rate application is much less thereby making it a more profitable and practical alternative to grid soil sampling. In 1999, the conventional farmer practice of uniform application of nutrients would have applied a total of 10,497 kg N (167 kg N ha^{-1}) based on the soil test N-recommendation for the most productive soil in the field. The management zone based variable rate application reduced N loading by a total of 805 kg N over 63 hectares (i.e. a reduction of 12.8 kg N ha^{-1}). A similar management zone based nutrient application on 1000 hectares of land would reduce N loadings by 12,800 kg, which translates into a saving of $5362 USD. In 1998 and 1999, we also investigated the management zone concept with pre-plant corn herbicides. Weed counts generally were lower in the zone-managed strips than in the farmer-managed strips of each field (each field contained 6 side-by-side comparison strips through the length of the field). This is an economical and environmental advantage to the producer and the agro-ecosystem. Likewise, knowing the spatial distribution of insect-pest infestation may provide the opportunity to target management efforts to those areas where pest action thresholds are exceeded. We have found that crops in adjacent fields influence insect distribution thereby raising the possibility that the "management-zone" concept holds potential for selective, spatially dependent insect management.

Conclusions

This project is enhancing the farming communities' capacity to integrate site specific technologies into their farming systems. Our project's preliminary data collection, analysis, and technology transfer initiatives are allowing us to begin to make site specific yield predictions based on the interaction of natural resources on different farmers' fields. Development and demonstration of management zones for variable rate nutrient, insecticide, miticide, herbicide, fungicide, and irrigation water management will be a valuable tool for decision support systems. Economic and environmental cost benefit analysis of precision farming will provide greater incentive to farmers for adoption of precision technologies into their operation. The use of management zone systems to better manage the inherent variability of farm fields should reduce environmentally sensitive agricultural inputs, maintain or increase grain production, increase net profit, and enhance efficiency of agricultural inputs.

APPLICATION OF A GEOREFERENCED SOIL DATABASE IN A PROTECTED AREA OF MIGLIARINO SAN ROSSORE MASSACIUCCOLI PARK

Silvestri N.[1], Risaliti R.[2], Ginanni M.[2], Accogli D.[1], Sabbatini T. [1], Tozzini C.[1]

[1] Department of Agronomy and Agro-ecosystem Management of University of Pisa , via S. Michele degli Scalzi, 2 - 56124 Pisa (Italy); [2] The University of Pisa "E. Avanzi" Agro-Environmental Interdepartmental Research Centre, via Vecchia di Marina, 6 – 56010 Pisa (Italy)

Introduction

To create a spatial database for the sustainable management and soil use compatible with environment protection, a territorial research was carried out and is still in progress inside the Regional Park of "Migliarino - San Rossore - Massaciuccoli". This area includes the Massaciuccoli lake and a large marshland. In the last years the lake trophic conditions have been described as on the eutrophic-hypertrophic border, and a monitoring program concerning water quality is in progress.

In order to reduce the risk of non-point source pollution by nitrate and phosphate, the research has been extended to soil quality. In the course of the study the relationships among fertilization management and soil and water quality were dealt with. As a matter of fact, the evaluation of the optimum relationships between agricultural management and environmental conservation is one of the main topic inside protected areas.

The soil campaign started in 1998 and is still in progress: in the first year soil samples were collected near to the Massaciuccoli lake, in "Migliarino" and "Padule Meridionale" estates, in 1999 in "Coltano" estate, in 2000 in "San Rossore" estate and in 2001 the area of "Tombolo" estate was investigated.

Methods

The project aimed to guarantee technical attendance to the farmers of the park. The starting point has been the physical-chemical characterization of lands; in order to make that, we have been taken advantage of the possibilities offered from integrated use of information technologies as: Global Positioning System, Geographical Information System and geo-statistic software.

Fig. 1 – Grid of sampling

The geographical reference was a technical regional map (1:5000 scale). Samples were collected at the vertex of square 141 m long (Fig. 1). The virtual grid was identified on the map by means of Arc-View GIS. The geographic coordinates of sampling points (waypoint) were located on GPS (Pathfinder Pro XRS by Trimble) and recorded working in real time. The differential corrections are assured by a satellite differential receiver under subscription to a differential service (RACAL). A data dictionary allowed to note further information concerning the soil (crops, moisture, owner, etc).

The selected soil parameters were:

- particle-size analysis, performed according to the pipette method, following the U.S.D.A. classification scheme,

- pH, determined in water (soil water ratio 1:2.5) by means of the potentiometric method,
- organic carbon, by dichromate oxidation method followed by colorimetric determination,
- total nitrogen, by Kjeldahl method,
- plant available phosphorus, extracted according to Olsen method ($NaHCO_3$ extracting solution) and determined by means of colorimetric analysis,
- exchangeable potassium, extracted by means of a neutral 1N NH_4OAc solution and determined by flame photometer.

Results

Analytical results and waypoints were archived. This note concerns with the soils of a farm placed in "Tombolo" estate, where 137 samples were collected and analyzed.
A first synthesis led us to the publication of a thematical map concerning soil organic matter (Fig. 2). The punctual information was converted into an areal information by means of IDW interpolation model (Inverse Distance Weighted). Small scale maps reporting points of sampling and analytical results were printed for each farm. These maps can be easily consulted in order to manage fertilization programs and to facilitate the agronomic choices.

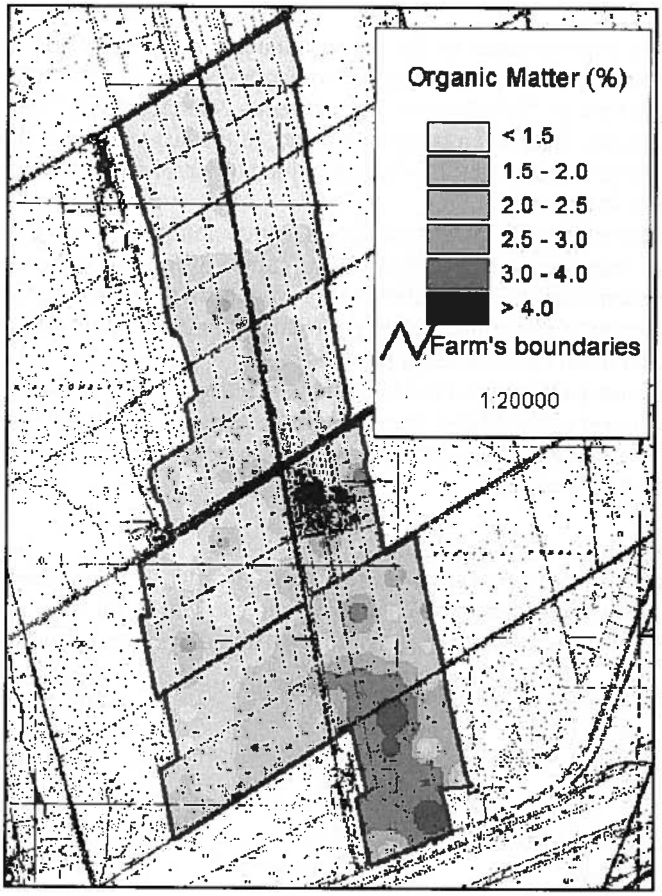

Fig. 2 Organic matter content

Conclusions

The regularity of the outline of sampling facilitates the passage from punctual information to space distributed information, that is of fundamental importance to evaluate the agronomic characteristics of lands.
Farmers themselves have been involved in this study participating to the analysis expense, giving information about soil use, cooperating to the selection of the chemical and physical parameters to be analyzed.

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ESTIMATION OF THE SOIL HEAT FLUX USING REMOTELY SENSED VARIABLES

Verhoef A. [1]
1 Department of Soil Science, The University of Reading, Reading RG6 6DW, UK

Introduction

Surface soil heat flux, G, is an important term of the surface energy balance (SEB) equation ($R_n = H + LE + G$), particularly for (semi)-arid regions and over a diurnal time scale. The SEB describes how net radiation, R_n, is partitioned between sensible heat flux, H, latent heat flux, LE, and G. Accurate quantification of the SEB fluxes for an agricultural area is important in understanding a crop's energy and water use. Field-averages of H and LE are relatively easy to obtain using current micro-meteorological techniques. However, existing methods used to determine G can only provide in-situ values (valid for an area of less than 1 m^2). A possible solution for finding area-average values, $\overline{G}$, is to use $\overline{G} = cR_n$, with c = 0.1-0.4. However, this approach provides misleading estimates of the diurnal course of G, as a result of the time lag between R_n and G. Furthermore, c will usually be unknown. A more promising approach is to use radiometric surface temperature, T_s (e.g. Wang & Bras, 1999). If an area-averaged T_s is available, e.g. from IR radiometry, and assuming $T_s = T_{soil}$ (z = 0), these methods could in principal be used to determine $\overline{G}$. However, estimates of thermal diffusivity, D_h, and heat capacity, C_h, are required to derive $\overline{G}$ from T_s. Currently, these can only be derived from in-situ measurements of soil physical variables. This paper will describe a method which calculates area-average estimates of thermal soil properties and G, from a combination of timeseries of T_s and night time values of R_n.

Methods

The experiment was performed over bare soil at the University of Reading's Crop Research Unit, located in Sonning, Berkshire, UK. T_s was back-calculated from longwave upwelling radiation as measured by a 4-component radiometer (Kipp & Zn, the Netherlands). A NRlite net radiometer (Kipp & Zn, the Netherlands) was employed to give night-time values of R_n as the 4-component radiometer gave faulty readings when dew occurred. All instruments were mounted at 3.8 m. The soil physical set-up comprised 16 pairs of thermistors (at depths, z, of 0.02 and 0.05 m), installed in a regular grid over a 50 by 50 m plot, to measure soil temperature, T_{soil} (z). At each gridpoint, a Thetaprobe (Delta-T Devices, UK) was installed at a depth of 0.05 m, to measure soil moisture content, θ, of the topsoil. The diurnal courses of T_{soil}(0.02) and T_{soil} (0.05) were used to calculate in-situ values of D_h using the Arctangent Method (Verhoef *et al.*, 1996) whereas C_h was estimated from dry bulk density and θ. In-situ values of G were calculated using the Exact Method (Horton & Wierenga, 1983) by first performing a Fourier Series analysis (20 harmonics) on T_{soil} (z=0.02 m). This method used in-situ estimates of $C_h\sqrt{D_h}$, also called the thermal inertia. Similarly, 'remote' values of G were calculated using;

$$G_{remote}(t) = \left(C_h\sqrt{D_h}\right)_{remote}\sum_{n=1}^{M} A_{0n}\sqrt{n\omega}\sin[n\omega t + \phi_{0n} + (\pi/4)] \quad (1)$$

This involves applying a Fourier Series analysis (with a total of M (=20) harmonics) on the diurnal course of T_s. Here A_{0n} (°C) and ϕ_{0n} are the amplitude and the phase shift of the n^{th} harmonic at z = 0, and ω is the radial frequency (rad s^{-1}). Remote values of $C_h\sqrt{D_h}$ were calculated using a manipulated version of a formula given by Brunt (1932), used to calculate the fall in ground temperature during a clear night:

$$\left(C_h\sqrt{D_h}\right)_{remote} = 2\overline{R_n}\sqrt{\Delta t}\,/\,\Delta T\sqrt{\pi} \quad (2)$$

where $\overline{R_n}$ is the average net radiation between sunset and sunrise (W m^{-2}), Δt is the time between sunset and sunrise (s) and ΔT is the decrease in ground temperature between sunset and sunrise (°C). Data of 8 nights were appropriate for use in Eq. 2 (cloudless and $u < 0.5$ m s^{-1}).

Results

Fig.1 shows the thermal inertia for 5 locations, and the average, as measured with in-situ methods over a 2-month period. Fig. 2 shows the dependence of in-situ thermal inertia on θ. Also shown are $\left(C_h\sqrt{D_h}\right)_{remote}$ and back-calculated values of $\left(C_h\sqrt{D_h}\right)$.

Figure 1

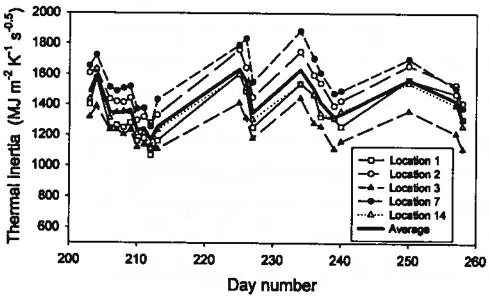


Figure 2

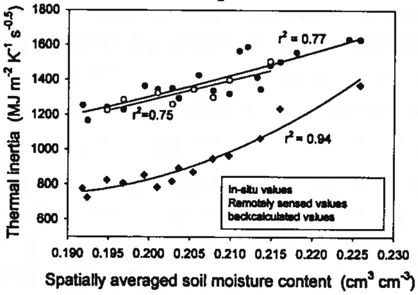
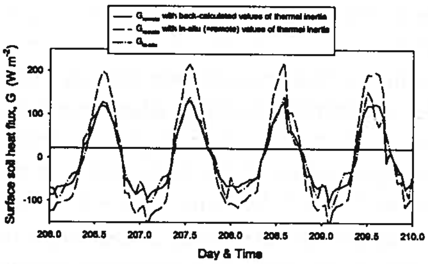


Fig. 3 gives the diurnal course of $G_{\text{in-situ}}$ and G_{remote} calculated using remote and back-calculated values of $\left(C_h\sqrt{D_h}\right)$, respectively. The latter were obtained by comparing $G_{\text{in-situ}}$ and G_{remote} between 12.00-14.00 hrs.

Discussion

The method used to calculate $\left(C_h\sqrt{D_h}\right)_{remote}$ gives values, and a θ-dependence, which are very similar to $\left(C_h\sqrt{D_h}\right)_{in-situ}$. This illustrates that Eq. 2 can be a powerful tool in determining thermal inertia remotely. Furthermore, it could provide a way of determining θ indirectly. However, if $\left(C_h\sqrt{D_h}\right)_{remote}$ is used for estimation of G using Eq. 1, G_{remote} considerably overestimates $G_{\text{in-s}}$

Figure 3



Good agreement can be obtained between G_{remote} and $G_{\text{in-situ}}$, but only if $\left(C_h\sqrt{D_h}\right)_{remote}$ is lowered significantly (back-calculated values in Fig. 2). This is possibly caused by the fact that soil moisture content close to the soil surface deviates considerably from θ at 0.05 m. Furthermore, uncertainties related to the interpretation and correction of radiative temperature (used here to estimate T_{soil} (z=0)) may also cause the apparent discrepancy between in-situ and remote estimates of $\left(C_h\sqrt{D_h}\right)$ and back-calculated values of $\left(C_h\sqrt{D_h}\right)$, respectively. Solving these problems will be the next step in this research.

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LEAF CHLOROPHYLL *a+b* AND CANOPY LAI ESTIMATION IN CROPS USING R-T MODELS AND HYPERSPECTRAL REFLECTANCE IMAGERY

Zarco-Tejada, P.J. [1], **Haboudane, D.**[2], **Miller, J.R.**[2,3], **Tremblay, N.**[4], **Dextraze, L.**[4]

[1] Grupo de Óptica Atmosférica (GOA-UVA), Dpto. de Óptica y Física Aplicada, Escuela Técnica Superior de Ingenierías Agrarias, Universidad de Valladolid, Spain
[2] Centre for Research in Earth and Space Science (CRESS), York University, Canada
[3] Department of Physics and Astronomy, York University, Toronto, ON, M3J 1P3, Canada.
[4] Agriculture and Agri-Food Canada Research Branch, Horticulture Research and Development Centre, 430 Blvd. Gouin, St. Jean-sur-Richelieu, Quebec J3B 3E6, Canada

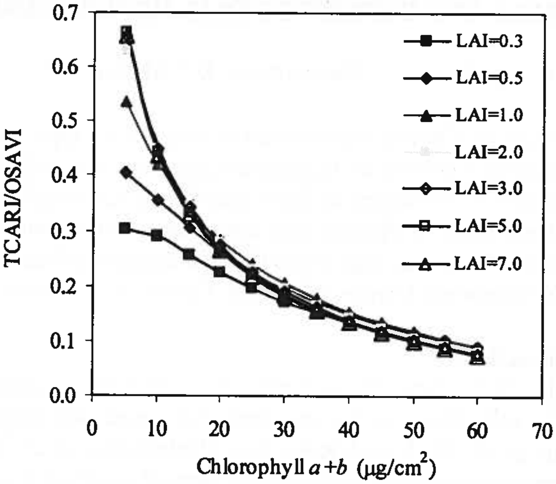
Introduction

Recent studies have demonstrated the usefulness of optical indices from hyperspectral remote sensing reflectance in the assessment of vegetation biophysical variables both in forestry (Zarco-Tejada *et al.,* 2001) and agriculture (Haboudane *et al.,* 2002). Those indices are, however, the combined response to variations of several vegetation and environmental properties, such as leaf area index (LAI), leaf angle distribution function (LADF), leaf chlorophyll *a+b* content (C_{ab}), canopy shadows, background reflectance, and illumination-observational conditions. Of particular significance to precision agriculture is C_{ab}, which is related to the nitrogen concentration and serves as a measure of crop response to nitrogen application. We present a modeling approach to predict C_{ab} from hyperspectral remote sensing while minimizing soil reflectance (ρ_s), shadow effects, and considering LAI variations. This method was developed using simulated data, followed by assessment using hyperspectral airborne imagery. Simulations consisted of leaf and canopy reflectance modeling with PROSPECT and SAILH radiative transfer (RT) models and developing optical indices that minimize bi-directional and soil background effects.

Methods

The study area is an experimental site of the *GEOmatics for Informed Decisions* (GEOIDE) project for precision agriculture, Agriculture and Agri-Food Canada, in Quebec, Canada. Corn was grown on four adjacent experimental fields with four experimental blocks, each containing four 20 x 20 m plots of 27 rows, to which the nitrogen fertilizer treatments were randomly assigned. Nitrogen fertilizer treatments were supplied in two applications, at the time of seeding and topdressing six weeks later, comprising a total of 64 experimental plots. Four major treatments were supplied: no fertilization (A), intermediate fertilization with uniform nitrogen application at top dressing (B), variable nitrogen application at top dressing (C), and over-fertilization (D). Hyperspectral images were acquired by the *Compact Airborne Spectrographic Imager* (CASI) during summer 2000. At the same time ground truth measurements included (i) leaf sampling for determination of leaf C_{ab}, (ii) corn leaf reflectance (ρ) and transmittance (τ) measurements using integrating sphere and spectrometer, (iii) LAI measurements using the LAI-2000 instrument, and (iv) crop growth measures. Leaf samples from 4 plants per experimental unit were used for analysis of C_{ab}. CASI airborne images were collected using a multispectral mode of operation, with 1 m spatial resolution and 7 spectral bands (489.5, 555.0, 624.6, 681.4, 706.1, 742.3, and 776.7 nm), and a hyperspectral mode, with 2 m spatial resolution and 72 channels covering the spectral range 408 to 947 nm. The processing of CASI imagery included radiance calibration, atmospheric corrections and reflectance retrieval, removal of aircraft motion, geo-referencing, and flat field spectral anomaly removal. Leaf optical properties were simulated with PROSPECT model for radiation fluxes between 400 and 2400 nm to relate biochemistry and scattering parameters to ρ and τ spectra with a leaf structure parameter (N) derived from laboratory measurements, and values of C_{ab}, water thickness C_w, and dry matter content C_m. Canopy reflectance were simulated using SAILH turbid-medium model, with inputs such as LAI, LADF, ρ, τ, and ρ_s. MCARI *(Modified Chlorophyll Absorption Index)* was modified to minimize background effects (TCARI), calculated as TCARI = $3\cdot[(R_{700}-R_{670})-0.2\cdot(R_{700}-R_{550})\cdot(R_{700}/R_{670})]$. To minimize soil effects on reflectance, TCARI was combined with OSAVI (*Optimized Soil-Adjusted Vegetation Index*) calculated as OSAVI = $[(1+0.16)\cdot(R_{800}-R_{670})/(R_{800}+R_{670}+0.16)]$ and used in a *scaling-up* approach with PROSPECT and SAILH RT models to study its relationship with C_{ab} and LAI (Figure 1).

Figure 1. TCARI/OSAVI as a function of Cab and LAI



Results

Simulated data show that TCARI/OSAVI reflectance index is very sensitive to C_{ab} variations and resistant to changes of LAI. A predictive equation to estimate leaf C_{ab} from the combined optical index TCARI/OSAVI derived from canopy reflectance was developed. This relationship was evaluated by application to hyperspectral imagery from corn plots. Images of predicted leaf C_{ab} were generated (Figure 2), showing retrieval accuracies of RMSE = 4.6 $\mu g/cm^2$. Assessment showed chlorophyll variability over crop plots with various levels of nitrogen fertilization, and revealed an excellent agreement with ground truth, with a correlation of $r^2=0.81$ between estimated and measured C_{ab}.

Figure 2. CASI hyperspectral reflectance image of study plots at 2 m resolution (left) and C_{ab} estimation (right)

Conclusions

Leaf and canopy RT models PROSPECT and SAILH were employed to simulate C_{ab} and LAI effects on crop canopy reflectance. A methodology for predicting C_{ab} status from hyperspectral reflectance data, based on combining optical indices through *scaling up*, was developed and tested with airborne CASI hyperspectral reflectance data of 2 m spatial resolution over a corn crop. This method was used to investigate the effects of non-photosynthetic materials and LAI on the retrieval of leaf chlorophyll at the canopy level. To address these issues, we transformed the MCARI optical index, called TCARI, more sensitive to low C_{ab} values and resistant to vegetation non-photosynthetic materials. An index that minimizes soil effects (OSAVI) was integrated with TCARI to remove LAI influence on C_{ab} predictions through RT modeling. The study shows that C_{ab} is correlated with TCARI/OSAVI which is insensitive to LAI from 0.5 to 8.

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Special session on nitrogen and management

USE OF A CLHOROPHYLL METER TO PREDICT SIDEDRESS NITROGEN REQUIREMENT OF WINTER CEREALS

Arregui L.M.[1] , Merina M.[1] , Irañeta I.[2], Lafarga A.[2] , Baroja E.[1], Quemada M.[3]

1 Dpto. Producción Agraria. Universidad Pública de Navarra. 31006 Pamplona, (Spain)
2 Instituto Técnico y de Gestión Agrícola de Navarra. Ctra. del Sadar 31006 Pamplona, (Spain)
3 Dpto. Producción Vegetal: Fitotecnia. E.T.S. Ingenieros Agrónomos. Universidad Politécnica de Madrid. 28040. Madrid (Spain).

Introduction

Leaf green color can be used as an indicator of the N status of the crop, when it is well correlated to chlorophyll and N content of a plant (Yadava, 1986). Small and portable meters have been developed to make instant, non-destructive readings of color in plant leaves. Therefore, tests based on these readings can be used to make N fertilizer recommendations for crops when other site factors are not limiting (Piekielek et al., 1995). Early-season tests allow different N management strategies, but its accuracy in identifying fields that will respond to sidedress N applications may be low. Late-season plant tests usually present a good correlation with crop yield, but it is to late to correct N deficiency. Reeves *et al.*, (1993) tested a chlorophyll meter for wheat, and found that it could be used in relative early stages (GS-30) as a predictor of grain yield. The aim of this work was to determine a possible application of a hand-held chlorophyll meter (N-Tester®) as a predictor of nitrogen status and grain yield in winter cereals under rainfed Mediterranean conditions.

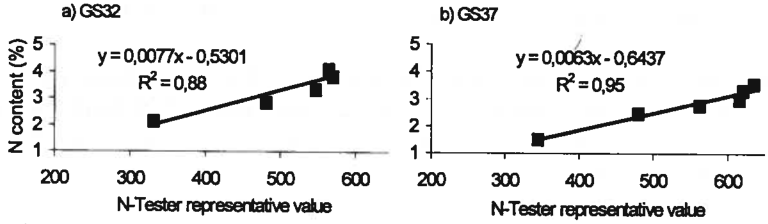
Methods

To achieve our goal, a total of fifteen field trials were established at different locations in Navarra (Spain), offering a variety of soil and meteorological conditions. The experiments were sown with either wheat (*Triticum aestivum* L.; cv. Marius and Soissons) or barley (*Hordeum vulgare* L.; cv. Sunrise, Hispanic and Puffin) in November 1999 and 2000. In all trials, plots (4 x 10 m) were distributed to five different nitrogen fertilizer levels (0, X-80, X-40, X, X+40, being X the recommended rate for the area) in a completely randomized block design with three replications. Nitrogen as ammonium sulfonitrate was hand broadcast at GS-20 and GS-30. Development stages were monitored according to the Zadocks-Chang-Konzak scale. Readings with the portable meter of chlorophyll N-Tester® (Hydro-Agri) were carried out at first node (GS-31), second node (GS-32), appearance of flag leaf (GS-37), and at the end of flowering (GS-69). For each treatment, development stage, and replication, the representative value was obtained as the average of 30 readings taken in the next to the last fully extended leaf. At each of the development stages mentioned before, two samples (0.25m^2) of each plot were harvested at ground level. Plant material was dried (48 h at 65 ºC), weighed and analysed for N content by Kjeldahl's method (AOAC, 1990). In July, 1.5 m-central fringe was harvested from each plot and grain yield (12% humidity) was recorded. The N-Tester® representative values were correlated to the values of N content at each development stage, and to the grain yield.

Results

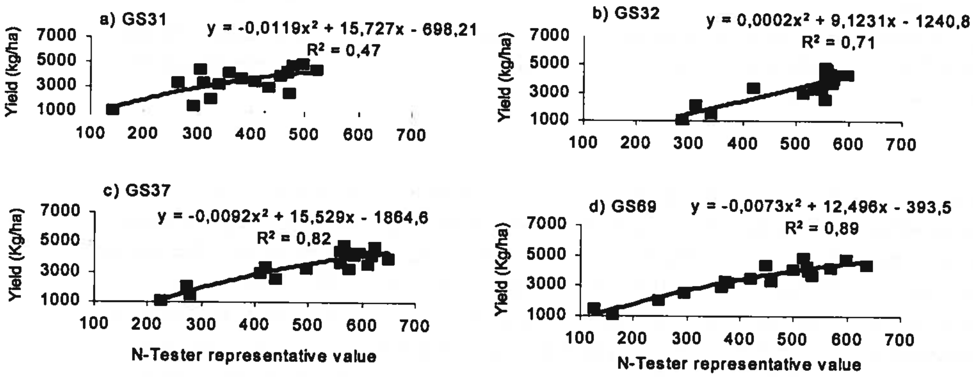
In most experiments (75%), we found a positive crop response to N fertilizer level, and a significant correlation ($R^2 > 0.8$) between the N-Tester® representative value and total N content (Fig. 1). The goodness of the correlation was independent of crop species, variety and development stage. The experiments where the correlation was not significant ($R^2 < 0.6$), were characterized by a low response to N fertilizer. That suggests that N-Tester® can be used as a plant N test when other site factors beside N availability are not affecting leaf chlorophyll levels.

Figure 1. Relationship between N-tester representative value and wheat nitrogen content at two different development stages: a) GS32, and b) GS37.



At early development stages (GS-31) we did not find a good relationship between N-Tester® representative values and grain yield, but after GS-32 the relationship between both variables improved considerably. In the experiments where a positive crop response to N fertilizer level was found, the relationship between N-Tester® representative value and grain yield improved with the development stage of the crop (Fig.2).

Figure 2. Relationship between N-tester representative value and grain yield for wheat at four different development stages: a) GS31, b) GS32, c) GS37, and d) GS69.



Conclusions

In most cases, N-Tester® readings presented a significant relationship with either N status of the crop or grain yield. In most of the Mediterranean region where spring weather conditions vary greatly, prediction of grain yield based on measurements of the nutritional status of the plant in early stages will be always uncertain. However, in humid or irrigated areas where N application may be justified in late development stages, N-Tester® could be used to adjust N fertilizer rates.

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GENOTYPIC VARIABILITY OF NITROGEN REMOBILISATION IN WHEAT

A.Barbottin, MH. Jeuffroy & C. Bouchard
UMR d'Agronomie INRA INAPG, 78 850 Thiverval-Grignon, France.

Introduction:
Grain protein content (GPC) is a major characteristic to the economic value of wheat in northern Europe. The GPC can be expressed as the ratio of grain nitrogen content versus grain biomass at harvest. Grain nitrogen content depends on the amount of nitrogen accumulated in the crop before anthesis and translocated to the grain during grain filling, and nitrogen accumulated in the crop from anthesis until harvest. Many studies have shown that genotypes differ in nitrogen uptake at anthesis and at harvest (Dhugga and Waines, 1989), and in the amount of nitrogen remobilised to the grains (Van Sanford and Mac Known, 1987). In the dynamic crop simulation model Azodyn, which simulates GPC at harvest, the amount of nitrogen remobilised is linearly linked to the amount of nitrogen in the crop at anthesis (Jeuffroy *et al.*, 2000). This model was calibrated and evaluated for one cultivar, Soissons. In order to adapt Azodyn to several genotypes, our aim is to analyse the genotypic variability of this relationship among several genotypes cultivated in various environments.

Methods:
A multilocal trial was carried out in 2000-01, in seven INRA experimental locations that differ in climate (temperature, rainfall), soil texture and soil nitrogen supply (Grignon, Lille, Mons, Rennes, Dijon, Le Moulon, Clermont-Ferrand and Toulouse). Various crop management were applied, including reduced nitrogen fertilisation, and no fungicide application, and optimum management. A set of ten genotypes was chosen for their GPC values (high, medium and low), their sensitivity to limiting factors (nitrogen, diseases) and for their precocity (Arche, Camp-rémy, DI9714, Hyno-précia, Isengrain, Oratorio, Récital, Renan, Rumba and Soissons). Every genotype was grown in each location for the different levels of limiting factors.

For each treatment (genotype*location*crop management), both biomass and nitrogen uptake were measured for the aerial parts of the crop at anthesis and harvest, and grain yield and protein content were determined at harvest. The amount of N remobilised was estimated as the difference between the amount of N in the crop at anthesis and the amount of N in the vegetative organs at harvest. In each location, notations determined disease intensity.

Results

- Estimation of the remobilisation efficiency for the cultivar Soissons.

The relation between nitrogen uptake at anthesis and nitrogen remobilised at harvest has been computed in the model for the genotype Soissons. We first evaluated for this genotype and for the disease-free experimental situations, the translocation efficiency. It was estimated as the slope of the regression of nitrogen remobilised (NR) to the grain versus nitrogen uptake at flowering (NF) (NR= f (NF)). The intercept of the relation was no significantly different from 0. Thus, the translocation efficiency was estimated at 0.70 ± 0.04 (on the order of the estimate used in the model Azodyn). A cross validation allowed to estimate the root mean square error of prediction of the equation at 8.12 $kg.ha^{-1}$, which is in the order of the experimental error.

- Influence of genotype effect on the remobilisation efficiency.

In order to improve the robustness of the estimate for nitrogen remobilisation among genotypes, the relation (NR= f (NF)) was tested against the results of the multilocal trials for the other nine genotypes in the situation without diseases, as this factor is known to modify nitrogen translocation. The results are presented here for the nine other genotypes (Figure 1), which highly differ in grain protein content (12.26 % for genotypes Renan, 11.34% for Camp-rémy and 10.38% for Isengrain), and in sensitivity to foliar diseases (resistant such as Renan and Oratorio, sensitive such as Camp-rémy, Récital and Isengrain).

The relation (NR= f (NF)) obtained for the genotype Soissons correctly predicts the remobilisation for the nine other genotypes in a wide range of environments. This result was further confirmed by non-significant genotypic effect on the slope of the NR= f (NF) function.

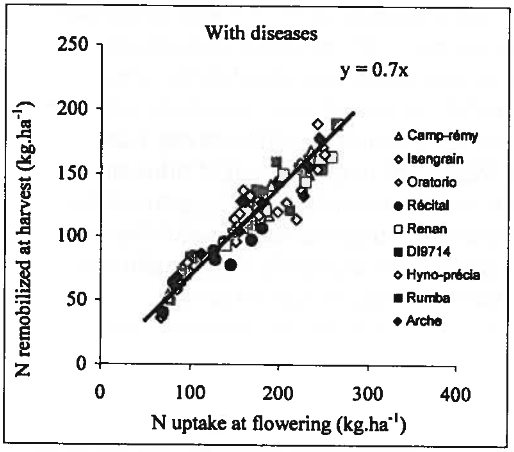

Figure 1: N remobilisation versus nitrogen uptake at anthesis in different disease-free environments of a multilocal trial, and linear relation calculated on the genotype Soissons.

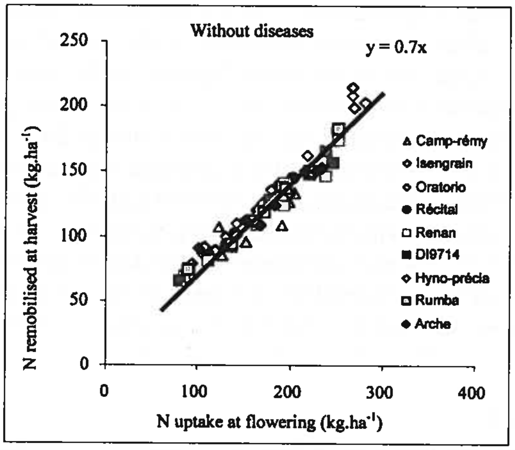

Figure 2: N remobilisation versus nitrogen uptake at anthesis in environments with diseases of a multilocal trial and linear relation calculated on the genotype Soissons.

➢ Influence of disease effect on the remobilisation efficiency.

The relation between N remobilised at harvest and nitrogen uptake at flowering is still robust in case of foliar diseases (Figure 2). As for disease-free environments, the genotype is found to have no significant effect on the relation. The root mean square error of prediction was of 12.6 $kg.ha^{-1}$ *i.e.* greater to that of disease-free cases (10.1 $kg.ha^{-1}$). No clear relation between genotype sensitivity to diseases and prediction error could be found, but the rate of remobilisation seems to have been overestimated for those genotypes in case of high disease level.

Conclusion

Genotypes and environments seem to have no significant effect on the slope of the NR= f (NF) relationship for these as for other trials carried out at Grignon. The non-significant effect of genotype on the remobilisation efficiency allows us to use the same parameter for various genotypes in the model Azodyn. Also it indicates that the observed differences in the amount of nitrogen remobilised among genotypes is manly linked to the variability in their nitrogen uptake at anthesis. Moreover, although the remobilisation efficiency is similar among genotypes and environments, the proportion of grain nitrogen due to remobilisation is highly variable. An effect of diseases on the remobilisation efficiency occurred and need to be investigated more thoroughly. The remobilisation of disease-resistant varieties could be less affected by the occurrence of disease than disease-sensitive varieties.

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LEAF AREA INDEX RELATIONSHIPS IN WINTER WHEAT CULTIVARS
II. EFFECS OF NITROGEN FERTILISATION

Bavec F.[1], Vukovic K.[2], Jakop M.[3], Bavec M.[4], Grobelnik-Mlakar S.[5]

[1,3,5] University of Maribor, Faculty of Agriculture, Vrbanska 30, 2000 Maribor, Slovenia
[4] Institute of Agriculture, Vinarska 14, Maribor
[2] Troja, Bednice 14, Trzin, Slovenia

Introduction

Increasing leaf area index (LAI) by increasing nitrogen rates was obtained by increasing tillering and number of leaves per plant (Sharma et al., 1994; Frederick and Camberato, 1995; Heidmann et al., 2000); but there exists a lack of data about LAI as affected by nitrogen target value based on soil nitrogen and different sowing densities. With cultivars spread in Slovenia, the effect of nitrogen fertilisation treatments on LAI changes and yield formation and correlations were studied, especially because increased LAI affected by nitrogen rates may decrease net assimilation rate depending on plant morphology and decrease light interception (Karimi and Siddique, 1991; Sharma et al., 1994). For that reason LAI relationships and yield performance of new cultivars in specific climate may be unknown.

Methods

A field experiment was conducted 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, a small shortage of water in May was noted and July was warmer (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 2 winter wheat cultivars spread in Slovenia and 10 nitrogen fertilising treatments (Table 1) were analysed. From A to I treatment 1st top dressing based on mineral nitrogen to soil depth 0.9 m, and for 2nd 3rd top dressing on the basis of nitrate sap test and chlorophyll meter (Hydro N tester) readings. 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. Seed was planted with an eight-row plot seeder with 12-cm row spacing. Sowing took place in mid October (optimal for this area). On sandy loam field common agriculture practices were used, except treatments. 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 significance of treatments means were 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

Nitrogen treatments and cultivar x nitrogen treatment interaction significantly influenced LAI, plant dry matter and grain yield. The higher LAI of cultivars Soissons and Marija at EC 70 stage was formed by treatments with rate of 60 kg N/ha for first top dressing, but higher LAI at stage

EC 80 was formed by treatments with 2nd and 3rd top dressing. Similar significant differences of LAI at EC 70 stage were found in plant dry matter and grain yield (Table 2). Ears dry matter was significantly lower in treatment A and G (from 0.5 to 0.6 g per ear) than in others (from 0.9 to 1.7 g per ear), such as stem dry matter (from 1.1 to 1.3, from 1.7 to 2.7, respectively). Leaf dry matter varied from 0.1 g per plant in A to 0.5 g per plant in D and E. Between plant dry matter and grain yield existed strong correlation (r = 0.86**). In case of LAI at EC 80 stage and grain yield correlation was stronger (r = 0,88**) than at EC 70 stage (r = 0.21**).

Table 1: Descriptions of treatments of top dressing with different nitrogen rates applied to cultivars Marija and Soissons and their effects on green LAI at milk maturity stage (EC 70) and waxy maturity stage (EC 80), plant dry matter (PDM = g $plant^{-1}$) and grain yield (GY = Mg/ha).

Treatment:				Cultivar Marija				Cultivar Soissons			
	Top dressing (kg N ha^{-1})			LAI		PDM	GY	LAI		PDM	GY
	1st	2nd	3rd	EC 70	EC 80			EC 70	EC 80		
A	0	0	0	1.5d	0.5c	1.8d	3.8c	1.0e	0.3c	1.7c	3.7d
B	30	30	0	4.6c	0.1c	5.0a	6.3b	3.3c	0.3c	3.7b	6.6b
C	60	30	0	7.0a	0.4c	6.1a	7.7ab	4.3b	0.7b	4.5a	7.7b
D	60	60	0	6.5ab	1.3c	4.9a	8.6a	5.8a	1.1b	4.8a	7.5b
E	60	30	40	5.7b	1.8a	5.2a	8.6a	4.3b	2.1a	5.0a	8.1a
F	120-Nmin = 0	0	50	1.8d	1.5ab	2.8c	4.4c	1.4e	0.8b	2.0c	4.1d
G	120-Nmin = 0	30	40	3.6c	2.4a	4.1b	6.1b	2.1d	1.1b	2.8b	5.8c
H	180-Nmin = 30	30	40	4.4c	2.6a	4.3b	6.9b	2.2d	0.8b	3.4b	6.8b
I	150-Nmin = 0	30	40	3.1c	1.6ab	3.5c	6.0b	2.2d	0.7b	3.0b	5.6c
J	90-Nmin = 0	60	40	6.1ab	2.5a	5.5a	7.0b	3.2c	3.2c	3.8b	6.9b

Means within a column followed by different letters 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 higher nitrogen rates for first top dressing influenced higher LAI in both stages (EC 70 and 80 stages), but associated second and third top dressing influenced higher plant dry matter and grain yield, than treatments without or with split applications. At EC 70 and 80 stages LAI significantly differed among nitrogen treatments and cultivar x treatment interaction. An important effect of nitrogen fertilisation on yield was associated with influence of green LAI at EC 80 stage, because correlation between LAI and grain yield was stronger than at EC 70 stage.

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TEST OF CROP MODEL STICS TO ASSESS NITRATE LEACHING AT THE CATCHMENT SCALE

Beaudoin N.[1], Ponsardin G.[1], Couturier A.[2], Maucorps J.[1], Mary B.[1]

[1] I.N.R.A. Unité d'Agronomie rue Fernand Christ F-02007 LAON Cedex
[2] I.N.R.A. Unité de Science du Sol BP 20619 Ardon F-45166 OLIVET Cedex

Introduction

This study is a part of a nitrate leaching experiment at the catchment scale. In order to take into account the variability of soils and cropping systems, we use a crop model linked to a Geographic Information System (GIS). Our objective is to simulate its impact on grain production and nitrogen losses. The evaluation of the model remains difficult at catchment scale (Eeles et al., 1990). The evaluation is now possible within an heterogeneous field, due to precision agriculture technology which can provide yield maps. This was used in 1998 in three fields of our catchment. In this paper, we first compare the yield map data with the yield map predicted by the crop model. Then we discuss the accuracy of model predictions relative to nitrate leaching.

Methods

The studied catchment includes 21 agricultural fields cropped with winter wheat, sugarbeet, winter barley and spring peas (Beaudoin *et al*, 1999). The present study focuses on 3 fields cropped in wheat in 1998 with a precise soil map (figure 1). The soils mainly consist in loam, marl and sandy materials.

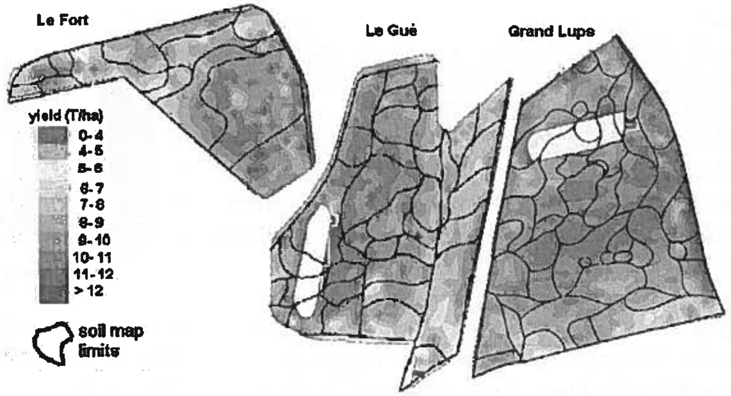

Figure 1: grain yield map and soil unit limits superposition over 3 fields.

The crop model STICS allows us to quantify water, carbon and nitrogen balance at the local scale (Brisson *et al.*, 1998). It simulates water and nitrogen stress. It has been linked to the GIS ArcInfo to integrate the field limits, the soil characteristics and the agricultural techniques (Nicoullaud *et al*, 1998). Pedotransfer functions have been established to determine the soil input parameters of STICS, specially : water contents at field capacity and wilting point in each layer and maximum rooting depth. These functions have been applied to the 102 soil type units composing the 3 fields.

Results

First, the reliability of the combine yield map has been successfully tested (Machet *et al*, 2001). The map showed that yield varied widely within each field, from 6.0 to 11.0 t grain ha^{-1} (at 15% water content). There was also a high variability within each soil unit (figure 1), since the standard error within unit was as large as the standard error between units.
The STICS model was previously tested against the soil and crop data collected on 36 sampling sites of the catchment. It gave satisfactory results: for example, the prediction of the soil mineral nitrogen was made with a model efficiency of 0.70 and a RMSE of 29 kg N ha^{-1} (data not shown).

The STICS-GIS model was used to simulate grain yields in the three fields. The visual comparison of simulated and observed maps showed that the zones with the extreme yields (low or high) were well located. However, the correlation between simulated yields and observed yields extracted from combine yield map, for each soil unit, was poor, as shown in figure 2.

A significant correlation was found for the sampling sites: $r^2 = 0.57$, $p<0.05$. On these sites, parameters were better known and the initial conditions of water and mineral nitrogen were measured. Since the sampling sites were representative of the 102 simulation units, the mean yield extrapolated from the sampling sites is close to the aggregated mean yield from the simulation units.

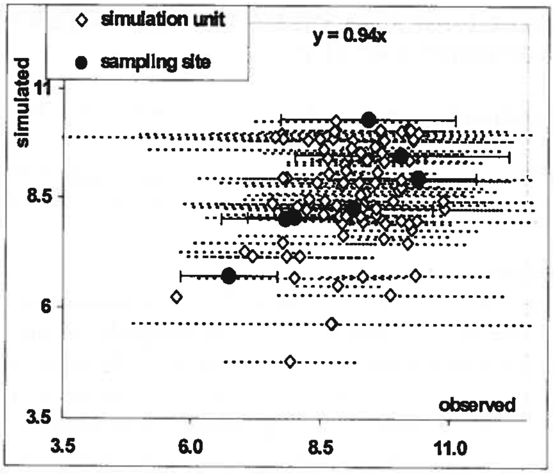

Figure 2 : comparison of simulated and observed grain yields, on 102 simulation units or 8 sampling sites.

Discussion

The poor agreement may have various explanations :

1) model limits : inadequate response to water or nitrogen stress, factors non accounted for
2) model parameterisation uncertainty :

a/ the soil map limits could be wrong; this is suggested by the large variability within each soil unit (see error bars in figure 2). Indeed, aggregating the soil map into 4 classes differing in plant available water yields better results (figure 3).

b/ errors could also arise from the pedotransfer functions or the procedure used to calculate initial conditions. The previous observation (figure 2) supports this hypothesis. The future map yields will be used to clarify these hypotheses and to improve soil parameters (such as rooting depth), using inverse methods.

Simulating properly yields does not guarantee that the model will predict correctly nitrate leaching. Figure 4 shows that the method of upscaling exerts a greater influence for N leaching than for grain yield prediction. Therefore the model must also be evaluated carefully with respect to soil mineral nitrogen using spatially distributed measurements.

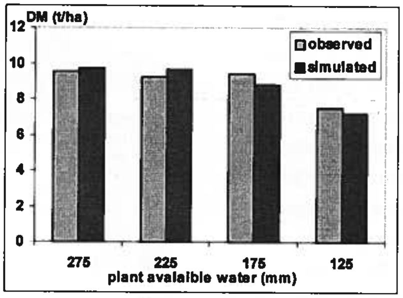

Figure 3 : simulated and observed grain yields obtained using a simplified soil map with 4 units.

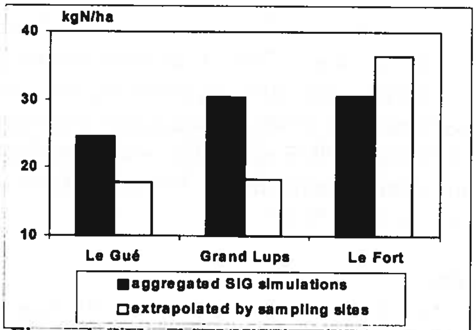

Figure 4 : N leaching calculated in each field according to 2 upscaling methods.

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USE OF FIELD BASED REMOTE SENSING FOR THE ASSESSMENT OF WATER AND NITROGEN STRESS EFFECTS ON POTATO CANOPY

R. Casa
Dipartimento di Produzione Vegetale, Università della Tuscia, Via San Camillo de Lellis, 01100 Viterbo, Italy

Introduction

Rapid and inexpensive methods for the estimation of canopy structure parameters such as leaf area index (LAI) and leaf angle distribution (LAD) are extremely valuable. These parameters influence most processes that couple plants to the surrounding environment, i.e. radiation balance, photosynthesis and evapotranspiration. Water and nitrogen stress also affect LAI and LAD. Field based remote sensing is a cost-effective way to obtain this information. However the vegetation indices (VI) often used (Baret et al., 1991), eg. NDVI, are influenced by leaf and soil spectral properties, canopy geometry, illumination and view zenith angles. In addition a saturation in the VI-LAI relationship can occur at LAI values higher than 3 (Baret et al., 1991). In this work a digital colour-infrared camera is employed to explore the possibility of using classified images to infer canopy properties.

Methods

A field trial was carried out at the experimental farm of the University of Viterbo (Italy) (lat. 42°25'12" N, long. 12°04'48" E, alt. 310 m). A split-plot experimental design with 4 replicates was used to impose water and/or nitrogen stress on a potato crop. The treatments in the main plots were zero vs. full irrigation and the treatments in the sub-plots were zero vs. full nitrogen fertilization. The soil had a loamy sand texture (72% sand, 21% silt, 7% clay) and 1.7% organic matter. In the irrigated plots water was applied 4 times weekly, restoring the soil moisture deficit to field capacity at each irrigation. On the fertilized plots, 150 kg N ha^{-1} were supplied as Urea at sowing time and additional 50 kg N ha^{-1} were applied as Urea just before flowering. Direct LAI and some phytometric characteristics were measured by harvesting 6 plants per plot on June 18th. Leaf nitrogen content was assessed on dried leaf discs using the Kjeldhal method. Yield was assessed by harvesting all the tubers in 1 m^2 quadrats.
A colour–near infrared digital camera, the Agricultural Digital Camera (ADC, Dycam Inc., Chatsthereworth, CA, USA) was used to acquire canopy images at nadir, at a height of 2.6 m above the soil, during several days close to the direct sampling date. The camera allows the acquisition of red and near infrared images (White et al., 2000) which were processed to obtain the average NDVI. The same images were also classified into the fractions of shaded and sunlit leaves and foliage, using supervised classification (minimum distance algorithm). A plant canopy ray-tracing model (Casa et al., 2002) was used to investigate the relationship between LAI and shaded and sunlit leaves and soil fractions at a sun zenith angle of 40°.

Table 1. Results of direct sampling on potato [a]

Treatment [b]	LAI	Leaves per plant	Leaf length (cm)	Leaflets per leaf	Leaflet length (cm)	SLA (cm^2 g^{-1})	Tuber yield (t ha^{-1})
N0.I0	0.7	37.5	16.5	6.8	5.2	32.2	24.5
N0.IF	1.0	37.4	18.1	6.8	5.8	27.8	36.8
NF.I0	1.5	49.1	20.9	7.9	5.8	34.1	40.5
NF.IF	2.9	65.0	21.0	7.3	6.5	35.0	68.7
Nitrogen	* *	* *	* *	* *	*	* *	*
Irrigation	*	n.s	n.s.	n.s.	n.s.	n.s.	*

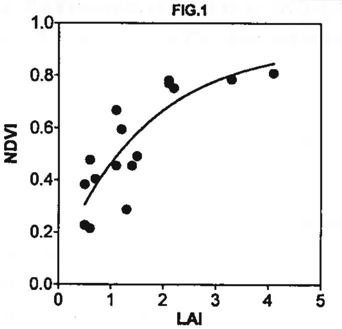
[a] Results for split-plot ANOVA (main plot: irrigation, sub-plot: N fertilization): * * P<0.01; * P<0.05; n.s. no significant differences

[b] Treatments are: N0.I0 = zero nitrogen non-irrigated ; N0.IF = zero nitrogen irrigated; NF.I0 = full nitrogen non-irrigated; NF.IF = full nitrogen irrigated

Results

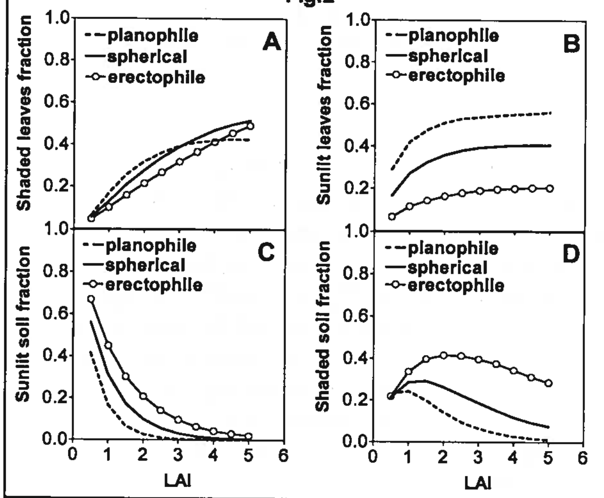
Nitrogen and irrigation stress strongly affected canopy structure (and yield) (Table 1). LAI was affected by both fertilization and irrigation. Nitrogen fertilization caused an increase in the number of leaves per plant and larger and thinner leaves, as expressed by SLA (specific leaf area). Leaf total nitrogen concentration was significantly increased by fertilization.

FIG.1



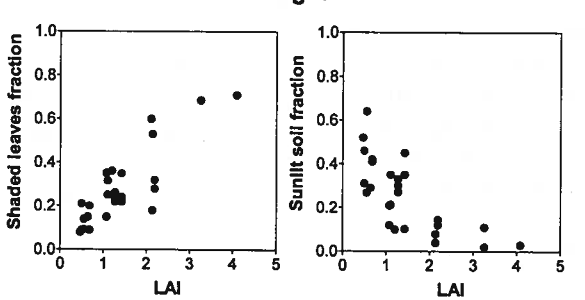
From the relationship between LAI and NDVI (Fig.1) it appeared that saturation occurred for LAI values higher than 2, making it difficult to use the relationship for the estimation of LAI from NDVI. Therefore as an alternative approach, the feasibility of using information obtained from classified images was explored. For instance the image fractions occupied by sunlit and shaded foliage and soil will depend on LAI as well as LAD and view and illumination angles, but will not be affected by leaf and soil spectral properties.

Fig.2



Results obtained using a ray-tracing canopy model (Casa et al., 2002) show that the relationship between LAI and image fractions is non-linear and confirm the effect of leaf angle distribution (Fig.2). The relationship between LAI and shaded leaves fraction (Fig. 2A) seems to offer the best possibilities for the estimation of LAI, especially for erectophile canopies. In that case the relation is nearly linear. However, even for a spherical leaf angle distribution, a plateau (saturation) does not occur for LAI up to 5. Measured data (Fig. 3) are in agreement with the model. However considerable scatter is present. This can be explained by the differences in leaf angle distribution between water and nitrogen treatments and by the effect of illumination angle.

Fig. 3



Discussion

Our results show that using an inexpensive colour-infrared digital camera it is possible to acquire remotely sensed data useful for the estimation of LAI. As an alternative to the use of vegetation indices such as NDVI, it is possible to classify the images into the sunlit and shaded leaves and soil fractions. Modelling and measurement suggest that these are potentially useful to estimate canopy structure properties.

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ROLE OF EARLY NITROGEN DRESSING ON DURUM WHEAT YIELD IN THE SOUTH OF FRANCE

Castillon P., ITCF, 31450 France

Introduction

In soils which contain a small amount of inorganic nitrogen at the time of sowing, the nitrogen fertilisation of durum wheat must often be liberal, and judiciously split in order to obtain high grain production with an adequate protein content. In particular, it must allow sufficient development and growth of the first tillers, which should have at least three leaves by the end of tillering in order to produce ears (Masle-Meynard 1981). However excess early nitrogen should be avoided as it is usually not efficiently used by wheat and can even prove to be harmful by encouraging lodging or certain diseases (Sylvester Bradley et al 1997). Rational management of nitrogen fertilisation thus means that the amount and the stage of early nitrogen application, when this is needed, should be clearly defined.

An investigation was carried out in the south of France from 1996 till 1999 to find the optimal stage for applying early nitrogen and its role in yield elaboration of durum wheat sown after crops which usually leave very little inorganic nitrogen in the soil, such as rice, sorghum, sunflower and maize. This paper presents the most striking of the results.

Methods

Fifteen field experiments with the durum wheat variety *Lloyd* sown in the autumn (October-December) were carried out on different soil types in the south of France, containing little inorganic nitrogen (<60 kg N ha^{-1}).

Three to five treatments were compared in randomised block designs with 3 or 4 replications so as to test the effect of an early nitrogen dressing on grain yield and to determine the ideal stage at which to make this dressing:

T1 = no early nitrogen application
T2 = 40 kg N ha^{-1} applied at the 3-4 leaf stage (Zadocks GS20)
T3 = 80 kg N ha^{-1} applied at the 3-4 leaf stage (Zadocks GS20)
T4 = 40 kg N ha^{-1} applied half-way through tillering (Zadocks GS23)
T5 = 80 kg N ha^{-1} applied half-way through tillering (Zadocks GS23)
(in 5 trials, only the first 3 treatments were present).

An additional nitrogen dressing was made at the beginning of stem elongation (GS30), at rates different from an experiment to the other, and such that in a given experiment the total amount of nitrogen applied would be the same for all treatments. The two applications were made using ammonium nitrate, 33.5% N.

The yield of grain, harvested with an experimental harvester, and its components, were measured.

Results

Early nitrogen dressing significantly increased grain yield (P<0.10) in 10 of the 15 experiments. Mean wheat yield without early nitrogen (T1) was 5.62 t ha^{-1} (dry grain). It was increased on average by 0.69 t ha^{-1} (0.44 - 1.71) in the 10 experiments in which this dressing proved effective. In 7 of these 10 experiments, 40 kg nitrogen ha^{-1} was sufficient to reach maximum grain yield.

When the early dressing increased grain yield, the application made at the beginning of tillering (GS20) was the most effective (figure 1).
The analysis of components of yield also showed that early nitrogen dressing affected grain production more through an increase in the fertility of the number of grains per ear and the mean grain weight (figure 2a) than by increasing the number of ears per m^2 (figure 2b).

Conclusion
In soils containing little inorganic nitrogen at the sowing stage of durum wheat an early nitrogen dressing is needed at the beginning of tillering (GS20) to assure maximum yield. Its effect on yield is due mainly to an increase in the number of grains per ear and mean grain weight, probably because of greater growth of the main stem and of the first tillers to emerge during the tillering period (Thorne et al 1988).

Figure 1: Effect of nitrogen applied at stages GS20 and GS23 on the increase in grain yield (t dry grain ha^{-1}) as compared with wheat receiving no early nitrogen

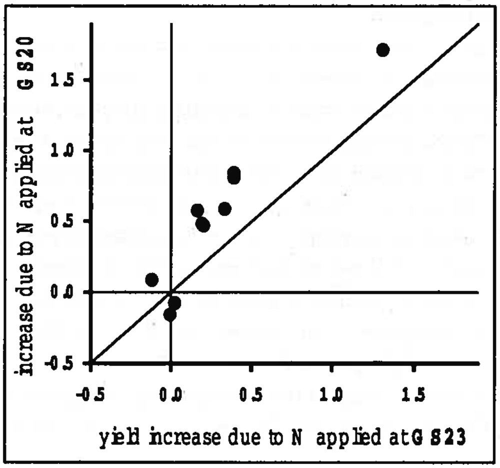

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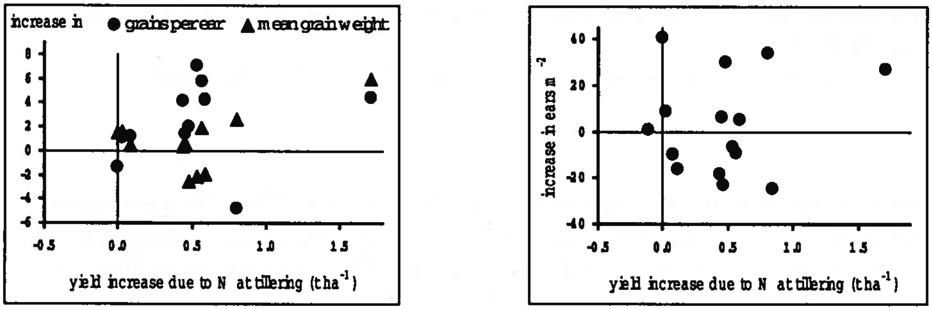
Figure 2: Effect of the most efficient early nitrogen dressing on increase in grain yield and the increase in; (a) the number of grains per ear and the mean grain weight, (b) the number of ears per m^2.

a b



N-MIN METHOD IN SUNFLOWER FERTILIZATION

Crnobarac J.,[1] Dušanic N.,[2] and Marinkovic B.[1]

[1]Agricultural Faculty, Trg D. Obradovica 8, 21000 Novi Sad (FR Yugoslavia)
[2]Institute of Field and Vegetable Crops, Novi Sad, FR Yugoslavia

Introduction

Nitrogen is a principal constituent of sunflower yield as well as in other crops. However, sunflower is specific in this respect, i.e., it is sensitive to excess N - because of a low harvest index, N encourages vegetative growth which in its turn makes sunflower plants more susceptible to diseases. Also, excess N reduces oil content in seeds (Crnobarac et al 1999). In order to obtain a good and healthy crop and a high seed yield with satisfactory oil content, it is necessary to determine precise amounts of N to be added to each production field (Dahnke et all.1992).

Material and methods

The research was carried out at the experiment field of the Institute of Field and Vegetable Crops in Novi Sad, in a stationary three-crop (corn, sunflower, wheat) experiment with increasing N doses and plowed-under harvest residues in the period 1998-2000.

This paper included the following fertilization treatments for the previous maize crop: 0 - no harvest residues and no N fertilizer; 100 - harvest residue and 50 kg of N fertilizer ha^{-1}; 200 - harvest residue and 150 kg of N fertilizer ha^{-1}; 300 - harvest residue and 250 kg of N fertilizer ha^{-1}. In all treatments with harvest residues, only with wheat harvest residue was applied 50 kg of N fertilizer ha^{-1}, to suppress nitrogen depression, and that quantity of N should be included in the calculation. In the sunflower crop, only the effect of N residue was monitored, because it was not fertilized with nitrogen.

In soil depth 0-120 cm, N-NO_3 was measured before sowing and at full anthesis - R6 (Schneiter and Miller, 1981). Also, N uptake by plant was measured at R6. Yield and oil content were analyzed by ANOVA and also their regressions were calculated with the amount of pre sowing N-NO3 in soil.

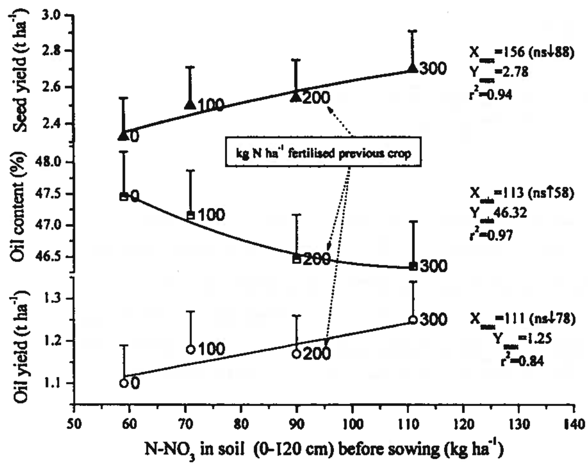
Results

On the three-year average, the amount of pre sowing N-NO3 in soil regularly raised with increasing N fertilizers (59, 71, 90 and 111 kg N ha^{-1}). The year itself also significantly affects the amount of pre sowing N-NO_3 in soil (Delphin, 2000). The respective values were 99, 69, 79 kg N ha^{-1}. The amount of N-NO3 in the soil at R6 stage was lower (2-48 kg ha^{-1}) and it followed the same pattern. It means that sunflowers effectively take up nutrients from the soil reserve; and the intensity of uptake increases with the size of soil reserve.

N uptake by plant at R6 stage corresponded to the amount of pre sowing N-NO3 in soil and was 108, 175, 206, 228 kg N ha^{-1}, respectively, for the treatments. N uptake also corresponded to seed yield and N requirements to produce 100 kg of seed while the corresponding vegetative mass increased regularly from 4.6 to 8.1 kg N in the fertilization treatments.

By subtracting the difference in N-NO_3 at the stages of pre sowing and R6 from the N uptake by plant, it is possible to establish the amount of mineralized N from soil. Mineralized N regularly raised with increasing N fertilizers form 24 to 149 kg N ha^{-1}, with average of 112 kg N ha^{-1}.

Seed yield increased significantly, as the dose of N fertilizing for the previous crop was raised. The unfertilized treatment had a significantly lower yield then the fertilized treatments of +200 and +300 (threshold of significance). Oil content decreased as the dose of N fertilizing for the previous crop was raised. The unfertilized treatment had a significantly higher oil content than the fertilized treatments +200 and +300. The treatment +100 also had significantly higher oil content than the treatment +300. Significant differences in oil content were registered among the years. The highest content (48.4%) was obtained in 1998, the lowest in 1999 and 2000 (46.47 % and 46.10 %, respectively). Oil yield as the final result of sunflower production, because of conflicting effects of N fertilization on seed yield and oil content, is the best indicator of sunflower N fertilization efficiency. Because oil yield is much more dependent on seed yield than on oil content, the effect of N fertilization of the previous crop on oil yield was similar to that on seed yield, except that the differences between the treatments were lower in the former case.



The direct effect of N-min in soil before sowing on the studied parameters follows an interesting pattern. In all years and on three-year average, seed yield increases with increases in N-min, but only to a certain point. The intensities of increase and the maximum yields differ significantly between years. According to the regression analysis with the coefficient of determination (CD) of 94 %, the calculated maximum yield of 2.78 t ha^{-1} is achieved with the pre sowing N level in the soil layer 0-120 cm of 156 kg N ha^{-1}. However, the pre sowing N level down to 88 kg N ha^{-1} does not cause statistically significant reduction in seed yield. Oil content decreases with increases in N-min before sowing. With the CD of 97%, the calculated minimum content of 46.3 % is achieved with the pre sowing N level of 113 kg N ha^{-1}. No significant increase in oil content was achieved until 58 kg N ha^{-1}. With increases in pre sowing N-min in soil, oil yield increases similarly to grain yield, but at a slower rate. According to the linear regression analysis with the CD of 84%, the calculated maximum yield of 1.25 t ha^{-1} is achieved with 111 kg N ha^{-1}. No significant decrease in oil yield was achieved till 78 kg N ha^{-1}.

Conclusions

The following conclusions may be drawn on the basis of the obtained three-year results.
N-min amount in soil before sunflower sowing and at R6 stage depends considerably on N fertilization intensity of previous crop and climatic conditions in the year of growing.
N uptake during R6 stage luxuriates with increased amounts of N-min in soil before sowing. The amount of N needed to form 100 kg of seed and corresponding mass ranges from 4.6 to 8.1 kg N.
Mineralization is more intensive in treatments with high amounts of N-min before sowing and varies greatly in years, from 95 to 133 kg N ha^{-1}.
Sunflower seed yield increases significantly with increases in N fertilization of previous crop, i.e., with the raise of N-min in soil before sowing, while oil content significantly decreases. Oil yield behaves similarly to seed yield, but the rate of increase is lower.
A general statement can be made for sunflowers that the optimum amount of pre sowing N-min in the soil layer 0-120 cm is approximately 80 kg N ha^{-1} with yearly estimate soil mineralization of 110 kg N ha^{-1}.

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THE USE OF LINEAR PARAMETERS IN LEAF OF TOBACCO FLUE-CURED TO ESTIMATE THE LEAF DEVELOPMENT, UNDER DIFFERENT IRRIGATION AND NITROGEN TREATMENTS.

García, M.I., Pulido, I., Arévalo, M.
SIA .Finca La Orden.
06187 Guadajira (Badajoz).

Blanco, I.
CETARSA. Finca La Cañalera.
Ctra Santa. María de las Lomas, Km 3,5
10310 Talayuela (Cáceres).

Introduction.

Extremadura is the first spanish region producing tobacco, 85% of the spanish tobacco is cultivated in the valleys of the rivers Alagón and Tiétar (Cáceres). The viability of this sector, with a big social and economic significance in the Extremadura region, depends on the tobacco quality and on a more efficient structure of the costs, in order to support or improve farmers income.

In tobacco culture, harvest value depends on yield- directly related to leaf area- and on quality. These aspects are influenced by two factors of production: irrigation and fertilization. With the aim of knowing the influence of these factors on tobacco behaviour, a project developed during 3 years began on year 2000. The experimental design combined different water and nitrogen quantities.

During the first year a relation between linear parameters (length and width) of the tobacco leaf with the leaf area was searched. Using this relation, the influence of the water and nitrogen over the plant development (Leaf Area Index) and finally over the yield was studied.

Materials and methods.

During two years, in the valley of the river Tiétar, a trial was undertaken, over a sandy soil (80% of sand). The Flue-Cured tobacco variety K-326 was used.

The experimental design was a split-plot, with three irrigation treatments, calculated starting from culture evapotranspiration (ETc): I1= 0.7 Etc, I2= ETc; I3= 1.3Etc, and four nitrogen treatments: N1= 40 UF/ha, N2= 60 UF/ha; N3= 80 UF/ha and N4= 100 UF/ha.

In every plot of the first repetition, 3 plants were taken through the crop growing period . The length and the width of every leaf in year 2000, and the length in year 2001, was measured every 15 days. The last measure was collected after flower head removal and before first harvest. At the same time, in the first year, ten plants of the same variety were collected. Leaf length, leaf width and leaf area were measured. A relationship between leaf length and leaf width, with leaf area was found, and using this relationship , the evolution of the Leaf Area Index along the crop growing period was estimated. Results in year 2000 were not reliable, some of the selected plants did not agreed in the development with the others in the same plot, and they are not showed.

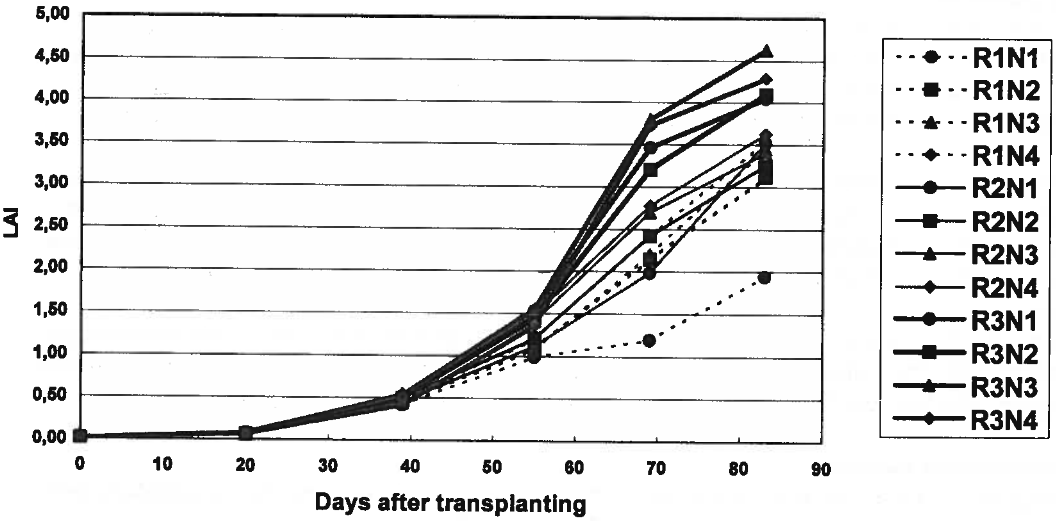
During the harvest, leaves were weighed (fresh yield), and afterwards leaves were dried, getting dry yield.

Results and discussion.

The first year,starting from leaves data of 10 plants collected in four different days trough the crop growing period, three relationship were established: 1.The leaf area(y) with the width of the leaf (a) multiply by the length of the leaf (b), 2.The leaf area (y) with the width of the leaf (a) and 3.The leaf area(y) with the length of the leaf(b). Regression equations and their R^2 were got.

Equation	R^2	Equation	R^2	Equation	R^2
$y= 0.683ab$	0.98	$y=47.44a-260.89$	0.90	$y= 23.04b-393.52$	0.90
$y= 0.507ab^{1.0401}$	0.99	$y=2.5471a^{1.8365}$	0.98	$y=0.0985b^{2.2685}$	0.96
$y= 77.085e^{0.0019ab}$	0.81	$y=31.858e^{0.1411a}$	0.91	$y=21.661e^{0.0683b}$	0.91

It is noticed that using leaf width and leaf length leaf area can be perfectly estimated in tobacco Flue-Cured. A linear or potential regression equation can be used. The linear equation y=0.683ab, approaches the equation got by Moustakas and Nizanis (1998) y=0.653ab in tobacco Flue-Cured, variety McN-944.
In the relationship between leaf area and leaf length or leaf width, it is noticed that leaf area can be determined with a big accuracy using a potential equation. The second year it was decided to measure only one of these parameters to optimize data collection . The length leaf was used to calculate the LAI evolution of the different treatments.



In year 2001, the development begins to be important around 40 days after transplanting (firsts irrigations), when LAI is around 0.5, to reach before flower head removal a LAI between 2 and 4 for most of the treatments. Last measure was after flower head removal, for this reason the increase of the LAI between the two last measures was not so fast, because the leaf number decreased but the size enlarged.
The factor with more influence over the development of the tobacco culture is the irrigation. The treatment I3 got the biggest LAI. On the other hand, increasing nitrogen dose increased LAI. Between N3 and N4 there was not any significant differences.
If we compare LAI data with fresh yield in the harvest, we have than Z (fresh yield (kg·ha^{-1}))=2029.7 ·LAI (measured before flower head removal)+23512, with R^2=0.4806, and Z (fresh yield (kg·ha^{-1}))=2100.7·LAI (measured after flower head removal)+21418, with R^2=0.403. Although the R^2 are not very high, they point to a narrow relation between fresh yield and LAI.

Conclusions.
LAI in tobacco Flue-Cured, variety K-326, can be determined in a practical way, using a potential equation that relate leaf area with length leaf.
The biggest LAI are got for the irrigation treatment I3, combined with treatments N3 and N4. LAI before and after flower head removal is a measure that pointed to the fresh yield in the harvest.

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SUITABILITY OF THE RAPID NITRATE TEST TO OPTIMIZE N SIDE DRESSING IN WINTER WHEAT UNDER THE CONDITIONS OF NORTHERN GERMANY

Gerendás J., Heuer I.

Institute for Plant Nutrition and Soil Science, University Kiel, 24098 Kiel (Germany)

Introduction

N fertilization has considerable influence on crop yield, quality and environmental impacts. N management in cereals can be optimised using several approaches, which are often based on the expected total N demand of a crop (depending on the yield), and the expected N availability of the soil. The latter can be separated into the mineral N ($NO_3 + NH_4$) present at vegetation start, which is used to predict the N fertilizer demand according to the N_{min} method (Wehrmann et al., 1988), and the N made available during crop growth by mineralisation. Monitoring the nitrate stored in the stem base (rapid nitrate test; RNT) is another option. This approach was compared with recommendations of the local extension service.

Material and Methods

Field experiments were established at Hohenschulen experimental station, 15 km west of Kiel, in autumn 2000. The site (sandy loam, 45 m NN) is characterised by 725 mm annual precipitation and an average temperature of 8.5°C. Details: Winter wheat variety 'Tarso', sown 21.09.00, harvested 17.08.00. N side dressings (ammonium nitrate with lime), where applicable: 03.04.00 (N1), 04.05.00 (N2; DC 32), 05.06.00 (N3; DC 45). Appropriate phytosanitary measures were taken. Treatments (n=4, completely randomised): I. Control. II. N1 according to N_{min} (110 kg N ha^{-1}), N2 and N3 according to RNT (Thüringer Landesanstalt für Landwirtschaft, Jena, Germany). III. N1 reduced to 70 kg N ha^{-1}, N2 and N3 according to RNT. IV. N1, N2 and N3 according to local extension service. V and VI as IV, but total N reduced or increased by 40 kg ha^{-1}, respectively. See Tab. 1 for further details. The N status of all treatments was monitored using the NRT from 02.05.00 to 27.06.00. After harvest yield, protein content (by near infrared transmission; 1229 Infratec Grain Analyser, Foss Tecator) and the N_{min} remaining in the soil were determined.

Results and Discussion

While the readings for the control remained very low throughout the observation period, those of the other treatments (Ts) initially were around 500 mg l^{-1}, and showed considerable variability later in the season (Fig. 1). N2 increased the readings with a delay of about two weeks, after which the size of the nitrate pool declined again in most cases. At the end of June the increase of the readings seen in most Ts only partly originates from N3, as T II also showed a substantial increase. It is speculated, that this resulted from an enhanced mineralisation during this time. Ts IV-VI, which were based on the recommendations of the official extension service, applied 180±40 kg N ha^{-1} in order to define the optimum, and showed a close positive relationship to the RNT readings at the end. T II, which followed the N_{min} approach for N1 and used the RNT for N2 and N3, resulted in low readings towards the end of the observation period, particularly when N1 was reduced (T III) in order to ovoid over-fertilization in the beginning and to check whether a lower N1 will be compensated by higher N2 and N3 dressings.

The control receiving no N responded strongly by low yields and low protein contents (Tab. 1). Comparing T II and T II it is evident that 130 kg N ha^{-1} were sufficient to give 94% of the maximum yield, and the higher N1 of T II did not result in any response of the RNT. The lower RNT readings of T III later in the season (Fig. 1), which were presumably due to a lower N1 dose, did not result in a compensatory increase of the N3 dressing. In both treatments the protein content was significantly increased as compared to the control, but remained lower than in the following treatments. T IV followed the recommendations of the local extension service, and since the crop was well established at the beginning of the growing season N1 was low, and emphasis was given to the N2 and N3 dressings. This approach proved superior, since high yields and high protein contents (about 13.6%) were obtained. However, T V indicates that the local recommendation could have been reduced by 40 kg N ha^{-1}. High N dressings towards the end of the season bare the risk of higher N_{min} values after harvest, which are prone to leaching in the following winter (Wehrmann et al., 1988). T V and VI show high variability of the N_{min} values, but the remaining data suggest, that a low N supply throughout (T III) resulted in lowest values, and high N3 doses (T IV-VI) in highest. The control shows intermediate values due to an insufficient recovery of mineralised N because of limited root growth and early senescence.

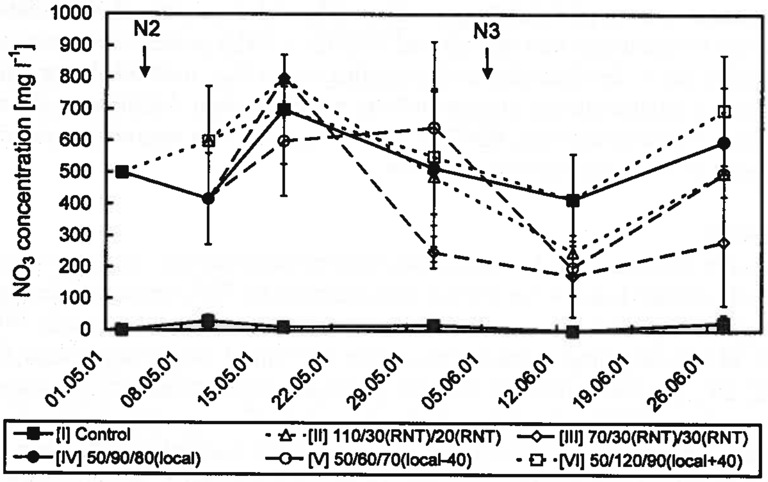

Fig. 1: Time course of NO_3 concentration in the sap of the stem base (rapid nitrate test) as influenced by N fertilization (n=4±SD). N side dressings indicated as N1/N2/N3. See table 1 and text for further details.

Tab. 1: Influence of different fertilisation strategies on yield and protein content of winter wheat, and residual N_{min} after harvest (n=4±SD).

Treat-ment	Fertiliser application [kg N ha^{-1}]					Harvest data		
	N side dressing	N1	N2	N3	N_{total}	Yield [t ha^{-1}]	Protein [%]	N_{min} [kg ha^{-1}]
I	0 / 0 / 0	0	0	0	0	4.402 ± 0.305	9.80 ± 0.58	62.50 ± 4.51
II	N_{min} / RNT / RNT	110	30	20	160	9.297 ± 0.194	12.52 ± 0.15	55.53 ± 7.12
III	70 / RNT / RNT	70	30	30	130	9.260 ± 0.271	12.26 ± 0.25	38.98 ± 4.09
IV	Local / local / local	50	90	80	220	9.763 ± 0.188	13.58 ± 0.16	67.87 ± 4.80
V	Treatment IV – 40 kg	50	60	70	180	9.772 ± 0.215	13.51 ± 0.40	74.35 ± 19.72
VI	Treatment IV + 40 kg	50	120	90	260	9.816 ± 0.225	13.68 ± 0.15	69.68 ± 25.35

Conclusions

Under the conditions of this experiment the RNT did not provide enough N later in the season to secure high yields and protein contents. The recommendations of the local extension service, which emphasized the N2 and N3 dressings, proved superior, although the total N supplied could be reduced by 40 kg N ha^{-1}. Further experiments are required to adapt the RNT.

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MODELLING OF NITROGEN REMOBILIZATION EFFECT ON NITROGEN DISTRIBUTION WITHIN CANOPY DURING SEED FILLING PERIOD IN SOYBEAN

Grandgirard D.[1], Munier-Jolain N.G.[1]

1 INRA Unité de Malherbologie et Agronomie, BP86510 - 21065 Dijon cedex (France)

Introduction

During the seed filling period (SFP), N requirements for soybean (*Glycine max* L.) seeds are too high to be sustained only by exogenous nitrogen nutrition. The self-destructive hypothesis proposed by Sinclair and de Wit (1976) states that the seed N demand is fulfilled by remobilisation of non-structural N from the vegetative organs, which decreases leaf N concentration. Because N remobilisation involves a large proportion of the leaf photosynthetic proteins, the CO_2 exchange rate is then depressed. As a consequence, leaf N content per unit area and leaf CO_2 assimilation rate are highly correlated. As the specific leaf nitrogen (SLN) in the foliar strata is irregularly distributed during seed filling, depending on the cumulative leaf area index (LAI) from the top to the bottom of the canopy, changes across time in the non-uniform distribution of SLN may allow to relate the remobilisation process to the limitation of C accumulation by the crop.

Methods

In a field experiment in 1999, three different levels of N nutrition were obtained for two soybean cultivars (cv. Essor (E) and cv. Labrador (L)) by inoculating seeds (i treatment), and by non-inoculating seeds but providing 0 or 120 kg.ha^{-1} of mineral N supplied as ammonium-nitrate (0 and 120 treatments resp.). During SFP, plants were harvested three times a week and dry weight and N concentration of each organ were determined. The amount of available vegetative N was calculated as in Munier-Jolain *et al* (1996) : it allowed to estimate the $\%N_{veg,min}$, which corresponds to the structural nitrogen concentration of the vegetative parts. At five successive sampling dates during SFP, leaves were separated according to the node number in order to determine LAI, N concentration and SLN (gN m^{-2}), with SLN_{inf}, the SLN of the lowest foliar strata and SLN_{top}, the SLN of the highest foliar strata.

In 2000 a field experiment was conducted with the cultivar Essor and the same N treatments as in 1999, in order to validate the model that predicts changes in N distribution in the canopy during SFP.

Results

Whatever the treatment, the structural N concentration of the vegetative parts was equal to 0.45 % and similar to the values obtained at physiological maturity for the stems and pods of soybean crops deficient in nitrogen (Streeter, 1978). The observed values of SLN_{inf} are therefore representative of the structural N in the leaflets: SLN_{inf} increases in parallel with the crop N nutrition level at the beginning of seed filling.

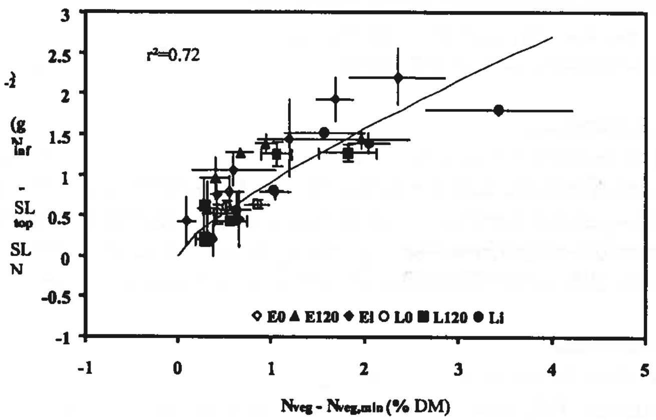

Fig 1 : Modelling of SLN_{top}

The change in SLN_{top} has been modelled for all the treatments as a function of the fall in the N concentration of the aerial vegetative compartment during SFP (Fig.1). For a given crop N nutrition level, SLN_{top} cannot be lower than SLN_{inf}. This minimum value of SLN_{top} is reached when the N content of the vegetative parts reached 0.45%. Consequently, the model chosen for SLN_{top} is centered on the single value of structural N concentration of the vegetative parts at maturity, and on the minimum value of the SLN (SLN_{inf}) for each crop N nutrition level.
The model was used to simulate the distribution of the SLN of the foliar strata during SFP for various N nutrition levels, and four dates after the beginning of SFP (BSFP) (Fig.2). The simulation of the distribution of SLN within the canopy is partially satisfactory. Whatever the crop N nutrition level, the model under-estimates SLN of the foliar strata at the top of the canopy; however the under-estimation of the SLN of the upper strata decreases as they approach physiological maturity. The under-estimation of the SLN of the foliar strata at the top and bottom of the canopy is closely linked to the linearity of the chosen model of the distribution of SLN along the mean stem. Indeed, in many species, the non-uniform N distribution within the canopy is not linear: the SLN falls exponentially high in the top of the canopy, then linearly in the middle strata of the canopy, and then rapidly again in the bottom strata of the canopy.

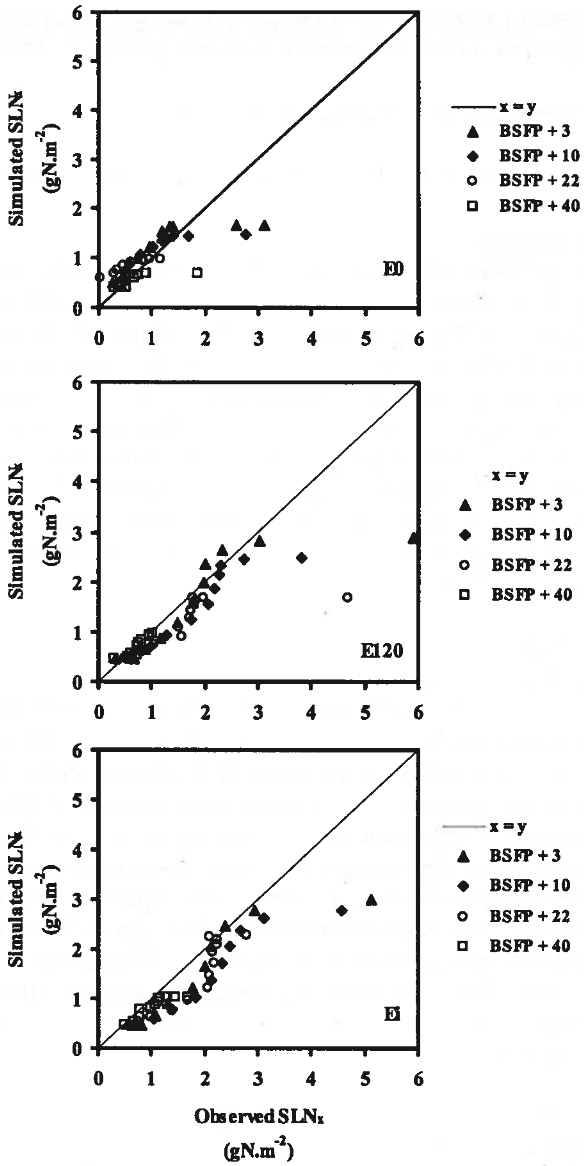

Fig.2 : Simulation of SLN

Conclusions

The model of N distribution in the canopy is a first step towards simulating at first the photosynthetic activity of the canopy during SFP and in the long-term, the duration of SFP and thus yield at harvest. It would thus make it possible to take into account the effect of N remobilization from the vegetative organs during seed filling on biomass accumulation by the crop and on the allocation of carbon assimilates to the seeds.

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THE EFFECT OF CATTLE MANURE RATE ON AMARANTH GRAIN YIELD AND FRESH MATTER

Grobelnik Mlakar S.[1], Mihelic M.[2], Bavec F.[3], Jakop M.[4]

[1,3,4] University of Maribor, Faculty of Agriculture, Vrbanska 30, 2000 Maribor, Slovenia
[2] Prigorica 95, Dolenja vas, Slovenia

Introduction

The high nutritional value of amaranth supports recent interest in using it as a grain crop in Slovenia, as well. We began producing grain amaranths in field trials in 1999. Some basic researches on appropriate amaranth genotypes, sowing date, plant population (Grobelnik Mlakar and Bavec, 2000), soil texture, sowing depth and soil water regime (Bavec and Grobelnik Mlakar, 2002) were investigated. Amaranths are known to have a high mineral uptake. In amaranth production P and K are applied according to soil test recommendations for sorghum (Myers, 1996) but yield responses to nitrogen application are not clear (Williams and Brenner, 1995; Carlsson, 1980). However, rates only up to 90 kg N ha^{-1} showed increasing yields, but lodging became prevalent at 55 kg N ha^{-1} and varieties differed in responsiveness (Elberhri et al., 1993). There are limited informations on the fertility requirements of amaranths, especially lack of data on organic fertiliser and additional researches are needed.

Methods

Two field experiments were conducted on loamy sand in Prigorica (continental climate; 45° 43' N, 14° 45' E) and Vrtojba (submediterranean climate; 45° 55' N, 13° 38' E) according to a randomised block design with four replications in 2000. The species of *Amaranthus cruentus* L. cultivar. 'G6' was investigated. Experimental plots of 6 m^2 (3 x 2m) with row spacings of 70 cm were sown in first decade of May. On each location fertilisation with composted cattle manure (1.66% N) at rates 0, 20, 40, 80, and 120 t ha^{-1} was applied before sowing. Stands were oversown and thinned by hand twice to establish a population of 30 plants per m^2. Precipitation and air temperature averages in the growing season (V-IX) were in Prigorica 76 mm, 16 °C and in Vrtojba 111 mm, 20 °C, respectively.

On both locations P and K levels in the soil are sufficient. Plots were hand-harvested. Grain yield and plant fresh matter were determined.

ANOVA and Tukey tests ($P \leqslant 0.05$) were carried out using procedure of the SPSS statistical package.

Results

Fresh matter and grain yield were in Prigorica 38.969 kg ha^{-1}, 1.948 kg ha^{-1} and inVrtojba 67.033 kg ha^{-1} 4.895 kg ha^{-1}, respectively. In spite of lower N-min contents in the soil (Table 1), yields in submediterranean climate (Vrtojba) were higher than in Prigorica.

In Prigorica grain yield and fresh matter were significantly influenced by manure fertilization (Figure 1). The manure application above 20 t ha^{-1} resulted in higher fresh matter and grain yield.

In Vrtojba fresh matter and grain yield were not influenced by manure fertilization (Figure 1).

Table1. Mineral nitrogen (N-min: NO_3-N + NH_4-N) to soil depth of 0.3m.

Location	pH	Manure rate	N-min (kg ha^{-1}), date of sampling 12.2	27.6	13.7	23.8, Vrtojba 8.9
Prigorica	6.7	0	52.02	23.94	51.12	55.8
		20		41.22	47.7	70.2
		40		42.84	40.5	113.04
		80		45.54	108.36	99.54
		120		53.46	107.1	135.18
Vrtojba	5.9	0	36.18	18.72	11.88	16.92
		20		36.54	16.74	17.28
		40		25.56	13.86	14.58
		80		35.64	36.00	24.66
		120		64.44	45.36	25.38

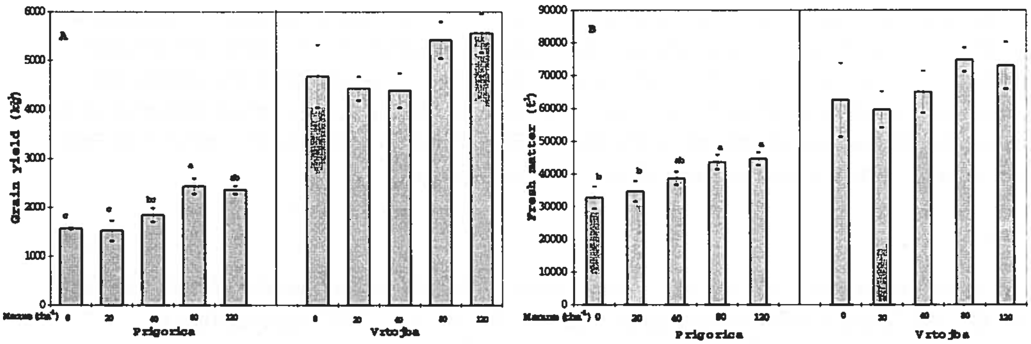

Figure 1. Grain yield (A) and fresh matter (B) as affected by manure application. Means ± S.E. followed by the same letter within a location are not significantly different $P \leqslant 0.05$.

Conclusions

On the basis of investigation of *Amaranthus cruentus* L. cultivar 'G6' the grain yield and fresh matter mainly depend on climatic conditions. The grain and fresh yield in Vrtojba (submediterranean climate with a high rainfall) are not affected by manure fertilisation. In Prigorica the yields were increased by manure rates above 20 t ha^{-1}.

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ANALYSIS OF THE VARIABILITY OF GRAIN PROTEIN CONTENT IN WHEAT: GENOTYPIC ADAPTATION OF THE CROP SIMULATION MODEL AZODYN

MH Jeuffroy[1], A Barbottin[1], A Champeil[1,2], P Gate[2], MC Philibert[1]
[1] UMR d'Agronomie INRA INAPG, 78850 Thiverval-Grignon, France
[2] ITCF, La Minière, 78280 Guyancourt, France

Introduction

Grain protein content (GPC) in wheat is a major characteristic for grain quality in commercial trades. It is highly variable among locations and crop managements but also among genotypes. Although GPC is proportional to the ratio between grain nitrogen and grain biomass (that is crop yield) at harvest, there is no close correlation between GPC and yield (Le Bail et al., 2002). In order to understand the variability of GPC among field crops, a simulation crop model was proposed to simulate the crop-soil system between flowering and maturity, Azodyn (Girard, 1997; Jeuffroy et al., 2000). The aim of this paper is to estimate some genotypic parameters of this model and to analyse their influence in the GPC variability among genotypes at harvest.

Methods

During the grain filling period, the model Azodyn simulates the daily accumulation of biomass and nitrogen in the grains, from the source availability and the grain demand. Grain nitrogen is determined by crop nitrogen uptake between anthesis and harvest and by nitrogen absorbed and stored in the vegetative organs before flowering and translocated to the grains after this stage. Grain biomass mainly originates from post-anthesis photosynthesis. The grain demand depends on the crop grain number and on the dynamics of maximum grain growth between flowering and maturity, which is determined with three parameters: (1) the initial grain weight, (2) the maximum duration for grain growth and (3) the maximum weight per grain (MWPG) at maturity. The first two parameters are constant among varieties, but the last one is variable. Previous studies (Leterme et al., 1994; Brancourt-Hulmel et al., 1999) showed that MWPG depends on the crop grain number per m² (GNM2), according to a boundary curve, characterised by four parameters, variable among genotypes (Gate, 1995, Brancourt-Hulmel et al., 1999).
In order to estimate these parameters for various genotypes and analyse their influence in the GPC, numerous field trials were conducted in France by ITCF and INRA, including three genotypes, Arche, HynoPrécia and Soissons, and various crop managements. On these trials, GNM2 and mean weight per grain were measured at harvest on each treatment.
Other experimental trials, varying in location, nitrogen fertilisation strategies and genotypes (including the three mentioned above), were conducted in France by INRA, aiming at analysing the genotypic x environment interaction. Grain protein content and yield were measured at harvest for each treatment on these trials.
Several simulations were then realised with the model Azodyn, for 10 climates and 5 nitrogen fertilisation strategies (the technique which has the main effect on GPC), taking into account the genotypic parameters of the MWPG curve.

Results

The numerous data of GNM2 and mean WPG allowed the estimation of the four parameters of the boundary curve for each genotype, as presented for Soissons (fig.1): (1) the potential weight per grain (potWPG), observed for low GNM2, (2) the grain number threshold (GNM2t), beyond which the MWPG decreases, (3) the two parameters of the decreasing line beyond GNM2 threshold (a and b).
The values of these four parameters for the three genotypes are given in Table 1, indicating variability among them.

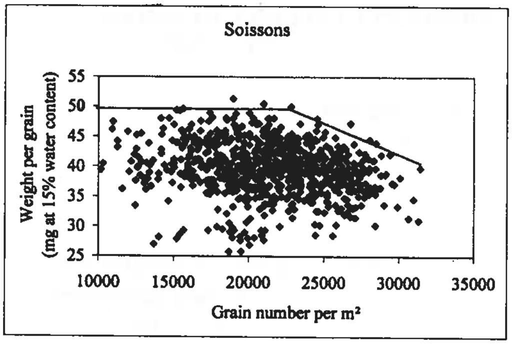

Figure 1 : Boundary curve of maximal weight per grain according to the grain number per m² for cultivar Soissons.

Table 1: Values of the four parameters of the boundary curve of maximum weight per grain according to grain number per m², for three genotypes.

Genotype	potWPG	GNM2t	a	B
Arche	49.5	28000	0.00099	70.79
HynoPrécia	53.7	25000	0.00835	259.2
Soissons	48.5	23000	0.0015	91.6

The simulated values of GPC from Azodyn for the 50 cases per genotype gave a good account of the GPC values observed among genotypes on the experimental trials: Arche is lower Soissons, which is lower than Hyno-Précia.

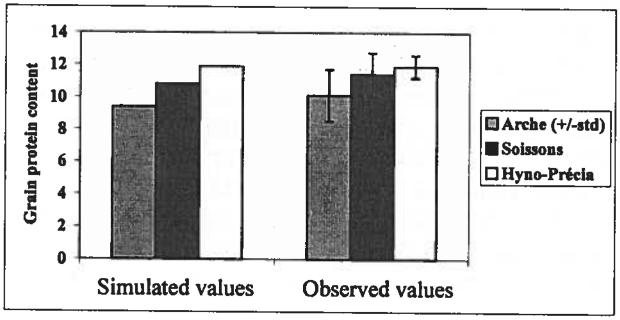

Figure 2 : Comparison of simulated values of grain protein content at harvest with Azodyn and observed values on experimental field trials for three genotypes.

Conclusions

Taking into account few genotypic parameters in the model Azodyn allowed to simulate the mean GPC of three genotypes. The data necessary to adapt these parameters to genotypes are frequently measured in the field trials conducted by advisory services, allowing an easy adaptation of the model for new genotypes. As the crop characteristics before flowering differed among genotypes, it would be necessary to analyse their influence on the GPC at harvest. As the model Azodyn requires several environmental characteristics (soil characteristics, climate) and information on cultural techniques (mainly nitrogen fertilisation), it seems to be a good tool to analyse the genotype x environment interaction on GPC for wheat.

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EVALUATION OF MAIZE INBRED LINES FOR THE LIMITED NITROGEN CONTENT IN THE BACKGROUND

Lipski S.

Institute of Soil Science & Plant Cultivation, Czartoryskich 8, 24-100 Pulawy (Poland)

Introduction

Big fertilizer doses application is the main source of high yields of maize. But it causes risk of pollution of environment by nitrates and phosphates. Also fertilization substantially contributes to the total costs of maize production. Ability of some maize genotypes to utilize nitrate ions more efficiently can be exploited towards fertilizers doses reduction. Efficiency of N utilization by plants depends, among others, on activity of enzymes; especially nitrate reductase (NR; EC 1.6.6.1), roots volume and morphology, photosynthesis activity (Bertin *et al.*, 1996, Pan *et al.*, 1985) etc. The results of own (Lipski, 2000) and other author's investigations (Chevalier *et al.*, 1977, Eichelberger *et al.*, 1989) show that wide genetic variability of these traits makes possible effective selection. The aim of the project was to find criteria of maize genotypes selection for ability to low nitrogen supply and to make first evaluation of Polish maize inbred lines.

Methods

The response of 58 inbred lines of maize („Breeding Company Smolice") on different nitrogen content in background was investigated in pot trial. The experiment included control treatment (N_0) receiving no N fertilizers (with only natural N content in the background) and the treatment with optimal N dose (N_1). Dry matter of plants (g), roots volume (dm^3) as well as nitrogen contents (%) in different parts of plant and chlorophyll content indicators (SPAD units) – by Chlorophyll Measurement Instrument of Minolta Inc. were evaluated at silking, whereas the yields were measured at full grain maturity.

Results

Nitrogen stress (N_0 treatment) caused aboveground biomass reduction, decreasing of N content in aboveground biomass and SPAD in leaves (table 1). Nitrogen content in roots was slightly lower in the treatment N_0 than in N_1. The least differences between the treatments were observed in dry matter of the roots. The ratio of aboveground biomass dry matter to roots dry matter was higher in N_0 than in N_1 treatments but the aboveground biomass was less in N_0. The coefficients of variation of investigated traits were higher in conditions of nitrogen deficit. In the N_0 treatment the biggest variation was observed in the case of root volume, N content in the roots and the SPAD indicators.

Variables	Average		Standard deviation		Coefficient of variation (%)	
	N_1	N_0	N_1	N_0	N_1	N_0
Aboveground biomass d.m.	34,3	28,2	3,48	3,16	10,1	14,2
Roots d.m.	13,0	12,3	1,59	1,26	12,2	13,3
Aboveground biomass / root d.m.	2,65	2,96	0,17	0,22	6,5	11,9
Root volume	144	102	32,1	23,1	22,2	25,6
SPAD	583	523	77,2	74,7	13,3	16,3
N% in roots	1,37	1,43	0,20	0,27	15,0	17,3
N% in aboveground biomass	1,62	1,49	0,17	0,17	10,1	14,1

Table 1 - elementary statistics of some traits of plants (in pot experiment)

Cluster analysis was used for genotype classification. For the better separation of genotypes, the values of differences between N_1 and N_0 for each measured character (expressed in percents) were used. The most numerous were the first (24) and the second cluster (30). They consist of genotypes characterized by average decrease of dry matter, roots and aboveground biomass, roots volume and SPAD values. Nitrogen content in the roots of genotypes classified to the first cluster was higher in N_0 treatment than in N_1. At the same time, the ratio between green and total leaves number in this cluster was slightly influenced by N supply. The third cluster consists of 2 genotypes the most resistant to N deficiency. Dry matters of roots and aboveground biomass as well as SPAD readings were not influenced by N deficiency but significant increase of roots volume and N content in roots was observed. The fourth cluster included two genotypes, the most sensitive to N deficit.

Variables	Cluster number			
	1	2	3	4
Aboveground biomass d.m.	12,7	22,1	-2,4	30,2
Roots d.m.	17,6	24,5	-6,4	35,0
Root volume	21,9	35,8	-20,8	50,3
SPAD	7,3	11,9	7,6	18,7
N content in roots	-23,3	-3,3	-54,8	12,1
N content in aboveground biomass	4,0	14,3	-12,7	23,3

Table 3 - clusters description by the values of centroids for each cluster (%)

Discussion

In studied base of maize inbred lines exists very large genetic variability of the response to reduced nitrogen supply in the background. High coefficients of variation of roots volume, SPAD indicator and N content in the roots make a chance for more effective selection towards improving their values. Nitrogen deficit favoured the disclosure of genetic expression of these characters. This phenomenon is described also by others researchers and used in plant selection (Presterl *et al.,* 1994, Bertin *et al.*, 1996). Bigger root traits variability was found also under other environmental stresses (Lipski, 2000). Regarding results of cluster analysis we may suppose, than roots volume and N content in roots may be ones from the reasons of the adaptation to limited N supply. Reed *et al.* (1980) were also found strong correlation between total N accumulated in plant and root dry weights or root/shoot ratio.

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GAS EXCHANGE OF SPRING BREWER'S BARLEY LEAVES DEPENDING ON PAR INTENSITY AND NITROGEN LEVEL

Loboda[1] T., Pietkiewicz[2] S., Karwowska[2] R., Wolejko[1] E., Wyszynski[3] Z., Gozdowski[3] D., Choluj[2] D.

[1]Technical Univ.. Dept. of Agriculture, Wiejska St. 45A, 15-541 Bialystok, Poland
[2]Warsaw Agric. Univ., Dept. of Plant Physiol., Rakowiecka St. 26/30, 02-528 Warsaw Poland
[3]Warsaw Agric. Univ., Dept. of Crop Science, Rakowiecka St. 26/30, 02-528 Warsaw Poland

Introduction

Plant biomass production is mainly determined by the sum of PAR absorbed by the plants and efficiency of photosynthesis, while nitrogen is one of the most important factors influencing crop productivity. An increase of nitrogen concentration in the leaves causes an increase of photosynthetic rate, both of leaf area and the persistence of this surface, called leaf area duration LAD, processes influencing both biomass production and grain yield. All these processes might be substantially affected by nitrogen fertilization. In the case of spring brewer's barley however, a reasonable evaluation of optimum rate of nitrogen fertilization is of great importance, because overfertilization causes an increase in nitrogen content in grains thus making the grains unsuitable for brewer's purposes. Nitrogen availability affects synthesis of various proteins *e.g.* prolamins in barley endosperm (Shewry et al. 2001).The aim of the study was to examine the influence of nitrogen fertilization and PAR level on gas exchange in spring brewer's barley grown in a greenhouse.

Material and methods

The experiment in randomized blocks design with three cultivars of spring brewer' barley Maresi, Poldek and Rasbet differentiated in chlorophyll content and grain yield was conducted in a greenhouse in 2000. Each combination was four times replicated. Plants in Wagner's pots (filled with a mixture of soil and sand with 7 and 2 kg, respectively) were grown under three PAR levels (0,25, 0,5 and 1,0 PAR, obtained by plants' shading with cheesecloth) and three nitrogen doses (0,5, 1,0 and 1,5 g N per Wagner pot). Modified Hoagland solution was added to the pots. All nitrogen was applied before sowing. Shading was imposed after the first measurement, on April,4th. On five occasions during sunny days (between 10:00 AM – 1:00 PM) gas exchange measurements [(photosynthetic rate (μmol CO_2 m^{-2} s^{-1}), transpiration (mmol H_2O m^{-2} s^{-1}), stomatal conductance (mol H_2O m^{-2} s^{-1}) and intercellular CO_2 concentration (μmol CO_2 mol^{-1})] were done with a portable gas analyzer Li-6200 (LI-COR, Lincoln, NE, USA) on middle part of young leaves, just after they reached maximal area. On the basis of the obtained parameters Water Use Efficiency (WUE) (μmol CO_2 $mmol^{-1}$ H_2O) and internal WUE (WUEi) (μmol CO_2 mol^{-1} H_2O) were determined.

Results and discussion

Photosynthetic rate of all studied plans was in the range 5,12-21,16 μmol CO_2 m^{-2} s^{-1} (Figs 1-3). Although nitrogen fertilization merely changed chlorophyll content (data not shown), during the first measurement photosynthetic rate under 1,5 g N/pot was higher than under other nitrogen doses (7,55 versus 5,12-6,00 μmol CO_2 m^{-2} s^{-1}), but thereafter it usually tended to be lower, and during the fourth measurement photosynthetic rate under 1,5 g N/pot was significantly lower than under other nitrogen doses (12,02 versus 14,67 and 15,34 μmol CO_2 m^{-2} s^{-1}, respectively). Increasing of PAR positively influenced photosynthetic rate (combination 0,25 PAR showed 8,82, 0,5 PAR 9,79 and 1 PAR 11,50 μmol CO_2 m^{-2} s^{-1}), and usually under 1 PAR

Fig.1. Photosynthesis of brewers barley grown under 0,5 g N/pot and various PARs

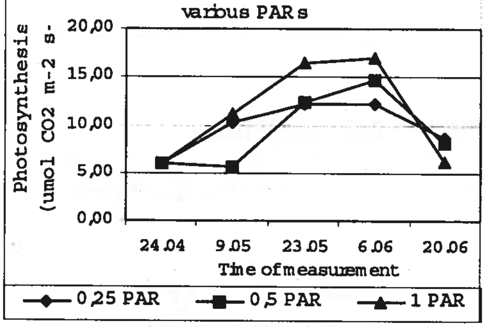
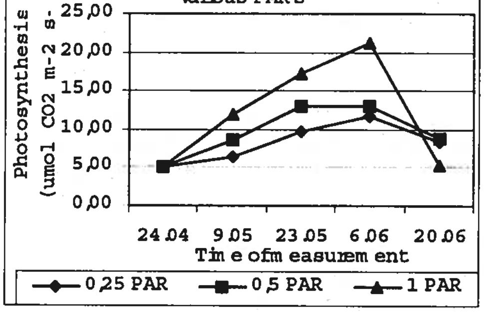
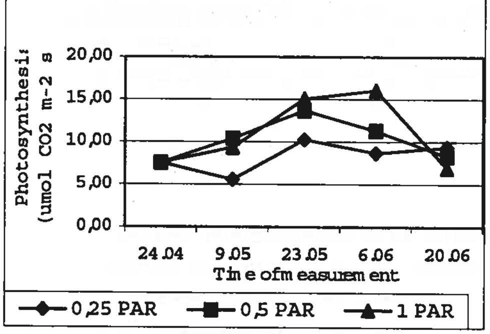


Fig.2. Photosynthesis of brewers barley grown under 1 g N/pot and various PARs



it was significantly higher than under lower ones and under 0,5 PAR significantly higher than under 0,25 PAR. Stomatal conductance of plants grown at 1,5 g N/pot was usually lower than under both other doses; for example during the 4th measurement it ranged from 0,194 to 0,255, while for 0,5 g N/pot it ranged from 0,256 to 0,313 and for 1 g N/pot from 0,224 to 0,305 mol H_2O m^{-2} s^{-1}. So under 1,5 g N/pot photosynthetic rate was lower than for other treatments, while stomatal conductance was substantially lower what in turn brought about a bit lower intrinsic water use efficiency; the contribution of photosynthetic rate was prevailing. On the other hand when nitrogen is limited stomatal conductance is decreasing (von Caemmerer and Farquhar 1981). Thus, it means that photosynthesis and stomatal conductance are the highest when nitrogen availability is in optimum. On the opposite, water use efficiency WUE, being the measure of internal factors impact on the gas exchange processes was higher, due to the substantial lowering of transpiration (data not shown). So, the plant physiologist's supplementary data strictly coincide with the observation by Ceccon et al. (1992) that found that in barley the efficiency of nitrogen fertilizer decreases at the highest application rates.

Fig.3. Photosynthesis of brewers barley grown under 1,5 g N/pot and various PARs



Conclusions:

It is concluded that high nitrogen fertilization may impair gas exchange of spring brewer's barley by affecting stomatal conductance and the resulting transpiration. Nitrogen not only does not cause an increase of photosynthetic rate, but simultaneously its content in the grain might substantially affect grain quality for brewer's purposes. This effect is observed independently of PAR intensity.

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INFLUENCE OF N FORM ON GROWTH AND WATER RELATIONS OF TOMATO PLANTS

Lugert I., Gerendás J., Sattelmacher B.

Institute for Plant Nutrition and Soil Science, University Kiel, 24098 Kiel (Germany)

Introduction

Plants may use a wide range of N forms, and the most important ones under field conditions are NO_3 and NH_4. In most cases NH_4-supplied plants show reduced growth and impaired leaf expansion resulting in reduced leaf area (Gerendás et al., 1997). The form of N affects not only growth, but also the water use efficiency. The interrelationship between leaf area, transpiration rate and water use efficiency as influenced by different N forms is still not fully understood. Therefore, the importance of N form for the water relations of tomato plants was investigated.

Material and Methods

The experiment was carried out under semi-controlled conditions (about 350 µmol m^{-2} s^{-1} PPFD) in the greenhouse. Two weeks after germination tomato plants were transplanted in 5 l pots filled with a perlite-sand mixture (1:3 Vol) and fertigated using complete nutrient solutions containing either 15 mM NO_3 or 15 mM NH_4 as sole N source with 4 replications (Tab. 1). Nitrification was inhibited using DMPP at 1% of the N provided and for the NH_4 treatment the substrate was buffered with marble (200 g pot^{-1}). Trace nutrients were included as follows (in µmol l^{-1}): Mn (10), Zn (4), Cu 0.75, B (20), Mo (3.5). Plants were fertigated according to the daily transpiration, which was determined gravimetrically to maintain 85% of the substrate's water hold capacity. 42 days after treatment initiation (DATI) growth parameters and the actual water content were determined. SPAD readings were taken (SPAD chlorophyll meter, Minolta) and the leaf area was determined using an area meter (LI-3100, Li-Cor).

Tab. 1: Composition of the nutrient solution (Macro elements in mmol l^{-1})

N form	$Ca(NO_3)_2$	KNO_3	$(NH_4)_2SO_4$	K_2SO_4	KH_2PO_4	$MgSO_4$	$CaSO_4$
NO_3	5	5	-	-	1.25	1.3	-
NH_4	-	-	7.5	2.5	1.25	1.3	2.5

Results and Discussion

As often observed at high N supply growth of tomato plants was impaired when supplied with NH_4 (Magalhaes and Wilcox, 1984; Gerendás et al., 1997), and because root growth is more drastically affected the root fraction is slightly increased (Tab. 2). Typically, the leaf area of NH_4-grown plants is substantially reduced resulting, in this case, in a slightly higher specific leaf area. As NO_3 contributes substantially to the osmotic homeostasis (McIntyre, 1997) this points to an impaired leaf expansion due to insufficient osmolyte contents of plants grown without NO_3 (Gerendás et al., 1997; Lugert et al., 2001). This hypothesis is supported by the lower leaf water content of NH_4-grown plants (Tab. 2) and agrees with previous observations (Lugert et al., 2001).

Tab. 2: Influence of N form on growth of tomato plants 42 DATI (means±SD)

N form	Shoot DM [g $plant^{-1}$]	Root DM [g $plant^{-1}$]	Plant DM [g $plant^{-1}$]	Root fraction	Leaf area [cm^2 $plant^{-1}$]	Specific leaf area [m^2 kg^{-1}]	Leaf water content [g g^{-1} DW]
NO_3	22.5±0.9	11.7±0.6	34.2±0.3	0.34±0.02	1536± 76	14.8±0.1	3.84±0.58
NH_4	8.5±0.8	5.8±1.3	14.3±2.0	0.40±0.04	440±110	16.5±1.4	3.28±0.23

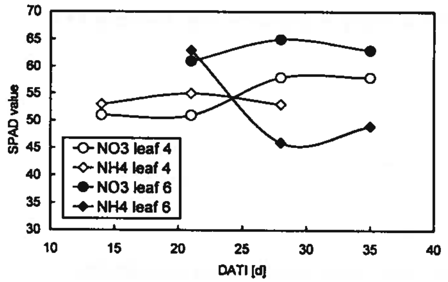

Fig. 1: Change of SPAD values of leaves of tomato plants as influenced by N form. Leaf position counted from the bases, excluding the cotyledons. Mean of 4 measurements.

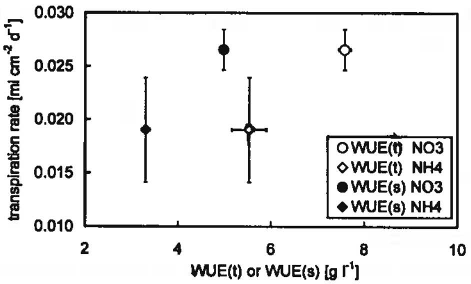

Fig. 2: Relationship between the transpiration rate (determined during the last week) and the water use efficiency based on total or shoot DM as influenced by the form of N supply. Mean±SD.

In leaves of nitrate-grown plants the chlorophyll density per unit area, as measured by the SPAD meter, increased over time and was higher in younger than in older leaves (Fig. 1). Due to the impaired leaf expansion a higher area-specific chlorophyll content of leaves of NH_4-treated plants was often observed (Gerendás et al., 1997). Contrary to this the area-specific chlorophyll content was substantially reduced in NH_4-grown plants (Fig. 1), indicating serious NH_4 toxicity (Zhu et al., 2000).

Contrary to previous experiments showing a higher transpiration rate per leaf area for NH_4-grown tomato plants (Lugert et al., 2001) the transpiration rate in this experiment, determined gravimetrically as water loss during the last week, was reduced by NH_4 supply (Fig. 2). This may relate to severe physiological disorders induced by the high NH_4 supply (15 mM in the nutrient solution). As discussed in more detail elsewhere, NH_4 reduces the hydraulic conductivity of the root system, presumably at the membrane level, resulting in reduced water uptake, water contents (Tab. 2) and leaf xylem pressure potential (Pill et al., 1978). In agreement with previous experiments NH_4-grown tomato plants exhibited a lower water use efficiency (WUE), whether based on total or on shoot DM (Fig. 2). As the transpiration rate of these plants was reduced, it is tempting to speculate that the lower WUE originates either from impaired photosynthetic efficiency or from increased respiratory losses (Farquhar and Richards, 1984).

Conclusions

As compared to NO_3-grown controls NH_4-supplied at high concentration impairs growth of tomato plants, and the largely reduced leaf area most likely originates from altered water relations. Contrary to previous observations the lower WUE of NH_4-grown plants cannot be explained by higher transpiration rates.

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EFFECT OF N DEPRIVATION IN POSTSILKING KERNEL GROWTH, AND GRAIN YIELD COMPONENTS IN CONTRASTING ENVIRONMENTS

M. Maturano[1], E, Guevara[1], A. De Juan Valero [2], F. Ortega[2], S. Meira[1], J. M. Tarjuelo[2].
(1) Instituto Nacional de Tecnología Agropecuaria. CC31. EEA Pergamino. 2700 Pergamino. Bs. As. Argentina. E-mail: mmaturano@pergamino.inta.gov.ar
(2) Centro Regional de Estudios del Agua. ETSIA. Albacete. Spain.

INTRODUCTION

In crop production, fertilization as irrigation are two fundamental practices to increase yields. However the incorrect management has as principal risks, a negative impact upon the environment, a lack of resource conservation and the unsuitable use of inputs. The objective of this work was to evaluate the nitrogen effect upon kernel growth rate, grain yield and its numeric components, in contrasting environments such as Pergamino, Bs. As., Argentina and Albacete, Castilla–La Mancha, Spain.

MATERIAL AND METHODS

Experiments were conducted at Albacete, Spain, (39° 02' 50'' N, 02° 05' 10'' W, altitude 699 m) on a calcixerollic-petrocalcic xerochrepts soil (Site 1) and Site 2)Pergamino, Argentina, (33° 56' S, 60° 33' W, altitude 65.5 m) on a silty clay loam soil (Typic Argiudol) (Site 2). In Albacete a 2-year study (1999-2000) corn was grown under three different nitrogen levels under irrigation conditions. The nitrogen levels were: 0, 175 and 300 for 1999 and 0, 150 and 300 kg N ha^{-1} for 2000 (T, Nop, and NC respectively). The trials were sown on 05 May 1999 and 19 May 2000.2) At Pergamino, the experiment was conducted during the crop season 1999-2000. The N levels studied were: 30, 90 and 130 kg N ha^{-1} (T1, T2, and T3 repectively)under irrigation conditions. The trial was sown the 08 october 1999. For both sites, the N rates were tested in a randomized complete-block design with three replications. Determinations of kernel growth rate, kernel weight (KG) , kernels number per unit area at maturity (KN) and grain yield were made. Statistical analyses were performed using the statistics package SPSS V 10.0 (SPSS Inc., 1992).

RESULTS

In SITE 1, 1999 kernel growth rates were 7.5, 7.6, and 7.1 mg d^{-1}. The grain filling period duration was 56, 55, and 56 d for Nop, Nc, and T treatment respectively. There was not statistically differences between treatments. In 2000, kernel growth rates were 7.0, 7.1, and 6.3 mg d^{-1}, for Nop, NC, and T respectively. Treatment "T" show statistical differences against Nop and NC, (Tuckey α= 0.05). The grain filling duration was of 59, 59, and 57 d for Nop, Nc, and T, without significant differences. For SITE 2 there were not statistically differences neither for kernel growth rates nor for the grain filling period duration. Values of 5.6, 5.7, and 6.0 mg d^{-1} for T1, T2, and T3 respectively were measured. The grain filling period was the same for all the treatments (51 d). These phase is highly dependent upon temperature and assimilate availability (Cirilo and Andrade, 1995).
Corn yield can be explained by two principal components: kernel number per square meter (KN) and kernel weight (KW) (Fleury, 1990).Grain yield in maize is highly dependent on KN (Fisher and Palmer, 1984); this yield component is mainly dependent on environmental conditions (Kiniry and Ritchie, 1985; Westgate and Boyer, 1986). N deprivation reduces kernel weight because it affects cell number and grain starch number after flowering, and decreases dry matter partitioning during the kernel growth rate caused by a decrease in photosynthetic rate and Leaf Area Duration (Uhart and Andrade, 1995). Only in 2000 cycle statistically differences were found within the Site 1. Kernel number (KN), kernel weight (KW), and grain yield, were significantly affected by N deprivation in T (Table 1), due to a lower value of the Radiation Use Efficiency (Data not shown)

SITE 1		
Cycle 1999		
Treatment	**KN**	**KW**
NOP	5036	310
NC	4955	320
T	5113	310
Level of significance	NS	NS
Cycle 2000		
NOP	5560 a	300 b
NC	5175 b	320 a
T	3228 c	250 c
Level of significance	**	**
SITE 2		
T1	4771	206
T2	5729	221
T3	5802	220
Level of significance	NS	NS

Table 1. Kernel number (#g m^{-2}), kernel weight (mg), and kernel yield (kg ha^{-1}) for both sites and agronomical cycles. Same letters means not significantly differences between treatments (Tuckey α= 0.05).*: $p \leq 0.05$; **: $p \leq 0.01$

The lack of response to N level between Nop and NC, showed that an increase of N fertilizer levels over 150 kg N ha^{-1} did not have effect neither for grain yield nor its components. In Site 2 statistically differences were found for yield, between T1, and the others treatments. Although not differences were found between the others yield components, KN and KW were lower for T1 compared to T2 and T3. In this environment KW is limiting corn yield, due to a lower kernel growth rate and grain filling period. There was photothermal differences that explain differences in grain yield between sites. In SITE 2 corn absorbed less photosynthetically active radiation (PAR) and had a lower dry matter accumulation and remobilization (Data not shown). In SITE 1 there was higher differences between maximum and minimum daily temperatures during grain filling, that increased the kernel growth rate and the duration of the effective grain filling period, hence KW.

CONCLUSIONS

There is an evidence of differences in genotype-environment interactions between sites. KW is the component that make yield differences between sites. The photothermal environment in SITE 1 allow corn to get highest yield. N deprivation had a higher effect at Site 1, due to the lower N reserves of the soil. The lack of response to N levels in 1999 due a high level of N in the soil profile at sowing as a consequence of the N management that farmers do, showed the importance to take into account this component into the nitrogen balance. An increase of N fertilizer levels over 150 kg N ha^{-1} did not have effect on grain yield. N are not the main factor limiting corn yield in Site 2, but probably, water availability do. Yield components differences between N levels are smoother in Site 2 than in 1. Soil N available at sowing allow to make a lower N inputs in this productive system.

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GROWTH ANALYSIS OF IRRIGATED CORN IN THE SEMIARID CASTILLA-LA MANCHA REGION, SPAIN

Maturano, Marisa [1], F. Ortega[2], A. De Juan Valero[2] and J. M. Tarjuelo[2]

(1) Instituto Nacional de Tecnología Agropecuaria. CC31. EEA Pergamino. 2700 Pergamino. Bs. As. Argentina. E-mail: mmaturano@pergamino.inta.gov.ar

(2) Centro Regional de Estudios del Agua. ETSIA. Albacete. Spain.

INTRODUCTION

The most intensively studied fertilizer element is nitrogen (N). The responsiveness of growth and grain yield in corn to the application of N fertilizer has long been recognized. Corn requires a large amount of N, which commonly limits growth and yields. Many fields trials have resulted in empirical yield response functions that demonstrate the importance of adequate availability of soil N on grain yield (e.g., Hanway, 1962). Such experiments have traditionally been analyzed statistically, and the equations generated are site and season specific.

The objective of this work was to evaluate the growth response of field-grown corn as influenced by N fertilization.

MATERIAL AND METHODS

The experiment was conducted at Albacete, Spain, (39° 02' 50'' N, 02° 05' 10'' O, altitude 699 m) on a calcixerollic-petrocalcic xerochrepts soil. The commercial hybrid Pregia (FAO 600) was used. The field experiment was a randomized complete-block design with three replications, carried out under irrigation. Weeds and insects were adequately controlled. The trial was sown on 05 May 1999, 19 May 2000, and 30 May 2001 in rows 0.7 m apart. The plots consisted of nine rows of 13-m length. Before sowing, 120 kg ha $^{-1}$ P_2O_5 (calcium superphosphate, 18% P_2O_5) and 80 kg ha $^{-1}$ K_2O (potassium sulfate, 50 % K_2O), was applied and incorporated into the soil in all plots. In the 3-year study (1999-2000-2001), corn was grown under three different nitrogen management. The nitrogen levels, sources, and timing of application are presented in Table 1.

Table 1. Treatments considered in study. Fertilizers, dosage and time of application.

Growing seasons		Treatments				
		Nc (Kg N ha^{-1})			Nop (Kg N ha^{-1})	No (Kg N ha^{-1})
1999	Dosage	80	140	80	175	-
	Time of application	11-Jun	05-Jul	13-Jul	11-Jun	-
	Fertilizer	Ammonium nitrate			Urea	-
2000	Dosage	80	140	80	150	-
	Time of application	05-Jul	12-Jul	20-Jul	05-Jul	-
	Fertilizer	Ammonium nitrate			Urea	-
2001	Dosage	100	100	100	130	-
	Time of application	05-Jul	13-Jul	18-Jul	05-Jul	-
	Fertilizer	Ammonium nitrate			Urea	-

Determinations of aboveground total dry matter (TDM) and leaf area (LA) were performed, in the following phenological phases (Ritchie and Hanway, 1982): V6, V9, V14, V_t – R1, R3, R4, and R6. Sample size was 5 plants.

Sample size was 5 plants. Samples were oven dried and weighted. At R6 a 3.65 m length of five center rows of each plot was harvest to measure grain yield Leaf area index (LAI; m^2 leaf area m^{-2} land area), crop growth rate (CGR; g m^{-2} land area d^{-1}),
relative growth rate (RGR; g g^{-1} m^{-2} land area d^{-1}), net assimilation rate (NAR; g m^{-2} leaf area d^{-1}), and leaf area duration (LAD; d^{-1}) were computed according to the procedures described by Radford (1967), Hunt (1982), France and Thornley (1984), and de Juan et al. (1992). In all the cases, classical growth analysis method was used. Statistical analyses were performed using the statistics package SPSS V 10.0 (SPSS Inc., 1992).

RESULTS

In the 1999 experiment, no significant differences on dry matter accumulation between N levels were found for TDM. In 2000 experiment since late vegetative stages differences between No and Nop and Nc were found. There were not differences between Nop and Nc. At R6 stage the TDM values were 1702, 2886, and 2663 g m^{-2} for No, Nop, and Nc treatments. In 2001 growing cycle, N fertilization significantly affected TDM values. Nitrogen shortage reduced aboveground dry matter accumulation, with maximum differences among N treatments in R6 stage: 1294, 2357, and 2643 g m^{-2} to No, Nop, and Nc treatments, respectively. Values of LAI during 1999, were no significant different among N treatments during most of the growth stages. LA and LAI were significantly reduced by N shortage during 2000 and 2001 growing seasons. Maximum LAI values were observed at flowering, varying between 3.9 (No) and 5.5 (Nc) in 2000 year and between 3.4 (No) and 5.5 (Nc) in 2001 experiment. The difference between Nop and Nc treatments were not significant. In 1999 there was not significantly differences in LAD between treatments. In the rest of the years there was significantly differences between No and the fertilized treatments, Nop and NC. The highest total LAD were obtained for Nop and NC treatments in 2000, and was closely related to grain number per square meter, and hence yield (data not shown). Significant differences among N treatments in CGR values were observed in the 2000 and 2001. Nitrogen fertilization increased CGR at all the reproductive stages in the two growing season, although the differences between Nop and Nc was not significant. In 1999 ranged between 43.0 (No) and 53.2 g m^{-2} day^{-1} (Nc). In 2000 cycle, between 16.6 (No), 42.8 (Nop treatment), and 44.3 g m^{-2} day^{-1} (Nc) at R1 stage. In general, RGR was initially very high and declined with crop age in 3-year experiment and all N treatments. Highest RGR values were found at V6 stage, the they decreased with a decline in NAR and LAR. At the Vt stages RGR values varied between 71.4 (To) and 94.5 mg $m^{-1}day^{-1}$ (Nop) in 1999, between 48.5 (To) and 81.8 mg $m^{-1}day^{-1}$ (Top) in 2000, and between 60.5 (To) and 65.1 mg $m^{-1}day^{-1}$ (Tc) in 2001 year experiment. It was observed that in 2000 growing season high levels of nitrogen (150 and 300 kg N ha^{-1}) recorded high NAR values during later stages of crop growth. In low nitrogen levels (To), the NAR was restricted. Particularly during 2000, NAR exhibited peaks and depressions till crop maturity, tended to decline with senescence in low nitrogen levels and was maintained high at Nop and Nc treatments during onset of grain filling. In R3 and R4 NAR values varied between 6.8 (To) and 9.2 mg m^{-2} day^{-1} (Top) in 1999 growing season and between 3.5 (To) and 10.7 mg m^{-2} day^{-1} (Nc) in 2000 year of the study.

CONCLUSION

Results showed that there was no increase in aboveground dry matter with nitrogen levels over 150 kg N ha^{-1}. The fact that the effect of a nitrogen shortage appeared for the second year in the 0 kg N ha^{-1} treatment shows that it is very important in this area to take into account the residual soil nitrogen for fertilization planning. Results shows the importance of adjust nitrogen in a crop system according to the production scope and the environment to ensure environmental quality.

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INFLUENCE OF NITROGEN FERTILIZER ON THE GRAIN YIELD OF BARLEY (*HORDEUM VULGARE* L.)

A. Moreno, M.M. Moreno, M.J. Cabello, F. Ribas
SITA de Castilla-la Mancha. CMA "El Chaparrillo". C/ Alarcos 21, 13071 Ciudad Real (Spain)

Introduction

Cereal crop is one of the basis of the agrarian economy of Castilla-La Mancha, together with vineyard and olive grove. At present, barley is the most widely cultivated and economically important cereal in this zone, meaning a high percentage of the total grain production. On the other hand, the present production systems are frequently based on generous applications of nitrogen (N) fertilizer, often in higher doses than those really required by the plants. Apart from the fact that this is of no benefit to the plant, it also presents a possible risk of underground water contamination from nitrates.

It is not possible to establish exact doses of nitrogen fertilizer since cereal requirements are dependent on factors such as climate, soil or growing system. However, it is possible to establish some guidelines taking into account that the total amount of N applied is as important as its partitioning and the moment in which it is applied.

Material and methods

A field study was conducted during three years (1998 to 2000) in Ciudad Real (Spain), in a loam-sandy, basic and non-saline soil. It presents a normal C/N relation, low to normal total nitrogen level and a very high content of assimilated potassium.

The Beka variety was used as it is well-established and highly-considered among cereal farmers in Castilla-La Mancha. Sowing was at a rate of 160 kg ha^{-1} (420 seeds m^{-2}), meaning 350 plants m^{-2} in the field. The crop was irrigated using a sprinkler irrigation system. The irrigation period varied depending on climatic conditions and development of the crop, from the 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% crop evapotranspiration (ETc). It appears to have been sufficiently demonstrated that this reduction in watering does not significantly vary barley yield (Martín de Santa Olalla et al., 1992; Moreno et al., 2000) and it can mean an important saving of water during dry seasons. The ETc was calculated by means of a water balance using a neutron probe in a nearby plot with similar soil characteristics and subjected to the same farming practices.

The fertilization consisted of 100 kg P_2O_5 ha^{-1} applied at pre-sowing (superphosphate), and the differential doses of N in the form of urea at sowing time and ammonia nitrate at top-dressing in the tillering stage. The high levels of assimilated potassium in the soil (415 ppm) made potassium fertilization unnecessary.

A split-plot statistical design with four repetitions was used, considering the total N dose as the main plots (0, 100, 150 and 200 kg ha^{-1}) and its partitioning between sowing time and top-dressing at tillering as the subplots (the total N dose applied at seeding time (S), two thirds at seeding time and one third as top-dressing (2S1T), one third at seeding time and one third as top-dressing (2S1T) and the total N dose as top-dressing (T)). There were a total of 64 subplots of 2.4 m width and 17 m length (42 m^2). Both yield and 1000-kernel weight were referred to 12% humidity.

Results

The effect of N dose was decisive in all of the measured parameters, resulting in a statistically significant ($P \leq 0.001$) trial. The enormous influence of the year factor is worth note, as the grain yield showed large differences each year.

No statistically significant differences were found ($P \leq 0.05$) between the yield corresponding to the 100 and 150 kg N ha^{-1} doses, but were found between the 200 and 0 kg N ha^{-1} doses. The treatment without N supply was the least productive ($P \leq 0.05$). Figure 1 shows that yield fits well ($P \leq 0.001$) to a quadratic function, with the maximum corresponding to a dose of 123 kg ha^{-1}.

The results also indicate that a single application of N fertilizer at top-dressing results in a significant reduction ($P \leq 0.05$) in barley grain yield. The other treatments showed a less conclusive inter-annual behavior, being 2S1T the most productive in the joint study over 3 years.

Table 1.- Effects of various N treatments on grain yield in barley. Years 1998 to 2000.

Treatment		Year			
		1998	1999	2000	Mean
N dose (kg ha^{-1})	0	1710 c	2005 c	3241 c	2319 c
	100	4973 a	4359 a	5247 a	4860 a
	150	4916 a	4096 a	5497 a	4837 a
	200	4287 b	3339 b	4060 b	3895 b
Partitioning	S	3911 ab	3460 a	4594 b	3988 b
	2S1T	4240 a	3599 a	4894 a	4244 a
	1S2T	4093 a	3563 a	4564 b	4073 b
	T	3642 b	3178 b	3993 c	3604 c
Mean		3971 B	3450 C	4512 A	3978

For each N treatment and year, different small letters differ at $P \leq 0.05$. Capital letters show differences between years at $P \leq 0.05$.

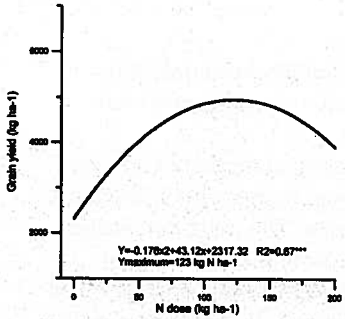

Fig. 1.- Response of grain yield in barley to the N fertilizer. ***Significant at $P \leq 0.001$.

The year factor showed interaction ($P \leq 0.001$) with the N dose, suggesting that the particular conditions of each year did not always have the same influence. There was no Year x Partitioning interaction, meaning that the pattern of differences detected between the different treatments was produced independently from the year in which the trial was carried out. With reference to Year x Dose x Partitioning interaction, the statistical study shows significant differences at $P \leq 0.001$, thus, the treatments proposed in this study were influenced differently by the particular conditions of each season (Table 2).

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Source	F calculated	Degree of freedom
N dose (N)	2	45.395***
Year	3	204.907***
Year x N	6	23.798***
Error a	27	1.222
Partitioning (P)	3	31.470**
Year x P	6	4.312***
N x P	9	2.288*
Year x N x P	18	4.440***
Error b	108	

*,***: Significant at $P \leq 0.05$ and $P \leq 0.001$, respectively.

Table 2.- Analysis of variance (F calculated) of grain yield in barley according to N-fertilizer. Years 1998 to 2000.

Conclusions

– The crop response to nitrogen applications depends largely on the seasonal variations determined by environmental factors.

– Yield is reduced by applying 200 kg N ha^{-1}, and no significant differences are obtained between 100 and 150 kg N ha^{-1} doses. The dose of N fertilizer for optimal yield is approximately 120 kg N ha^{-1}.

– The application of N fertilizer only at top-dressing significantly reduces the grain yield in barley.

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SOWING TIME AND N FERTILIZATION EFFECTS ON YIELD OF LOW INPUT SUNFLOWER CROP

Mori M., Sifola M. I., Caputo R., De Luca S., Quaglietta Chiarandà F.

Dipartimento di Ingegneria Agraria ed agronomia, Università degli Studi di Napoli Federico II, Via Università 100, 800 55 Portici , Italy

Introduction

Nitrogen fertilization and watering reduction are among the most valuable possibilities to reduce energetic input in sunflower cultivation; this is essentially possible because of sunflower roots ability to deepen and exploit soil water and nutritional resources. On the other hand, recurrent summer drought, peculiar of southern Italy, hampers the plant to reach productive fulfilling levels without irrigation. Sowing time anticipation in winter (and subsequent flowering anticipation in spring) could solve this problem because of greater water availability during developing and maturing stages. This practice has already been experienced, with positive results, in areas with a milder winter the one peculiar of present research environment: Spain, Greece, Morocco and Sicily (Sobrino Vesperinas et al., 1992; Hadjichristodoulou, 1987; Boujghagh, 1990; Leto et al, 2001). In consideration of UE concessions to the oil-producing crops, this experiments has the aim to evaluate the possibility of introduce in Campania a low energetic input sunflower crop, exploiting the quoted resistance characteristics.

Methods

The search has been carried out in a three years period, from 1999 to 2001, at "Torre Lama", the experimental farm of the University of Naples situated in Sele Plane (long. 14° 58' E; lat. 40° 37' N), on *Gloriasol* sunflower variety.

Three sowing times, anticipated, regular, and postponed (January, March and late April – early may respectively) have been confronted in factorial combination with three N fertilization levels: control not fertilized (N0), 50 kg ha^{-1} of nitrogen (N1) and 100 kg ha^{-1} of nitrogen (N2). The experiment did not include irrigation. A statistical analysis has been performed on subdivided plots with three repetitions according to the experimental outline.

In the third year an additional sowing has been done in the first decade of December. For this reason a one year statistical analysis has been performed separately for the 2001.

Results

The three years thermo-pluviometric course has reflected the typical mid-southern Italian climate, with minimal temperatures, often close to 0°C, in the first months of the year, and gradually increasing until 20°C in July and August; maximum temperatures frequently exceed 30 °C in summer. Precipitations (700-750 mm y-^{1}) are concentrated mainly in the period from November to April, summer weather is rather dry (30-40 mm).

In 1999 because of consistent rains (194 mm) occurred in June and July, the crop has been favourite independently from sowing time. In September 2001 a huge raining event took place, damaging all the crops in Campania Region.

Significant effects are reported in figures 1 and 2. The positive effect of the N fertilization (Fig.1) has turned out increasing with the increment of the dose. The greater production of fertilized treatments, seems to be due essentially to the effect of nitrogen during the vegetative stage, influencing the development of larger head (16.3 cm vs 6.8 cm). The interaction Years x Sowing time is shown in figure 2. Is clearly visible that, every year, anticipated sowing has given larger productions (approximately 2.7 t ha^{-1}).

In 1999, thanks to the particularly favourable June and July precipitations, the other two sowings gave almost the same yield. In the following years, in contrast, when the thermo-pluviometric course has been typical, these two sowing time gave clearly inferior yields, approximately 2 t ha^{-1} for the regular time (March), for as concerns the delayed one (late April-early May) the yield was reduced further. The intense rainy event, occurred the day before the harvest of 2001 delayed sowing, induced the lodging of nearly all the plants and the fall of the greater part of the seeds, giving a very poor yield (less than 1 t ha^{-1}). Apart this event, the differences between the yields obtained with the regular and delayed sowings seem to be related essentially to the number of achenes on the head, showing the influence of water stress during the anthesis. An additional anticipated sowing (early December) has been carried out in the year 2001. The results (fig. 3) were disappointing because of winter rains that, in clay and poorly draining soil, caused large water logging areas that killed of more than the 50 % of the plants.

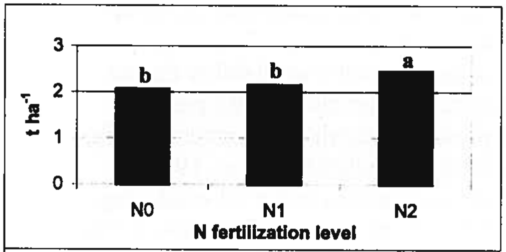

Fig. 1 Achene production as affected by N fertilization.
Significantly different means are indicated by different letters (p0.05).

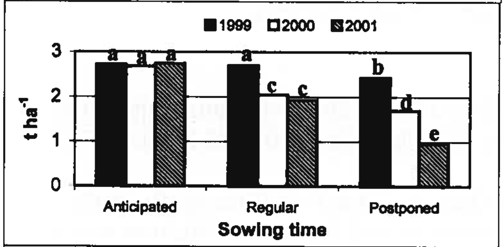

Fig. 2 Achene production as affected by years x sowing time interaction.
Significantly different means are indicated by different letters (p0.05).

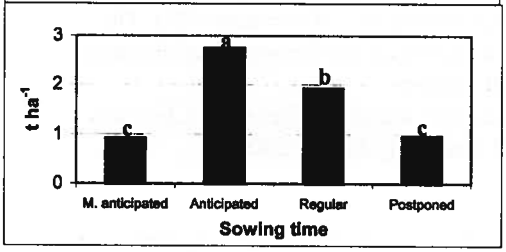

Fig. 3 Year 2001 achene production as affected by sowing time.
Significantly different means are indicated by different letters (p0.05).

Conclusions

In case of a low energy input sunflower crop, without irrigation, as much as possible sowing anticipation seems to be the most important factor. The results show clearly that January sowing, bring the most sensitive crop stage in a more favourable period from the water point of view, avoiding the stress that, without irrigation, occurs naturally when the sunflower is sown in March or later on. On the other hand, a very early sowing is to be excluded in climatic and soil conditions in which this experiment has been carried out. Concerning N fertilisation, the positive effect of maximum level adopted (100 kg $ha^{-1}$of N) seems to be clear; but yield increase has been limited and the economic convenience of bigger doses application should be well studied.

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INTERACTIONS BETWEEN CULTIVAR AND FUNGICIDES ON FLAG LEAF SENESCENCE, YIELD AND PROTEIN CONTENT OF WINTER WHEAT

Pepler S., Ford K.E., Gooding M.J., Gregory P.J.

Crops Research Unit, The University of Reading, School of Agriculture, Earley Gate, PO Box 237, Reading, RG6 6AR, UK.

Introduction

Fungicides have long been used to protect yield by controlling disease. Recently, strobilurins have been introduced which may also increase yield by extending the life of the plant longer than can be explained by disease control alone (Bayles *et al.*, 2000). This yield increase reduces grain protein concentrations (GPC) if the accumulation of grain carbohydrate is increased more than that of grain nitrogen (Ruske *et al.*, 2001). However, the effect of fungicides on GPC appears to depend on the species of pathogen controlled (Dimmock *et al.*, 2002*a*). The control of brown rust (*Puccinia recondita*) and powdery mildew (*Erisyphe graminis*) have often increased or had no effect on GPC whereas the control of *Septoria* spp. has often decreased GPC. This experiment studied how the green leaf life, disease, yield and protein concentrations of several winter wheat cultivars were affected by fungicide programmes which included strobilurins.

Methods

A field experiment was carried out at the Crops Research Unit, The University of Reading, UK (51°29'N, 0°56'W) in the 2000/2001 growing season and was of a split-plot factorial design with cultivar main plots divided into 10 x 2m fungicide treatment sub plots. Six UK winter wheat cultivars including feed, biscuit- and bread-making wheats and three fungicide treatments were used. Treatment 1 was 63g a.i. ha^{-1} epoxiconazole at Growth Stage (GS) 31, Treatment 2 was Treatment 1 plus 63g a.i. ha^{-1} epoxiconazole and 125g a.i. ha^{-1} azoxystrobin at GS 39, and Treatment 3 was Treatment 2 plus 63g a.i. ha^{-1} epoxiconazole and 125g a.i. ha^{-1} azoxystrobin at GS 59. Other than for fungicide treatment, all plots were managed as per commercial practice. Weekly visual assessments of the flag leaf were made from 21 June until harvest. Ten stems were randomly chosen per sub plot and the percentage disease and green leaf area of the flag leaf was visually assessed. Modified Gompertz curves (Dimmock *et al.*, 2002*b*) were then fitted to the green leaf area decline over time and *m*, the time for the flag leaf to senesce to 37% green leaf area, was calculated for each sub plot. Harvest was on 14 August 2001. Protein concentration (% DM) was measured with an oxidative combustion process.

Results & discussion

When the canopy was assessed two diseases predominated – *S. tritici* and brown rust. Different cultivars were affected to different extents by these diseases (Table 1). Shamrock and Consort were mostly affected by brown rust and Savannah and Malacca by *S. tritici*. Treatment 3 controlled brown rust more effectively than *S. tritici*.

A cultivar x treatment interaction occurred on the time taken for the flag leaf to senesce to 37% green area (Gompertz *m*) (Table 2) reflecting the relative disease susceptibility of the cultivars. There was no similar interaction on grain yield. Although Claire was the most resistant cultivar and did not experience an increase in *m* between Treatments 1 and 3, yield was increased by a similar extent to the other cultivars. The feed wheats had higher yields than the bread-making wheats. There was a mean increase of 0.57 t ha^{-1} between Treatments 1 and 2 and 0.15 t ha^{-1} between Treatments 2 and 3 (SED= 0.089). When averaged over cultivars, it can be seen that for every 1 day increase in *m* there is a 0.11 t DM increase in yield, a result consistent with that of Gooding *et al.* (2002).

Table 1. The effect of fungicide treatment on disease area on the flag leaf on 11 July 2001 showing both untransformed and transformed data. SED 1 refers to the SED when comparing means across cultivars and SED 2 refers to means within cultivars

Cultivar	Brown rust area per flag leaf on 11 July			*S. tritici* area per flag leaf on 11 July					
	%			%			Logit transformed data		
	1	2	3	1	2	3	1	2	3
Shamrock	6.62	0.05	0.00	2.92	1.78	2.53	-1.76	-2.04	-1.86
Claire	0.03	0.00	0.00	2.05	1.45	1.42	-2.26	-2.41	-2.42
Consort	5.33	0.12	0.00	3.77	1.78	1.88	-1.65	-2.19	-2.45
Hereward	0.75	0.02	0.00	3.43	2.47	2.65	-1.66	-1.84	-1.81
Savannah	0.00	0.00	0.03	9.28	2.95	3.00	-1.17	-1.77	-1.74
Malacca	0.30	0.12	0.02	7.28	3.58	6.10	-1.33	-1.67	-1.50
SED 1	Not			Not			0.382		
SED 2	applicable			Applicable			0.146		

Table 2. The effect of fungicide treatment on time for the flag leaf green area to decline to 37% (Gompertz *m*), grain yield and grain protein concentration (GPC). SED 1 refers to the SED when comparing means across cultivars and SED 2 refers to means within cultivars.

Cultivar	Gompertz *m* (days)			Yield t DM ha^{-1}			GPC (% DM)		
	1	2	3	1	2	3	1	2	3
Shamrock	56.3	65.0	66.5	9.02	9.64	9.86	12.1	12.1	12.6
Claire	59.0	60.6	61.2	9.45	10.09	9.97	11.4	11.4	11.3
Consort	56.2	63.9	64.4	8.97	9.83	10.12	12.0	11.8	12.0
Hereward	60.3	65.8	65.8	9.15	9.64	9.56	12.8	12.8	13.0
Savannah	56.1	62.7	64.3	9.44	10.06	10.10	11.4	11.0	11.0
Malacca	55.7	59.1	59.7	8.53	8.75	9.31	12.1	12.2	11.9
SED 1	1.58			0.300			0.17		
SED 2	0.91			0.219			0.16		

Protein concentration showed an interaction between fungicide treatment and cultivar, although for most cultivars the effects of increasing fungicide application on GPC were not significant (Table 2). The increase in GPC of Shamrock when brown rust was controlled and the decrease in GPC of Savannah when *S. tritici* was controlled is consistent with the findings of Dimmock *et al.* (2002*a*).

The HGCA is thanked for partially funding this research.

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GROWTH ANALYSIS AND PAR INTERCEPTION IN SPRING BREWER'S BARLEY CANOPIES UNDER DIFFERENT NITROGEN FERTILIZATION

Pietkiewicz[1] S., Loboda[2] T., Wyszynski[3] Z., Gozdowski[3] D., Wolejko[2] E.

[1]Warsaw Agric. Univ., Dept. of Plant Physiol., Rakowiecka St. 26/30, 02-528 Warsaw Poland
[2]Technical Univ.. Dept. of Agriculture, Wiejska St. 45A, 15-541 Bialystok, Poland
[3]Warsaw Agric. Univ., Dept. of Crop Science, Rakowiecka St. 26/30, 02-528 Warsaw Poland

Introduction

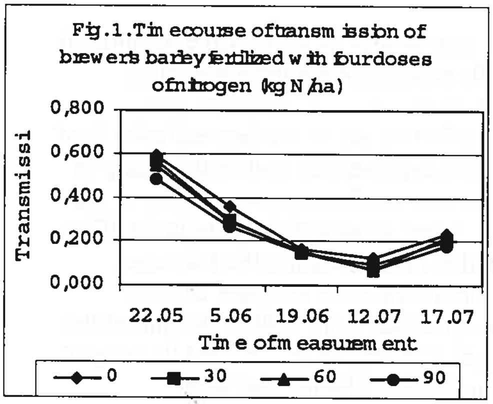
PAR absorption by the canopy depends on incident PAR and the size of its absorber, quantified as leaf area index LAI. Each canopy has its own spatial distribution of photosynthesizing surfaces, yet both incident PAR varies during day as well its direction of incidence does according to solar circulation (Nobel el al. 1993). So, the effective use of varying radiation is of great interest for plant productivity (Pearcy et al. 1996). The absorber size and activity may be affected to a great degree by different nitrogen fertilization that conditions a persistence of the leaves. Under mineral deficiency substantial changes may occur in optical characteristics of the leaves, leaf age and their location on the plant. The limitation of the magnitude of nitrogen fertilization doses in the case of spring brewer's barley implies the need to obtain enough efficiency of harvesting PAR and converting it to biomass (Loboda et al. 2000). The aim of the study was to evaluate a promoting role of different nitrogen fertilization on LAI and its integral LAD thus affecting radiation use efficiency RUE in spring brewer's barley canopies.

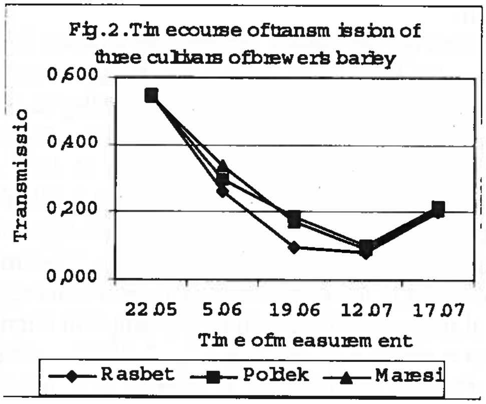
Material and methods

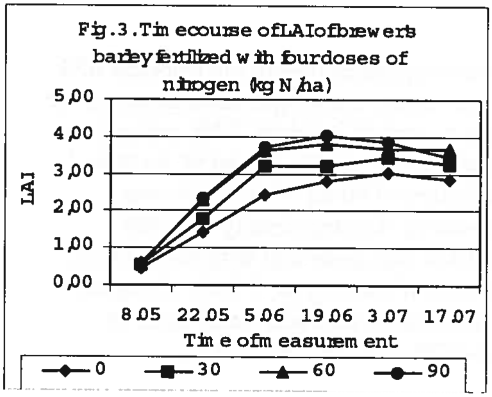
In a field experiment conducted in randomized blocks with 4 replicates design the response of 3 leading spring brewer's barley cultivars Maresi, Poldek and Rasbet to nitrogen fertilization in the view of leaf size and persistence as well as their efficiency to capture incident PAR and convert it into biomass production was analyzed. Four doses of nitrogen i.e.: 0, 30, 60 and 90 kg N ha^{-1} were used which were applied before sowing with the exception of 90 kg N/ha which was splitted in 60 kg N/ha before sowing and 30 kg N/ha in shooting. Sowing density was 350 grains/m^2, independently of the cultivar. Transmission of PAR was measured with Li-191 S.A., combined with Data-Logger Li-1000 according to the method of Gallo et al. (1986). Dynamics of leaves' PAR absorbing area under different nitrogen fertilization rate was determined as measured LAI with LAI 2000 (Plant Canopy Analyzer LI-COR, Lincoln, NE, USA).

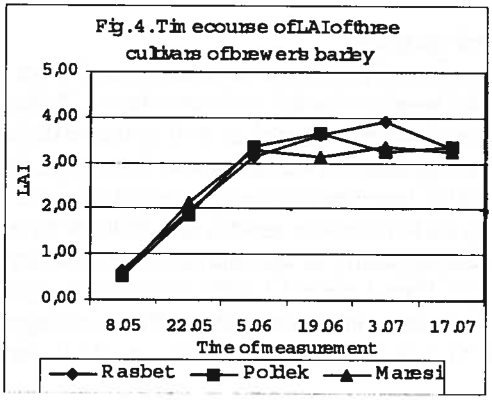
Results and discussion

No significant difference was found among the time course of transmission of PAR to the bottom of canopy as influenced by nitrogen fertilization (Fig.1). The common pattern was a steady decline, i.e. much better level of PAR absorption till 12 July, though later on, due to the increase of dead leaves number, the transmission somewhat increased. Instead, substantial difference was found between the time course of transmission by canopy of cv. Rasbet and 2 others (Fig. 2). Just after 5.06 it had displayed much higher decrease of transmission (from 0,55 through 0,26, then 0,10 versus 0,17-0,19 in other cases till 0,08 on 12.07). Maximum LAI value was found on 19.06 and though it exceeded 4, there was no indication that it was the critical one, i.e. the canopy already reached such size that absorbs 95 % of incident PAR (Hay and Walker 1989). No significant difference appeared among the LAI as fertilized with 60 or 90 kg N/ha, whereas significant differences occurred between the latter and the lower rates of nitrogen fertilization (Fig. 3). The treatments 0 kg N/ha and 30 kg N/ha characterized with lower LAI values (3,05 and 3,45, respectively) however, the maximum occurred 2 weeks later as compared with that for higher doses (3,83 and 4,05). There were some differences in persistence and magnitude of canopy leaf size. LAD for treatment 0 kg N/ha was only 173, it increased for 30 kg N/ha to 206 and further reached the same level for highest doses (235 and 241, respectively).Clear differences among the varieties were found after 5.06 (Fig. 4). Since then it was found that canopy of cv.Rasbet reached the higher LAI (3,93), yet it was done 2 weeks later than in the case of cv. Poldek, but then value for cv. Rasbet equaled that for the former (3,63 versus 3,64, respectively). Practically canopy of cv. Maresi ceased to grow about 5.06. (steady state of LAI 3,3 till the end of green surfaces vegetation). LAD did not differ significantly (208 Maresi, 212 Poldek and 222 Rasbet). Optimum RUE (1,66 g MJ PAR^{-1}) was noted at 60 kg N/ha, with this all treatments but 0 kg N/ha have led to better efficiency of PAR use. Cv. Maresi was the best among the others in the view of RUE (1,39 g MJ PAR^{-1}) (data not shown).









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USE OF CHLOROPHYLL-SPAD METER ON POTATO AND SORGHUM

M. Ângelo Rodrigues, Anabela Martins and Helder Ferraz

Escola Superior Agrária, Campus Sta Apolónia, 5301-855 Bragança, Portugal

Introduction

The SPAD-502 chlorophyll meter measures the transmittance of leaves at 430 nm, which is a peak of maximum absorbance by chl, providing an indication of its chl content. Chlorophyll content of leaves or SPAD readings can be used as a nitrogen nutrition index of plants since most leaf N is contained in chl molecules. In order to avoid the interference of factors besides N fertility on the interpretation of results, Peterson et al. (1993) suggest the use of a N sufficiency index calculated as follows:

Sufficiency index = (Average bulk readings)/(Average reference strip readings) x 100 %.

The reference strips must be well supplied with N. A sufficiency index lower than 95 % indicates a shortage of N. In this work we study the relation between SPAD readings and laboratory measurements of chl pigments on potato and sorghum as a function of N applied. We inquire into some aspects of the use of the N sufficiency index related to the reference strips.

Material and methods

In the experimental farm of the Polytechnical Institute of Bragança two N-fertilizer experiments with potato and sorghum were imposed on a loamy textured soil. During the growing season the chlorophyll content of leaves was measured in the field with the SPAD meter and determined in the laboratory. The laboratory method uses 1 cm^2 of green tissue and methanol as solvent and the extracts are read spectrofotometrically in 3 wavelengths: 470, 651 and 664 nm. Lab chl analysis and SPAD readings were made on 15 randomly chosen plants per plot at mid-length for sorghum and at the distal leaflet for potato on the uppermost fully expanded leaves. The leaf's midrib was avoided in both crops.

Results and discussion

The quadratic relations found between laboratory and SPAD readings of chlorophyll indicated that the SPAD meter underestimated the chl content of leaves for most fertilized plants, with higher chl content (fig 1), relatively to the lab method. Changes in the relation between the two chl pigments as a result of N fertilization (fig 2) with probable changes in peaks of absorbance and the fact that the laboratory method reads in two wavelengths (651 nm for chl a and 654 for chl b), whereas the SPAD meter only reads one wavelength (430 nm), can justify the result.

The chlorophyll content of leaves (lab method) as well as the SPAD readings increased with moderate N rates and decreased with high N rates (fig 3 and 4). The initial increase is justified by the synthesis of more chl associated with more available N. The decrease is attributed to the lesser thickness of the leaves, with less optical density, caused by higher N rates and higher mutual shading of plants. With SPAD readings that effect is more evident and the reasons for this are the same as those presented to justify the results of fig 1. The effect was also more evident for the potato crop because of the higher extinction coefficient of its canopy.

Conclusion

The SPAD meter seems to have limitations in detecting minor changes in chlorophyll pigments that could occur, motivated by crop management and ecological factors, in so far as the portable tool only reads one wavelength.

The results suggest that there must be caution in the use of N sufficiency index on crops like the potato, where the effect of high N rates on chlorophyll-SPAD readings could be confounded with the effect of insufficient N. In this crop the reference strips would never be supplied with excessive N.

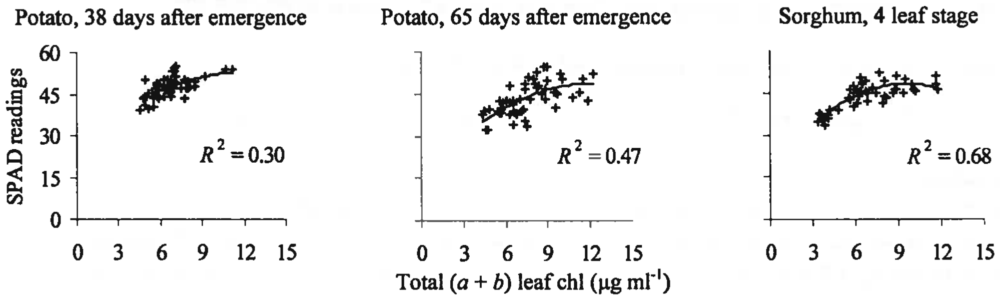

Figure 1 – Relation between leaf chlorophyll (lab. method) and SPAD readings.

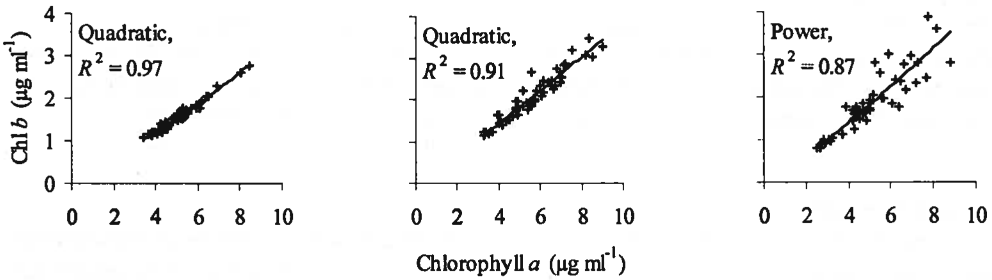

Figure 2 – Relation between chlorophyll *a* and chlorophyll *b* for all N-fertilizer treatments.

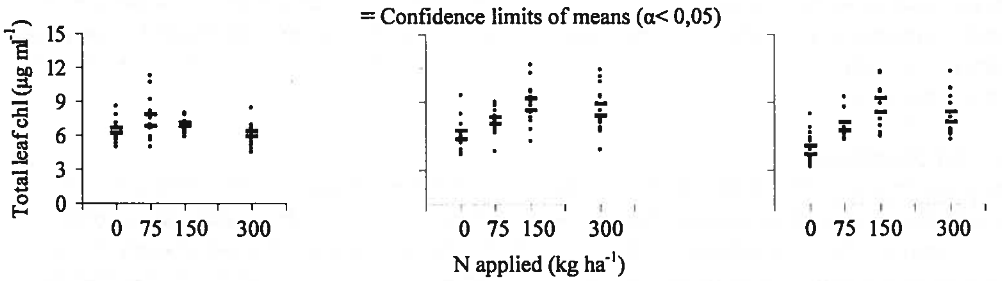

Figure 3 – Relation between N applied and total (*a*+*b*) leaf chlorophyll.

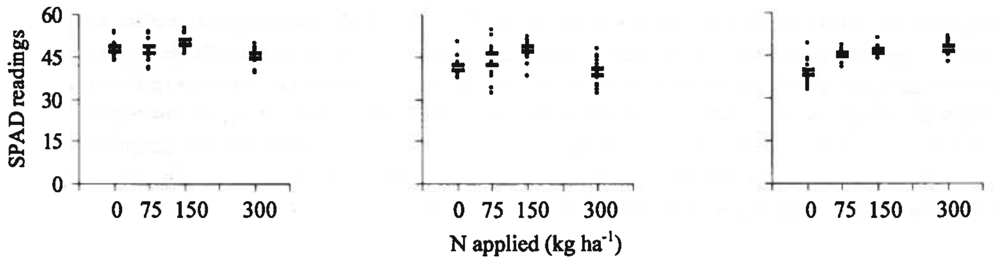

Figure 4 – Relation between N applied and SPAD readings.

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NITROGEN FIXATION AND CROP PRODUCTION IN AHIPA (*PACHYRHIZUS AHIPA*)

Rodríguez D.N.[1], Vidueira J.M.[2], Camacho M.[1], Temprano F.[1] and Leidi E.O.[2]

1 Departamento de Inoculantes Algodón, CIFA Las Torres-Tomejil, DGIEA, Consejería de Agricultura y Pesca, Junta de Andalucía, Apdo Oficial, 41200 Alcalá del Río, Sevilla, Spain.
2 Departamento de Biología Vegetal, Instituto de Recursos Naturales y Agrobiología de Sevilla, CSIC, Av. Reina Mercedes 10, 41012 Sevilla, Spain.

Introduction.

Ahipa (*Pachyrhizus ahipa* (Wedd.) Parodi) is a tuberous root-producing legume which was cultivated by Andean Cultures of pre-Columbian South America (Sørensen, 1996). Ahipa produces a carbohydrate-rich tuberous root and protein- and oil-rich seeds (Leidi, 2001). It shows resistance to several pests which has been associated to plant compounds rotenone and canavanine (Sørensen, 1996; Leidi, 2001). Another distinctive feature of ahipa over other carbohydrate-producing crops relies in its N_2 fixation ability in symbiosis with rhizobia (Rodríguez-Navarro et al., 2000). That fact together with the low capacity to utilize mineral N (Leidi et al., 2001) makes ahipa suitable for ecological agriculture, with a low environmental impact. The aim of the present work was to select efficient rhizobia for ahipa and to test selected strains under field conditions.

Methods

Greenhouse trials. Twelve strains rescued from a lyophilized collection of *Rhizobium* spp. (originally isolated from *P. erosus* and *P. ferrugineus* root nodules) were cultured and assayed for symbiotic effectiveness in a greenhouse trial using *P. ahipa* AC521 as plant host. The best performing strains were used for preparing a peat-based inoculant and further field testing.
Field trial. Two ahipa accessions (AC102 and AC521) were planted at the Experimental Station Las Torres (Seville) to determine N_2-fixation after inoculation with selected rhizobia strains (PAC48, PAC51, PAC55) and a commercial strain as reference (Spec-1). Non-inoculated controls were included. Planting was made in 7 m rows 0.50 m apart with a seed density 10 seeds per meter. Watering was done by furrow irrigation every two weeks approximately. Soil samples for chemical analyses were taken before sowing.

Results

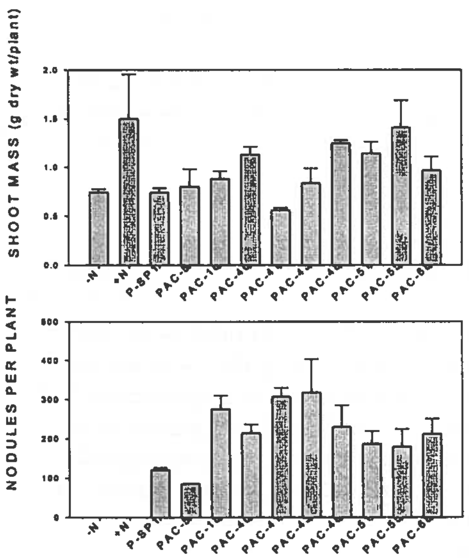
A preliminary test, under greenhouse conditions, of N_2 fixation efficiency performed on 10 rhizobia isolates led to the selection of two strains (PAC48 and PAC51) which were as efficient as the control (+N treatment) for shoot growth (Figure 1). Important variation in symbiotic parameters were recorded (Figure 1), with significant differences in nodular mass, nodule size and number of nodules.
Soil rhizobia populations at different locations were unable of nodulating ahipa roots. The lack of specific rhizobia encouraged us in the search for effective strains to provide ahipa N requirements by symbiotic N_2 fixation. Nodulation failed under soil extreme conditions at sowing (dryness, high temperature) that might have negatively affected rhizobia survival on inoculated seeds (data not presented). However, abundant nodulation was obtained when germination and seedling establishement occurred in soils with adequate water content and lower temperature. Inoculation with selected rhizobia strains produced a significant increase in root, pod and seed yield per hectare in comparison with the non-inoculated control (Table 1). The increase in crop yield provided by effective nodulation in comparison with non-inoculated control was consequence of a greater root weight and fruit load per plant.

Tabla 1. Root, pod and seed yield in two ahipa accessions inoculated with different rhizobia strains (in tonnes ha^{-1}).

	Treatment	Root	Pod	Seed
AC521	Control	15.7 a	11.9 a	0.7 a
	PAC48	30.1 b	32.5 b	2.0 b
	PAC51	23.4 ab	17.3 a	1.1 a
	PAC55	16.2 a	22.9 ab	1.4 ab
AC102	Control	24.3 a	17.8 ab	1.1 ab
	Spec1	27.9 a	24.9 ab	1.5 ab
	PAC48	32.8 a	25.3 a	1.6 a
	PAC55	57.8 b	15.5 b	0.9 a

Conclusion

It has been shown that N demand of ahipa can be satisfied by N_2 fixation under field conditions and high yield have resulted after inoculation with selected strains. These results show it is feasible the cultivation of this crop in the Mediterranean area without adding N fertilizers.



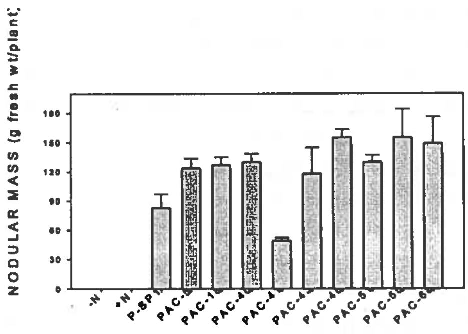


Figure 1. Shoot growth, nodular mass, and number of nodules in ahipa AC521 plants inoculated with different rhizobia strains and non-inoculated controls (-N and +N treatments).

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USE OF NITROGEN SUFICIENCY INDEX FOR CALIBRATION OF A CHLOROPHYLL METER SPAD-502 READINGS IN WINTER TRITICALE

Samborski S., Rozbicki J.
Faculty of Agronomy, Warsaw Agricultural University, Poland

Introduction

One of the tools widely used in N management is the chlorophyll meter (SPAD-502) a simple, portable electronic device that measures the greenness or relative chlorophyll content of leaves. The readings are expressed in SPAD values that indicate relative chlorophyll contents. The basis for the chlorophyll meter response to leaf N is that most leaf N is contained in chlorophyll molecules, and the relationship between SPAD values and foliar N concentration is very strong with a correlation coefficient of 0,88-0,90 for winter wheat (Peltonen et al. 1995) and 0,98 (Uzik et al. 2000) depending on the growth stage, N treatments and genotypes. However, the SPAD device has to be calibrated for special growing conditions which will result in creating SPAD thresholds or critical values which will tell us when the crop suffers from N deficiency. Establishing such thresholds is possible by comparing the SPAD values to the nitrogen nutrition index (NNI) proposed by Justes et al. (1992), but this method requires determining the N concentration and above-ground dry matter of plants and may not result in similar SPAD critical values for different years, genotypes and sites.
The aim of this study was to quantify the relationship between SPAD values and NNI and to check the nitrogen sufficiency index (NSI) described by Blackmer et al. (1994) as an alternative method for SPAD readings normalization.

Methods

In a field experiment combinations of five factors resulted in different nitrogen rates used, ranging from 90 to 180 kg ha^{-1} in 10kg intervals. Chlorophyll meter readings were taken by means of the SPAD-502 electronic device. The newest fully expanded leaf that had a leaf collar exposed was used for SPAD measurements. On each plot 20 readings were taken from which the averages were calculated automatically. Representative plants were chosen for this procedure and unusual or damaged parts of the leaf were avoided. Weight of aboveground biomass and N concentration as a percentage of dry matter, determined by means of the Kjeldahl method, were used to calculate the NNI. The level of NNI=0,9 was considered as an optimal for not limited growth rate of the crop at this time and based on this assumption the SPAD critical values were calculated. Plots with the highest nitrogen rate were used as the adequately fertilized area to obtain the NSI proposed for corn by Blackmer et al. (1994) and expressed as a quotient between field meter readings and reference meter readings. According to these authors an additional N application is required for optimum crop yield if the average meter reading of the field is less than 95% of the high N reference value. Each of the measurements investigating triticale plant-nourishment with nitrogen (i.e., SPAD readings, NNI and NSI values) was determined at three development stages: GS 31, 49, 65. However, the stage GS 49 (first awns visible) was taken into consideration as it was earlier suggested by Rozbicki et al. (2001).
The data were analyzed by means of regression analysis using linear function included in the STATGRAPHICS Plus v.3.0 program.

Results

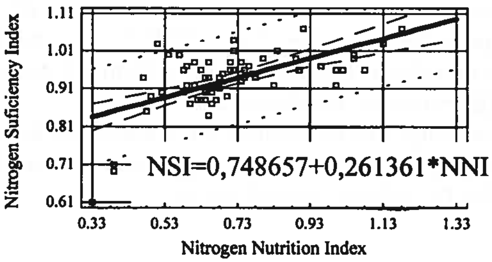
The rate of nitrogen at the beginning of vegetation and the successive N rate given at the beginning of stem elongation (GS 31) were the factors which significantly influenced the SPAD readings (data not shown).

Results of a statistical analysis presented in table 1 indicated a moderately strong relationship between the SPAD values and NNI. The critical SPAD values varied in two successive years probably due to different climatic conditions.

Table 1. Regression analysis for SPAD values versus NNI and optimal SPAD values in years 1998-1999.

Years	Determination coefficient (%)	Correlation coefficient	Critical SPAD values	Level of significance
1998	48,1	0,69	53,7	0,01
1999	60,5	0,78	47,5	0,01
1998-1999	31,0	0,56	48,7	0,01

In order to find the optimal NSI level regression analysis between NSI and NNI was conducted. The linear model as fitted explained respectively 48,5% (r=0,70; P<0,01) and 60,0% (r=0,77; P<0,01) of the variability in nitrogen sufficiency index in years 1998 and 1999. The average for two years correlation coefficient equaled 0,61 and indicated a moderately strong relationship between the values of NSI and NNI. The relationship between NSI and NNI is described by the equation presented on a graph. Our data indicate that the optimal NSI is 0,98 assuming that recommended NNI should equal about 0,9. Nitrogen sufficiency lower than 0,98 is considered deficient and it showed that there is a need to use an additional rate of nitrogen to satisfy the crop demand.



Conclusions

The optimal level of nitrogen sufficiency index obtained in this research using NNI is similar to that one calculated by Blackmer et al. (1994) with using relative grain yield as a comparison, and may be considered as a recommended one. Therefore, the relationship between NSI and NNI was alternatively investigated and turned out to be even slightly higher than that one obtained for SPAD values and NNI, indicating that NSI may eliminate some part of the variability in SPAD readings caused by different factors. A farmer establishing reference areas in a field for NSI calculation may avoid the laborious and time consuming procedure needed for NNI calculation, since using of NSI is much faster and easier.

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SPECTROSCOPIC MEASUREMENTS OF POTATO CANOPIES

Schächtl J., Maidl F.X.

Chair of Agronomy and Plant Breeding, TU München-Weihenstephan, Alte Akademie 12, 85350 Freising-Weihenstephan (Germany)

Introduction

A sustainable plant production can be achieved by a reduction of unproductive nitrogen losses and by an increase in nitrogen efficiency. This applies mainly for row cultivars like potatoes. Late nitrogen dressings given in a period when the potato shows high nitrogen uptake rates are less endangered to leaching losses. Different field trials prove the advantages of split doses (Maidl et al., 2000). With late nitrogen dressings, the actual plant development and the nutrient supply of the canopy can be taken into account. Here new sensor techniques can help. Up to now, the farmers use this technology for nitrogen application in corn production. Now the question is, if it also can be used in potato cultivars.

Methods

In the years 2000 and 2001 a plot trial was carried out for making contact-free measurements with two potato cultivars: Bonanza and Tomba. They are different according their foliage architecture: Bonanza is a leaf type and Tomba a stem type. The trial had four replications and the nitrogen fertilisation was 0, 50, 100 and 150 kg N ha^{-1} given at emergence.
The contact-free measurements were carried out with a two channel hand-held field spectrometer (tec5, 1999). The upper channel detects the incoming light and the lower one the reflected light by the crop. The spectral resolution was 3,2 nm in a range of 360 to 1050 nm wavelength. The reflection at different wavelengths (e.g. R_{780} = Reflection at 780 nm) was used for calculating vegetation indices (=VI) known from literature (Reusch, 1997): REIP $=700+40*((R_{670}+R_{780})/2-R_{700})/(R_{740}-R_{700})$; IRG=$R_{780}/R_{550}$; R740R730=$R_{740}/R_{730}$; R740R720 =$R_{740}/R_{720}$. Plant samples were gathered every two weeks in an area of 2,25 m² and the N concentration was investigated. At final harvest a whole plot of 15 m² was harvested.

Results and Discussion

With early measurements (18 days after emergence) it was not possible to detect the nitrogen supply of the potato canopy by spectroscopic measurements (Tab. 1). The reason might be a mixed signal, because the soil wasn´t totally covered by the crop canopy. Another point might be the inaccuracy with the sampling which has an impact on the determination of the biomass mainly in the early development stages.

26 days after emergence the four VI showed similar correlations to foliage N uptake. The correlations of the VI to the foliage N uptake at later growth stages were rather high. Similar results were achieved with the cv. Tomba. Other VI showed lower correlations to plant parameters.

Table 1 - Correlation coefficients between different vegetation indices and foliage N uptake (cv. Bonanza)

days (d) after emergence	vegetation index (VI) REIP	IRG	R740R730	R740R720
18	n.s.	n.s.	n.s.	n.s.
26	0.88**	0.90**	0.88**	0.89**
41	0.95**	0.93**	0.94**	0.94**
48	0.94**	0.92**	0.93**	0.93**

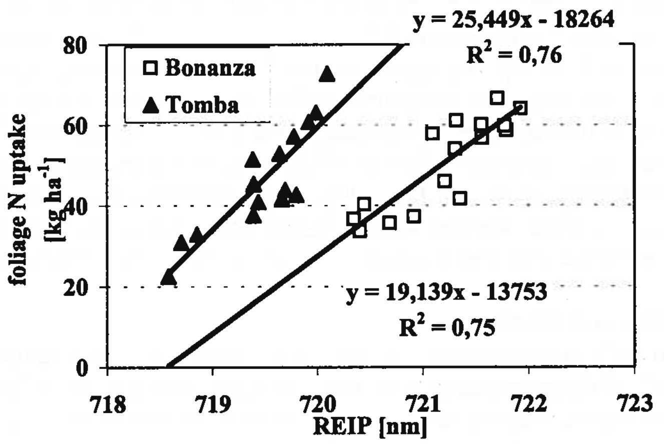
Some characteristic differences of the two cultivars are presented in table 2. Although they showed a similar foliage dry matter production 26 days after emergence (one week before flowering), the LAI values were significantly different. Bonanza is a leaf type and has a pronounced leaf production. This means that the effect of shadowing is higher than with Tomba. The more pronounced stem production of Tomba led to higher plants where the incoming sunlight could go deeper into the canopy. Bonanza also had a significantly higher foliage N concentration and accordingly a significant higher foliage N uptake than Tomba. This changed during the vegetation period. At later developmental stages, Tomba had to equalise the disadvantage of a smaller assimilation area and produced a higher foliage dry matter. So the tuber yield was similar for the two cultivars.

Table 2 - Foliage dry matter, N concentration, N uptake and LAI for the two cultivars (26 d after emergence)

	foliage dry matter [t ha^{-1}]	N concentration [%]	N uptake [kg ha^{-1}]	LAI [m^2 m^{-2} soil]
cv. Bonanza	1.16 a	4.35 a	50.8 a	2.34 a
cv. Tomba	1.16 a	3.95 b	46.4 b	2.12 b

The influence of the cultivar on the reflectance spectra has to be considered when making spectroscopic measurements. Fig. 1 shows the linear regression between foliage N uptake and REIP for the two cultivars (26 d after emergence). The fit of the equation is similar for the two cultivars. The same nitrogen uptake rate by the foliage was accorded with a higher REIP for Bonanza than for Tomba. The higher shadowness of the leaves is the reason for the lower slope in the regression line for Bonanza. A saturation effect is earlier achieved with Bonanza. The relationship is also influenced by the time of measurement (not shown). At later developmental stages, the slope in the regression line increases. The low with nitrogen supplied plots began earlier to break down than the high-supplied plots.

Fig. 1 - Linear regression between REIP and foliage N uptake (26 d a.e.)



Conclusions

Heterogenous fields are characterized by a variable soil nitrogen mineralisation within the field. This leads to different developed and supplied crop stands. Spectroscopic measurements can detect these differences within a heterogenous field. Without limitation of water, the foliage dry matter production was highly correlated to the tuber yield ($r^2 = 0.70$, 26 d after emergence). A late nitrogen fertilisation in this period, before flowering, should take the actual growth stand and nitrogen supply into account. So a site specific nitrogen fertilisation might be possible when using a spectroscopic sensor system.

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MEAN RESIDENCE TIME OF NITROGEN IN RED FESCUE (*FESTUCA RUBRA* L.) COMPARED TO ENGLISH RYEGRASS (*LOLIUM PERENNE* L.)

Schulte auf'm Erley G.[1,2], Rademacher I.[2], Kühbauch W.[2]

1 Institut für Pflanzenbau und Pflanzenzüchtung, Gregor Mendel-Straße 33, 1180 Wien (Austria)
2 Institut für Pflanzenbau, Allgemeiner Pflanzenbau, Katzenburgweg 5, 53115 Bonn (Germany)

Introduction

The grass species red fescue (*Festuca rubra* L.) and english ryegrass (*Lolium perenne* L.) are found on sites with differing nitrogen availability. It can be presumed, that *F. rubra* can cope better with sites of low nitrogen supply due to a more efficient nitrogen use. Besides the instantanous nitrogen efficiency an important plant trait for a high long-term nitrogen use efficiency is the length of the period nitrogen is used in the plant. This can be expressed as the mean residence time of nitrogen (Berendse and Aerts, 1987). The mean residence time can be estimated through the leaf life span and the retranslocation efficiency, i. e. the portion of nitrogen that is retranslocated prior to leaf senescence. To explore possible differences in the period of nitrogen conservation between *F. rubra* and *L. perenne*, the leaf life span and retranslocation efficiency were determined and mean residence time of nitrogen was calculated.

Methods

Seedlings of *Lolium perenne* cv. "Liprinta" and *Festuca rubra* cv. "NFG Theodor Roemer" were raised under a controlled environment (day/night: 500/0 µmol $m^{-2}s^{-1}$ PPFD, 10/14 h, 20/15°C, 80/70% rH) on hydroponics. Plants were supplied either 13 mg N l^{-1} (N+) or 1.4 mg N l^{-1} (N-). Nitrogen concentrations were held almost constant over time by regular monitoring of the nutrient solution.
To calculate the leaf life span of the third leaf of the main tiller the decline of photosynthesis from the time when a leaf was fully expanded to leaf death was used. Because there was a constant decrease of photosynthesis over time, linear regressions could be fitted to the data. The day the light saturated rate of net photosynthesis was projected to zero was defined as leaf death. Gas exchange of the leaves was measured with a portable photosynthesis system (Ciras-1, PP-Systems, Hitchin, UK) equipped with a narrow Parkinson leaf cuvette. Measurements were made at ambient CO_2-concentration (360 µl l^{-1}) and at light saturation, i. e. at 1200 µmol m^{-2} s^{-1} PPFD. Measurements started when the third leaf was fully expanded and repeated every three days on ten plants per treatment until the seven-leaf stage of the plants (i. e. when the sixth true leaf was fully expanded and the seventh leaf was visible but still growing).
For calculation of retranslocation efficiency, the nitrogen amounts of the third leaf of the main tiller at the four-leaf stage and at the seven-leaf stage were used. The leaves were sampled on ten plants per treatment in two replications at all growth stages from the four-leaf stage up to seven-leaf stage. From leaf maturity to the seven-leaf stage the third leaf was shaded with aluminum foil to ensure complete retranslocation had taken place. The leaves were dried at 70 °C for 48 h and nitrogen content of dry matter was analysed by an elementar analyser (NA 1500, Carlo Erba Instruments, Milano).
Mean residence time (MRT) was estimated as (Small, 1972):

MRT = leaf life span * 1/(1-retranslocation efficiency)

Results

Independent of nitrogen supply, the leaf life span of *F. rubra* was longer compared to *L. perenne*, but the species difference was pronounced only under N+, while under N- it dimished (Fig.1, Tab.1).

Retranslocation efficiency at 7-leaf stage was lower for *L. perenne* than for *F. rubra* (Fig.2, Tab.1). While the retranslocation efficiency of *F. rubra* was considerably higher under N- compared to N+, it did not differ between nitrogen treatments in *L. perenne*.

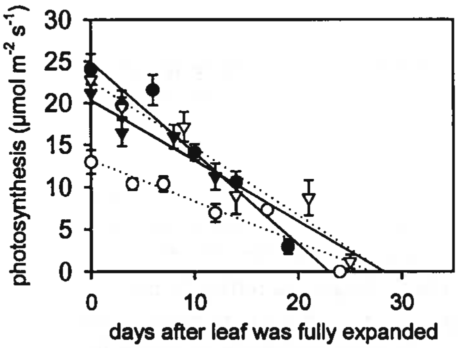

Fig 1 - Photosynthesis of leaf 3 on the main tiller over time for *L. perenne* (Lp) and *F. rubra* (Fr) at a high (N+) and a low (N-) level of nitrogen supply. Entries are means ± SE (n=10)

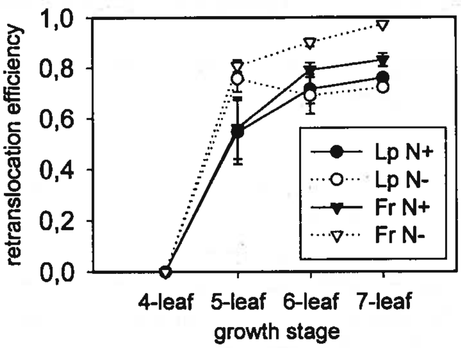

Fig 2 - Retranslocation efficiency of nitrogen of leaf 3 on the main tiller for *L. perenne* (Lp) and *F. rubra* (Fr) at a high (N+) and a low (N-) level of nitrogen supply at different growth stages. Entries are means ± SE (n=2)

As a result of these two plant traits, the calculated mean residence time of nitrogen was higher for *F. rubra* compared to *L. perenne* (Tab.1). Under N+, the mean residence time was 1.8fold higher for *F. rubra* compared to *L. perenne*; under N-, it was about 10fold higher.

Tab 1 – Leaf life span, retranslocation efficiency and mean residence time of nitrogen for *L. perenne* (Lp) and *F. rubra* (Fr) under high (N+) and low (N-) nitrogen supply.

	N+		N-	
	Lp	Fr	Lp	Fr
Leaf life span (d)	23.0	28.8	27.1	28.4
Retranslocation efficiency (-)	0.76	0.83	0.72	0.97
Mean residence time (d)	96	169	97	943

Conclusions

It is concluded, that mean residence time of nitrogen might be a major factor for the success of the investigated species on sites of differing nitrogen availability.

This difference in mean residence time is caused by an exceptionally high retranslocation efficiency of *F. rubra* at low nitrogen supply (Tab. 1). In contrast, the often drawn conclusion, that plants originating from habitats with a low nitrogen supply attain a better nutrient conservation through a longer leaf life span, can not be supported here (see also Schulte auf'm Erley et al., 2002). Though *F. rubra* had a longer leaf life span on average, this advantage with regard to nutrient conservation disappeared under low nitrogen supply (Tab.1). Possibly, differences in leaf life span are of greater importance when plants of different growth forms are compared (see Escudero et al., 1992; Eckstein et al., 1999), whereas in taxonomic closely related plant groups, like grasses, retranslocation efficiency can become more relevant with regard to nitrogen conservation.

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INFLUENCE OF N-NITRATE SOIL CONTENT ON HYDRO N-TESTER ® VALUES FOR RAINFED WHEAT IN NORTHEAST OF CATALONIA (SPAIN)

Serra J.[1], Teixidor N.[2], Domingo F.[1], Salvia J.[1], Sió J.[3]

1 IRTA-Estació Experimental Agrícola Mas Badia, Mas Badia, E-17134 La Tallada d'Empordà, Girona (Spain)
2 Servei de Producció Agrícola, Subd. General d'Agricultura, DARP, Generalitat de Catalunya
3 Departament d'Agricultura, Ramaderia i Pesca (DARP), Generalitat de Catalunya

Introduction

Hydro N-Tester ® values have been reported as a good indicator of N nutrition for several winter cereal crops. Although, this link does not appear to be consistent when crops suffer from some stress (water, diseases,...). The area of study, where wheat is widely cropped, has a large climatic variability. So, three main agro-climatic areas have been defined: i) 'Mediterranean Coast' with hot and dry springs and warm and wet weather during winter, ii) 'Inland' area with cold and wet winters and warm and wet springs, and iii) 'Medium Inland' with intermediate meteorological characteristics. Some parts of these areas have been considered as vulnerable zones for nitrate pollution. So, especial management must be carried out in order to improve N efficiency. Within a global aim to study the use of Hydro N-Tester ® values as a tool to recommend N applications in the field, this paper deals with the relationship between Hydro N-Tester ® values at different crop growth stages and N-available soil content at late winter.

Methods

Twelve field experiments (four in each agro-climatic area; one each year 1998,1999,2000 and 2001) were carried out for wheat (*Triticum aestivum* var: Soissons). A randomised block design with 4 replicates and 4 or 6 treatments was used in all sites (zone * year). Treatments consisted on different N, applied as ammonium nitrate at late winter, rates (0, 30, 60, 90, 120 and 150 Kg N ha^{-1} for years 1998 and 1999; 0, 40, 80 and 120 Kg N ha^{-1} for years 2000 and 2001).

Soil in each experiment was sampled (0-30, 30-60 and 60-90 cm) at late winter prior to fertiliser applications. $N\text{-}NO_3^-$ soil content was determined extracting soil with water (1:1) and ulterior analysis of the extract by colorimetry. N-available soil content was considered to be that determined as before plus the amount of N added through fertiliser, different in each treatment.

At GS 31Z, 32Z, 37Z and 68Z, Hydro N-Tester ® measures were taken on next to last developed leaf. Relationship between late winter N-available soil content (0-90 cm) and Hydro N-Tester ® values at those different growth stages mentioned was statistically analysed using a linear model.

Results

The linear model used, including site and N-available soil content, explained most of the variability ($0.74<R^2<0.83$) found on Hydro N-Tester ® values, at the different GS measured. Both, site and N-available soil content, had a significant influence ($p<0.001$) on those values. Slope of the linear model was found to be different from null for some sites and GS (Table 1). In these cases, a response to fertilisation was observed, although it was not the same in all cases.

At early GS no clear pattern could be deduced from these data. At late GS (68 Z) a significant negative slope is found for years 1998 and 2001 at 'Mediterranean Coast' areas (Table 1). In this area fungal diseases (mainly rust *Puccinia recondita*) frequently develop due to high temperature and relative humidity on spring. Normally no treatment is applied to control them. This affection highly influenced Hydro N-Tester ® values although no direct link with N fertilisation could be assumed. In the same area, clearly positive slopes were found for year 1999.

Area	Year	Growth stage							
		31 Z		*32 Z*		*37 Z*		*68 Z*	
Mediterranean	*1998*	0.62500	NS	0.51929	NS	0.32857	NS	-0.26571	**
Coast	*1999*	0.95929	*	0.94310	**	1.05738	***	1.76881	***
	2000	0.20313	NS	0.07500	NS	0.15188	NS	0.06938	NS
	2001	0.10063	NS	-0.00062	NS	-0.06313	NS	-0.76063	**
Medium	*1998*	0.42048	NS	0.58190	*	0.28286	NS	0.25262	NS
Inland	*1999*	0.51048	NS	0.92381	**	0.85286	**	0.72214	NS
	2000	-0.45375	*	0.43188	NS	0.62375	*	0.84438	NS
	2001	0.28375	NS	0.12750	NS	0.18125	NS	0.50250	*
Inland	*1998*	0.06381	NS	0.00619	NS	-0.13262	NS	0.12714	NS
	1999	0.32619	NS	0.23810	NS	0.61214	**	0.66738	NS
	2000	0.14625	NS	0.65563	*	0.45125	NS	0.12188	NS
	2001	0.87375	*	0.68563	*	0.17813	NS	0.25688	NS

Table 1. Slope of the linear model relating Hydro N-Tester ® values to N-available soil content at late winter for different years and areas in the Northeast of Catalonia on a rainfed wheat crop.
Symbols beside slopes indicate no difference (NS) from null, significance at $p<0.1$ (*), $p<0.01$ (**) and $p<0.001$(***).

At GS 37 Z, no response, on Hydro N-Tester ® values, due to fertilisation was found for $N\text{-}NO_3^-$ soil content (0-90 cm), at late winter, higher than 200 Kg N ha^{-1}. For lower values a response existed in 44 % of the sites (Figure 1). At earlier GS, nearer to fertilisation application, similar results were found for $N\text{-}NO_3^-$ soil content, at late winter, less than 200 kg N ha^{-1}. For higher contents there was an increase on Hydro N-Tester ® values, due to fertilisers, for some sites. Such evolutions suggested that, in most cases, soil during spring is able to mineralise high amounts of N, enough to mask fertilisation effects (Domingo *et al.*, 2002).

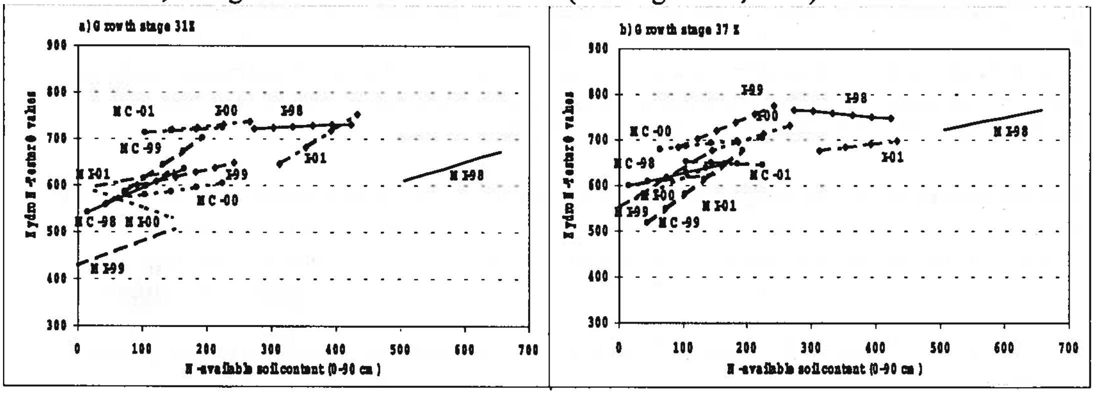

Figure 1. Site (year * zone) linear model relating Hydro N-Tester values and late winter N-available soil content (0-90 cm) at growth stages a) 31Z and b) 37Z of a rainfed wheat crop in the Northeast of Catalonia. *Each line is identified by letters (MC-Mediterranean coast; MI-Medium inland; I-Inland) and numbers (years).*

Conclusions

Influence of N-available soil content on Hydro N-Tester ® values depends on the experiment. For $N\text{-}NO_3^-$ soil (0-90 cm) content less than 200 Kg N ha^{-1} at late winter, due to N applied there is an increase of Hydro N-Tester ® values in almost half of the cases at early GS (till 37Z). This effect disappears at GS 68Z.

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THE EFFECT OF NITROGEN APPLICATION IN POTTED BARLEY PLANTS GROWN UNDER SALINE CONDITIONS.

Sifola M.I., Mori M., Galotta A., Mazzei M., Quaglietta Chiarandà F.

Department of Agricultural Engineering and Agronomy, University of Naples "Federico II", Via Università 100, 80055 Portici, Italy.

Introduction

In barley, as in other cereals and grain crops, the partitioning of nitrogen (N) to reproductive parts is the most important process for yield performance. The N present in grains comes from both N uptaken during the pre-anthesis period and temporarily stored in vegetative parts, and that uptaken during the grain-filling period. Barley is considered one of the most resistant crops to salinity, as it produces normally at 8 dS m^{-1} soil electrical conductivity and shows the yield potential 50% reduction at 18 dS m^{-1} (Maas et al., 1977). Since soil salinity decreases N uptake and alters the balance between nutrients because of antagonism and displacement mechanisms, it is important to understand how salinity affects N partitioning in salt-tolerant crops. The objective of this work was to determine the effect of salinity on partitioning of dry matter (DM) and N in barley fertilized with different doses of N.

Methods

Spring barley plants (*Hordeum vulgare* cv. Alexis) were grown in about 200 l pots containing a mixture of sand:silt:clay (77.7:13.5:8.8%) under a rain-shelter. Three levels of N fertilization (50, 100 and 150 kg N ha^{-1}) were factorially combined with two saline treatments (irrigated with tap water at 0.5 dS m^{-1} or saline water at 12 dS m^{-1} EC_w). The total N content of different plant parts was determined by the Kjeldahl method at early anthesis and physiological maturity. Plant N content was calculated as the sum of the Kjeldahl N content of each plant part (% DM) multiplied by the corresponding biomass. Net above-ground N accumulated during grain filling (ANAG) and the amount of pre-anthesis N mobilized to grains during grain filling (PNMG) were calculated according to Muchow (1990):

$$ANAG = B_A \cdot N_A - B_M \cdot N_M$$

$$PNMG = Y \cdot N_Y - ANAG$$

where N_A, N_M were the plant N content at anthesis and maturity, Y was the grain yield (g m^{-2}) and N_Y the N content of grains (g g^{-1}). The respective partitioning indexes for DM (ABAG and PBMG) were calculated using the above equations where N content was replaced by DM.

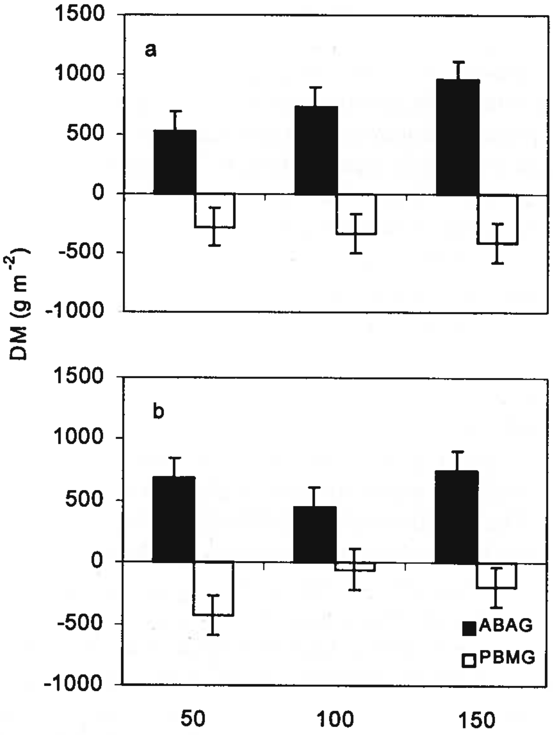

Fig. 1. The effect of N fertilization levels (kg ha^{-1}) on dry matter (DM) partitioning indexes in barley plants irrigated with water at 0.5 dS m^{-1} (a) or saline water at 12 dS m^{-1} (b). Legend: ABAG, above-ground biomass accumulated during grain filling; PBMG, pre-anthesis biomass mobilized to grains during grain filling. Symbols are means± SE of 3 replicates.

Results

There was a net accumulation of DM in both control and salt-treated plants during the grain filling period (ABAG in Fig. 1). Increasing N levels progressively increased ABAG of control plants, but not that of salt-treated ones. Average ABAG values were 736 and 623 g m^{-2} in control and salt-treated plants, respectively (Fig. 1). The PBMG index was always negative regardless of treatment, that is there was no net contribution of biomass accumulated before anthesis to grain filling. In plants irrigated with good quality water the N accumulated during the grain filling period (ANAG) increased as the level of N fertilization was increased (Fig. 2). On the other hand, the response of salt-treated plants to increasing N levels did not follow the pattern shown by control plants. The N absorbed before anthesis and remobilized to grains during the grain filling period (PNMG) was similar to the amount absorbed during the same period in control plants fertilized with 50 kg N ha^{-1}, virtually zero (0.408 g m^{-2}) in plants that received 100 kg N ha^{-1}, and negative for those fertilized with 150 kg N ha^{-1}. Under saline conditions PNMG was negative for plants fertilized with the lowest amount of N and relatively high for the other two levels of N.

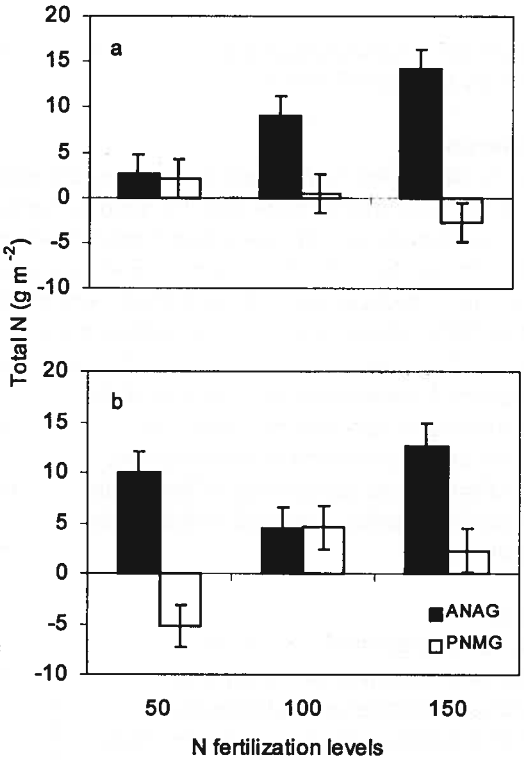

Fig. 2. The effect of N fertilization levels (kg ha^{-1}) on N partitioning indexes in plants irrigated with water at 0.5 dS m^{-1} (a) or saline water at 12 dS m^{-1} (b). Legend: ANAG, above-ground N accumulated during grain filling; PNMG, pre-anthesis-N-mobilized to grains during grain filling. Symbols are means$\pm$ SE of 3 replicates.

Conclusions

In general, the ABAG index was quite high and reached values of 70% of biomass calculated over the entire season in plants irrigated with good quality water. The negative values of PBMG can be explained by the great accumulation of DM during the grain-filling period, that not only supported grain yield but also the emergence of secondary culms during the grain-filling phase.

The response of ANAG and PNMG to salinity or increasing N levels were usually similar to those of ABAG and PBMG, which confirmed that accumulation of DM was closely correlated with that of N (Novoa et al., 1981). Salinity did not induce a clear pattern of response in DM or N partitioning indexes, which may indicate that N uptake was relatively independent of soil salinity in barley. However, these results need to be substantiated by field trials.

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ACCUMULATION OF MINERAL NITROGEN IN SOILS UNDER GRASS AND MAIZE

Hein ten Berge, Saskia Burgers, Jaap Schröder, Egon Hofstad

Plant Research International, P.O. Box 16, 6700 AA Wageningen, The Netherlands

Introduction

Nitrate leaching from farmland is regarded as being too high in large parts of all sand districts in the Netherlands. A national policy has been implemented to address this problem. This policy is referred to as MINAS, for Minerals Accounting System, which requires of farmers that they keep an account of in- and outflows of minerals (nitrogen (N) and phosphorus (P)) at the whole-farm-level. The resulting surplus on the farm gate balance should not exceed an a priori fixed allowable value, lest a levy be paid per kg of excess N or P. The allowable or levy-free N-surplus is differentiated according to soil type (soils sensitive to leaching, versus all other soils) and crop type (grass versus arable crops). With this balance approach, the levy-free surplus must be set so low as to guarantee that nitrate concentrations in shallow groundwater do not exceed a defined threshold, currently 50 mg/liter following the European Commission's Nitrate Directive.

Against the background of this legislation, monitoring programs are currently in place to assess the efficacy of the MINAS balance approach, notably to build up a database enabling better understanding of the relations between farm surplus and nitrate levels. This might show that a further tightening is needed of the allowed surplus, in order to meet the nitrate threshold on all leaching-sensitive soils and under all conditions. The collected information might also provide a basis for further differentiation of the allowed surplus – among the leaching sensitive soils - according to local biophysical conditions such as groundwater dynamics, soil properties and management practices.

As a possible alternative to the above generic tightening or differentiation of the levy-free MINAS farm surplus, additional indicators measurable on-farm could be introduced. Such new 'measuring stick' would then be used as a complement to the MINAS farm surplus, while maintaining a generic levy-free MINAS farm surplus value for all leaching sensitive soils. Among the few candidate variables that could sensibly play this role of 'additional indicator', is the amount of residual mineral nitrogen present in the soil profile after the growing season ($N_{min,H}$, kg N/ha). This study explores the behaviour of $N_{min,H}$ in response to applied N-rates, on the basis of historical data sets from N-response trials. Its purpose is to assess how $N_{min,H}$ is related to N-surplus, and to identify causes for the high noise level in this relation. This should provide a basis for the interpretation of newly acquired monitoring data in the near future, and for the assessment of $N_{min,H}$ as a potential new indictor additional to the MINAS surplus.

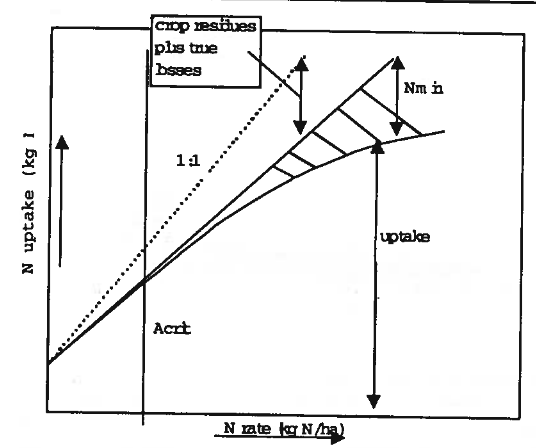

Figure 1. Schematic representation of accumulation of residual mineral soil nitrogen Nmin at the time of harvest, in function of the applied N rate. The base level $N_{minH,0}$ in zero-N plots is here assumed to be zero.

Methods

Data sets from N-response trials on cut grass and silage maize were collected from existing sources. We used only sets where

biomass yield as well as N-yield were measured, in addition to $N_{min,H}$. All experiments included at least four N-levels, and all refer to sandy soils in the Netherlands.
A mechanistic balance approach is used in combination with linear regression. First, the balance equation for mineral N in the soil profile is defined, which is then used by subtraction to express the difference in $N_{min,H}$ between plots within the same trial that did receive N-input and those that did not (zero-N plots). Two hypotheses underlying the resulting expression are tested: (1) no $N_{min,H}$ accumulation occurs at N rates below the level where the apparent N-recovery starts to deviate (decrease) from its initially constant value ρ_{ini}, even though this recovery is well below unity; (2) although $N_{min,H}$ increases with N rates from this level (the critical N rate) onward, the fraction (1- ρ_{ini}) remains 'lost' and is hence not found in the form of $N_{min,H}$. This concept is illustrated in Figure 1.
Next, a series of linear and non-linear regression equations is defined, each of which include different combinations of terms borrowed from the mechanistic balance equation. The coefficients are determined by regression and the correlation coefficients are compared.

Results
Figure 2 shows the performance of the mechanistic balance expression for grass; the result for maize is similar but shows more scatter. The regression equations support the above two hypotheses, but some of them give a better result (fit) than the straight balance equation. $N_{min,H}$ is highly variable among zero-N plots, and $N_{min,H}$ on zero-N plots introduced as regressor accounts for a large fraction of the variance in $N_{min,H}$ across all treatments. The amount of precipitation during the growing season too has a significant effect on $N_{min,H}$. N-surplus is a rather coarse indicator for $N_{min,H}$, both in grass and maize. In both crops, prediction errors are reduced by 30 to 50% if the N-yield on zero-N plots (U_0) is taken into account in the regression. The mechanistic balance equation explains why this should be so: at any given N-rate, high U_0-values are associated with lower N-surplus (because of higher N-offtake), but with higher $N_{min,H}$ (because less N-input is needed to reach the critical N rate). Variation in U_0 therefore leads to increased scatter in the relation between $N_{min,H}$ and N-surplus. This contribution is quantified for both crops.

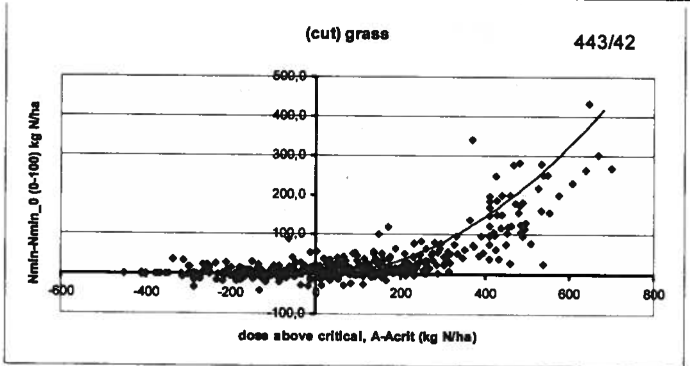

Figure 2. Increment in residual soil N (0-100 cm) at the last cut harvest (N_{minH}) in grass, relative to residual soil N observed at the same time in plots that received no N input ($N_{minH,0}$), versus the amount by which the applied N rate exceeds the critical N rate, A_{crit}. The values of $N_{minH,0}$ and A_{crit} are case-specific: they vary with the location and the year of the experiment. Solid line is predicted by the model proposed in Figure 1.

MINAS DETERMINES NITROGEN FERTILIZATION ON DUTCH DAIRY FARMS

Frits van Evert, Hugo van der Meer, Hein ten Berge, Ben Rutgers and Saskia Burgers

Plant Research International, P.O. Box 16, 6700 AA Wageningen, The Netherlands

Introduction

MINAS ("Minerals accounting system") is the instrument with which the Dutch government aims to limit agricultural nitrogen pollution. MINAS requires farmers to keep book of all nitrogen (N) and phosphorus (P) entering the farm (in feeds, fertilizers, manure and livestock) or leaving it (in manure, crop and livestock products); a fine is levied if the N and/or P surplus exceeds the allowable surplus. The allowable N surplus is specific to the combination of crop and soil; moreover, allowable surpluses are reduced over time. For example, on dry sandy soils - sensitive to nitrate leaching-, the allowable surplus of 100 kg/ha for maize in 2002 will be reduced to 60 kg/ha in 2003; a further reduction to 40 kg/ha is being considered. The requirement to calculate farm nutrient surpluses makes effective monitoring possible but it does not provide information on nutrient surpluses and nitrate leaching on the individual crops on a farm - information which is needed to estimate nitrate leaching to ground- and surface waters. The objective of our work is to deduce N application rates and N surpluses for maize and pasture on MINAS-compliant dairy farms in The Netherlands under various scenarios with the eventual aim of calculating nitrate leaching on a country-wide basis.

Methods

Figure 1 shows the flows of nutrients in fertilizer, feed and manure on a mixed dairy farm. The N surplus of a farm, being the balance of imports and exports, is affected by fertilizer application rates on maize and pasture, by the amounts of grass and maize bought or sold, by the amount of concentrates bought, and by the amount of manure imported to or exported from the farm. Management to reduce farm N surplus may either increase or decrease costs. Buying less fertilizer may reduce costs as well as the nutrient surplus – in many cases, extra feed may profitably be bought. On the other hand, exporting manure will increase costs because manure carries a negative price. Also, in general, producing roughage on farm is cheaper than buying feed. However, the additional amount of grass or maize produced with an additional kg of fertilizer N contains less than a kg of N (efficiency << 1), while the efficiency of N in feedstuffs bought outside the farm is 1 by definition. Because both options have the same effect on MINAS, buying feed may be more attractive in situations where MINAS compliance is difficult to achieve (although this is limited by the allowable P surplus).

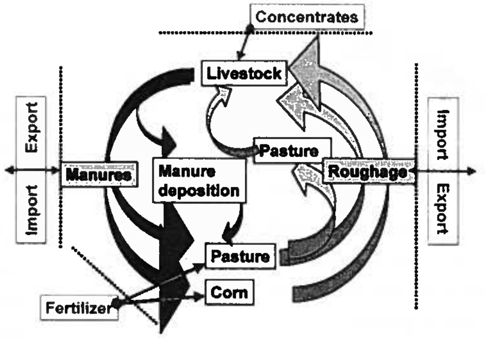

Figure 1. Nutrient flows on a mixed dairy farm.

We constructed a model, FarmMin v2, to calculate crop production levels and nutrient surpluses for the above system with its many feedbacks and counter-intuitive responses for given acreages and stocking rates (Van der Meer et al, 2002; Figure 2). FarmMin is a static model (does not consider time) and is composed of a number of components. Quadmod (Ten Berge et al., 2000) is a parametric model of crop growth response to applied N and is used to calculate maize and pasture production. Feed requirement and N excretion (of dairy cows, calfs, heifers) are calculated with the simple models described by Ketelaars & van der Meer (1999). FarmMin implements a strategy for the allocation of feeds to the three groups of animals so that the system is completely determined by five parameters: fertilizer application rates on maize and pasture, a factor describing the distribution of manures between maize and pasture, the fraction of the milk production-dependent concentrate requirement of dairy cows that is met by concentrates with a high N-content, and a factor describing the extent to which grass produced in excess of livestock requirements replaces imported maize (this is cheaper, but it increases the N-content of the diet and thus the nutrient surplus).

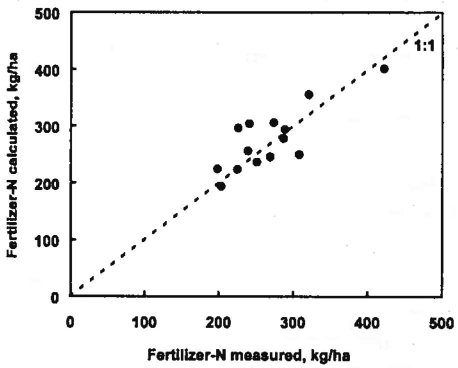

Figure 2. Modeled N fertilization matches observed rates on intensively monitored farms.

Results

We calculated rates of N, crop N yields and crop N surpluses corresponding to allowable surplus levels from 1998 to 2003 and beyond (Figure 3). The Dutch dairy industry was represented by 85 different "super-farms". Acreages and stocking rates were provided by the National Institute of Public Health and the Environment (unpublished data). These varied over years but were assumed constant in any one scenario. We used a controlled random search optimization algorithm to determine for each configuration the set of parameters yielding the lowest cost (cost of buying feed and fertilizers minus proceeds of selling grass and maize produced in excess of animal requirements). Figure 3 shows calculated N surplus on maize and pasture, as well as allowable surpluses on these crops under various scenarios (calculated surpluses are slightly higher than allowable surpluses because the former include NH_3-N losses from barn and manure storage). The ratio of calculated crop surpluses is often substantially different from the ratio of allowable crop surpluses. Thus, studies that are based on the N surplus of crops should use calculated surpluses rather than allowable surpluses.

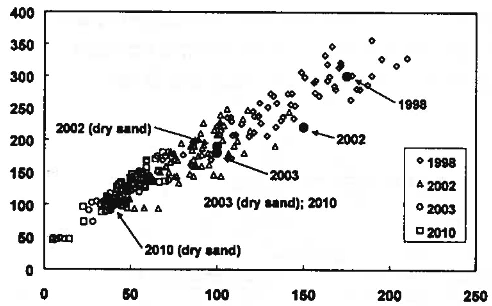

Figure 3. Calculated N surplus (kg/ha) on maize (horizontal axis) and on pasture (vertical axis) under various scenarios. Allowable surpluses are indicated.

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EFFECTS OF N, P AND K FERTILISATION ON THE PRODUCTION OF A PERMANENT MIXED MEADOW IN THE PADANO-VENETA VALLEY (NE ITALY). I. MAIN EFFECTS OF SINGLE ELEMENTS.

Ziliotto U., Scotton M., Da Ronch F.

Dipartimento di Agronomia ambientale e Produzioni vegetali dell'Università degli Studi di Padova, Agripolis – Strada Romea, 16 – 35020 Legnaro (PD) Italy
E-mail: flavio.daronch@unipd.it

Introduction

In sustainable agriculture, permanent mixed meadows usually have a lot of functions, such as protection of soil from erosion and improvement of chemical and physical soil characteristics. However, in the second half of the XX century, in large areas of the Padano-Veneta Valley, the management modalities for permanent meadows were lost and little studied (Ziliotto *et al.*, 1996).

In order to study the effects of the main nutritive elements on the characteristics of these crops, a trial plot on a mixed plain-meadow was established and managed for six years. 27 (3 levels each of N, P and K) fertilisation treatments were compared. The main effects of these nutrients on the average annual yields (t ha^{-1} of dry matter) will be reported and discussed in this paper.

Materials and methods

The trial plot was studied between 1992 and 1997 in a mixed permanent meadow, in rainfed conditions, established the 02/04/1991 on the Experimental Farm of Padova University (Legnaro, Padova, N.E. Italy) on a level area 8 m a.s.l. Cut up hay, obtained from natural grass, was sown. The hay was harvested in July 1990, when most of species were in graining phase. The soil was loamy-clay, sub-basic (pH=8,1). At the beginning it contained an average amount of calcium, limestone and potassium; from low to average of nitrogen and organic matter contents; rich in total and available phosphorus. It had a C/N ratio fluctuating between 7.8 and 8.7, owing to an excessive mineralisation of organic matter, and a high CEC (Cation Exchange Capacity). The climate in Legnaro is characterised by a mean annual rainfall of 824 mm, abundant from April to November and scarce in February. The mean annual temperature is 12.2 °C; the higher and lower are respectively 22.1 and 1.3 °C. The annual temperature range of 20.8 °C is indicative of a sub-continental climate.

The compared 27 fertilisation treatments were obtained from factorial combinations of 3 levels of N (0, 150 and 300 kg ha^{-1} $year^{-1}$ of N: N0, N1 and N2); 3 of P (0, 75 and 150 kg $ha^{-1}year^{-1}$ of P_2O_5:P0, P1 and P2) and 3 of K (0, 150 and 300 kg ha^{-1} $year^{-1}$ of K_2O: K0, K1 and K2). The intermediate level of nitrogen and potassium fertilizers was based on the previous crop uptakes (9 t ha^{-1} of dry matter). The P level was fixed at double that of the uptake, on account of phosphorous immobilisation in the soil. The experimental design consisted in 4 randomised blocks with 4 x 6 m plots in which the test area was the central strip (18 m^2).

In all the thesis 4 cuttings per year were carried out. The first one between 18 and 28 May, the second between 2 and 7 July, the third between 11 and 22 August and the fourth between 30 September and 9 October. The dry matter production was calculated for every cut for each area on the basis of the forage produced in the test area, and the dry matter content (%) of 1 kg grass sample.

Results and discussion

During the 6 years trial, the average yield of the meadow was 9,63 t ha^{-1} of dry matter (Table 1). This value was obtained from the total yield of each year, in which some appreciable, but not always significant, variations were recorded. A high variability was noted even between years in the single cuts production, in consequence of the climate trends in different years.

Table 1: Average yield with the different treatments (t ha^{-1} of d.m.). In the same line, values with different letters are significantly different at P0.05 (Duncan test).

Cuts	1992	1993	1994	1995	1996	1997	Mean
1	5,72 ab	5,77 a	5,58 b	4,32 d	4,83 c	4,26 d	5,08
2	2,49 b	1,16 e	1,19 e	2,98 a	1,85 d	2,17 c	1,97
3	1,87 a	0,91 f	1,23 e	1,29 d	1,45 b	1,35 c	1,35
4	1,36 b	1,38 b	1,95 a	1,08 c	1,11 c	0,52 d	1,23
Total	11,44 a	9,17 d	9.95 b	9,67 c	9,24 d	8,30 e	9,63

The main effect of nutrients level is to increase the yield. Significance is high with all the treatments in the total annual yield and for the first cut, but only with N and K in the following cuts (Table 2). N and K had significant effects resulted for both the doses 1 and 2.

Table 2: Single cut and total average yield (t ha^{-1} of d.m.). In the same line, values with different letters are significantly different at P0.05 (Duncan test).

	N			P			K		
Cut	N0	N1	N2	P0	P1	P2	K0	K1	K2
1	3,86 c	4,83 b	6,55 a	4,86 b	5,17 a	5,21 a	4,99 b	5,07 ab	5,17 a
2	1,63 c	1,79 b	2,49 a	1,96	1,98	1,98	1,87 b	2,01 a	2,04 a
3	1,03 c	1,30 b	1,72 a	1,35	1,34	1,37	1,24 c	1,37 b	1,44 a
4	0,70 c	1,24 b	1,72 a	1,20	1,23	1,21	1.14 c	1,23 b	1,29 a
Total	7,23 c	9,16 b	12,48 a	9,38 b	9,72 a	9,77 a	9,25 c	9,68 b	9,95 a

With first doses of N e K, the annual yield increased respectively by 26.7 and 4.6%, compared to their respective 0 doses. With N2 and K2, the increase was 72.6 and 7.6% (compared to 0). Respect to P, the yield rose only with the 1 dose (3.6% more than 0). Therefore, fertiliser efficiency was high with N (12.9 and 22.1 kg of d.m. kg^{-1} of N, with N1 and N2 respectively) and quite low with P1 (4.5 kg of d.m. kg^{-1} of P_2O_5) and K_2O (2.9 e 1.8 kg of d.m. kg^{-1} with K1 e K2). The results about the N effect showed, curiously, a lower efficiency of the first dose than the second. This trend could be caused both by the average content of P and K in the soil, and by the fertilisation formulas within this two elements in absence of N. For this reasons there were an increase of Leguminosae species in thesis without N. It partly compensated the effect of the first N 150 units, which whereas increased Graminaceae species. The N efficiency was in any case upper than the threshold of 10 kg in d.m. kg^{-1} year^{-1}of N, that is an acceptable standard value on the economic profit aspect, too. (Paris et al. 1990; Schmid et al 1990).

The efficiency of P on the first cut, and consequently on the annual production, depended on that all the Graminaceae were in flowering phase, because P supports starch mobilisation from leaves to flowers and fruits (Marschner H., 1986).

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EFFECTS OF N, P AND K FERTILISATION ON THE PRODUCTION OF A PERMANENT MIXED MEADOW IN THE PADANO-VENETA VALLEY (NE ITALY). 2 INTERACTIONS AND CONCLUSIONS.

Ziliotto U., Scotton M., Da Ronch F.

Dipartimento di Agronomia ambientale e Produzioni vegetali dell'Università degli Studi di Padova
Agripolis – Strada Romea, 16 – 35020 Legnaro (PD) Italy
E-mail: flavio.daronch@unipd.it

Introduction

As indicated in a previous paper (Ziliotto *et al.* 2002), in order to contribute to the permanent mixed meadows management knowledge, a trial plot was established and managed for six years. In this trial plot, 27 fertilisation treatments (3 levels each of N, P and K) were compared. The results of the interactions between these elements on the yield (t ha^{-1} of d.m.) will be reported and discussed in this paper.

Materials and methods

The principal notes about materials are reported in detail in the mentioned work (*Ziliotto et al.*, 2002). For an easier understanding of the reported results, we recall that the meadow was sown on 02/04/1991, the trial plot was conducted from 1992 to 1997, in all the thesis 4 cuttings were carried out, the levels of N were 0, 150 and 300 kg of N ha^{-1} $year^{-1}$; the levels of P were 0, 75 and 150 kg of P_2O_5 ha^{-1} $year^{-1}$, and the levels of K were 0, 150 and 300 kg of K_2O ha^{-1} $year^{-1}$. All the elements increased the annual dry matter production and the first cut yield; but only for N and K there was a positive effect on the following three cuts. N and K had significant effects with both the doses 1 and 2, while P with the first one only.

Results and discussion

The significant (at $P \leqslant 0.01$) interactions were: "Year*N" for every cuts and for the annual total yield, and "Year*K" for the 1st, 3rd and 4th cut and annual total yield. However, examining the annual total yield only (Table 1), the K doses had limited effects, whereas the N1 level determined, in all the years, a constant significant increase respect to N0 (Figure 1), so the average yields in both these thesis had parallel lowering trends. On the other hand, the second 150 N units increased its effect in the years and so the N2 thesis yield was almost unchanged in all the experimental period. In the end, as regards to the N role, it should be noted that the treatments without P and K (N0 P0 K0; N1 P0 K0; N2 P0 K0), provided a 6 years average yield only 0.78, 0.57 and 0.49 t ha^{-1} lower than the others with the same N dose (N0, N1 and N2 respectively).

Table: Total annual yield during the trial period of thesis with various N and K levels. The interactions "Years*N" and "Years*K" are statistically significant at $P \leqslant 0.01$.

Thesis/year	1992	1993	1994	1995	1996	1997	Mean
Mean N0	9,77	7,54	6,80	6,54	7,36	5,36	7,23
Mean N1	11,72	9,08	9,70	8,80	8,13	7,54	9,16
Mean N2	12,84	10,91	13,26	13,66	12,22	11,99	12,48
Mean K0	11,15	9,10	9,77	9,22	8,54	7,65	9,24
Mean K1	11,35	9,06	10,1	9,83	9,39	8,35	9,68
Mean K2	11,83	9,36	9,89	9,94	9,78	8,89	9,95
Mean	11,44	9,18	9,92	9,67	9,24	8,30	9,63

Among the possible interactions between elements "N*P" at the first cut and "N*K" at the third were statistically significant (P□0.05) (Figure 2). The first interaction caused an increase of P effect at the N dose raising, even if in correspondence with N2P2 a yield decreasing respect to

N2P1 thesis was noted. This is probably the reason why there were not significant differences between average yield levels at P1 and P2.
At the third cut, the interaction "N*K" showed a summer stress (1.48 t ha^{-1} of d.m.) in the thesis without N and K, compared to the ones with N1, K1, K2 alone, or N1K1 or N1K2 which provided yields from 1.70 to1.84 t ha^{-1} of d.m..

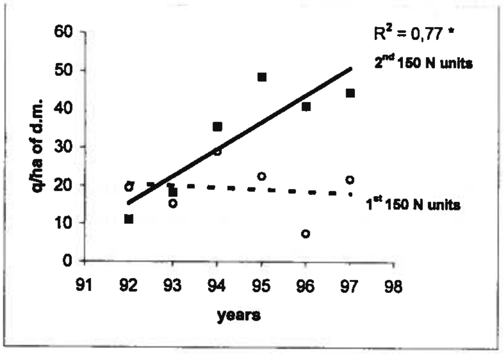

Figure 1: Yield trends with the first and the second 150 N units during six years of trials.

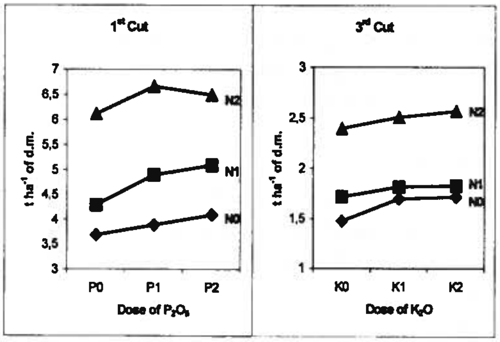

Figure 2: Interactions "N*P" at the 1st cut and "N*K" at the 3rd cut.

Conclusions

Probably in consequences of the soil characteristics at the trial beginning, the three studied elements increased the meadow yield, but only for N there was substantial variations. Besides, even if the N and K effects were emphasised in course of time, while the K effect remained anyway on limited levels, the effect of N2 considerably increased, so much to balance the yield decrease that occurred with all the others fertilisation formulas.
In the same experimental conditions of the trial, as the intensive farming areas where large amounts of P and K are distributed, N is the element that assures the best yield performances to meadows. It must be distributed massively, to maintain the high yield levels of the beginning for medium periods (5-6 years).

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Special session on nitrogen and environment

NUTRIENT BALANCE OF ARABLE SOILS IN ESTONIA

Alar Astover[1] and Hugo Roostalu[2]
Estonian Agricultural University, Institut of Soil Science and Agrochemistry
Kerika, 50412 Tartu, Estonia. E-mail: [1]astover@eau.ee; [2]roostalu@eau.ee

Introduction

The nutrient balance is the basic element describing the sustainability. A careful nutrient balance must be maintained in agricultural systems because excess can be caused environmental pollution and is a waste of resources. On the other hand, continuous nutrient deficit will decline soil fertility. After regaining independence the agricultural production in Estonia has undergone a drastic decline. In terms of land use, 25% of the country consists of agricultural land. The level of productivity of arable crops in Estonia is 2–3-fold lower compared with Sweden and Finland. Of the yield potential of cereals and potato only 40% are utilized at present (Roostalu *et al.*, 2001).

Methods

Nutrient balances for nitrogen, phosphorus and potassium is calculated at the national level. The estimation of nutrient balances were based on the data of 60 years of fertilizer application and yields of field crops.

Results

The use of fertlizers increased since 1960s up to the late 1980s. While an average of up to 50–60 kg of mineral nitrogen, 70–80 kg of potassium, 20–25 kg of phosphorus and 10–12 t of manure were used per hectare of arable land, the general balance of these nutrient elements was markedly positive (Figure). The amount of total nitrogen input was 1.5-fold greater than removed with yield. In the case of phosphorus and potassium total input of this nutrients was 3-fold and 2-fold greater then removed with yield, respectively. Proceeding from this, the content of lactate soluble potassium in the soil increased on average by 22%, while the content of lactate soluble phosphorus increased more than twice during this period. The surplus of nutrients can be explained by the low effectiviness of fertilizers in the collective farms and state farms of that time. Research carried out in Estonia has shown that plants make use of only 26% of nitrogen, 12% of phosphorus and 8% of potassium applied (Mander *et al.*, 1994). Intensive use of mineral fertilizers in recent decades brought about substantial diffused pollution in agricultural landscapes. Diffused pollution had caused extensive eutrophication of surface waters and pollution of groundwater. On the average, agricultere is estimateted to account for 30–35% of the nitrogen load and 10–15% of the phosphorus load to the Baltic Sea. In the period of the re-independence of Estonia the balance of all main nutrient elements has become negative as a consequence of inadequate fertilization. Compared with other European countries the level of fertilization in Estonia is among the lowest. The average amounts removed from the soil with the yield are 55 kg N ha^{-1}, 9 kg P ha^{-1} and 45 kg K ha^{-1}, while the amounts returned to the soil are 40 kg N ha^{-1}, 4 kg P ha^{-1} and 18 kg K ha^{-1}. Thus present production takes place largely at the expense of the soil resources created by farmers in the 1970s–1990s. The removal of nutrients from soil cannot continue indefinitely without depleting the productivity of the soil; nutrients must be replaced. The utilization efficiency of nitrogen and phosphorus improved 2-fold and 3-fold in Estonia from 1989 to 1994, respectively (Löfgren *et al.*, 1999). Nowadays the share of total nitrogen and phosphorus input from mineral fertlizers makes up 33–35% and in the case of potassium only 24%.

Conclusions

In the 1970s–1990s nutrient balance of arable soils of nitrogen, phosphorus and potassium in

Estonia was markedly postive. Therefore the loss of nutrients as well as impact on the environment were quite appreciable. At present with the decrease of agricultural activities pollution pressure has lessened and the nutrient balance has become negative. To preserve soil fertility as basis for life and economic activity for future generations in Estonia, the use of fertlizers must be increase.

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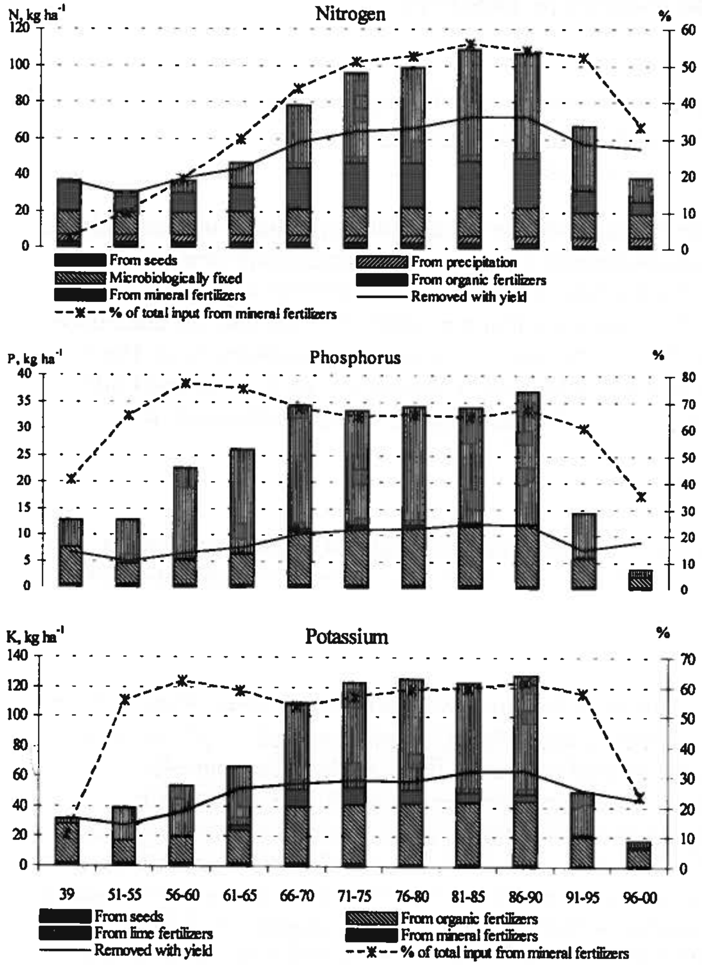

Figure. Nitrogen, phosphorus and potassium balances of arable soils in Estonia (1939–2000)

NFLUENCE OF THE NITRIFICATION INHIBITORS DMPP AND DCD ON NITROUS)XIDE EMISSIONS DURING WINTER IN A FIELD EXPERIMENT

3áez D., Trindade H., Moreira N., Coutinho J.
)epartment of Plant Science and Rural Engineering, Universidade de Trás-os-Montes e Alto)ouro – Apartado 202, 5001-911 Vila Real (Portugal)

ntroduction

\gricultural soils are recognised as an important source of atmospheric nitrous oxide (N_2O), vhich is responsible for 5 % of the global greenhouse effect (Mosier, 1998) and involved.in lepletion of stratospheric O_3. The N_2O emissions are the result of soil microbial processes during ıitrification and also during denitrification of nitrate. The European Union, under the Kyoto 'rotocol was committed to a reduction of greenhouse gases; in that way the development of everal modifications to agronomic practices are necessary. Studies with nitrification inhibitors NI) have demonstrated they improve fertiliser efficiency and indirectly control N_2O emissions y preventing nitrate accumulation in the soil. Recently, several studies showed that a new NI, 3-l-dimethylpyrazole phosphate (DMPP) (Zerulla et al., 2001), besides presenting the agronomic ıdvantages of NI use, showed the ability to reduce N_2O losses more effectively than licyandiamide (DCD), (Weiske et al., 2001) one of the most widely used NI in agriculture. Field :xperiments under different edafoclimatic conditions and cropping systems are required in order o improve that results.

[he aim of this study was to investigate the combined effects of the NIs: DCD and DMPP on ;oil NO_3^- and NH_4^+ levels and N_2O emissions during winter oat growing season in 2001.

Viethods

[his work was conducted at Vila Real in the NW region of Portugal. The mean annual)recipitation is 1013 mm and the mean annual temperature is 13.6 °C. The experiment was :arried out on a poorly drained silty loam soil classified as Dystric Cambisols (FAO :lassification) with (0-30 cm) pH value of 4.6, organic matter content of 29 g kg^{-1} and 4.9 :mol(+)kg^{-1} of CEC.

)at (*Avena sativa* L.) was sown at 120 kg ha^{-1} seeding rate in November 13th. A randomised :omplete block design with three replicates and 4 treatments was established.

Ammonium sulphate nitrate (ASN, 19,5 % NH_4^+-N 6,5 % NO_3^--N) split into two applications: 30 :g N ha^{-1} (9 November 2001) and 60 kg N ha^{-1} (1 March 2002) was used as the N mineral source. ASN with DMPP (ENTEC 26, registered trademark of COMPO, Germany, 1% DMPP :elative to NH_4^+-N in the ASN) and ASN with DCD (7 % DCD-N relative to NH_4^+-N in the ASN) were tested and compared to ASN without inhibitors. ASN and Entec were surface applied in granular form by hand. DCD was dissolved in distilled water and pulverised on the soil surface. A control with no fertiliser application and without inhibitor was also included in the :xperiment.

N_2O emissions were measured using the closed chamber method from November 2001 to March 2002. After the enclosure period of 45 up to 90 min 10 ml of gas were removed from the chambers and stored in vacuutainers. Standards of N_2O in N_2 were also transferred to vacuutainers at that time. About 5 ml of gas were remove from vacuutainers and injected into a gas chromatograph (Dany 86.10) equipped with a 63Ni ECD to measure the concentration of N_2O. Values for N_2O emissions were calculated on a per area basis.

At each gas sampling soil samples were taken to a depth of 10 cm. The soil samples were analysed for mineral N content (NH_4^+-N and NO_3^--N) by automatic segmented-flow spectrophotometric methods. The water-filled pore space (WFPS) was calculated using the mean bulk density measured at the experimental site and gravimetric soil water content.

Statistical differences between treatments on NH_4^+-N and NO_3^--N soil content and N_2O emissions were calculated using GLM procedure of the Statistical Analysis System (SAS, Institute, Version 6.12).

Results and discussion

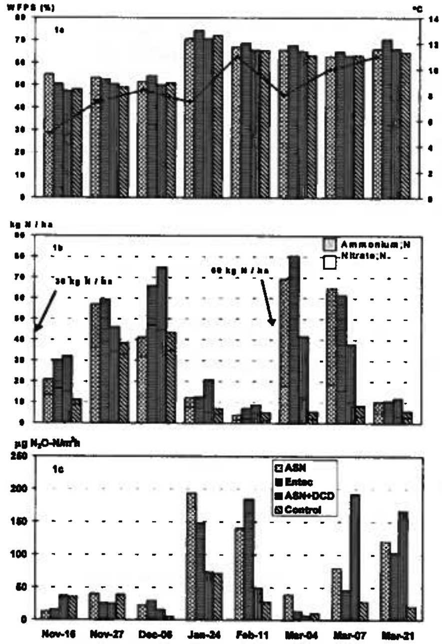

Figure 1. Mean water-filled pore space and soil temperature (1a), mineral N content at 10 cm depth (1b) and N_2O emissions (1c).

No significant effects on the NO_3^--N content were observed between treatments (Fig. 1b). After rainfall occurred between December 12th and January 24th sampling dates, considerable amount of NO_3^--N might have been leached from the surface layer to deeper depths. A significant effect on the NH_4^+-N content of the NI treatments in comparison to the ASN was observed 7 days and also in the DCD treatment 27 days after the first fertilization. After the second N application no significant direct effect of the NI treatments was observed on ammonium content.

N_2O emissions were regulated largely by climatic factors, such as amount and distribution of rainfall and soil temperature. In dry periods, WFPS values were maintained lower than 50% (Fig. 1a) and N_2O (Fig. 1c) emissions were no promoted despite of high mineral N content in the 0-10 cm soil layer. In rainy periods WFPS rose and N_2O peaked. DCD showed the highest inhibitory effect on N_2O emissions after soil rewetting and N_2O emissions from ASN-DCD plots were lower than those of the ASN plots. However, after the second N fertilization, DMPP revealed a slight inhibitory effect on N_2O emission, whereas in DCD plots N_2O emissions were higher than those obtained in ASN plots. Since DCD is highly water soluble, intensive precipitation occurred immediately after DCD application may have lead to its spatial separation from the ammonium to be stabilised. This may explain the lack of inhibitory effect on N_2O emissions.

Conclusions

N_2O emissions were influenced by weather conditions, N_2O was not always found after fertilization but quite often after intensive rainfall. DCD showed an inhibitory effect on N_2O emissions after dry periods while in rainy periods DMPP showed better results with respect to N_2O emissions occurred in ASN treatment without NI.

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INTEGRATED VEGETABLE PRODUCTION IN SLOVENIA AND THE ANALYSIS OF NITRATE NITROGEN IN THE SOIL AT HARVEST

Bavec M.[1], Bavec F.[2]
[1] - Institute of Agriculture Maribor, Vinarska 14, 2000 Maribor, Slovenia
[2] - University of Maribor; Faculty of Agriculture, Vrbanska 30, 2000 Maribor, Slovenia

Introduction

Slovenia is declared a nitrogen sensitive area with the resources of ground water endangered because of agriculture and other kinds of pollutions. Many intensive systems of field vegetable production are not sustainable because they lose excessive amounts of nitrogen to the environment. In field vegetable production, nitrate leaching is a dominant process affecting the environment (Neeteson and Carton, 2001). In spite of this, integrated and organic vegetable production are advised to the vegetable producers. Market vegetables were produced in Slovenia in 2000 on 2114 ha (1.23% of arable land) on 1970 farms (2.28% of all farms). Vegetable production structure with regards to the production area shows that white cabbage with 22% (449 ha) and early potatoes with 13 % (270 ha) were prevailing. Other vegetables were half as frequent as white cabbage: lettuce 9% or 197 ha, sweet peppers 7 % or 146 ha, onion 6% or 134 ha, and chicory 5.5 or 114 ha. They are followed by endive, beetroot, cauliflower and tomatoes with 3% (Zagorc et al., 2001). Integrated vegetable production was introduced in 1998 and spred over Slovenia (Bavec et al., 2000). In 2001 176 farms with 508 ha main area or approximately 750 ha (35%) production area were included into integrated vegetable production. In the same year organic vegetables were produced on 45 ha (2%) on 37 farms (Bavec, 2002). In the Netherlands the amount of nitrogen left in the soil after cabbage was low and amounted to a maximum of around 30 kg N ha^{-1} for the soil layer 0-0.9 m (Everaarts and Booij, 2000).

Methods

From 1998 to 2001 soil samples were taken at the harvest time (end or start) from the fields of integrated vegetable production to check the mineral nitrogen content (presented are only results of nitrate nitrogen) at the end of the season. Samples were taken according to the Guidelines for integrated vegetable production in Slovenia and compared to allowed values (Bavec, 2000). Detailed results of nitrate remains per ha are presented for vegetables sampled 3 or more times in investigated years. Sampling was correlated with the frequency of vegetables. In the first two years close to average temperature and rainfall were noted whereas in the last two years higher temperature and lower rainfall were observed in the vegetation period from April to September in all locations.

Results

Higher rates of above allowed values (65 and 59%) in the last two years are result of two dry vegetation seasons and lower average yields of vegetables (table 1).
Results show that average values are above allowed values with variations between 8 and 3377 kg ha^{-1} nitrate nitrogen except cauliflowers with average value bellow allowed value (table 2). Higher average remains (over 200 kg ha^{-1}) of nitrate nitrogen are noted in indoor production of tomatoes, slice cucumbers, sweet peppers and in field production of egg plants and chicory. In most cases (n=67) in field production of sweet pepper, cabbage, lettuce, carrot, onion and pickling cucumbers nitrate remains were between 100 and 200 kg ha^{-1}.

Table 1: Number of farms and main area of integrated vegetable production, number of soil samples and rate of remains of nitrate nitrogen in top soil with above allowed values after harvesting of vegetable from 1998 to 2001

Year	number of farms	main area (ha)	number of soil samples	Number of samples with above allowed values	rate of above allowed values (%)
1998	9	19.0	20	4	20
1999	43	116.5	23	6	26
2000	111	333.5	41	27	65
2001	176	508.1	47	28	59
Sum	/	/	131	65	49

Table 2: Remains of nitrate nitrogen (kg ha^{-1}) in top soil after harvesting of vegetables from 1998 to 2001

Vegetable	number of analysis	depth of sampling (m)	allowed value (kg ha^{-1})	Maximum value (kg ha^{-1})	minimum value (kg ha^{-1})	average value (kg ha^{-1})
sweet pepper	19	0.6	100	481	8	169
cabbage	18	0.9	60	495	18	136
lettuce	18	0.3	60	272	9	107
tomato (i)	17	0.6	100	3377	18	492
cauliflower	9	0.6	100	156	18	78
sweet pepper (i)	7	0.6	100	884	25	205
chicory heading type	6	0.6	80	1672	12	376
slice cucumbers (i)	5	0.6	100	888	45	252
carrots	5	0.6	80	389	29	111
onion	4	0.6	80	331	64	193
early potato	4	0.6	80	206	61	90
pickling cucumbers	3	0.6	80	154	46	110
egg plant	3	0.6	100	646	24	294

(i) – indoors production

Conclusions

On the basis of investigation of nitrate remains at harvesting of vegetables it is concluded that vegetable production is not suitable in ground water sensitive areas due to large amounts of nitrate nitrogen and risk of leaching and denitrifying in the period after harvest.

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:OMPARISON OF THE GROUNDWATER-POLLUTION BY NITRATE UNDER 'ASTURE AND "SIMULATED PASTURE"

/I. Büchter[1], M. Wachendorf[2] and F. Taube[2]

Institute of Agronomy and Plant Breeding, University of Agricultural Sciences, Gregor Mendel-Straße 33, 1180 Vienna (Austria)
Institute of Crop Science and Plant Breeding – Grass and Forage Science/Organic Agriculture, Christian-Albrechts-University, Herrmann-Rodewald-Straße 9, 24118 Kiel (Germany)

ntroduction

)n pastures the nitrogen cycle is especially influenced by the grazing animals. Only 5-25 % of he nitrogen amount which has been introduced with the feed is exported with milk and/or meat ıtilization (Van der Meer et al., 1986), while 75-95 % are applied onto the sward with the :xcreta. References to the nitrate leaching under pasture are exceptionally variable (MacDuff et ıl., 1990; Watson et al., 1991; Scholefield et al., 1993). The investigation of pastures requires arge plots and is expensive. Therefore, for experiments the grazing is often replaced by cutting. n this case, the cutting frequency is adapted to an actual grazing system. Sward damages due to rampling and ate, which reduce the capability of the sward and consequently also affect the ›otential nitrate leaching, remain unconsidered (MacDuff et al., 1990). A recycling of the ıutrients by settling of excrement and urine of the grazing animal onto the soil-surface is not eproduced in an adequate way, either. The present investigation is part of the interdisciplinary esearch project "N-flows of specialized dairy farms on sandy soils in Northern Germany" which shall derive optimized management strategies for improvement of nitrogen efficiency.

Materials and Methods

A permanent grassland trial was conducted on the experimental farm Karkendamm in Northern Germany with very sandy soils (temp.: 8,3 °C year^{-1}; precipitation: 824 mm year^{-1}). An old sward was oversown with seeds of clover/grass in the year before the experiment started. Management systems (SYS) were pasture and simulated pasture. Within these treatments there were four mineral N fertilizer levels (N: 0, 100, 200, 300 kg N ha^{-1}) as well as two slurry levels (G: 0, 20 m³ ha^{-1} (=73 kg N ha^{-1})). Grazing was carried out with heifers in a rotational system. The amount of N fixed by the clover was calculated by a regression based on the clover yield of non-fertilized treatments. The N deposition was estimated as 20 kg N ha^{-1} year^{-1}. Leaching losses were sampled by ceramic cups installed at 60 cm below ground-surface. The vacuum station was controlled by an automatic tensiometer system. Samples were taken weekly. The soil mineral N content was studied in the middle of November.

Results and Discussion

The calculation of the cumulative climatic water balance for the investigation site showed for the experimental periods 1997-2001 an average leaching water amount of 205 mm year^{-1}. The statistical evaluation of the data revealed a significant influence of the mineral nitrogen fertilizer on the nitrate leaching. A weak effect of the slurry application was obtained only under grazing. The mineral N content of the soil at the end of growing season was significantly affected by the nitrogen mineral fertilizer only under grazing. Comparing the system "pasture" with the "simulated pasture", highly significant differences were found as well as interactions of the systems on the fertilizing factors (Tab. 1). The nitrogen dynamics and the water balance are decisive for the nitrate leaching. Different soil mineral N levels between the two systems can be explained by the nitrogen recycling via excrement and urine by the grazing animals (the estimated return to the field by the grazing animals is about 155-305 kg N ha^{-1} year^{-1} depending on the experimental variation). Small nitrate leaching losses under the "simulated pasture" reflected nutrient extraction due to cutting. The investigation of the N dynamic in the plots showed a positive correlation between soil mineral N and nitrate leaching (Fig. 1). However, a complete leaching of soil mineral N content cannot be assumed. A simplified criterion to estimate the environmental pressure is the N-balance. Eckert et al. (1999) suggest a range of ±50 kg N ha^{-1} of the N-balance as an indicator to estimate nitrate leaching losses. For improved protection of groundwater with the destination to reduce nitrate leaching to an unavoidable minimum, the agricultural practice has to be considered. The amount of nitrate leaching losses under pastures is loosely connected with the cultivation management. Reduced or omitted nitrogen fertilizing and smaller stocking densities are possibilities to reduce nitrate leaching.

Tab.1: Probability levels of the ANOVA for soil mineral N content at the end of the growing season (kg N ha^{-1}) and nitrate leaching losses (kg N ha^{-1}) (means over leaching periods 1997/98 to 2000/01).

	analysis of variance (97-01) (soil mineral N)		analysis of variance (97-01) (nitrate leaching losses)	
Effect	F-Value	Pr>F	F-Value	Pr>F
SYS	70,21	0,0139	45,03	0,0215
N	4,78	0,0169	6,15	0,0050
G	2,35	0,1472	6,70	0,0192
N x G	4,57	0,0197	0,36	0,7802
SYS x N	3,31	0,0515	7,92	0,0016
SYS x G	2,72	0,1214	4,42	0,0508
SYS x N x G	4,97	0,0148	0,25	0,8631

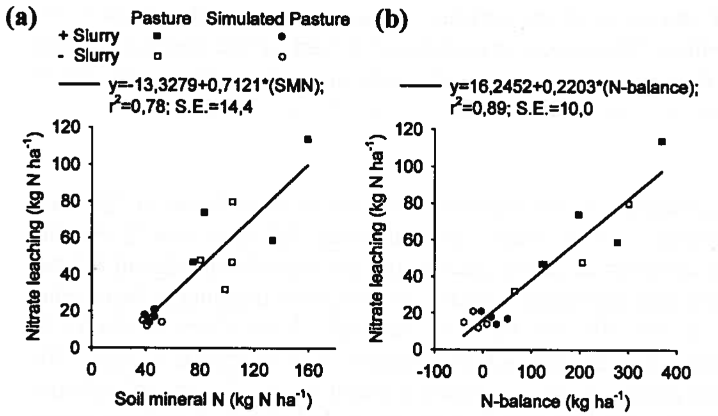

Fig. 1: Relationship between soil mineral N (SMN) at the end of the growing season (kg N ha^{-1}) and nitrate leaching losses (kg N ha^{-1}) **(a)**, as well as N-balance (kg ha^{-1}) and nitrate leaching losses (kg N ha^{-1}) **(b)**.

Conclusions

Simulated pastures show small nitrate leaching losses even in case of high N rates because N is exported with the harvested grass from the field. Pastures caused a higher leaching potential due to the nitrogen refluxes to the soil. Our results suggest that data concerning the nitrate leaching and/or the soil mineral N at the end of the growing season cannot be obtained by simulating a pasture using a cutting system.

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NITRATE EXPORTED IN THE DRAINAGE WATERS OF TWO SPRINKLER IRRIGATED DISTRICTS

Cavero J.[1], Beltrán A.[2], Aragüés A.[3]

[1] Estación Experimental de Aula Dei (CSIC), Apdo. 202, 50080 Zaragoza (Spain)
[2] Dirección General de Estructuras Agrarias (DGA), P. Mª Agustín 36, 50004 Zaragoza (Spain)
[3] Servicio de Investigación Agroalimentaria (DGA), Apdo. 727, 50080 Zaragoza (Spain)
[1,3] Laboratorio Asociado de Agronomía y Medio Ambiente (DGA-CSIC)

Introduction

The concerns of society about the negative environmental impacts of intensive agriculture threatens the expansion of irrigation in the semiarid south of Europe. Yet, the climate of these areas allows for the achievement of high yields in most field crops, so that a compromise should be attained between profitability and the alleviation of these negative impacts.

Water and nitrate losses below the crop's root zone are almost unavoidable in surface- irrigation due to its typical low efficiency and uniformity. However, properly designed and managed sprinkler-irrigation allows more easily for the uniform and efficient application of irrigation water as well as for the split and timely application of N fertigation, therefore minimizing water and nitrate losses (Power et al., 2000). The aim of this work was to quantify the concentration and mass of nitrates exported in the drainage waters of two sprinkler-irrigated districts and to analyze their relationships with irrigation and N management.

Methods

The study was conducted in the D-IX (558 ha; from Apr-97 to Mar-99) and D-XI (1007 ha; from Oct-97 to Sept-98) districts of the Monegros II irrigated area (middle Ebro Basin, Spain). The PETc of each crop was calculated using the Penman-Monteith equation and the appropriate crop coefficients. The net irrigation requirement (NIR) was computed as the difference between PETc and the effective precipitation (taken as 75 % of precipitation).

The volumes of irrigation water diverted by each turnout were measured weekly. Irrigation efficiency was characterized by the irrigation performance index (IPI), (IPI = 100 NIR/V_{iw}), where V_{iw} is the volume of irrigation water delivered to the crops. A farmer's survey was conducted to determine the acreage, yield (Table 1) and the N management of crops. Drainage flow rates were continuously measured at the exit of the districts, and NO_3-N concentrations were measured in drainage water samples taken every two days with automatic water samplers.

Crop	D-IX				D-XI	
	Apr.-Sept. 97		Oct. 97-Sept. 98		Oct. 97-Sept. 98	
	ha	t ha^{-1}	ha	t ha^{-1}	ha	t ha^{-1}
Maize	269	11.2	208	14.0	267	10.7
Alfalfa	72	18.2	97		156	14.8
Sunflower	19	2.0	61		21	1.9
Winter cereals	70	5.0	110		10	3.5
Peas and beans	0		0		16	
Non cropped	64		18		0	

Table 1. Irrigated acreage and mean yield of crops grown in the D-IX and D-XI districts.

Results

Maize and alfalfa were properly irrigated (IPI within 100 ± 15%), whereas the rest of crops were deficit-irrigated. Considering all the crops, the seasonal mean IPI values were close to 100%, although the IPI values computed at the irrigation turnout level were rather variable (CV between 25% and 36%), and over-irrigation (i.e., IPI < 85%) occurred in 17% (D-IX, 1997), 27% (D-IX, 1998) and 44% (D-XI, 1998) of the total irrigated areas. IPI tended to increase as the irrigation season progressed, and over-irrigation was preponderant in April (i.e., average IPI = 60%) due to the maize post-planting irrigations given to promote maize emergence.

The estimated mass of N fertilizer and manure applied to the D-IX and D-XI districts varied between 166 and 221 kg ha^{-1} in the irrigated seasons and between 3 and 32 kg ha^{-1} in the non-irrigated seasons. Maize received the highest rates of fertilizer N (average = 319 kg N ha^{-1}).

Fig. 1 shows the variation in drainage flow rates, which were parallel but much higher in D-XI than in D-IX (Table 2), mainly due to the precipitation falling in its larger watershed area.

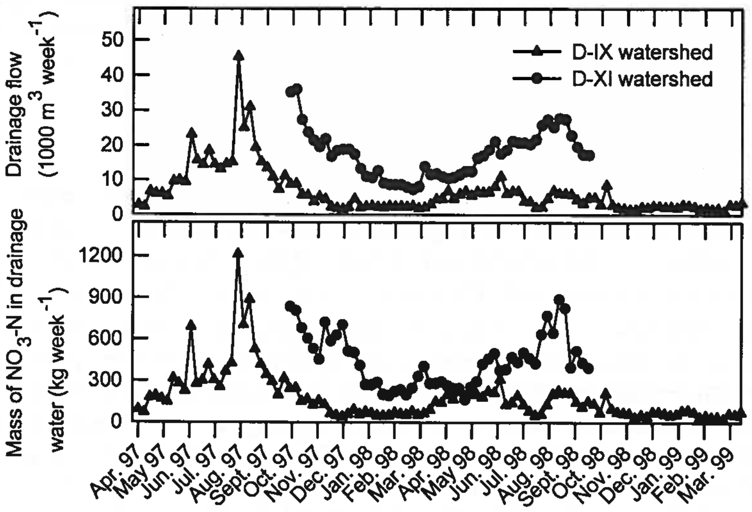

Fig. 1. Drainage flow rates and mass of NO_3-N in the drainage waters of the D-IX and D-XI irrigation districts.

NO_3-N concentrations in drainage waters were high, independent of flow rates, and quite similar in the irrigated and non-irrigated periods (Table 2). The volumes of drainage determined the exported mass of NO_3-N (Fig. 1), which varied from 18 (D-IX) to 49 (D-XI) kg ha^{-1} yr^{-1} (Table 2). These values represent only 8 % (D-IX) and 22 % (D-XI) of the total applied fertilizer plus manure N.

Conclusions

The high irrigation efficiencies attainable with well designed and managed sprinkler irrigation systems coupled to the splitting (i.e., fertigation) of fertilizer N, are effective ways to minimize nitrate drainage losses.

	D (mm)	NO_3-N (mg L^{-1})	NO_3-N (kg ha^{-1})
D-IX			
Irrig. Apr. 97-Sept. 97	74	26.3	19.4
Non-irrig. Oct. 97-Mar. 98	18	26.9	5.0
Irrig. Apr. 98-Sept. 98	30	29.2	8.9
Non-irrig. Oct. 98-Mar. 99	13	26.1	3.5
D-XI			
Non-irrig. Oct. 97-Mar. 98	89	28.1	24.2
Irrig. Apr. 98-Sept. 98	105	23.1	24.8

Table 2. Drainage (D), NO_3-N concentration and NO_3-N mass in drainage waters of the D-IX and D-XI districts.

Although nitrogen pollution regulations are generally based on maximum allowable concentrations, the mass of nitrogen exported per unit irrigated area is most important for controlling the nitrogen contamination in the receiving water bodies. Thus, even though drainage nitrate concentrations in the study areas were high, their low nitrogen loads allow for the attainment of a sensible compromise between profitability and the control of N pollution in irrigation return flows. In consequence, under the present water and fertilizer management, there are not nitrogen-pollution reasons for limiting the irrigation in these semiarid areas where the leaching requirement of crops are negligible due to the high-quality irrigation waters.

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NITROGEN STATUS AND NITROGEN USE EFFICIENCY OF WHEAT GROWN IN ORGANIC AND CONVENTIONAL LOW INPUT CROPPING SYSTEMS. A CASE STUDY FOR TESTING DECISION MODELS IN SOUTHERN FRANCE.

Colomb B.[1], Debaeke P.[1], Nolot J.M.[1], Meynard J.M.[2], David C.[3]
1 INRA Agronomie. BP 27 Auzeville. F-31326 Castanet-Tolosan. – colomb@toulouse.inra.fr
2 Unité Mixte de Recherche d'Agronomie INRA INA-PG., F-78850 Thiverval-Grignon
3 Institut Supérieur d'Agriculture Rhône-Alpes, F-69288 Lyon

Introduction

The policy for the development of organic production adopted in France in 1998 promoted the growth of specialised organic cereal systems in stockless farms, particularly in the southern part of the country (ONAB, 2001). In contexts with low organic matter soil content and low proportion of legumes in crop succession, N deficiencies are likely to occur at an early stage in wheat (Triticum aestivum L.) development and to reach high levels before anthesis. Because crops are poorly protected against stem and leaf diseases, the period of active photosynthesis after anthesis is generally reduced, leading to low C and N accumulation and poor remobilisation of pre-floral accumulated N. This study aimed at documenting these processes in the case of wheat grown in the Lauragais area, as part of an experimental network set up to obtain data sets for testing N recommendation systems (Meynard, 2000; David et al., 2001).

Methods

Table 1 : Dates, forms (O : feather meal; M : NH_4NO_3), amounts and number of N applications.

Date	2/6/2001	2/20/2001	4/20/2001
DAS	91	105	164
Treatments		Kg N ha^{-1}	
O-110-1	0	110	0
O-150-1	0	150	0
O-150-2	0	75	75
O-240-1	0	240	0
M- 25-1	25	0	0
M-110-2	25	85	0
M-150-2	25	125	0
M-150-3	25	50	75
M-180-3	25	115	40

The study was carried out in 2000-2001 at the INRA Toulouse Research Center (43.5° N, 1.43°E) on a deep silty-clay loam, with a total carbon content of 0.9%.Wheat Soissons cultivar was sown on November 7, 2000 and harvested on July 4, 2001. Organic N strategies (O) differed by the amount of N applied as hydrolysed feather meal and the timing of applications (Table 1). One control treatment with only 25 kg N ha^{-1} and 4 conventional low-input N strategies (M) were introduced for a better separation between N deficiencies and diseases effects, with amounts of N as NH4NO3 ranging from 85 to 180 kg ha^{-1} and one fungicide application (epoxiconazol, 125 g ha^{-1}). Following the method proposed by Colomb et al. (2002) to explain wheat relative grain number, deficiency N nutrition indexes (DNNI) were derived from the time-course of N nutrition indexes (NNI) calculated according to Lemaire and Gastal (1997). Fertiliser N use efficiencies (NUE) were calculated at anthesis and harvest stage, using data from the control treatment as a reference in both cases. N remobilisation efficiency (NRE) of pre-anthesis uptake and N harvest index (NHI) were calculated according to Debaeke et al. (1996).

Results

As expected, NNI trajectories (Fig. 1) over thermal time revealed some early and acute N deficiencies in O treatments from the beginning of stem elongation onwards to anthesis. DNNI were larger in organic treatments at similar N inputs than in M treatments, leading to significant losses in grain number (Fig. 2), the number of spike per m² being more affected than the grain number per spike (Table 2). At flowering, NUE ranged from 22 to 31 % and 47 to 86 % in O and M treatments respectively. Due to mild winter and wet spring conditions, leaf brown rust (Puccinia recondita) spread in the area at an early stage. The disease moderately reduced the grain filling period in M treatments, but severely decreased it in O treatments (LAI values not shown). The lack of post-anthesis C accumulation in O treatments was so large that 1000-seed weights remained lower than values observed for M treatments, in spite of lower grain numbers. There was no N post-anthesis uptake at all in O treatments (NU [h] = NU [a] in table 2). NRE did not differ among treatments, excepted for O-240. NHI tended to decrease with the amounts applied for both forms of N. Nitrogen deficiency, and disease attack led to lower grain yield and N uptake but a similar protein content in O in comparison to M treatments. Differences in fertiliser NUE among them were higher at harvest than at anthesis.

Table 2 : Yields, yield components, biomass (AGW) and nitrogen status criteria at anthesis [a] or harvest [h] for each N treatment (mean separation following Tukey method).

Yield components	Organic N treatments				Conventional N treatments				
	O-110-1	O-150-1	O-150-2	O-240-1	M-25-1	M-110-2	M-150-2	M-150-3	M-180-3
Yield ($g\ m^{-2}$)	345 b	369 b	382 b	375 b	308 a	494 c	553 d	575 d	560
Grain m^{-2}	10501 b	11906bc	12400 c	13525 c	8359 a	14004 c	15491 d	15336 d	15852
Spike m^{-2}	439 bc	502 c	456 c	503 c	369 a	506 c	569 c	484 c	588
Grain $spike^{-1}$	23.9 a	24.0 a	27.3 b	27.4 b	22.9 a	27.9 b	28.1 b	32 bc	28
1000-seeds W. (g)	32.9 c	31.1 d	30.8 d	27.7 e	36.8 a	35.3 b	35.5 b	37.5 a	35.3
Protein (%)	9.83 b	10.48 c	10.42 c	11.38 d	9.46 a	9.77 b	10.29 bc	11.14d	11.51
AGW [a] ($g\ m^{-2}$)	964 b	1017 bc	1037 bc	1114 c	862 a	1198 d	1346 e	1155 d	1425
NNI[a]	0.46 a	0.53 bc	0.59 bc	0.66 c	0.38 a	0.50 b	0.63 c	0.61 c	0.85
DNNI (DD)	172 b	112 b	148 b	61 c	240 a	89 c	31 d	55 cd	0
NU [a] ($g\ m^{-2}$)	8.8 ab	10.5 b	11.6 b	13.6 bc	6.9 a	10.9 b	14.4 cd	12.8 bc	20.1
NU [h] ($g\ m^{-2}$)	8.7 a	10.2 ab	10.8 ab	13.3 b	7.1 a	12.2 b	15.1 c	16.2 c	18.0
NUE [a]	0.22 a	0.29 a	0.38 b	0.31 ab	---	0.47 b	0.61 b	0.47 b	0.86
NUE [h]	0.18 a	0.25 ab	0.29 b	0.29 b	---	0.6 c	0.64 c	0.72 c	0.70
Harvest Index	0.40 b	0.40 b	0.39 b	0.36 a	0.39 b	0.39 b	0.39 b	0.41 b	0.41
NRE [h]	0.69 a	0.66 a	0.68 a	0.57 b	0.70 a	0.66 a	0.63 a	0.60 a	0.67
NHI [h]	0.69 a	0.67 ab	0.65 b	0.56 c	0.72 c	0.70 a	0.66 b	0.70 a	0.63

Fig. 1 - NNI as a function of thermal time from stem elongation onset to anthesis

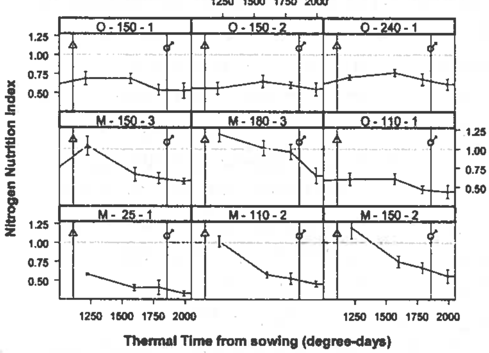
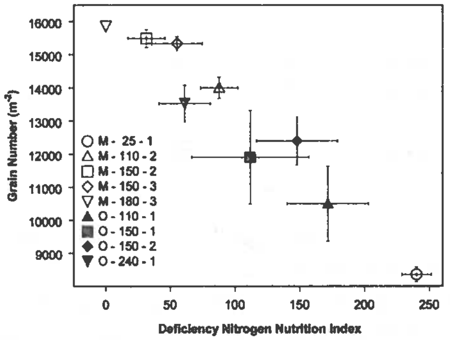


Fig.2 - Grain number per m² vs Deficiency Nitrogen Nutrition Index



Conclusions

This study matched the results reported by David et al. (2001) for organic wheat grown in the eastern part of South France, and by Debaeke et al. (1996) for conventional wheat grown in the Midi-Pyrénées region in low-input systems with no fungicide application. Our data could then be used to test models for wheat N fertilisation assessment, taking into account the likely effect of leaf diseases.

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EFFECT OF PIG SLURRY ON CORN YIELD AND SOIL NITRATE CONCENTRATIONS

A. Daudén, D. Quílez

Servicio de Investigación Agroalimentaria, Diputación General de Aragón.y Laboratorio de Agronomía y Medio Ambiente (DGA-CSIC), Apdo. 727, 50080 Zaragoza (Spain)

Introduction

In many regions of Spain there had been an intensification of pig production over the last twenty years. Since most of the pig manure is applied to agricultural fields, it is important to evaluate the effects of pig slurry on plant production and to assess the risk of potential adverse environmental effects, such as nitrate leaching and groundwater pollution.

The objectives of this work are to evaluate the effects of different pig slurry (PS) doses in comparison to a control mineral treatment on 1) the development and yield of a maize crop and 2) the residual soil nitrate as an indicator of the potentially leachable nitrate.

Methods

The experiment was conducted in the experimental farm of the Gobierno de Aragón Agronomic Research Service in Zaragoza in a typic xerofluvent soil from 1996 to 1998. Three different rates of fresh pig slurry (PS) and a control mineral fertilizer treatment (T0) were applied in 33 m long x 6 m width strips, in a completely randomized design with three replicates.

PS was applied before sowing at theoretical doses of 50 m^3 ha^{-1} in treatment T1 (low rate), 100 m^3 ha^{-1} in treatment T2 (moderate rate), and 150 m^3 ha^{-1} in treatment T3 (high rate). Treatment T1 was also supplied at sidedress with inorganic N (Table 1). In 1996 PS was applied by the traditional splash plate method and buried into the soil 24 hours after application. In 1997 and 1998 PS was applied using a slurry incorporator that buried the PS during application.

Table 1. Mineral Nitrogen applied (kg N ha^{-1}) in the different treatments for the three years of the experiment.

	Before sowing			Sidedress			Total		
	96	97	98	96	97	98	96	97	98
T0	100	110	110	175	165	165	275	275	275
T1	315	183	299	175	125	20	490	308	319
T2	430	365	458	-	-	-	430	365	458
T3	585	547	733	-	-	-	585	547	733

Cultivation was carried out following traditional practices in the area. Maize cv. *Juanita* was sowed at a density of 80,000 plants ha^{-1}. The plot was surface irrigated using 9,260 m^3 ha^{-1} in 1996, 9,334 m^3 ha^{-1} in 1997, and 12,131 m^3 ha^{-1} in 1998. The soil was sampled three times each year, at intervals of 0.3 m up to a depth of 1.2 m, before application of PS, before sidedressing, and after harvesting. Nitrate concentrations ($[NO_3^-]$) were determined by ion chromatography in 1:3 soil extracts using a saturated calcium sulfate solution. At harvest, two 2.25 m^2 control areas were collected in each plot to measure grain yield and above ground dry matter. Total N concentration in samples of leaves, stalks, cobs and ears was determined using a Khjendall method. Differences between variables were assessed by analysis of variance and Duncan test for mean separation at the 95% confidence level (P=0.05).

Results

Not significant differences between treatments were observed in the number of plants and ears. The harvest index was similar for all treatments with a mean value of 0.56. Grain yield was higher in 1996 (13.4 t ha^{-1}) than in 1998 (10.3 t ha^{-1}) and 1997 (9.3 t ha^{-1}) due to climatic differences between years. However, above ground dry matter and grain yield did not differ significantly among treatments. Neither a significant effect of the treatments was detected on N in above ground biomass that ranged between 227 kg N ha^{-1} for the T3 treatment in year 1996 to 109 kg N ha^{-1} for the T2 treatment in year 1997 (Table 2).

Table 2. Grain yield, above ground dry matter (AGDM) and N in above ground biomass (NAG) for the different treatments during the three experimental years.

	Grain yield (t ha^{-1})			AGDM (t ha^{-1})			NAG (kg N ha^{-1})		
	1996	1997	1998	1996	1997	1998	1996	1997	1998
T0	13.5	10.2	11.2	21.3	16.1	18.5	225	158	200
T1	13.3	9.4	10.3	21.7	15.2	17.1	217	144	177
T2	13.5	7.6	9.9	21.6	12.4	16.7	210	109	156
T3	13.4	10.0	9.9	22.2	16.2	16.6	227	163	186

On July 11th 1996 [NO_3^-] at the 0.3-0.6 m depth was higher in treatment T0 (51 mg kg^{-1}) than in the PS treatments (average of 24 mg kg^{-1}). However, the amount of applied nitrogen was higher in the PS treatments (Table 1) indicating that nitrogen volatilization after PS application was high due to the spread of the PS over the soil. For all sampling times between October 1996 and April 1998, soil solution nitrate concentrations at the 0.9-1.2 m depth were higher in treatment T0 (mean of 175 mg L^{-1}) than in all the PS treatments (means between 32 mg L^{-1} for T2 to 74 mg L^{-1} for T1) indicating a higher susceptibility to nitrate leaching in the T0 treatment than in the PS treatments (Fig. 1).

In June 1998 and at the end of the experiment (October 1998) no differences were observed between treatments at any depth. This year the doses of N applied to the PS treatments were 30% higher than in 1997.

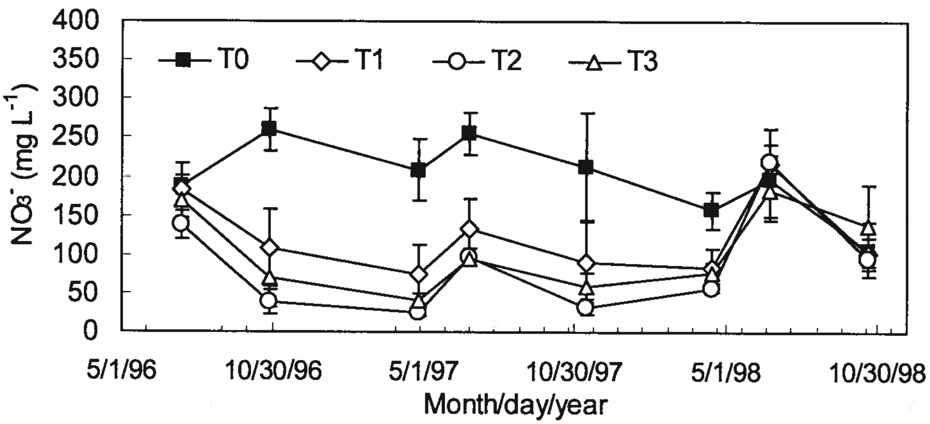

Fig. 1. Soil solution nitrate concentration at the 0.9-1.2 m depth for the different treatments during the three experimental years. Bars indicate one standard error.

Conclusions

Pig slurry treatments with (T1) or without (T2 and T3) sidedress mineral nitrogen had the same crop development and yields than the control mineral nitrogen treatment (T0).

Soil nitrate concentrations at the 0.9-1.2 m depth were lower in the PS treatments than in the control mineral treatment indicating a lower susceptibility to nitrate leaching in the PS treatments, even when the amounts of nitrogen applied were higher than for the mineral treatment.

MACRONUTRIENTS IN FRESH WATERS IN AN AGRICULTURAL AREA IN GALICIA, SPAIN

M. L. Fernández Marcos[1], C. López Mateo[1], L. García Calvo[2], E. Álvarez Rodríguez[1]
[1]Universidade de Santiago de Compostela. Escola Politécnica Superior. Departamento de Edafoloxía e Química Agrícola. 27002 Lugo. España
[2]Instituto do Campo. Deputación Provincial de Ourense. c/Dos de Mayo, 37. 32630 Xinzo de Limia. España

Introduction

The region of A Limia, in Ourense (Spain), crossed by the River Limia, is occupied to a large extent by the depression of Antela, a level surface, with an average altitude of 630 m. The climate is transitional oceanic (Gómez Nieto, 1996), with some continental and Mediterranean characteristics. The rainfall (888 mm/yr) is maximum in December and January and minimum in July and August. The flow of the River Limia is maximum in January, February and May and minimum in August, September and October (Perez Alberti, 1986).
The soils in the area, developed from sediments, show generally coarse-textured surface horizons, and a clayey layer at a variable depth. The pH is acid; the organic matter content is high in some uncropped soils and low in cropped soils; the cation exchange capacity (CEC) of the surface horizons is very low (often less than 5 $cmol_c$/kg); the phosphate adsorption capacity is also low. The water table often reaches the soil surface in wintertime, causing a risk of mobilization of soluble substances applied to the soil. Agriculture is the main economical activity of this region, potato being the staple crop. The potato fields receive usually strong fertilization rates, often exceeding the agricultural optimum and posing a notable environmental risk (Prado et al., 2000; Fernández Marcos et al., 2001). Macronutrients, particularly N and P, usually constitute the main concern related to contamination from agricultural sources. This work aims to study N, P and K concentrations in ground- and surface waters in A Limia and to relate them to agricultural and climatic factors and to soil properties.

Materials and Methods

Fifty six surface- and shallow ground waters were sampled in the region of A Limia (Ourense, Spain) at three dates: 19/09/01 (dry season), 23/10/01 (moderate flow of running waters) and 5/03/02 (high flow of running waters). Ammonium (NH_4) and nitrate (NO_3) were determined by steam distillation of the sample alkalinised (without and with addition of Devarda alloy, respectively) and titration of the distilled NH_3 with H_2SO_4; Phosphate (PO_4) was determined by visible spectrometry with molibdate and potassium (K) by atomic emission spectrophotometry. Comparison of means was made by using the statistical programme SPSS 10.0 for Windows.

Results and Discussion

Results from the analyses are summarised in Table 1.

Table 1.Ranges of macronutrient concentrations in fresh-water samples from A Limia

Date	NH_4, mg N/L	NO_3, mg N/L	PO_4, mg P/L	K, mg/L	NH_4, mg N/L	NO_3, mg N/L	PO_4, mg P/L	K, mg/L
	Surface waters				Shallow ground waters			
19-9-01	0.2-0.9^{ab}	0.3-3.2^{a}	0.3-7.3^{a}	1.6-26.9^{a}	0.3-1.1^{a}	0.3-8.0^{a}	0.2-0.9^{a}	1.5-22.0^{a}
23-10-02	0.2-1.6^{a}	0.3-9.7^{b}	0.0-1.3^{b}	1.8-11.9^{ab}	0.3-1.5^{b}	0.2-13.4^{b}	0.0-1.3^{b}	2.3-27.5^{a}
5-3-02	0.1-1.3^{b}	0.2-6.8^{ab}	0.0-0.3^{b}	1.3-9.7^{b}	0.2-1.8^{a}	0.2-20.5^{b}	0.0-1.2^{c}	2.4-34.9^{a}

different letters in the same column indicate significant differences ($P<0.05$)

The concentrations of nitrate and potassium (except in September) were significantly ($P<0,05$) higher in ground- than in surface waters. Ammonium and phosphate did not show significant differences between ground- and surface waters. High NH_4, NO_3 and K concentrations in ground waters indicate a high mobility of these species. High NH_4 concentrations in ground waters may reflect the low capacity of soils to adsorb ammonium (low CEC) and unfavourable conditions for nitrification in ground waters. The high usual mobility of NO_3 explains the high concentrations reached in ground waters.

The maximum NH_4 concentrations in surface- and ground waters were reached in October, when winter wheat has been fertilized, the nutrient requirements by crops are low, and moderate rainfall occurred allows nutrient mobility. The value of 0.9 mg/L of NH_4-N, specified by Spanish law as toxic to fish (Real Decreto 927/1988), and the value of 1.5 mg NH_4/L, specified by the EU as the maximum admissible concentration (MAC) in water intended for drinking water abstraction (Directive 75/440/EEC), were rarely exceeded. Nitrate in surface waters varied seasonally similarly to ammonium, whereas ground water concentrations were significantly higher ($P<0,05$) in October and March than in September, presumably as a result of the absence of rainfall to mobilize nitrate in September, and of the nitrate availability from wheat and potato fertilisation in October and March. The guideline of 5.6 mg NO_3-N/L for drinking waters, (EU Directive 75/440/EEC), was exceeded in 35% of the analysed ground water samples in March 2002 and by one sample in September 2001. The MAC in drinking waters of 11.3 mg NO_3-N/L was exceeded in 18% of the samples analysed in October 2001 and in none in September. The PO_4 concentrations were high and decreased significantly from September to March, in both ground- and surface waters. The low phosphate adsorption capacity of soils in the area, coarse-textured and lacking noncrystalline materials, favours the mobility of this nutrient in the soil surface horizons. The diminution of the phosphate concentration from September to March results apparently from the dilution of surface- and ground waters by rainwater. The value of 0.1 mg P/L, specified by the OECD (OECD, 1982) as being critical for eutrophication, was exceeded in all the surface waters analysed in September, in 89% in October, and in 12% in March. Potassium presented always high concentrations in fresh waters from A Limia, as a result of the strong potassium fertilization of crops.

The highest concentrations of macronutrients in surface waters occurred in the main channel, which drains the crop fields of the old lagoon of Antela, or in small streams. The seasonal variation of the NH_4, NO_3 and K concentrations was higher in streams than in the River Limia (excepted the samples located after the urban centre of Xinzo).

Conclusions

The risk of water contamination by macronutrients is high in an area having a shallow water table and very permeable soil surface horizons. The agriculture is in the origin of high nitrate and phosphate concentrations in fresh waters. The greatest risk of contamination by nitrate takes place at the rainy season, resulting from nitrate leaching from crop fields. The opposite happens to phosphorus, whose maximum concentrations are observed at the dry season, when a high risk of eutrophication exists. The contamination by ammonium seems to be mainly of urban origin.

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COMBINATION OF TENSIONIC-TENSIOMETERS MEASUREMENTS AND CROP MODELS TO EVALUATE NITRATE LEACHING IN FARMERS FIELDS : A CASE STUDY ON LETTUCE FIELDS IN A MEDITERRANEAN COASTAL PLAIN.

F. Gay[(1)], J. Wery[(1)], P. Bertuzzi[(2)], N. Brisson[(2)] and F. Lafolie[(2)],

1. UMR SYSTEM (Agro.M-CIRAD-INRA) CIRAD TA 179/01, Bat. 1, Campus Lavalette, Avenue Agropolis 34398 Montpellier Cedex 5 (France)
2. UR Climat, Sols et Environnement INRA, Avignon (France).

Introduction

Irrigated crops such as lettuce are considered as undesirable in protection areas of the watersheds because they induce a high level of nitrate leaching. Measurements of soil water potential and nitrate content in vegetables farmer's fields, using tensionics (Moutonnet et al., 1993), showed that farmers are managing irrigation and nitrogen fertilisation in order to avoid any water or nitrogen stress but with continuous drainage of water having nitrate concentration above the EU threshold for drinking water (Gay and Wery, unpublished). On the other hand, vegetables are among the only profitable crops in Mediterranean coastal plains where irrigation water is rare and expensive and where farm size is limited. In order to help in the negotiation between farmers and water companies, there is a need of information on the actual level of nitrate leaching below the rooting zone of vegetable crops in farmers fields. Firstly, direct measurements with tensionics can give information on the nitrate content of drained water and the direction of the water gradient. They do not allow the calculation of the fluxes of leached nitrate, but this qualitative evaluation appeared to be an efficient way to open the dialog with farmers about theirs agricultural practices. Secondly, quantitative evaluations of the amount of nitrate leached below the crop are necessary to compare farmers practices and to adjust cropping techniques. Crop models have many potentials uses for answering this question, but they require beforehand long and expensive process of evaluation and calibration. In this work, nitrate leaching was evaluated using measurements of nitrate content of the drained water (Cuny *et al.*, 1998) and simulated water flows. A model based on an analog approach treating the soil as a collection of water layers (STICS, Brisson *et al.*, 1998) and a model based on transfer equations (PASTIS, Lafolie, 1991) were compared for their ability to reproduce the dynamic of drainage periods measured in lettuce fields.

Methods

A greenhouse grown lettuce crop was followed from plantation on 23 February to harvesting on 12 march 1999 in a farmer's field near Montpellier (south-eastern France). The crop was conducted by the farmer without any access to our measurements. Soil texture was loamy clay with 2.3% organic matter. Measurements were conducted on 3 sites located on the central plantation band, with 15 m between sites. Each one was equipped with five tensionic allowing simultaneous measurement of soil water potential and nitrate content at 0.1, 0.2, 0.3, 0.5 and 0.7m. Each site was also equipped for rainfall measurement after each irrigation. Water potential was measured every 2 or 3 days with portable pressure transducer. Ceramic cup solution was extracted every 10 days, after equilibrium with soil solution, and NO3- concentration was then analysed using colorimetric strips and Rqflex meter. On each site, 3 soil samples were taken at four dates from 0-0.6m for gravimetric water content determination. Simulation models STICS and PASTIS were previously adapted for lettuce crop, and calibrated with independent data sets for crop water requirements and root growth (Gay and Bertuzzi, unpublished). Soil parameters were measured or estimated for 0-0.3 and 0.3-0.6m layers. STICS requires easily available parameters : water content at field capacity and wilting point, dry bulk density. PASTIS requires soil hydraulic proprieties which are more difficult to obtain. The water retention curve was fitted for the 2 layers with van Genuchten equation using simultaneous measurements of water potential and water content. The relationship between hydraulic conductivity and volumetric water content was taken from a previous experiment on a field of the same farm with the same soil texture, and optimised on water potential data from one site of tensionics.

Results

Both models gave a good simulation of the evolution of soil water content during the crop cycle (not shown). Figure 1 shows evolution with time of daily water flows at 0.6m simulated with PASTIS and STICS, and hydraulic gradient calculated with water potential measured at 0.5 and 0.7m. Patterns of water flows given by the models are very different. STICS calculated only positive flow corresponding to drainage. These drainage events occurred only the day after irrigation during the first half of crop cycle. With PASTIS the drainage period was longer and almost constant from plantation to 10 days before harvest. Moreover, PASTIS simulates negative water flow, corresponding to capillary rise, when irrigation was stopped to harvest the lettuce. This evolution of water flow simulated with PASTIS is quite consistent with the hydraulic gradient calculated from tensionic measurements. The volume of water flow given by the models were used to calculate the amount of $N\text{-}NO_3^-$ leached below the root zone. For a day i, $N\text{-}NO_3^-$ leached was calculated as the product of the simulated water flow, and the mean nitrate concentration of the soil solution measured on the 2 previous dates. Figure 2 shows evolution with time of the cumulative $N\text{-}NO_3^-$ leached calculated with water flow simulated with the 2 models. Total $N\text{-}NO_3^-$ leached was 19.7 kg $N.ha^{-1}$ with STICS and 18.4 kg $N.ha^{-1}$ with PASTIS. In the latter case, calculation includes capillary rise which compensate a part of the total nitrate leached (24.5 kg $N.ha^{-1}$). Despite a bad simulation of the dynamic of drainage and capillary rise STICS gave a correct simulation of the amount of nitrate leached (simulated with PASTIS). This can be explained by the constant nitrate concentration of the drained water (fig. 2), but this was not the case in all the fields we evaluated (Gay and Wery, unpublished).

Figure 1: Comparison of simulated daily water flow with PASTIS and STICS, measured hydraulic gradient. Arrows indicate time of irrigation.

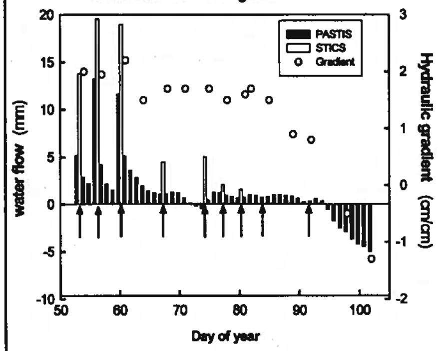
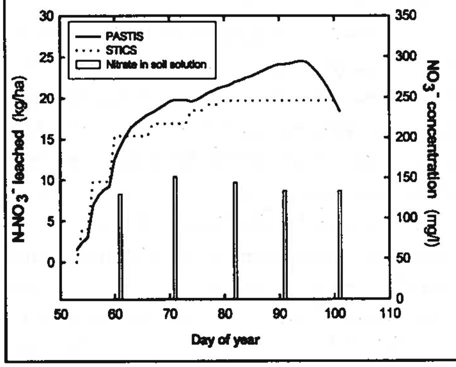


Figure 2 : Comparison of cumulative amount of $N\text{-}NO_3^-$ leached calculated from simulated water flow and measured nitrate in soil solution



Conclusion

The 2 models gave similar results for the total amount of water drained but the STICS model was not able to reproduce the dynamics of drainage during the crop cycle and the capillary rise when irrigation was reduced. The PASTIS model provide a good simulation of the observed water flows and could therefore be used to calculated N leaching even in situations where nitrate concentration of the drained water is not constant and to simulate alternative scenario based on reduction of irrigation. Its calibration is more complex but the availability of soil water potential measured with tensionics allows the optimisation of the key parameters for each field. These results show that tensionics-measurements and simulation models are complementary tools that can be simultaneously used to provide a precise evaluation of nitrate leaching in farmers fields.

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RESIDUAL EFFECTS OF FERTILIZER NITROGEN APPLICATIONS IN IRRIGATED WHEAT FIELDS

Guillaumes E.[1], Villar J.M.[1], Carrasco I.[1], Villar P.[1,2], Aran M.[2]

1 Universitat de Lleida. ETSEA. MACS. Av. Alc. Rovira Roure, 177- 25198 Lleida (Spain)
2 Laboratori d'Anàlisi i Fertilitat de Sòls. Partida Setsambs, s/n. Sidamon (Spain)

Introduction

In the present study, a 2-year N rate response experiment was conducted to compute the residual N for the following year's crop. Residual effects are not taken into account when N fertiliser recommendations are established. Although N fertiliser recommendations are generally controversial, residual effects of N fertiliser need to be considered. In general, it has been estimated that about 30% of the N may remain as residual for the following year's crop (Havlin et al, 1999). This study is part of a broader project that deals with the improvement of N management and assesses the behaviour of a new nitrification inhibitor, DMPP, developed by BASF (Conrad, 1999).

Methods

A wheat (*Triticum aestivum* L.) field experiment was conducted during the 1999-2001 growing season in the area irrigated by the Canal d'Urgell (north-east Spain). The soil was a coarse-loamy, mixed, mesic, Petrocalcic Calcixerept (Bellvís Series). This is a shallow (50-60 cm), well-drained soil, with 2.6 % organic matter, 24 % $CaCO_3$ equivalent, a pH of 8.2 and a 30 % gravel content. A randomised block design was used with three replications and four fertiliser treatments:

0: A control with no N applications
150: 150 kg N ha^{-1} as ammonium nitrate-sulphate (ANS-26) applied before planting
50+100: 50 kg N ha^{-1} as ammonium nitrate-sulphate (ANS-26) applied before planting plus 100 kg N ha^{-1} as ammonium nitrate-sulphate (ANS-26) at stage V6
150 DMPP: 150 kg N ha^{-1} as ENTEC 26® (ammonium nitrate-sulphate (ANS-26) +DMPP) applied before planting.

Nitrogen fertilisers were only applied during the first year (1999-2000). Data were analysed by variance procedures using the SAS.

Results

Results provided information on N behaviour in irrigated agricultural systems. Simplified budget of nitrogen is shown in table 1. Unaccounted N comprises mineralised N from organic matter, N content in irrigation water, N supplied by rainfall and N from crop residues.

Table 1. Soil NO_3-N content (kg NO_3-N ha^{-1}) in the profile taken at pre-planting and N uptake, for the N rate treatments

Treatment (kg N ha^{-1})	Available nitrogen before planting (0-60 cm) (kg N ha^{-1})	N uptake First year (kg N ha^{-1})	N uptake Second year (kg N ha^{-1})	Unaccounted N (kg N ha^{-1})
0	67	76 b	62 b	71
150	67	163 a	119 a	65
50+100	67	168 a	121 a	72
150_{dmpp}	67	163 a	127 a	73

Within columns, means followed by the same letter are not significantly different at the 0.05 significance level

Yields of N treatments dropped by 23 % in the second year with respect to the first (from 6.422 $kgha^{-1}$ to 4.947 $kgha^{-1}$). Control treatment dropped by 20% (from 4.293 $kgha^{-1}$ to 3.443 $kgha^{-1}$). While the nitrogen recovery fraction (NREC) was around 60% (59%) in the first year, it reached 100% in the second. Several nitrogen efficiency indexes were also calculated (Table 2). NUE_1: Nitrogen Use Efficiency (kg of grain yield per kg of applied fertiliser), NUE_2: Nitrogen Uptake Efficiency (kg of N uptake per kg of applied fertiliser), NUE_3: Nitrogen Utilisation Efficiency (kg of grain yield per kg of N uptake). These indexes were quite constant from treatment to treatment.

Table 2. Grain yield, Recovery of fertiliser-N (NREC) and nitrogen use efficiencies NEU_1, NUE_2 and NUE_3, for the N rate treatments

Treatment	1999-2000					2000-2001				
	NREC	NUE_1	NUE_2	NUE_3	Yield ($kg\ ha^{-1}$)	NREC	NUE_1	NUE_2	NUE_3	Yield ($kg\ ha^{-1}$)
0	-	-	-	56.4	4.293b	-	-	-	56.1	3443 c
150	0.58	43.6	1.1	40.1	6.534a	0.96	76.2	1.9	40.6	4903 ab
50+100	0.61	43.3	1.1	38.6	6.489a	1.01	81.4	1.9	42.3	5727 a
150_{dmpp}	0.58	41.6	1.1	38.3	6.244a	1.01	69.7	1.9	36.1	4212 bc

Within columns, means followed by the same letter are not significantly different at the 0.05 significance level

Agronomic efficiency was estimated using the expression: (Yield – Yield for zero treatment) divided by N applied in the first year. That index is associated with economic criteria. The percentage of residual N for the second year's crop was estimated using: (N uptake second year minus N uptake second year for zero treatment) divided by N applied in the first year. Table 3 shows that 40% of the N could be considered residual for the following season.

Table 3. Accumulated yield and N uptake, agronomic efficiency and percentage of residual N for the second year's wheat crop

Treatment	Accumulated Yield ($kg\ ha^{-1}$) 1999-2001	Total N uptake $kgNha^{-1}$ 1999-2001	Agronomic Efficiency	% of Residual N for second year's crop
0	7.736 b	138	-	-
150	11.437 a	282	24.7	38
50+100	12.216 a	289	29.9	39
150_{dmpp}	10.456 a	290	18.1	43

Within columns, means followed by the same letter are not significantly different at the 0.05 significance level

Conclusions

We estimated that 60% of the N was recovery by the crop during the first year and that 40% was used during the second year. Nitrogen recovery fraction was therefore computed as 100% after the second year. It appears that in cases where N is not used in excess, efficiency is very high. The conditions of the experiment (rapid percolation) make the results of even greater interest. The residual effects of nitrogen fertiliser deserve further attention.

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RISK OF WATER POLLUTION BY NITRATES FROM AGRICULTURAL ACTIVITIES IN POLAND

Janusz Igras
Institute of Soil Science and Plant Cultivation, Czartoryskich 8, 24-100, Poland

Introduction

There are two main important goals in sustainable agriculture; the quantity and quality of agricultural products and protection of environment quality so-called soil and water. Agricultural intensification of production has led to serious problem in nitrogen balance.
Incorrect application of manures and mineral fertilizers negatively influence the nutrient dispersion. Excess of nutrients is lost into the wider environment with consequences for water, soil and atmospheric quality [Cameron and Trenouth 1999; Schleff and Kleinhanb 1994].
The object of the study was to present the influence of doses and surplus of nitrogen fertilization on nitrate content in groundwater in main river catchments of Poland.

Methods

Monitoring of groundwater was performed during years 1998-2001 in catchments of main rivers in Poland. The points of monitoring were localized in regularly seated farms. In the course of 4 years the 8496 water samples from outlets were analysed. Water samples were collected in autum, after plant harvests. The nitrates were measured colorimetrically using authoanalyser. In chosen farms simultaneously yield crops and fertilizer consumption were monitored. Nitrogen balance were estimated according to OECD methods [OECD 1998]. The regression model for nitrate concentration in groundwater depending on annual doses and balance of nitrogen was derived. For statistical analyses the variable averages values for each year were used.

Results

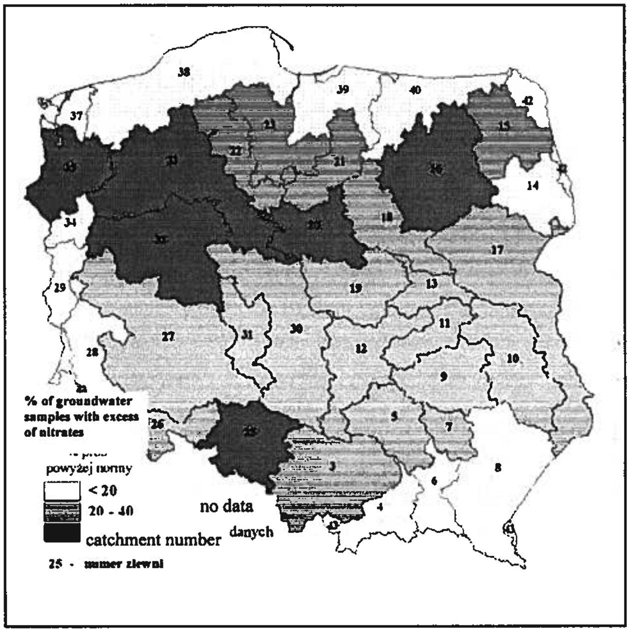

Figure 1. Percentage of groundwater samples with excess of nitrate according to Nitrate Directive norm

Nitrate concentration in groundwater is differed by both time and space and depends on farming intensity and also infrastructure system in the country. On the area with low animal concentration the nitrate content in groundwater is relatively lower than in the regions with

intensive farming production. The main source of pollutions of shallow groundwater is nitrogen, originating mostly from field production, but nitrates from farms is first source of pollution of deeper groundwater. In most of catchments of Polish rivers not large excess of nitrates was found (fig. 2). Only in about 35 % of water samples in the central part of Poland in Wielkopolska region and in Narew, Biebrza and also Odra rivers from border to Nysa Luzycka river catchments limit of Nitrate Directive was exceed [Nitrate Directive 1991].
Utilization of nitrogen in crop production is very important factor the nitrogen dispersion in ground water. In Polish soil and climatic conditions the risk of water pollution might come from nitrogen doses about 120 kg N ha $^{-1}$ and surplus of nitrogen balance more than 50 kg N ha $^{-1}$ per year (fig. 2).

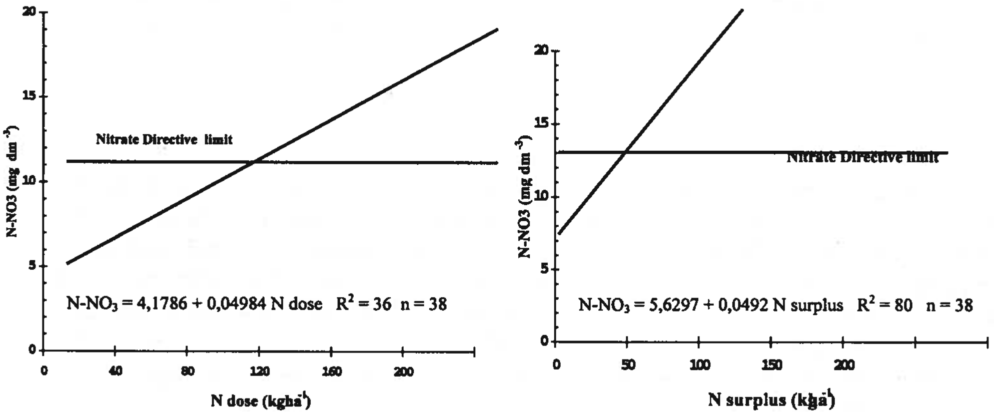

Figure 2. Relationship between nitrate concentration in groundwater collected in autumn and nitrogen dose and nitrogen balance surplus

Conclusions
The highest nitrate excess was found in the catchments with intensive farming production. The risk of Nitrate Directive limit excess in Poland might come from doses of nitrogen about 120 kg N ha $^{-1}$ and surplus of nitrogen balance more than 50 kg N ha $^{-1}$ per year.

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IS NITRATE CONCENTRATION IN LEACHATE INFLUENCED BY NITROGEN UPTAKE EFFICIENCY OF SPRING WHEAT GENOTYPES?

Liedgens, M.[1], Herrera, J.[1], Soldati, A.[1], Stamp, P.[2]

[1] Institute of Plant Sciences - ETH Zürich - Eschikon 33 - CH 8315 Lindau (Switzerland)
[2] Institute of Plant Sciences - ETH Zürich - LFW - Universitätstr. 2 - CH 8092 Zürich (Switzerland)

Introduction

Nitrogen (N) uptake by spring wheat (*Triticum aestivum* L.) is determined by its availability and uptake efficiency, the former of which can be manipulated by N fertilisation and the latter by the choice of the cultivar. These two agricultural management strategies are expected to influence soil N dynamics and, thus, the concentration of nitrate in the leachate (NO_3-L), which is a highly relevant environmental issue. This study evaluates the impact of three spring wheat genotypes varying in N use efficiency at two levels of N fertilisation on the NO_3-L during and after the crop season.

Methods

The experiment was conducted in drainage lysimeters from spring 2000 to spring 2001. Each lysimeter had a square area of $1m^2$ and a soil column of 1.5 m (Liedgens et al., 2000). The soil was a slightly alkaline (pH 7.2 to 7.5) sandy loam with a low content of organic matter. The spring wheat cultivars Albis (old standard cultivar) and Toronit (high-yielding newer cultivar) and the experimental line 94491 (high in grain N, low biomass) were sown on the 23 March 2000 at 400 seeds m^{-2} in seven rows, 14 cm apart. Half of the plots were fertilised (N1) or not (N0) with 250 kg N ha^{-1} (as NH_4NO_3) split into four applications (90, 40, 60, and 60 kg N ha^{-1}) at planting and at the developmental stages EC30, EC50, and EC60, respectively. Each N fertiliser x spring wheat genotype combination was replicated four times. The plants were harvested on 5 August 2000. Straw residues were removed from the plots. After the harvest, the plots were either left bare or cover crops were sown while the original experimental design was retained. Cover crop plots were harvested on 18 November after the first severe frost. Cover crop residues were uniformly distributed over the plot, which was left without plant cover thereafter. Drainage sub-samples were collected from the lysimeters at weekly intervals (31 March 2000 to 2 April 2001) for NO_3 analysis. The statistical analysis of NO_3-L was calculated for selected periods of the experiment using time as continuous repeated measurement.

Results

Genotype and N fertilisation, but not their interaction, influenced the N yield of the shoot (Table 1). The overall impact of N fertilisation on N yield was stronger than that of the genotype. The old cultivar Albis yielded the smallest amount of N. Its ability to improve N yield in response to N fertilisation was limited.

Following the harvest of the spring wheat, the NO_3-L was subdivided into three phases: (I) increasing, (II) high until the middle of November, (III) decreasing rapidly and remaining low until the following spring. During phases (I) and (II) NO_3-L was lowest for L94491 and highest for Albis, especially in the fertilized plots (Table 2). During phase (III) none of the treatment effects were significant.

Table 1. Results of the ANOVA for genotype (G), nitrogen fertilisation (N), and their interaction effect (G x N) on N yield of the shoot at harvest.

Effect	G	N	G x N
Pr > F	0.019	<0.001	0.379
	N1	N0	mean
Genotype	------- g m^{-2}	--------	
Albis	26.7 b	19.5 a	23.1 b
L94491	33.1 a	21.6 a	27.3 a
Toronit	32.0 a	22.2 a	27.1 a

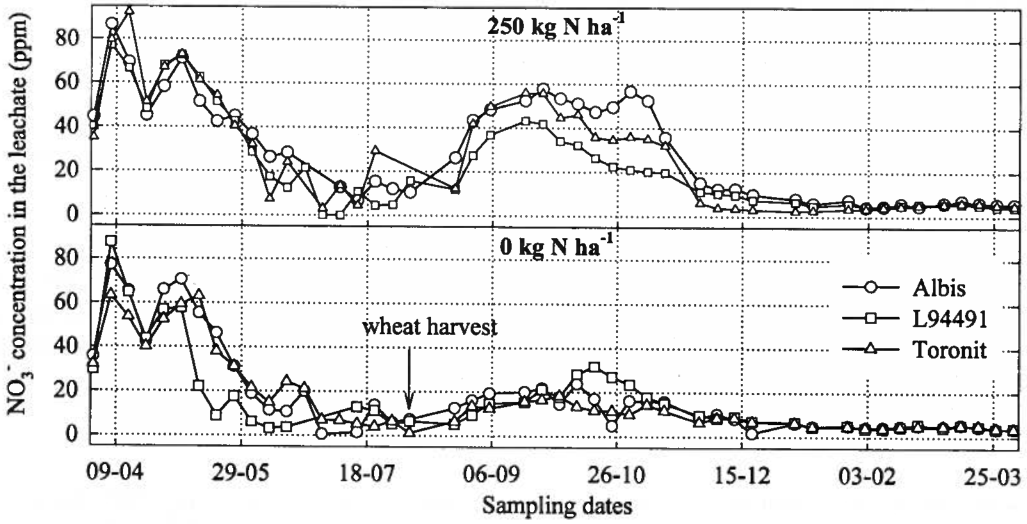

Fig. 1. Genotype and N fertilization effects on NO_3-L observed during and after the crop season.

Discussion

The very high NO_3-L following the sowing of spring wheat was probably a consequence of high N mineralization as a result of the soil disturbance during the filling of the lysimeters, which was terminated shortly before the start of the experiment. This may have masked an effect of N fertilization on NO_3-L during the growth of spring wheat. The absence of a treatment effect on NO_3-L during the growth of the crop can be explained by: (a) The small volume of soil that was explored by the root system early in the season when the leaching potential was high. (b) The rapid drying of the soil during the crop season, thus reducing N mobility. The genotype selection was relevant for NO_3-L after the harvest, especially for the N1 treatment. N uptake by Albis (small) and L94491 (high) explains the high (Albis) and low (L94491) NO_3-L during the post harvest phases (I) and (II). However, shoot N uptake does not explain the difference in NO_3-L between Toronit and L94491. Toronit yielded as much N in the shoot as L94491 but the NO_3-L of Toronit during the post harvest phases (I) and (II) was higher. Possibly, the root system of Toronit stores more N, which is mineralized during decomposition following the harvest, thus increasing NO_3-L.

Table 2 Results of the ANOVA for spring wheat genotype (G), nitrogen fertilisation (N), and their interaction effects (G x N) on NO_3-L.

Phase	(I) 235 – 270			(II) 277 – 312		
Effect	G	N	G x N	G	N	G x N
Pr > F	0.003	<0.001	0.064	0.454	<0.001	0.028
Genotype	N0	N1	mean	N0	N1	mean
	ppm					
Albis	18 a	46 a	32 a	15 a	51 a	33 b
L94491	13 a	32 b	23 b	23 a	26 b	25 a
Toronit	13 a	43 a	28 a	14 a	42 ab	28 a

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MONITORING NITRATES IN DRINKING WATER WITH A PORTABLE REFLECTOMETER

M. Ângelo Rodrigues, Margarida Arrobas and Nisa Pinto

Escola Superior Agrária, Campus de Sta Apolónia, 5301-855 Bragança, Portugal

Introduction

The maximum admissible concentration (MAC) of nitrate in drinking water is 50 mg/l (EEC, 1991). This limit was established because of the toxicity of nitrate/nitrite to human health, though the discussion about the acceptable daily intake of nitrate persists (Boink and Speijers, 2001).

Bragança is a rural district of the NE Portugal with a significant part of its population dispersed among little villages with 50 to 500 inhabitants. Despite practically the whole territory having a public supply of piped potable water many people prefer to collect the water for drinking from old fountains of local and shallow captation of water, perhaps to avoid the taste of chlorine. Due to the great number and dispersion of those fountains the sanitary authorities have not the means to monitor their water quality. Taking into account that this is a farm region, it is logical to suppose that nitrate could be an important contaminant of water.

In this work results of the nitrate concentration in water, determined with a portable reflectometer, of more than 40 fountains and some rivers, streams and shallow lakes of the region were presented. The objective of the work was also to evaluate the potentialities of the portable tool to determine on site the concentration of nitrate in water.

Material and methods

The concentration of nitrate in water was determined several times during the period June, 2001-March, 2002. The analyses of nitrate in water were performed on site using Reflectoquant® test strips and the portable reflectometer RQflex® (MERCK). When a test strip is immersed into a solution that contains nitrate a red-violet azo dye is formed, the concentration of which is determined reflectometrically. The RQflex measures the amount of light reflected and converts the reflectance into nitrate in solution. After every one of the RQflex-nitrate readings the temperature of the water was also recorded.

The accuracy of the RQflex reflectometer was checked in the laboratory using standard calcium nitrate solutions within the measuring range of the test strips. The sensivity of the test strips to water temperature was also calibrated in the range of 2 to 30 °C.

Results and discussion

The calibration of the RQflex results with standard solutions of $Ca(NO_3)_2$ showed that nitrate concentrations were underestimated by the RQflex (figure 1a). The statistical test of hypothesis H_0: $\beta_1 = 1$ showed that the slope of the strainght line was significantly lower than 1 ($\beta_1 = 0,98$), it being necessary to correct on site measurements. On the other hand, the coefficient of determination associated to the linear model was very high ($r^2 = 0,998$). Calibration of RQflex results was also needed depending on the temperature of the water. The reactivity of test strips had a linear decrease for temperatures of water lower than 20 °C (figure 1b).

The results of the six fountains most polluted with nitrates are presented in figure 2. In the autumn, after the first rainfalls, the concentration of nitrate in water increased slightly, maybe due to the leaching of nitrates from soils which are available after the mineralization of summer crop residues and N-fertilization of winter crops. However, among the 40 fountains monitored, only in one of them did the values of nitrate in water exceed MAC (50 mg NO_3^-/l). The result could be justified by the fact that the points of captation of water were in the upper and sloped lands and therefore in the areas with less intensive agriculture.

The nitrate concentration in water of rivers, streams and shallow lakes was always lower than 5 mg/l NO_3^- (data not shown). The large volumes of water involved (dilution factor), the fact that the agriculture in general is not intensive in the use of fertilizers and the large areas of sloped and uncultivated soils involved could combine to explain the results.

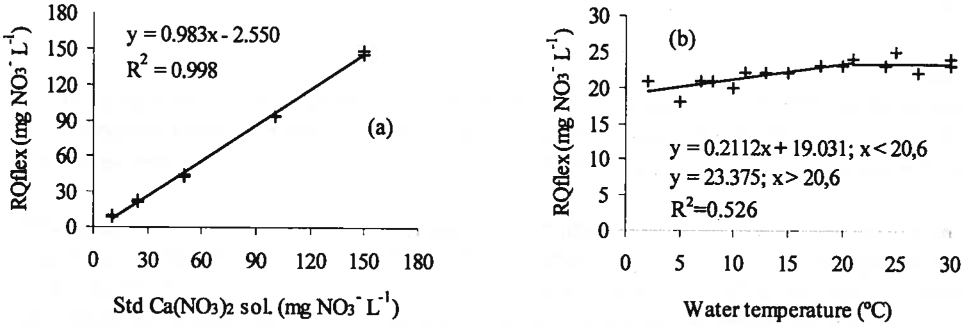

Figure 1 – (a) relation between nitrate concentration in standard $Ca(NO_3)_2$ solutions and RQflex readings; and (b) reactivity of test strips to water temperature.

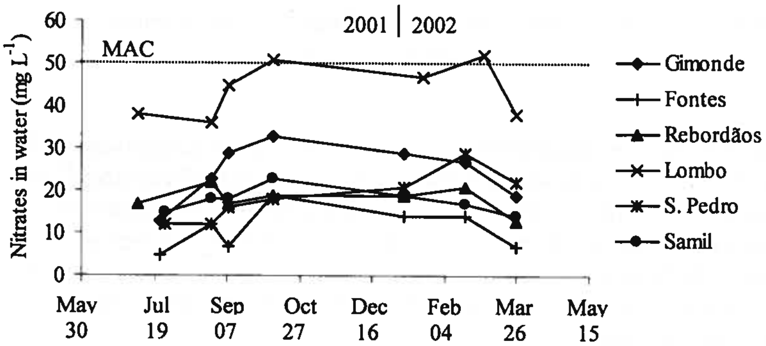

Figure 2 – Water nitrate concentration of the six most contaminated fountains.

Conclusions

The results showed (i) an environmentally-sound region where the water is not yet contaminated with nitrates, and (ii) the usefulness of that portable tool in monitoring the nitrate concentration in water, although previous calibration of its results seems to be necessary.

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RISK OF NITRATE LEACHING FROM THE HORTICULTURAL INDUSTRY OF ALMERIA, SPAIN

R. B. Thompson[1], M. Gallardo[1], and C. Giménez[2]

[1]Dpto. Producción Vegetal, Universidad de Almeria, 04120 La Cañada, Almeria, Spain

[2]Dpto. Agronomía, Universidad de Córdoba, 14080 Córdoba, Spain

Introduction

Approximately 24,000 ha of plastic greenhouses are used for intensive horticultural production in the coastal region of Almeria, in south-eastern Spain. The major crops grown are: tomato, pepper, melon, watermelon, cucumber, aubergine, zucchini, and green beans. Eighty percent of cropping occurs on soils, the other 20% in "open" hydroponic systems. Most of the soil used is an artificial soil system ("enarenado"), in which 20–30 cm of imported loam soil is placed over the indigenous gravely soil, and 8–12 cm of coarse sand mulch is placed over the loam soil. In some cases, the sand mulch is placed over the indigenous soil. Drip irrigation with fertigation is used. Every 2–3 years, manure is commonly applied under the sand mulch before cropping. Underlying aquifers have appreciable concentrations of nitrate (NO_3^-) (Jiménez et. al., 1997), suggesting contamination from the horticultural industry. A study was conducted to assess the risk of NO_3^- leaching loss from this industry, and to identify contributing management practices.

Methods

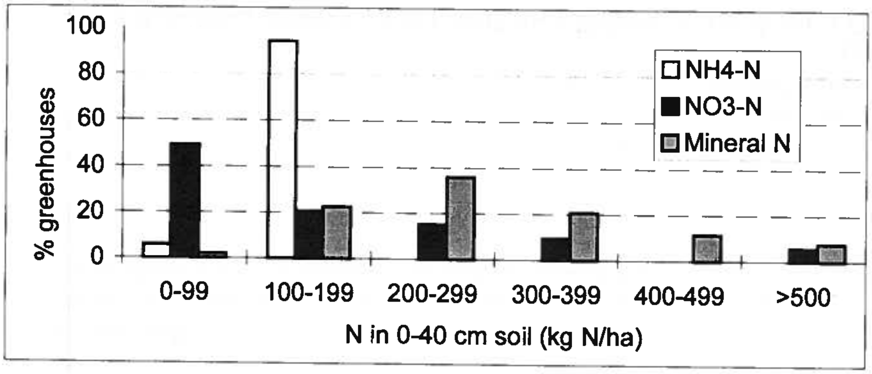
Fifty-three commercial greenhouses were studied. At least 4 greenhouses, were selected, for each of the 9 major vegetable species (see Introduction), and the numbers for each species broadly reflected their distribution within the local industry.

At the end of each crop, the soil was sampled to measure residual NH_4^+-N and NO_3^--N. The sand mulch was cleared, and the soil sampled with an auger. Sampling depth was measured from the surface of the loam soil. 38 greenhouses were sampled to 40 cm depth, and 15 to 60 cm depth. Soil samples were immediately chilled, and were frozen within several hours of collection. Extraction was with 2M KCl at solution to soil ratio of 10:1, analysis was by standard colorimetric methods. Crop N uptake was estimated for each crop. On each farm, four representative plants were sampled for final biomass and N content; farmers provided production data. Data regarding pruning, and fruit N contents were obtained from 1–2 crops per species.

Participating farmers kept a record of irrigations, which were used to estimate total volume of irrigation water. A model developed for greenhouse crops in Almeria (Cajamar, 2001), using solar radiation and temperature data was used to calculate crop water requirements (Fernandez et al., 2000). The applied volumes were compared with the calculated requirements to assess the adequacy of irrigation practices. Participating farmers completed a questionnaire of nutrient and irrigation management practices.

Results

Mean and median values of residual soil mineral N (combined NH_4^+–N and NO_3^-–N), to 40 cm, were 318 and 257 kg N ha^{-1}, respectively (Fig). In 75% of greenhouses, there was >200 kg mineral N ha^{-1}, in 40% >300 kg N ha^{-1}, and in 19% >400 kg N ha^{-1} (Fig). On average, 57% of soil mineral N was in the form of NH_4^+–N. 94% of greenhouses had 100–199 kg NH_4^+–N ha^{-1}. The distribution of residual soil NO_3^-–N was considerably skewed (Fig). Half had <100 kg NO_3^-–N ha^{-1}, and a small number had much larger amounts, *e.g.* 15% had >200 kg NO_3^-–N ha^{-1}, and 6% >500 kg NO_3^-–N ha^{-1}. In 15 greenhouses, the 40–60 cm depth was also sampled, the mean and median amounts of mineral N were 167 and 121 kg N ha^{-1}, respectively; the percentage distributions between NH_4^+–N and NO_3^-–N, and within both NH_4^+–N and NO_3^-–N, were similar to those of the 0–40 cm depth (see Fig). For 8 of the 9 vegetable species examined, mean estimated crop N uptake was <350 kg N ha^{-1}, in 4 of 9 it was <200 kg N ha^{-1}.



The questionnaire data indicated that N fertilizer management was based on experience in 100% of farms (8% farmer, 42% technical advisor, 50% both). Soil testing and foliar analysis were not used by 81 and 100%, respectively, for the particular crop surveyed. Manure applications, within the previous 2 years, were made by 75% of farmers; however, only 26% considered the manure N in their N fertiliser planning. Also, 57% did not consider the N content of irrigation water.

Irrigation management was based on experience for 87% of farmers (15% farmer, 25% advisor, 47% both); the rest combined tensiometers with experience. Irrigations to leach salts were used on 98% of farms (mostly before a crop); volumes exceeded 30 mm on 60% of farms. 57% of farms had disinfected the soil; of which 60% used volumes $\geq$20 mm.

Discussion

Soil mineral N (to 40 cm depth) after cropping was generally appreciable. Commonly, it was equivalent to a large proportion, or more, of crop N requirements. This suggested that, in many greenhouses, during the current or recent crops, that the N supply was appreciably in excess of crop N uptake.

The accumulation of large amounts of mineral N in soil is consistent with the nutrient management practices of a majority of the farmers who did not use soil and plant testing, and did not consider N supplied by recent manure applications and irrigation water.

The comparison of total applied volumes of irrigation water to calculated crop water requirements suggested one third of farms applied considerably too much irrigation water, which would contribute to drainage. Even on the two thirds of farms where irrigation during the crop was not appreciably excessive, the large additional water applications for salinity management and disinfections are a consideration when assessing the drainage of mobile nutrients.

Combining the 0–40 cm and more limited 40–60 cm data, suggested that the mean and median mineral N contents for 0–60 cm were 485 and 378 kg N ha^{-1}; more would be at depths >60 cm. Although, an average of approx. 60% of mineral N was in the immobile form of NH_4^+–N, this would be at risk of leaching after nitrification, where appreciable drainage occurred.

This study demonstrated an appreciable risk of NO_3^- leaching in this horticultural industry, which is consistent with reported NO_3^- contamination of underlying aquifers (Jiménez et. al., 1997). There is considerable scope for improving N and irrigation management practices.

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FFECTIVENESS OF BUFFER STRIPS IN REMOVING SEDIMENT, NITROGEN ND PHOSPHORUS FROM CROPLAND RUNOFF

ianello M.[1], Morari F.[1], Zanin G.[2], Borin M.[1]

Dipartimento di Agronomia Ambientale e Produzioni Vegetali, Università di Padova, Agripolis, Via Romea 16, 35020 Legnaro (Pd) (Italy)
Centro di Studio sulla Biologia ed il Controllo delle Piante Infestanti-CeBI-CNR, Agripolis, Via Romea 16, 35020 Legnaro (Pd) (Italy)

ntroduction

uffer strips are an efficient and economical system for reducing nonpoint source pollution from cultivated agricultural source. Several studies have been conducted to investigate buffer strip ffectiveness in removing sediment, nutrients and pesticides from the runoff (Daniels et al., 996; Cole et al., 1997). Buffer strips can be very effective, depending on factors such as runoff olume, nature and length of the strip, and pollutant source area characteristics (Chaubey et al., 995). Buffer vegetation, especially grass, slows down surface runoff speed and filters sediment nd sediment-bound pollutants. At the same time vegetation increases water and soluble ollutants infiltration into the soil (Lee et al., 2000).

o evaluate the effectiveness of different types of narrow buffer strips in removing sediment, itrogen, phosphorus and herbicides from cropland runoff, a study has been conducted since 998 at the Experimental Farm of Padova University (Italy). This paper presents the results, in erms of mass retention, from 1998 to 2001, concerning two extreme situations: absence of uffer and 6 m wide buffer strip.

Methods

The study site is on the Experimental Farm of Padova University (45°12' N, 11°58' E, altitude 6 m) in the north-eastern Italy. This is located on a flat plain, with mean annual rainfall of 830 mm. The experimental site is composed of a field with different types of narrow buffer strips between the cropland and the stream. We investigated the effectiveness of a 6 m grass and double tree row filter, compared with no buffer strip. The grass was *Festuca arundinacea* L., the trees were *Viburnum opulus* L. and *Platanus hybrida* Brot. Each treatment had two replicates.

To measure runoff volumes and collect water samples for the laboratory analyses, collector systems with multi-pipe divisors were designed and built (Morari et al., 2001). Water volume was measured and samples collected for analysis after every runoff event.

All runoff samples were analysed for total suspended sediment, total nitrogen, NO_3-N, NH_4-N, PO_4-P and total phosphorus. The runoff amount and sediment and nutrients concentration data were used to compute the mass transport of each constituent at the end of the buffer strip and of the cropland.

The field was cropped with winter wheat (1998), maize (1999), maize (2000), winter wheat and soyabean (2001), following standard agronomic practices.

The Mann-Whitney U Test was used to determine the statistical significance of the buffer strip effect.

Results

From 1998 to 2001 average annual rainfall was 716 mm: the wettest year was 1999, with 825 mm of total rainfall, the driest 2001 with 673 mm. A total of 69 runoff events occurred, determining 231 mm of runoff without the buffer strip and 52 mm with the buffer (fig.1). Runoff load reduction was 78% ($p<0.01$).

Buffer strips had a significant effect ($p<0.01$) on the mass transport of sediment and all the investigated nutrients. Mass losses, with and without the buffer, were 0.4 and 6.9 t ha^{-1}

respectively for the sediment (94% reduction), 2.9 and 13.4 kg ha^{-1} for total N (78% reduction), 1.3 and 3.1 kg ha^{-1} for NO_3-N (59% reduction), 0.3 and 0.8 kg ha^{-1} for NH_4-N (56% reduction), 0.6 and 3.2 kg ha^{-1} for total P (80% reduction), and 0.1 and 0.6 kg ha^{-1} for PO_4-P (76% reduction) (figs. 2, 3, 4).

The highest runoff events and nutrient losses were concentrated in three periods which corresponded to the highest rainfall values: from 1/10/98 to 26/10/98 (171 mm of rain), from 20/5/99 to 22/6/99 (163 mm), and from 20/10/99 to 28/12/99 (297 mm).

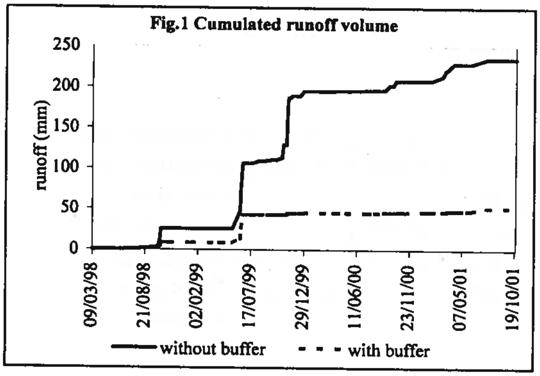

Fig.1 Cumulated runoff volume

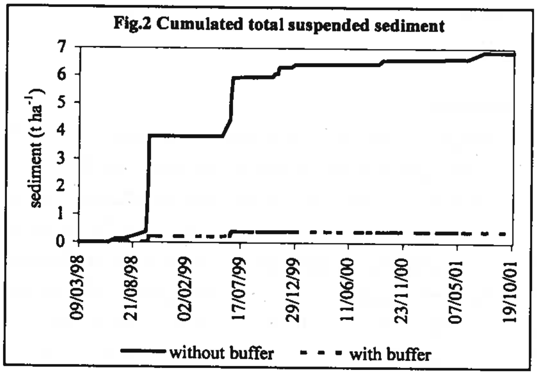

Fig.2 Cumulated total suspended sediment

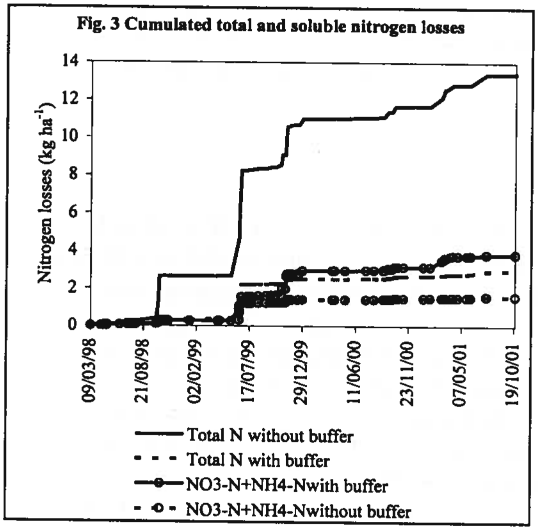

Fig. 3 Cumulated total and soluble nitrogen losses

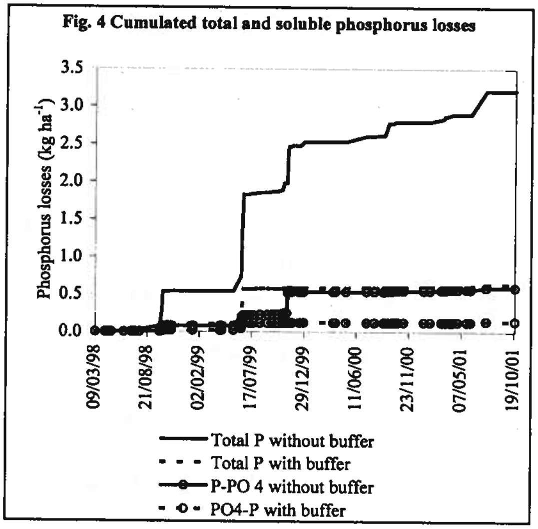

Fig. 4 Cumulated total and soluble phosphorus losses

Conclusions

During the monitored period, runoff volumes and nutrient losses were quite low, nevertheless the 6 m wide buffer strip significantly removed sediment, total nitrogen, NO_3-N, NH_4-N, PO_4-P and total phosphorus. Most nutrient losses were concentrated in a few events occurring during the wettest periods. The buffer strip was particularly effective in removing sediment and sediment-bound pollutants: infiltration and trapping/adsorption appear to be the mechanisms most responsible for mass pollutant removal.

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'ORTUGUESE AGRICULTURE AND CLIMATE CHANGE

'**edro Aguiar Pinto** (*Associate Professor, Secççăo de Agricultura, Instituto Superior de*
lgronomia, UTL, Tapada da Ajuda, 1349-017, Lisboa, +351.21.3653182, papinto@isa.utl.pt)
\na Paiva Brandão (*Phd student, Secççăo de Agricultura, Instituto Superior de Agronomia,*
JTL, Tapada da Ajuda, 1349-017, Lisboa, +351.21.3653182 anapb@isa.utl.pt)

ntroduction

Veather and climate affect agriculture in many ways, from the biological productivity of .gricultural crops, the possibility of execution of agricultural operations, the incidence of pests nd diseases to the geographical distribution of crops in a region or country. Present crop listribution is conditioned by climate, availability of irrigation water and soil type, while social nd economical influences strongly determine what crops to grow, when the other requirements ire adequately met. Therefore, although it is expected that the foreseeable climate changes will iave important effects on agriculture, it is impossible to predict clear patterns of change in arable and use. As a result, this work focuses on the estimation of the effect of climate change on the iological performance of selected crops.

The study of impacts in natural and social systems and their vulnerability is essential in view of he effects of potential climate change. The SIAM project (Climate Change in Portugal: Scenarios, Impacts and Adaptation Measures) aims to foresee climate change impacts using :stimated climate scenarios, in order to propose adequate adaptation measures. The Agriculture Section at the Institute of Agronomy is responsible for the Agriculture component in this nultidisciplinary project (http://www.siam.fc.ul.pt/).

Methods

Assessment approach

The assessment of impacts of climate change on agricultural crops was based primarily on the ıse of crop simulation models of the series DSSAT (Decision Support Systems for Agrotechnology Transfer) (Jones *et al.*,1998). Since these models are not of common use in Portugal it was necessary to calibrate them with available historical crop and weather data and expert judgement which has been done successfully for the models CERES-WHEAT and CERES-MAIZE. Expert judgement on calibration was necessary due to the deficient statistical information and irregular matching of aggregated crop data with historical weather records. Wheat and maize are the two most important field crops occupying 7% and 4% of an overall arable area of 3.8 x 10^6 ha.

The CERES WHEAT model was validated for the region of Alentejo with historical crop data of the Direcção Regional do Alentejo where wheat is grown in an average of 203348±36522 ha (in the period 1986-1998). The CERES MAIZE model was validated for the region of Ribatejo with historical data of the Direcção Regional do Ribatejo e Oeste where maize is grown in an average of 29275±5246 ha (in the same period; maize area in 1998 was 42500 ha).

Two sets of climate data were used: the baseline data set, simulating daily weather data from present conditions and a data set simulated by the HadRM3 model for the period spanning from 2080 to 2099 (Jones *et al.*, 1995 and Jones *et al.*, 1997).

Results

Wheat

The CERES WHEAT model was run for the baseline and for the period from 2080-2099 for a location situated at 38° 16' N and 7° 52' W (near Beja). There was a yield decrease of 25% (from a present simulated yield average of 2780 kg.ha^{-1} and an increase in yield variability (from a coefficient of variation of 46% to 86%), mainly due to increased water stress, in spite of a shorter crop cycle. However, a simple anticipation of two weeks in planting date (from November 1 to

October 15), made possible by the absence of frosts during flowering, increases average yield by 34%. The effect of an increased atmospheric CO_2 concentration is responsible for most part of the yield increase. In fact, without the CO_2 increase, there is only a yield increase of 2%.

Maize

The CERES MAIZE model was run for the baseline and for the period 2080-2099 for a location situated at 39° 17' N and 8° 41' W (near Santarém). There was a yield increase of 12% (from a present simulated yield average of 12 Mg/ha) using a variety that allowed the same crop duration. It was also possible to anticipate the planting date from April 1 to March 15 due to more favourable germination temperatures in the future scenario. The increase in atmospheric CO_2 concentration is partially responsible for this yield increase, but its effect is smaller than that simulated in the wheat crop, which is to be expected in a C_4 plant. The coefficients of variation are much smaller than in the case of wheat in both simulations (from 10 to 20%) since an irrigated crop is less influenced by climate variability.

The model also simulates irrigation water used (supplied in order to completely satisfy crop ET) and it predicts an increase of 37% in water use. Yet, the model is not prepared to deal with the increased water use efficiency that is verified in CO_2 enriched environments, so this should be an overestimation.

Other crops

The absence of operational crop simulation models for other relevant crops in Portugal (such as the perennial crops - vineyard and olive trees -) makes it difficult to make quantitative estimations of impacts on productivity. However, it is foreseeable that from the point of view of plant protection, the future scenario will be beneficial since higher temperatures and lower humidity will decrease the incidence of diseases. Additionally, the sugar and oil content of the fruits of these crops will tend to increase. Lower rainfall in Spring and Summer will increase water stress, but this might be partially compensated for by the faster developmental rate that will have a certain effect of stress avoidance.

The substantial increase in growing season length will allow the growth of several horticultural crops that are currently limited to the frost free areas near the Atlantic or in the Algarve. Yet, the large variety of possibilities of fruits and vegetables precludes any reasonable estimation of their impact.

Conclusions

The main adaptation measures to counteract the negative effects of climate change will lay on changes in planting and harvesting dates, adequate varieties for a warmer and drier climate (shorter or longer season length depending on the strategy of stress avoidance or stress elimination, adapted to higher temperatures, water stress resistant) and adaptation of cultural practices to a drier climate.

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ASSESSMENT OF THE EFFECTS OF CLIMATE CHANGE AND ELEVATED CO_2: A CASE STUDY IN NORTHERN ITALY

Bellocchi G., Maestrini C., Fila G., Fontana F.
Research Institute for Industrial Crops, via di Corticella 133 – 40128 Bologna (Italy)

Introduction

The regional assessment of the impact of climate change and atmospheric CO_2 enrichment on agricultural productivity and the environment is an important application of cropping system models. Global circulation models (GCMs) are currently used to provide climate change scenarios. Such scenarios vary according to different GCMs, and different climate estimates are produced as advancements are made in GCM development. Hence, an update in the study of the effects of climate change is needed. The potential effects of climate change, due to an increase of atmospheric CO_2 concentration, were investigated on crop biomass production of a typical cropping system implemented in Northern Italy.

Methods

Long term weather records at Budrio (province of Bologna, Italy) (lat.: 44.53 North, long.: 11.48 East, elev.: 29 m a.s.l.) were used to generate current and future climate datasets (50 years), by using the ClimGen stochastic generator (Stöckle et al., 2001). The changes in climate conditions were introduced using two different climate scenarios with sulfate aerosols effects (Table 1). Specifically, the output of two GCMs - United Kingdom Hadley Centre HCGS (Johns et al., 1997) and Canadian Centre for Climate Modelling and Analysis CCGS (Flato et al., 1997) - was used as weather input for a cropping system simulator, CropSyst (Stöckle et al., 2002). The atmospheric CO_2 concentration was set to 350 ppmv for the current climate, and to 450 ppmv and 660 ppmv for future scenarios. A typical crop rotation was simulated at the site: sugarbeet-winter wheat-potato-winter wheat. Irrigation was simulated for sugarbeet and potato, using CropSyst automatic irrigation mode to mimic irrigation schedule commonly adopted in the area. Nitrogen simulation was switched off, thus the crops are meant as being conducted under potential nitrogen conditions. An experiment was started in 1999 with the cropping system of interest on a shallow loamy-silty soil at Budrio. Crop and soil data collected in the period 1999-2001 were used to calibrate CropSyst. The main effects due to weather scenarios on above ground biomass at maturity (mean and coefficient of variability) were evaluated.

Table 1. Mean annual values of rain, maximum and minimum temperature and solar radiation for current and future climate scenarios at Budrio (Italy).

meteo variable	current	HCGS		CCGS	
		450 ppmv	660 ppmv	450 ppmv	660 ppmv
Rain (mm)	661	725	670	703	624
Tmax (°C)	20.1	20.8	23.3	21.1	22.6
Tmin (°C)	8.1	9.2	11.7	9.5	11.1
Rad ($MJ\ m^{-2}\ d^{-1}$)	12.1	12.0	12.2	12.2	12.3

Results

The simulated values of above ground biomass for current and future climate conditions are reported (Table 2). Little increase in biomass production was observed, mostly due to the increase of temperature and the increased photosynthetic efficiency at higher than current atmospheric CO_2. Therefore, the general shortening of the growing season (Table 3) was compensated by a better avoidance of the summer water stress. The evaporative demand did not increase under global warming, thus a larger supply of water was not required for irrigated crops as a consequence of the climate change (Table 4).

Table 2. Mean simulated above ground biomass (avg, t ha^{-1}), and coefficient of variation (CV, %) with different climate scenarios.

Crop	current		HCGS				CCGS			
			450 ppmv		660 ppmv		450 ppmv		660 ppmv	
	avg	CV	avg	CV	avg	CV	avg	CV	avg	CV
Rainfed										
Sugarbeet	11.5	13.2	12.3	13.0	12.2	13.2	11.8	14.2	12.7	12.7
winter wheat	14.1	7.5	14.5	9.2	12.9	15.4	14.5	9.4	14.6	12.6
Potato	4.2	22.0	4.2	20.5	4.3	14.5	4.2	20.3	4.6	14.5
irrigated sugarbeet and potato										
Sugarbeet	13.5	7.7	13.8	7.6	14.9	7.3	14.2	7.5	15.2	7.3
winter wheat	14.1	7.7	14.5	9.2	12.9	15.4	14.5	9.4	14.6	12.6
Potato	4.5	23.1	4.5	22.2	4.9	18.4	4.7	22.3	5.1	18.5

Table 3. Mean simulated maturity date (calendar day, and CV, %) with different climate scenarios.

Crop	current		HCGS				CCGS			
			450 ppmv		660 ppmv		450 ppmv		660 ppmv	
	avg	CV	avg	CV	avg	CV	avg	CV	avg	CV
Sugarbeet	224	1.9	219	1.9	212	1.8	221	1.8	213	1.8
winter wheat	161	3.9	151	4.2	129	5.2	154	11.3	137	4.7
Potato	180	3.5	172	4.5	164	2.7	175	3.4	166	2.8

Table 4. Mean simulated irrigation (avg, mm), and coefficient of variation (CV, %) for sugarbeet and potato with different climate scenarios.

Crop	current		HCGS				CCGS			
			450 ppmv		660 ppmv		450 ppmv		660 ppmv	
	avg	CV	avg	CV	avg	CV	avg	CV	Avg	CV
Sugarbeet	246	25.8	219	29.6	251	25.4	254	25.5	238	26.2
Potato	118	33.5	106	32.8	134	27.0	129	26.6	124	26.3

Conclusions

Spring sown crops (i.e., sugarbeet and potato) responded better than autumn sown crop (wheat) to climate change from two GCMs. However, the preliminary results from this study indicated that crop biomass production in Northern Italy may not be greatly affected by future climate change, characterized by increased temperature. In particular, no additional irrigation was needed to maintain current levels of biomass production. The effect on crop biomass production was positive with both GCMs at 450 ppmv, whereas the response was different according to the GCM used. The sensitivity of simulation outputs to GCM estimates confirmed that cropping systems simulation is, at this stage, still related to GCMs evolution.

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'REE AIR CO_2 ENRICHMENT (FACE) OF POTATO (*SOLANUM TUBEROSUM* L.): I.)EVELOPMENT AND TESTING OF THE SYSTEM FOR CO_2 ENRICHMENT

/I. Bindi [1], L. Fibbi [2]

DISAT - University of Florence, P.le delle Cascine 18, 50144 - Florence, Italy.
CeSIA - Accademia dei Georgofili, Logge Uffizi Corti, 50122 - Florence, Italy.

ntroduction

;everal types of plant exposure systems have been developed to investigate the impacts of teadily rising levels of global atmospheric CO_2 concentrations (leaf chambers, greenhouses, ›pen top chambers, etc.). The investigators recognised, however, that plant exposure systems nay interfere on above and below-ground growth of plants. Thus, the need for adequate rooting 'olume and for avoiding "chamber effects" led to the development of Free Air CO_2 Enrichment FACE) facilities for studying the effects of future levels of CO_2 under natural field conditions. 'echnologically updated FACE systems have been recently tested by the Brookhaven National ,aboratory (BNL) FACE systems for CO_2 enrichment of field plots ranging from 18 to 30 m of liameter. Then, following the same system concept or different concepts many other FACE ,ystems were developed.

This paper describes the FACE system developed to investigate the effects of elevated CO_2 on ›otato cv. Bintje within the CHIP (Changing Climate and Potential Impacts on Potato Yield and Quality) project and provides relevant information to evaluate its performances in terms of ;patial and temporal CO_2 control.

Methods

The FACE system consisted of 3 circular emission arrays, carbon dioxide supply components, CO_2 concentration monitoring components and a PC-based control program (Fig. 1).

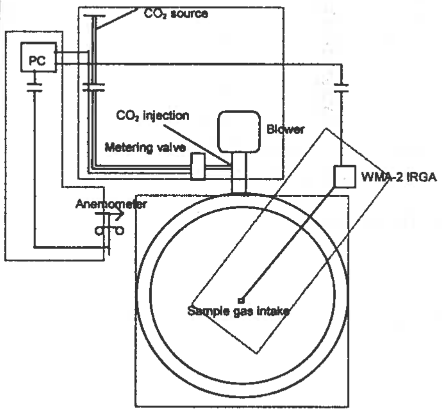

Figure 1 - Sketch diagram showing the assemblage of the different FACE components.

The 3 circular emission arrays were made in polyethylene with an internal diameter of 20, each array had more than 250 jet gas emission holes (1 cm). The array heights were raised to keep in face with the vegetation growth using extensible poles. High volume blowers injected air into the plenums. Pure carbon dioxide was mixed with ambient air by placing the outlets immediately after the blowers at the level of flexible pipes which connected the blowers to the plenums. CO_2 injection rate was controlled by a modulating control valves located next to the blowers. CO_2 concentrations in the center of the FACE arrays were read by infra-red gas analysers. Membrane pumps located at the center of the FACE arrays at an height of 5 cm above the top of plant canopy were used to sample and pump air through 5 meters of polyethylene tubes of 4 mm internal diameter, into the gas analysers. The control of valves opening to regulate the amount of CO_2 that was metered into the plenums was made using the same Proportional Integral Differential (PID) algorithm described by Lewin et al. (1994). This algorithm made use of both mass horizontal flow based on wind velocity and a PID component based on CO_2 concentrations read in the center of the arrays to calculate output voltage used to control the metering valves. Wind velocity was a direct mass-horizontal-transport component of the algorithm, and the PID adjusted the deviations to achieve a closer fit to the CO_2 set points. The FACE system adopted for the field experiment used geologic CO_2 as gas source.

Results

The reliability of subsystems and components showed that all the plots operated for greater than 88% of the potential exposure period. The maintenance of temporal and spatial control of the CO_2 concentration within the experimental plots was evaluated by continuously recording 1 minute average values of wind velocity and direction, CO_2 injection rates and CO_2 concentration measured in the arrays; and making detailed measurements of horizontal concentration gradients during the growing season. Over the course of the season the CO_2 concentration in enriched plots was between 550 and 554 ppmv depending on the plot, with coefficients of variability (CV) ranging between 10% and 13%. Whilst, in monitored control plot the mean seasonally CO_2 concentration was 365 ppmv with a 8% CV. The FACE system maintains the CO_2 concentration very close to the set point also when short time periods (1min. average) were considered (Tab. 1). System performances varied with wind speed (Fig. 2). Control was lower under calm and low wind speeds, than for the other wind speed categories. Whilst, during the day, control was worse in the early morning and afternoon hours (Fig. 2) due to the increase in vertical turbulence induced by solar energy during the daytime.

Table 1 - % time that average CO_2 concentrations deviated from the set point for 1 min. averages.

	1 minute Average		
Ring	<10%	<20%	<30%
F1	81.364	96.190	98.404
F2	81.211	95.906	98.099
F3	81.737	96.000	97.893

Data on the gas horizontal gradients within the FACE, showed that the spatial distribution of CO_2 concentration is function of distance from the center of the ring (Fig. 3).

Conclusions

Spatial and temporal uniformity of CO_2 concentrations were adequate both for long and short time periods. Thus, this FACE facility can provide a useful and reliable research tool for studying the effects of elevated atmospheric carbon dioxide levels on plant growth in an open-field setting.

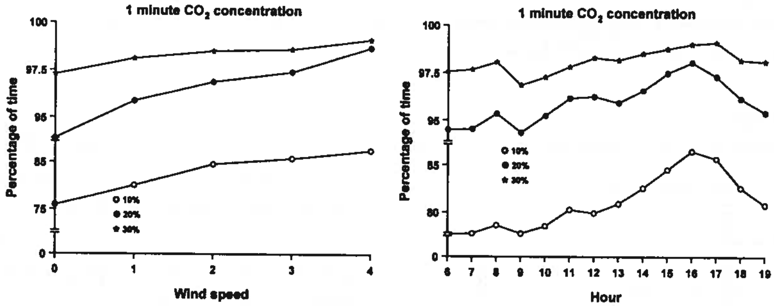

Figure 2 - Percentage of time that average CO_2 concentrations deviated from the set point for 1 minute averages versus wind speed and hour of day.

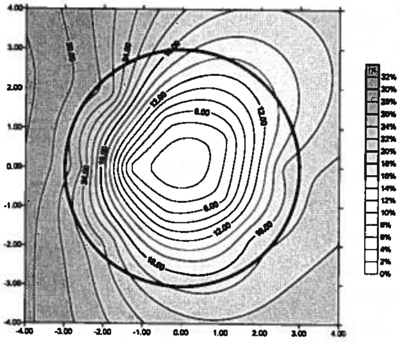

Figure 3 - Spatial distribution of CO_2 within FACE sampling areas expressed as mean percentage differences from the set point (550 ppmv)

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'REE AIR CO_2 ENRICHMENT (FACE) OF POTATO (*SOLANUM TUBEROSUM* L.): II.)EVELOPMENT AND GROWTH OF POTATO IN RESPONSE TO ELEVATED CO_2 :ONCENTRATIONS

/I. Bindi [1], L. Fibbi [2], M. Chiesi [2], V. Magliulo [3]

DISAT - University of Florence, P.le delle Cascine 18, 50144 - Florence, Italy.
CeSIA - Accademia dei Georgofili, Logge Uffizi Corti, 50122 - Florence, Italy.
ISPAIM, Consiglio Nazionale delle Ricerche, Via Patacca, 42 80000 Ercolano, Napoli, Italy.

ntroduction

'ositive effects of elevated CO_2 on growth and yield of plants were already observed more than . century ago and since then hundreds of experiments made in the laboratory, controlled and ield conditions have shown that crop yields are enhanced by elevated CO_2. On the other hand, ncreases in yield achievable under elevated CO_2 were shown to be very much species-lependent. Potato (*Solanum tuberosum* L.) features very large sink organs for carbohydrates and ises an apoplastic mechanism for phloem loading based on a sucrose transporter. These are mportant pre-requisites for a large CO_2 response. In fact, substantial stimulation of tuber yield ias been observed in a number of CO_2 enrichment experiments (Wheeler et al., 1994; Miglietta :t al., 1998).

This paper, together with a companion paper (Bindi et al., 2002c), describes the results of the 999 FACE experimental campaign carried out to collect information on the impact of elevated :O_2 concentrations (550 ppmv) on potato development and growth, and on physical and :hemical quality of tuber yield.

/lethods

The FACE experiment was carried out at the field station of Rapolano Terme, Italy (43°17' N, 11°39' E). Six FACE rings were installed immediately after planting and fumigation started at :rop emergence. Three rings were kept at 550 ppmv and other three were at ambient CO_2 :oncentrations. Square plots having the same areas as the ringed plots, were also used as non-:inged controls. Distances between the plots ranged from 30 to 40 m, which was considered sufficient to avoid unintended CO_2 enrichment of the controls (Fig .1).

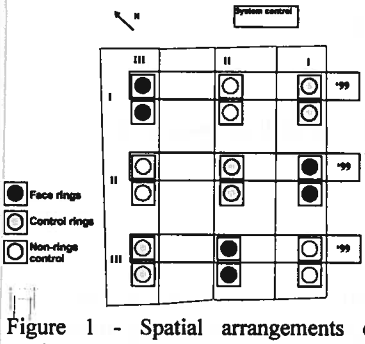

Figure 1 - Spatial arrangements of FACE and control plots in the experimental design at Rapolano field station.

Tubers of cv. Bintje were directly sown in 9 square plots with a planting density of 5.7 plants per m^2 and planting depth of 0.10 m. In the rest of the field, ray-grass was sown to reduce weed problems and to maintain an almost uniform spatial distribution of CO_2 within the rings. The height of ray-grass was constantly controlled and regulated. Irrigation was provided to the crop throughout the growing season with complete restitution after the cumulative pan evaporation had attained a threshold level of 15 mm. Cultural practices included weed, pest and disease control treatments. All the crop measurements were made on plants located in the "sweet spot" in which CO_2 concentration were minimally affected by wind speed and direction (28.3 m^{-2}). Plant development was monitored at weekly intervals on ten plants measuring non-destructively the leaves number, plant height and LAI. Plant growth was monitored on 5 dates collecting data from 5 plants of fresh and dry weights of leaf, stem and tuber, green and yellow leaf number and their area, and number of tubers. As no ring effect was detected the ringed and non-ringed controls were used together for testing the significance of CO_2 effect as a factor.

Results

Development

The number of leaves per plant was also not affected by the treatment (Fig. 2A). Similarly, leaf area index only evidenced minor variations among the treatments although some differences were detectable in the late part of the growing cycle (Fig. 2A). However, significant differences between the enriched and ambient plots were observed in plant height (Fig. 2A).

Growth

The increase in the number of tubers was particularly high at the first two sampling dates and then it remained still apparent showing a 32% positive CO_2 effect in the last sampling date (Fig. 2B). The dry mass of tubers showed that plants under elevated CO_2 accumulated tuber biomass at a higher rate than those in ambient CO_2. Thus, at the last sampling, tuber dry mass was 48% greater under elevated CO_2 (Fig. 2B). Aboveground components were affected by CO_2 especially at the end of the growing season when the sampled plants exhibited a greater and earlier reduction of stem and green leaf dry mass under elevated CO_2 (Fig. 2B).

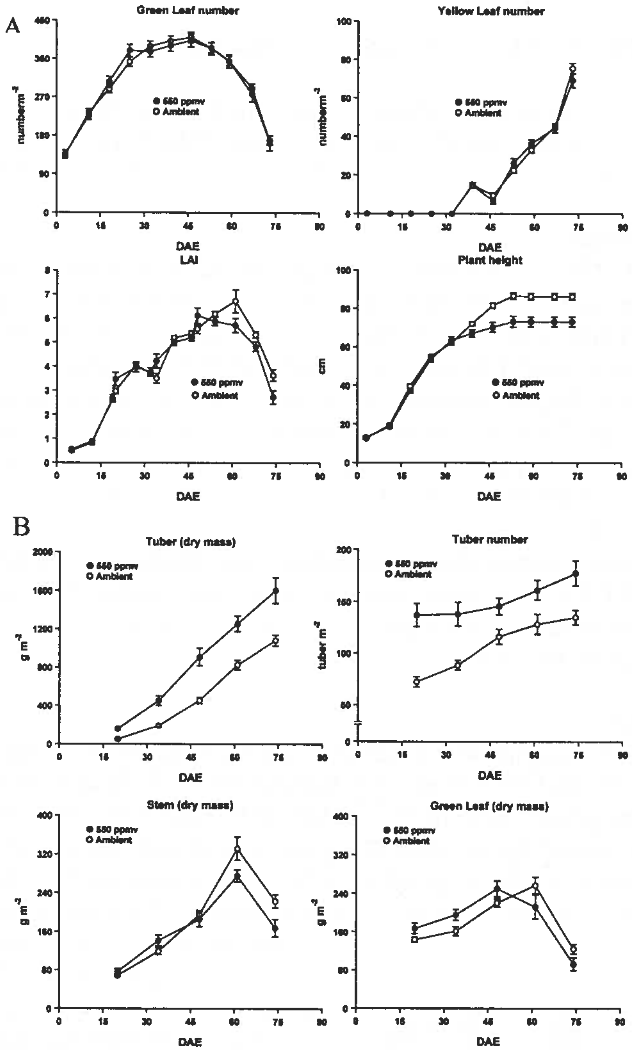

Figure 2 – Mean and standard error of the main development (A) and growth (B) parameters during growing season. DAE: day after emergence

Conclusions

Tuber growth was strongly affected by increasing levels of CO_2. Both the number and dry mass of tubers were stimulated in FACE plots, and highly significant differences between ambient and 550 ppmv CO_2 plots were found. On above-ground biomass components a negative CO_2 effect was evident, in agreement with that observed in development parameters, at the end of the growing season, allowing to assume a faster plant senescence under elevated CO_2 levels.

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FREE AIR CO_2 ENRICHMENT (FACE) OF POTATO (*SOLANUM TUBEROSUM* L.): III. YIELD AND QUALITY OF POTATO IN RESPONSE TO ELEVATED CO_2 CONCENTRATIONS

M. Bindi [1], L. Fibbi [2], M. Chiesi [2], V. Magliulo [3]

[1] DISAT - University of Florence, P.le delle Cascine 18, 50144 - Florence, Italy.
[2] CeSIA - Accademia dei Georgofili, Logge Uffizi Corti, 50122 - Florence, Italy.
[3] ISPAIM, Consiglio Nazionale delle Ricerche, Via Patacca, 42 80000 Ercolano, Napoli, Italy.

Introduction

With its high nutritive value and ability to grow in various climates, potato is one of the highest consumption vegetables in the world. Potato is used on a large scale in industry, where the most important products are potato starch, fries and chips and alcohol. Both physical (e.g. tuber size, green and malformed tubers, underwater weight) and chemical (e.g. starch, sugars and organic acids) characteristics of potato tubers have a relevant role in determining its commercial and nutritive values. All these quality aspects are cultivar linked and depend largely on growing conditions. As atmospheric CO_2 increases and climate change not only growth, but also the quality of the potato could be affected. Literature on this aspect is scant, thus this paper aimed to describe, using the data of the 1999 FACE experimental campaign, the impact of elevated CO_2 concentrations (550 ppmv) on the potato yield and the main physical and chemical potato quality parameters.

Methods

The FACE experiment was carried out at the field station of Rapolano Terme, Italy (43°17' N, 11°39' E) (detailed information on the experiment are reported in the companion paper Bindi et al., 2002b). All the crop measurements were made on plants located in the "sweet spot" in which CO_2 concentration were minimally affected by wind speed and direction (28.3 m^{-2}). The final harvest was made on 48 plants per plots located in sweet-plots. The harvesting procedure consisted of removing 3 plants from 72 cm section of rows in locations randomly selected within the sampling areas. Specifically, on 18 August the aboveground biomass was removed and the fresh weight of leaves and stems was determined; a week after (25 August) the tubers were removed and weighted. In both cases dry weight of leaves, stems and tubers were determined on sub-samples randomly chosen. Moreover, of the tuber harvested, malformations, occurrence of common scab, glassy and green tubers, specific gravity were determined to evaluate physical quality of tubers. Finally, 18 lyophilised samples (2 samples per plot) were prepared to determine chemical quality of tubers (nitrate, Kjeldahl nitrogen, starch, sugar and organic acids, glycoalkaloids).

Results

Final Harvest

Significant variations in tuber number and dry matter between the treatments were noticed at final harvest time (Fig. 1). Moreover, also the final aboveground biomass was affected by CO_2 (Fig. 1) showing lower dry mass for both the components (stem and leaf).

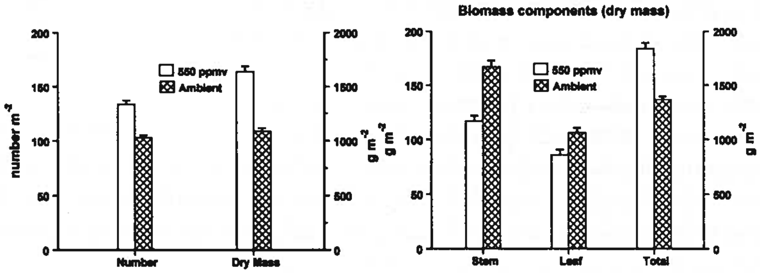

Figure 1 - Means and standard error of number and dry mass of tubers and biomass components at harvest date

Quality analyses

Physical quality. The physical quality analyses showed clearly that the effect of CO_2 on tuber production was mainly due to the higher production of tubers in commercial classes (>35 mm and >50 mm) (Fig. 2). Whilst, the number of lowest tubers (<35 mm) as well as their dry weights were less affected. With the exception of the glassy tubers, none of the other parameters measured were significantly affected by CO_2 (Fig. 2). The data of the dry matter content showed that the tubers of both treatments reached values of UWW higher than 360 (minimum score for normal tuber quality) and that under elevated CO_2 the UWW was over the bonus limit (UUW > 400) (Fig. 2).

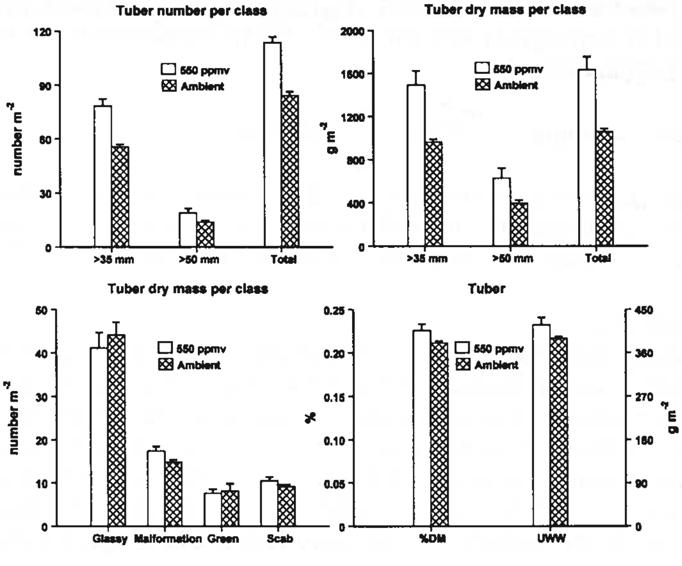

Figure 2 - Means and standard error of physical quality tuber

Chemical quality. The chemical quality analyses for the tubers showed that the effect of CO_2 on tuber production was statistically significant for several parameters (e.g. citric acid, starch and nitrate). Moreover, with the exception of starch content, elevated CO_2 caused reductions in all the parameters (higher than the 30% for nitrate) (Fig. 3).

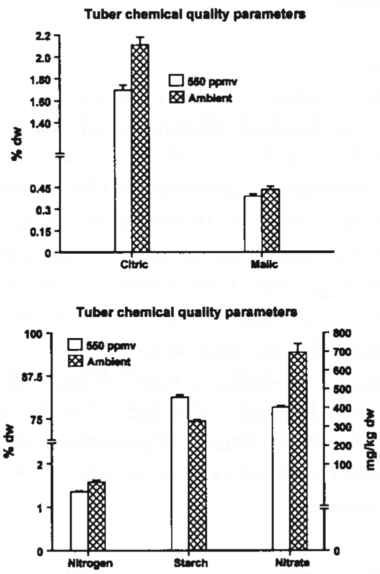

Figure 3 - Means and standard error of chemical quality tuber parameters

Conclusions

Data from this experiment showed that rising atmospheric levels of CO_2 have a large positive effect on tuber yield (43%) and on the number of tubers per plant (35%). These results are in agreement with observations reported by Miglietta et al., 1998. Our study also showed that yield enhancement in potato under elevated CO_2 was at the most due to an increase in the number of tubers per plant, especially in >35 mm classes. Moreover, the data collected for evaluating physical and chemical quality of tubers showed that the former was in general positively affected by elevated CO_2; whereas the response of the latter didn't allow any consistent forecast in terms of chemical quality, except causing substantial reduction in citric acid and nitrate and the increase in starch content.

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AGROCLIMATIC FACTORS WHICH INFLUENCE THE YIELDS IN POLAND

Michalska Bozena
Department of Agrometeorology, Agricultural University in Szczecin, Papieza PawlaVI, 3 71-434 Szczecin, Poland

Introduction

Of the four main yield-creating factors, which are soil, agrotechnique, climate and biological progress, meteorological conditions display the greatest variability in time and space. Thus their impact on plant growth and development as well as on yield and its variability is significant. These factors also highlight the main processes of energy and water flow in agricultural production (Kozmizski 2001). For the first time the agroclimatic conditions in Poland in the secod half of the 20th century were worked out, and their comparison with data from earlier studies enables to assess climate changes in Poland.

Methods

The energy, temperature, humidity factors presented in the Atlas of Climatic Risk of Plant Cultivation in Poland – Part 2, were worked out by several authors. Data had been gathered from 50 meteorological stations of the Institute of Meteorology and Water Management, concerning solar radiation, insolation, air and soil temperature, air humidity, precipitation and evaporation, for the main period of 1961-1995, and for the evaluation of climate changes – from 1701 to 2000. Energy, heat and moisture resources were presented as maps and diagrams for monthly and longer periods.

Results

The average annual energy resources, expressed by total radiation, range in Poland from 3400 MJ m^{-2} to 3900 MJ m^{-2}. The highest values of radiation occur in the eastern part of Wielkopolska Lowland and along the coast, while the lowest radiation energy is noticed in the southern and western part of the country. Compared to the earlier studies (Atlas... 1978), one can see an increase of radiation intensity in the northern part of Pomerania, particularly in the Baltic coastal region. In that part of Poland, from May to July the highest amounts of radiation were noticed. The total hours with sun amount on the average from 1400 to 1700 per year, and the best insolation occurs in mideastern Poland. Comparing the data of earlier studies (Atlas... 1978) it can be seen that this parameter of the climate increased by ca 120 hours in industrial areas, such as Górnylsk, and also in northern Pomerania and central Poland. At the same time June is by 10 to 30 hours less insolated, as compared with May and July.
Another climatic factor which determines the energy resources is the air temperature. The year-average (except mountains) oscillates from 6°C to 9°C. An increase of temperature by ca 0.5°C can be seen in western Poland, and a shift of the lowest temperatures (7°C and 6.5°C) toward the north-east, as compared to 1881-1930. January has become warmer by 0.5°C in the west, and by ca 1,0°C in the north-east. July is by 0.5°C cooler in Pomerania Lakeland. The difference between the highest and the lowest air temperature was 81°C (40°C in July 1994 and –41°C in January 1987).
In Poland winter is the most differentiated part of the year, its duration varies from 45 to over 105 days. In western Poland winter has become shorter by 5 days, in the east by 15 days. Summer is the shortest in the northern part of Poland (less than 70 days), whereas the longest in zlaska Lowland and Sandomierska Valley (over 95 days), a decrease of the difference between regions of the shortest and the longest summer, which amounted to 50 days, could be noticed (Atlas...)Information about heat resources is given also by the duration of vegetation season.The best conditions are in the western part of Poland, where a temperature above 5°C is on the average during 230 days, whereas in Suwalskie Lakeland the length of vegetation period is 200

to 205 days. At present, vegetation period in Poland is by 10 days longer than that determined for the period of 1881-1930 (Atlas... 1973).

The moisture resources are characterised by average yearly precipitation, number of days with snow cover and climatic water balance. In Poland's lowland, precipitation is below 500 mm in the eastern part of Wielkopolskie Lakeland to 850 mm in Carpatien Submountains. Rain in the vegetation period (April-September) makes 60-70% of the yearly total. Months of the largest rain are June and July, of the lowest – February. Lately, a decrease of the total yearly precipitation could be noticed (by 50 to 100 mm), particularly in the eastern and north-eastern part of Poland.

A snow cover of at least 1 cm lasts for less than 40 days in western Poland, and for ca 60-70 days in the south and south-east. Winter has become less and less snowy, the number of days with snow cover is lesser, from 10 to 30 days, depending on the region (Atlas... 1973).

The average yearly values of climatic water balance, described as differences between precipitation and evaporation index are from -50 to 300 mm. Negative differences are in central Poland – Wielkopolskie Lakeland and Mazowiecka Lowland. During the vegetation season the differences of the climatic water balance are larger by 3 times, which indicates unfavourable water conditions in these parts of Poland.

The climate in Poland changes, which is proven by the diagrams of temperature and precipitation changes during centuries in Warsaw. The yearly temperature trend is 0.7°C per 100 years. The greatest temperature increase (1.4°C) is in December, in the other months (except August) it increases from 0.2 to 1.2°C. However observations of the theoretical curves show that in 2000-2075 the temperature will decrease because of the natural climatic cycle, which will moderate the temperature increase caused by human activities. As far as precipitation is concerned the yearly trend is negative (-4.2 mm per 100 years). From November to June the trend is positive, from July to October – negative. The greatest decrease by 8.4 mm is in August, accompanied by not changing air temperature in that month.

Conclusions

- In the second half of the 20th century changes of the basic elements of the climate can be seen in Poland, which are expressed as increases of radiation intensity, insolation and air temperature, and as slight decrease of precipitation.
- Changes of energy, heat and moisture resources, and particularly lenghthening of the vegetation season, will caused alterations of land usage structure.

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DESIGN OF SIMULATION EXPERIMENTS: AN EXAMPLE FOR ASSESSING POTENTIAL IMPACT OF CLIMATE CHANGE ON WHEAT YIELDS AND DEEP DRAINAGE IN WESTERN AUSTRALIA.

S.C. de Vries[1], M.K. van Ittersum[1,2], S.M. Howden[2], S. Asseng[3]

[1]*Plant Production Systems Group, Wageningen University, P.O. Box 430, 6700 AK Wageningen, The Netherlands*
[2]*CSIRO Sustainable Ecosystems, GPO Box 284, Canberra, ACT 2601, Australia*
[3]*CSIRO Plant Industry, Private Bag No. 5, Wembley, WA 6913, Australia*

Introduction

Simulation experiments can be a powerful tool for enhancing understanding of properties and behaviour of agricultural systems. Assessing the potential effects of climate change on wheat yields and deep drainage in Western Australia (WA) using simulation experiments is a good example (Van Ittersum et al., 2002). Both climate change and deep drainage, being an important driver of dryland salinity, pose serious threats to agriculture throughout Australia. Similar to the design of field or laboratory experiments, the design of simulation experiments is critical to their outcomes. An important aspect in this design is the choice between resetting certain variables to a fixed value in between consecutive seasons or taking simulated results from the preceding run (year) as input to the following (not resetting). We investigated the consequences of resetting or not resetting soil water content, soil nitrogen content, and soil residue content on simulation results for wheat yield and deep drainage in WA.

Methods

In an earlier simulation study on the potential effects of climate change on wheat production and deep drainage in WA (Van Ittersum et al., 2002), simulations were carried out with the APSIM framework (McCown et al., 1996), using modules for simulation of wheat growth, soil water, soil nitrogen and crop residues. The model has been well validated for WA conditions, both in terms of wheat production and the water balance (e.g. Asseng et al., 2001). The model was run for 90 consecutive years (1907-1996) of historical weather data, altered to reflect possible changes in climate. Runs were carried out for three locations in WA with different annual rainfall figures. All experiments were done for a deep sandy soil (plant available water (PAW) up to 150 cm = 55 mm) and a clay soil (PAW up to 130 cm =109 mm). Nitrogen was a treatment in all experiments; it is well known that climate change affects N allocation and concentrations within the crop. Only a low (30 kg N/ha) and high N treatment (90 kg N/ha on clay, 150 kg N/ha on sand) were fully analysed. All runs were carried out for 'ambient' CO_2 concentration (350 ppm) and for an elevated CO_2 concentration (550 ppm). In the model, the influence of [CO_2] was reflected by means of a higher Radiation Use Efficiency (RUE) and a higher Transpiration Efficiency (TE). In the earlier study, to remove the influence of the previous crop, *total soil nitrogen* was reset to 40 kg mineral N/ha in the 0-100cm soil layer (mainly as NO_3) on 20 April of each year. *Soil water content* was reset to the lower limit of plant-available water on January 1 of each year. *Crop residues in the soil* were reset on January 1 to 2 t/ha of straw and 1 t/ha of root biomass with C/N ratios of 70 and 40, respectively. In the present study we investigated the influence of this resetting on simulated wheat yields and deep drainage by rerunning the simulations, this time omitting to reset the mentioned soil variables, both alone and in combinations, in a factorial arrangement.

Results

We found substantial differences between outcomes of simulations with and without resetting; in annual results, yield differences larger than 1 t/ha often occurred (with average yields of 1.8

t/ha). Not resetting *soil water content* resulted, on average, in higher water availability and consequently higher average wheat yields and deep drainage. Not resetting *total soil nitrogen* resulted in lower soil nitrogen content and wheat yields that were lower than control yields. In general a slight increase in deep drainage was observed. Not resetting *crop residues* had the greatest influence (not resetting water *and* residues had even greater influence however); it resulted in a much larger pool of crop residues on the soil, which inhibited evaporation, hence more water was retained in the soil. On average, this resulted in higher yields (8% higher on clay, 4% on sand) but also in higher deep drainage (100% higher on clay, 19% higher on sand). In some cases with high rainfall where nutrients instead of water were limiting, yields were reduced by the additional amount of residues. This was probably due to immobilisation of N, but this needs further investigation. Resetting affected [CO_2] effects on both yield and deep drainage. Yields on clay increased by 18% due to elevated [CO_2] if residues were reset; they increased by 14 % if residues were not reset. Deep drainage on clay increased by 13% due to elevated [CO_2] under resetting conditions and by 7% if resetting was omitted. It is well known that [CO_2] effects on yield tend to be smaller under lower moisture stress.

Discussion

The difference between resetting and not resetting in our study was largest when it concerned crop residues. Under some conditions (clay soils, relatively low rainfall) average effects of resetting on yield and particularly deep drainage were substantial compared to the effects of elevated [CO_2]. However, for the outcomes to be reliable, it is necessary that residue amount (addition and decomposition of crop residues) and evaporation from the soil are simulated accurately. Errors may accumulate when 90 consecutive years are simulated without resetting. This is an important argument in favour of resetting. However, an argument against resetting is that events like a slow build-up of organic matter through the years are not simulated. Our findings stress that the design of simulation experiments may importantly influence their outcomes. The design of simulation studies and the rationale behind the design should therefore be clearly explained. Moreover, we recommend a sensitivity analysis of the effects of different designs on the results. The effects of resetting residues also have practical implications. In farming practice, the farmer can relatively easily influence the amount of crop residues: removal of residues (similar to resetting) reduces deep drainage but also wheat yields; accumulation or mulching (similar to not resetting) is beneficial to wheat yields but aggravates deep drainage.

Conclusions

Seasonal resetting of variables may yield simulation results that differ markedly from results of simulations in which these variables are not reset. In our study, this was the case for soil residue content, soil water content and soil nitrogen; the difference was greatest for the amount of residues on the soil. We found that not resetting residues (similar to mulching) increases the amount of residues on the soil hence reduces evaporation. More water can then become available to the crop; however, deep drainage is also likely to increase. These results stress the importance of the design of simulation experiments and how it may affect results.

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EFFECTS OF THE CLIMATIC CHANGE ON THREE FORAGE SYSTEMS IN MIDDLE MOUNTAIN ZONE.

S. Juin, N. Brisson
Unité Sol Climat Environnement, Institut National de Recherche Agronomique d'Avignon, France.

Introduction

The greenhouse gas concentration increase leads to the temperature elevation of the terrestrial surface and should have many effects on the agriculture of tomorrow. The present study consists in analysing the impact of the predicted temperature increase on the geographic partitioning and production schedules of three forage crops in the middle mountain zone of the south-east of France, by the mean of the STICS crop model (Brisson et al., 1998).
Indeed, in mountain zone, the climate change impact is supposed to result in variations of vegetation layers in altitude and increase in frost damage. For the forages, the changes would appear in the crop management with an earlier coming out of animals in spring. For silage corn crop, the production zone has extended for ten years and this phenomenon should increase.

Methods

The climate change scenarios supplied by the GCM (LMD Laboratory- France) and the climate generator LARS (Semenov et al.,1999) have permitted to create climate series taking into account temperature increase. So, four data sets have been introduced as inputs in STICS :

- Two existent series, the first one(series 1 between 1961 and 1989) being used as a reference not affected by climatic change and the second one (series 2 between 1990 and 2000) for which the climate change is supposed to have started
- Two scenarios, one taking into account temperature elevation (scenario 3) and an other including both the temperature increase and its monthly standard deviation (scenario 4) for the 2070-2100 horizon with a CO2 doubling.

In order to inform the climate of the studied zone, two meteorological stations were selected for the northern and the southern parts. Then we elaborated a model relying on empirical relationships, allowing to vary the temperatures as a function of height and orientation. An indirect validation of this model was made by comparing phenological dates simulated with STICS to the equivalent observed dates for alfalfa and grass crops for different height in the studied zone (fig. 1).

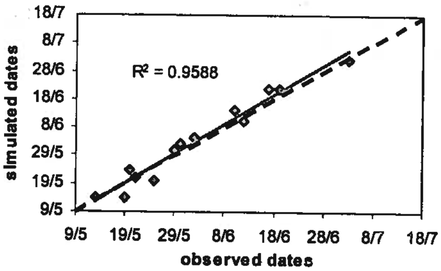

Figure 1 : indirect validation of module permitted to make vary the temperature in mountain zone.

Three forage systems (alfalfa, grassland composed of a mixture of cocksfoot and tall fescue and silage corn) were studied. Two silage corn varieties were used, a semi-early (DEA) and a late (Volga) varieties. The harvesting dates for silage corn and cuttings for alfalfa and grass crops were calculated from growing degrees-days. In this mountainous context, the frost can be a limiting factor, which led us to define damage temperature thresholds for each crop. All the information was included in a GIS using a digital elevation model, which allowed to spatialize the outputs (maps) .

Results

Concerning the silage corn crops, the harvesting dates are earlier for both varieties with the scenarios 3 and 4. The differences between simulations of series 1 and scenarios 3 and 4 can be over one month (fig. 2). The maps showed an enlargement of the silage corn zone, in the higher areas, and the possibility to grow varieties with longer crop cycles in the lower areas. For the yields, the results are different between the scenarios 3 and 4. The scenario 3 results in a yield increase. Because of frost damages that can be important some years, the scenario 4 results in a yield decrease. This phenomena is enhanced for the northern zone and for the highest heights.

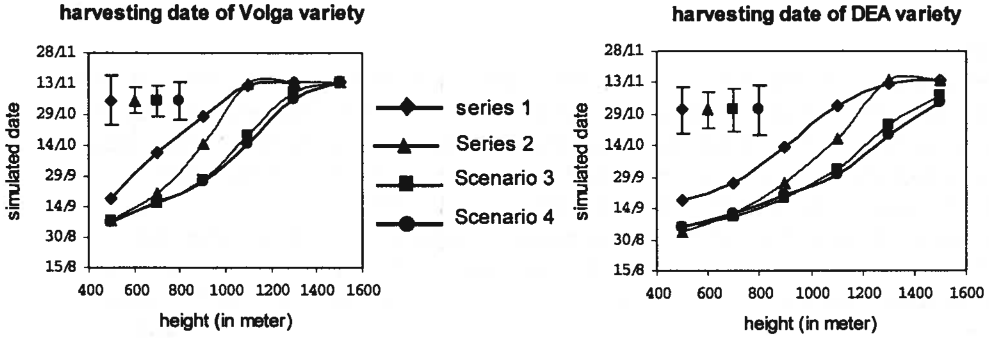

Figure 2 Simulated harvesting dates as a function of the height for the silage corn DEA and Volga varieties with the northern reference climate assuming a southern orientation.

Concerning alfalfa and grasses lands, we obtain a lengthening of the growing period. The first

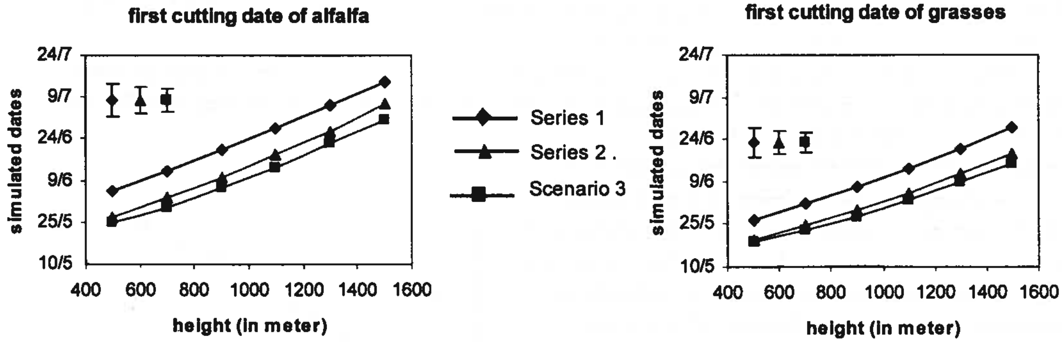

Figure 3 : Simulated first cutting dates as a function of the height for alfalfa and grass crops with the northern reference climate assuming a southern orientation.

cutting is earlier (fig.3) and there is either an additional cutting or a longer pasture period. This two forage systems could also be implemented at higher heights. As far as the yield is concerned, the climate heating impacts (scenario 3) are more important for alfalfa than for grasses crops.

Conclusions

The simulation provided by STICS predict displacement in height of about 200 to 400 meters. However frost risks could limit this extension in particular for silage corn which is more sensitive.

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THE VALUE OF ENERGY CROPS TO CARBON SAVING AND SEQUESTRATION FROM ARABLE LAND MANAGEMENT CHANGES.

King J. A., Bullard M. J
ADAS Consulting Ltd., Boxworth Research Centre, Boxworth, Cambridgeshire, CB3 8NN.

Introduction

To counteract the rise in global CO_2 levels, the Kyoto protocol measures (UN, 1997) aim at reducing emissions of radiatively forcing gases to 1990 levels by 2008-2012. To contribute, the UK is committed to cutting annual emissions by 20% (33.6 Mt C a^{-1}). World-wide, agriculture only accounts for 5% of anthropogenic CO_2 emissions, but 50 -75 % of CH_4 and N_2O emissions (56 and 280 times more effect than CO_2 respectively). However, when considering mechanisms for the mitigation of CO_2 emissions, the IPCC distinguish three main options by which agriculture can act (Batjes, 1998); (1) the strengthening of soil C sinks, (2) the production of biofuels to replace fossil fuels, and (3) the reduction of agriculture related emissions. Some also consider a fourth option, of increasing vegetative standing biomass, as sequestration.
In this study we consider how short-rotation willow and *Miscanthus* grass energy crops offer carbon savings by all four of the above mitigation mechanisms. We have done this with reference to a typical area of arable land in Norfolk, UK, (the Norfolk Arable Land Management Initiative (NALMI)), and include other arable management changes. These changes were; set-aside field margins (10% of area), applied livestock (30%), and reduced tillage and straw incorporation (40%) (King *et al.*, 2001). They have been modelled for NALMI area soils at rates likely to be taken up by the agricultural community (the results here being taken from a fuller report to the Countryside Agency (Bullard *et al.* 2001)).

Methods

When modelling the carbon sequestration potential for various arable management changes, Smith *et al* (1997) derived soil carbon accrual factors from a range of long-term experiments. However, no data were available from energy crop plantations and doubt has been expressed about the validity of soil related coefficients in this application. For these reasons we attempted to model the possible carbon accrual to arable land converted to energy crops from first principles, and include contributing pools of soil carbon, surface standing litter, and perennial root/rhizome systems as well as a component from the standing crop. Energy crops are also seen as an opportunity to dispose of livestock wastes or sewage sludge, and so an estimate of 10% of the carbon so applied has been included as remaining in the litter layer. This has been estimated assuming the generic exponential decay of organic materials, and the details for this and the origins of increments to litter, root and soil pools are given in King *et al.*(2001). In making such estimates correction for the possible emissions of other greenhouse gases, N_2O and CH_4, from these wastes has also been made, with attenuation of the carbon sequestration by a CO_2 equivalent amount of carbon.

Results

An example of the quantities of carbon accruing to soil and crop pools for the two main energy crops (with and without cattle FYM) over a 4 year term (one crop of willow) is shown in Table 1. In addition to these benefits there would also be an increase in the standing biomass of crops on site, and although this carbon is recycled to the atmosphere *via* the power station, whilst on site it does constitute an increase in sequestered carbon over arable or grassland crops. Typically short rotation willow coppice puts on 5.4 t C ha^{-1} a^{-1} and *Miscanthus* grass 6.75 t C ha^{-1} a^{-1}. The values for potential sequestration in Table 1 were included as the contribution of energy crops established over 10 % of the NALMI arable land to carbon sequestration, alongside estimates of sequestration from other managment changes on the remaining 90%. The total potential carbon sequestration over 5 and 15 years (typical willow lifespan) were then of the order of those shown in Table 2. The figures in Table 2 demonstrate how relatively modest changes can enhance the carbon sink value of arable land.

Table 1. Carbon equivalent fluxes (C t ha^{-1}) on willow and *Miscanthus* plantation four years after planting, with Cattle FYM (10.5 t ha^{-1} DM) applied after harvest

Carbon Pool	Willow	Willow + FYM (1yr)	*Miscanthus*	*Miscanthus* + FYM (1yr)	*Miscanthus* + FYM (1-4yr)
C in litter (6 t/ha DM)	2.70	2.70	2.70	2.70	2.70
C in roots (9 t/ha DM)	4.30	4.30	4.05	4.05	4.00
C in SOM (0.5 t/ha/a)	2.00	2.00	2.00	2.00	2.00
C from waste to SOM (10%)	0	0.47	0	0.47	1.89
N_20 efflux (t/ha CO_2-C equivalent)	0	0.60	0	0.60	2.40
CH_4 efflux (t/ha CO_2-C equivalent)	0	0.44	0	0.44	1.75
Total C sequestered	9.02	9.49	8.75	9.22	10.64
Site balance of C sequestration	9.02	8.46	8.75	8.19	6.49

Table 2. Estimated accrual of soil carbon (kt C) (to 30 cm depth) and biomass carbon in the arable land (133 km^2) portion of the NALMI area.

Land use change	5 years	15 years
Arable changes without energy crops	18.63	55.90
Arable changes with willow	31.98	63.95
Arable changes with willow and waste applied	34.64	71.96
Arable changes with *Miscanthus*	35.61	67.59
Arable changes with *Miscanthus* and waste applied	35.97	68.69

The valuable role of livestock waste (or sewage sludge) is clear, though it is also apparent that this must be handled carefully and applied infrequently, to minimise the negative effect of possible N_2O (or even CH_4) emissions. Further savings on CO_2 emissions would also be realised by indirect energy savings in the fuel and agrochemical supply chains. It has been calculated that growing willow over 15 years causes emissions of only 6.7 t ha^{-1} C and *Miscanthus* only 10.2 t ha^{-1} C compared with 18.9 t ha^{-1} C from a standard arable rotation in this region (3 years cereals, 1 year sugar beet and 1 year oilseed rape) (Bullard *et al.*, 2001). In addition the energy gained from a crop of *Miscanthus* is 36 times that used in its production, and 25 times for willow.

Conclusions

Our projections indicate that a significant contribution to greenhouse gas abatement strategies can be gained from soil and biomass carbon sequestration attendant upon the more widespread use of biomass energy crops. Although small when set against the reduction target for the UK, it is in addition to savings made by the substitution of fossil fuel energy by the crop itself. However, if the above 10% level of energy crop planting is applied over the entire UK arable area (7000 km^2), then theoretically 20 % of the UK's abatement needs over 5 years could be accounted for in sequestration and energy savings. However, renewable energy from biomass crops is only just becoming viable in the UK and the current target is only 125 000 ha (18% of the above scenario).

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CLIMATIC RISK OF PLANT CULTIVATION IN POLAND

Cz. Kozminski
Department of Agrometeorology, Agricultural University in Szczecin. Papie□a PawlaVI,3 str.
71-434 Szczecin, Poland

Introduction

Climate changes cause, among others, an increase of frequency and extremes of unfavourable weather conditions, which pose a growing hazard for plants cultivated in Poland. For this reason it is necessary to assess losses of crops in various regions of the country, and changes of land usage (Kozminski et al., 1993, Parry, 1988). This was the goal of Atlas of Climatic Risk of Plant Cultivation in Poland, 2001, which was the third monography following the Climatic Atlas of Elements and Unfavourable Phenomena in Agriculture 1990, and Atlas of Soil Moisture in Poland, 1995.

In Poland, over 20 unfavourable meteorological factors and atmospheric phenomena are noticed which can be the cause of more or less pronounced losses of crops, depending on the quality of soil, agrotechnique and plant species.

Methods

The Atlas is based upon agrometeorological data from 60 meteorological Stations of IMGW as well as from experiment stations of COBORU for the basic period of 1961-1995, and also data from GUS and PZU (GUS= Main Office for Statistics, PZU= State Insurance Company) for the years 1970-1994. Using the method of regression and probability distribution of random variables, and also numerous meteorological index, yield losses (% and tons) of 12 cultivated plants, caused by unfavourable meteorological conditions in Poland were determined. Furthermore, the distribution in time and space and the probability of occurence of these factors, and crop losses in various regions of Poland were determined. The majority of the maps were drawn on the background of 1:2000000, which were then transferred into maps 1:4000000 and 1:6000000, generalizing their content.

Results

The Atlas contains ca 1000 maps, diagrams and tables, presented on 84 multicolor posters in English and Polish, and it is the result of multiyear research of 27 authors from 8 scientific institutions in Poland. It consists of 4 basic parts: I – Survey maps of Poland's geographical features, II – Agroclimatic yield-forming factors, III – Agrophenology and yield variability of cultivated plnts and IV – Risk of plant cultivation caused by unfavourable agroclimatic conditions in winter and during vegetation season.

The I part of the Atlas contains: soil-agricultural map of Poland, erosion map (water, wind, ravine), ground water map, capacity of farm wells, air pollution by sulphur – and nitrogen dioxides.

The II part of the Atlas covers energy factors (radiation and insolation), heat (soil and air temperature, thermal seasons, and agricultural seasons), moisture (deficiency and relative air humidity, precipitation, snow cover). This chapter pays great attention to energy capacity of wind, heat balance of active surfaces, climatic water balance and century changes of air temperature and precipitation.

In the III part of the Atlas, the distribution in time (spectra) and in space of the more important agrophenophases of 13 cultivated plants and their yield variability is presented.

In the last, basic part of the Atlas, basing upon an excessive and long lasting snow cover, severe frost and lack of snow, and also atmospheric and soil thaw, the degree of overwintering, winter losses expressed as percentage of ploughed-in plantations of 6 plant species were determined. Yield decreases caused by excessive rain in fall, winter and spring, delay of spring vegetation

start, delay of sowing and planting, insufficient rain, drought, frost, hail and extreme moisture of top soil (excessive or insufficient moisture), were determined for the most important plants cultivated in Poland. At the same time, the intensity and probability of occurence of these factors were determined for various regions of Poland. Additionally diagrams describing the dimensions of crop losses depending on the intensity of the given factor were included. In Poland a great hazard for cultivated plants, particularly for spring cereals and root crops is posed by insufficient rain, particularly during the second half of spring and begin of summer. In Poland, on the average, out of 10 years three are characterized by soil drought, and two by excessive soil moisture, thus posing an increasing hazard for plant growth, since the extremes of these factors is on the rise. The final effect of the evaluation of climatic risk of plant cultivation in Poland are hazard zones for cultivated plants caused by unfavourable climatic factors.
Beside traditional methods of assessment of the extent of the climatic hazard for plants, the Atlas features also maps which show soil drought and conditions for cultivated plants based on satelite images. Of winter crops the most affected by unfavourable meteorological factors are oil-seed-rape and barley, whose yield can be decreased by 9 to 17% on yearly average, whereas the least influenced is winter rye, from 7 to 15%. Among winter crops, the lowest climatic risk occurs in the western part of Poland, the greatest in south-eastern regions (except Kotlina Sandomierska) and in the higher parts of Pojezierze Kaszubskie. Stands of spring cereals suffer from unfavourable climate by several percent more than the winter cereals. The lowest climatic risk is observed for sugar beet, whose yield decreases on the average by 6 to 10%.
The Atlas is used for such purposes as spatial distribution of new cultivars, assessment of the climatic risk in various parts of Poland, estimation of insurance premiums, and organisation of meteorological protection of agriculture, and also by extention services and education at universities.

Conclusions

Despite reservations expressed by some of the authors concerning the extent of the predicted climate changes, the proceeding pollution and degradation of the environment, and particularly chemical changes of the atmosphere will lead to progressing instability and extreme weather conditions, thus an increased climatic risk of plant cultivation.

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OPEN TOP CHAMBER TRIALS WITH CLOVER BIOTYPES IN SOUTHERN ITALY

Merola G., Forlani A., Fagnano M.
Dipartimento di Ingegneria Agraria e Agronomia del Territorio. Università degli Studi di Napoli Federico II- Via Università 100- Portici (Na) Italy.

Introduction

Tropospheric ozone is a highly powerful oxiding molecule and the damage it causes has been recorded also in various areas in Italy (Postiglione et al., 1993, 1995). Open Top Chambers (OTC) were used in order to get an effective assessment of the damage because they allow the composition of the atmosphere to be modified without any dramatic alterations of the natural microclimatic conditions (Schenone et al., 1992; Fuher, 1994).

Methods

The experiment was carried out in 2001 at Portici (Naples), in open air (OA) and in 8 OTC, provided with a system of ventilation. In 4 OTC air was filtered using carbon-active filters (F) and environmental air (NF) was introduced into the other four.
Two biotypes of *Trifolium repens* L. cv. "Regal" were compared, one of which was resistant (R) and the other sensitive (S) to ozone. Plants were grown in pots provided with a water reservoir according to the experimental protocol defined by ICP-Vegetation (UN/ECE, 1998). When the water reservoir was refilled, water use was measured and a number of plants were given back 100% of the ETe and the rest 50%. Four harvests were performed at 28 day intervals, starting from 24 July. Total biomass and leaf area were measured in the laboratory. Ozone pattern was measured with a spectra-photometric cell analyser which recorded the maximum daily value. AOT_{40} (ppb x h) was calculated as the sum of the differences between the hourly concentration and 40 ppb for every hour in which the concentration was higher than 40 ppb during daylight.
A split-plot experimental design (harvest x environment x water stress x biotype) with 4 replications was used.

Results

As shown in Tab. 1, average values of maximum temperature and of the highest ozone levels were recorded during the second period of growth in all the environments. It is also evident that average values of temperature 4 –5° C over the environmental air temperature were recorded in OTC. On average R produced a higher dry matter yield than S (Tab. 2). In particular, from biotype-environment interaction, it emerges that R produced more than S in OA (20.9 vs 24.6 g pt^{-1}). Instead in F the same yield was recorded in two clones (16.2 vs 16.9 g pt^{-1}). As regards water stress, pots regularly filled with water on average had higher yields (+62%). Greater differences in water use were recorded for plants grown in OA than those in OTC. In addition maximum SWU values were recorded for S and NF (4.0 and 4.4 kg m^{-2} LA respectively) probably due to alteration in the stomatal regulation even if the differences were of insignificant importance. In Tab.3 yield losses estimated by S/R ratio. In environmental air temperatures NF yield loss S was higher than clone R both for plants regularly refilled with water and those under water stress (31 % vs 22% respectively).

Conclusions

In presence of ozone and under conditions of water stress, R yield was higher than S. Water stress in this experiment have reduced the amount of ozone damage even though it caused a drastic yield loss. In particular yield loss in NF was greater because the higher temperature altered stomatal regulation, increasing ozone uptake. In the same environment water stress have reduced ozone damage. These data support further research into the factors that regulate stomatal conductance in order to study damages caused by this pollutant through ozone uptake.

Environment	T max (°C)	T min (°C)	Rainfall (mm)	O_3 max (ppb)	AOT_{40} (ppb x h)
Open Air	27.9	19.1	178.0	64.4	14857
Not Filtered	31.8	18.4	178.0	61.0	12175
Filtered	32.6	18.5	178.0	35.4	563

Table 1. Average principal environmental conditions.

		Yield ($g\ pt^{-1}$)	Water Use (Kg water pt^{-1})	Leaf Area ($m^2\ pt^{-1}$)	SWU (kg m^{-2} LA)
Environment	Open Air	27.0 A	19.8 A	0.43 A	3.1 ns.
	Not filtered air	13.1 C	14.7 B	0.24 C	4.4 ns.
	Filtered air	16.4 B	16.5 B	0.32 B	3.6 ns.
Harvest	1	23.3 A	21.3 A	0.26 C	3.4 B
	2	17.9 B	17.4 B	0.26 C	3.8 B
	3	17.8 B	17.3 B	0.32 B	5.4 A
	4	16.4 B	11.9 C	0.48 A	2.1 C
Water supply	50%	14.4 A	12.2 A	0.25 A	4.4 B
	100%	23.3 B	21.8 B	0.41 B	3.0 A
Biotype	R	20.4 A	17.0 ns.	0.33 ns.	3.4 ns.
	S	17.3 B	17.0 ns.	0.33 ns.	4.0 ns.

Table 2. Average principal factor. ($P \leq 0.01$)

Water supply	Open air	Not filtered OTC	Filtered OTC
100%	-19 %	-31%	+14%
50%	-16%	-22%	+9%

Table 3. Yield losses estimated with dry matter ratio (S/R).

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ACCOUNTING FOR GREENHOUSE GAS SOURCES AND SINKS IN A TEMPERATE ARABLE AGRICULTURAL ECOSYSTEM

B. A. Osborne[(1)], J. I. Burke[(2)], M. Williams[(3)], J. Clifton-Brown[(3)] and M. B. Jones[(3)]

[(1)]Botany Department, University College Dublin, Belfield, Dublin 4, Ireland
[(2)]Oak Park Research Centre, Carlow, Ireland
[(3)]Botany Department, Trinity College, Dublin 2, Ireland

Introduction

Whilst much attention has been focussed on greenhouse gas sources and sinks associated with forested landscapes, due to their considerable potential to sequester carbon, less attention has been directed towards agricultural, particularly arable, ecosystems. This does not mean, however, that their contribution is insignificant. For instance, cropland soils in Europe could provide a sink for ~1.0% of global carbon dioxide emissions from fossil fuels (Smith et al., 1997). Agricultural activities also contribute about 20% of greenhouse gas emissions and are a major source of methane and nitrous oxide, which have a global warming potential up to more than two orders of magnitude greater than carbon dioxide (IPCC, 2001). Of particular significance, as far as carbon sequestration is concerned, is the organic matter content of arable soils which, on the basis of full accounting practices, can only be maintained or increased through appropriate management practices and not through increased irrigation or fertiliser applications (Schlesinger, 1999). Clearly, increased applications of water and fertilisers could also lead to increased emissions of nitrous oxide, and are practices inconsistent with current EU measures aimed at reducing agricultural inputs. To date, however, we have little information on greenhouse gas sources and sinks associated with arable agriculture or the best management practices for minimising these emissions. Such assessments are also essential for accurate predictions of regional and countrywide estimates of greenhouse gas emissions and their potential for producing alterations in climate.

In this presentation we report on the initiation and preliminary results of a joint 5 year project, funded by the Environmental Protection Agency (Ireland), to examine greenhouse gas sources and sinks associated with arable land subjected to low and conventional tillage practices.

Methods

Field site

A 14ha site under permanent tillage at Oakpark, Co. Carlow, with a free draining clay loam soil, has been selected for the experiments. Half of the site will be subjected to conventional tillage practices, the other half to low tillage management. The major crop grown will be spring barley (*Hordeum vulgare* L.)

Ecosystem gas exchange studies

Measurements of ecosystem carbon and water fluxes will be made over a 4 year period using two closed path eddy flux systems (Aubinet et al., 2000), whilst measurements of N_2O flux will be made using chamber methods combined with gas chromatography (Hutchinson and Mosier, 1981).

Process-based measurements

To identify the relative contribution of different components to ecosystem carbon fluxes and to provide a better understanding of the processes that contribute to carbon cycling in arable ecosystems, measurements of net photosynthesis and respiration will be made on plants and soils at regular intervals using conventional gas-exchange techniques.

Estimation of carbon stocks and litter production.

Primary productivity of the standing crop will be assessed by measurements of changes in biomass and estimates of rates of decomposition using conventional harvesting and litter bag techniques. These will be used to validate the estimates of net ecosystem productivity determined from the eddy flux methodology. This approach will also allow us to calculate the net input of carbon to the soil, a necessary input parameter to the modelling studies described below.

Modelling exercises

Various models have been developed for soils and vegetation that have increased our understanding of the effects of both climate change and land use management on carbon fluxes and sequestration. This project will examine their suitability in modelling greenhouse gas fluxes, and enable the development of a predictive model applicable to arable ecosystems. These models will be tested against empirical data obtained from the arable site and adjusted in the light of experimental results. This will then allow an upscaling of the measured fluxes and the development of a GIS-based regional map for arable land in Ireland.

Conclusions

These results will provide some of the first large-scale measurements of greenhouse gas fluxes associated with arable agriculture and the first ever in Ireland. Such results should be of more general utility in identifying the major causes and consequences of greenhouse gas emissions from comparable ecosystems world-wide. The modelled data should also highlight potential areas for the mitigation of greenhouse gas emissions and increasing the amounts of carbon sequestered. The results of this study will also be incorporated with parallel investigations on forests, peatlands and grasslands to provide National inventories for major land use categories in Ireland.

Acknowledgements

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DROUGHT–GREATER RISK FOR FUTURE WHEAT PRODUCTION IN ENGLAND?

GM Richter, MA Semenov, RAC Mitchell
Agriculture Environment Division, IACR-Rothamsted, Harpenden, AL5 2JQ, United Kingdom

Introduction

Global warming and greenhouse gas emissions are likely to affect crop production in the near future. According to the HADCM2 predictions temperature will rise by 1 to 2°C in the UK by 2050 (Hulme and Jenkins 1998). Evapotranspiration (ET) will increase by 14 % and with more winter but less summer rainfall drought could become more likely. The objective of a regional simulation study was to assess the likelihood of future drought and its impact on yield of winter wheat. We present sample results for representative UK regions.

Material and Methods

Regional input data: Suitable soils were selected from the Soil Map of England, and available water capacities (*AWC*) of representative soil classes were calculated from texture and horizon thickness (Soil Survey 1984). *AWC* of soils ranged from 105 to more than 200 mm. 30 years of daily weather data (temperature, radiation and rainfall) from the national archive were used to derive the statistical parameters. Rainfall ranged from 980 to 550 mm from West to East. The annual climatic water balance (rainfall-potential ET) ranged from 317 to 3 mm.

Climate scenarios were generated with the LARS weather generator (Semenov & Barrow 1997) for the past (1960-90) and future (2035-64). They were based on the medium high scenario of HADCM2 with greenhouse gas only.

Modelling water balance and wheat yield: We used SIRIUS (Jamieson et al. 1998) to simulate the response of winter wheat to environmental change. The water balance was simplified using the Priestley-Taylor approach for potential ET, the α-value (1-1.35) being adjusted for ground cover. ET decreases linearly once more than 50 % of *AWC* is depleted. Similarly, growth rate decreases, and senescence and plant phenology is accelerated with increasing drought.

Risk assessment: Multiple simulations were run for each region using the major soil series with their mean *AWC* and three different sowing dates (20/09, 11/10, 31/10). Drought indices are the distribution of maximum soil moisture deficit (SMD_{max}), its relative equivalent (SMD_{max}/AWC) and the yield reduction factor, Y_{WL}/Y_0. The latter was calculated from simulations with (Y_{WL}) and without water limitation (Y_0). Future yields were simulated accounting for increased radiation use efficiency due to rising CO_2 concentration (334 ppmv in the 1980s to 554 ppmv by 2050).

Results

The likelihood of drought stress is demonstrated for the East Midlands: In the past, the median (0.5 probability) SMD_{max} was close to the average seasonal moisture deficit. According to the scenario for the 2050s SMD_{max} will increase in the East Midlands by *c.* 20 mm and the probability of not exceeding the present seasonal moisture deficit will decrease from 0.5 to 0.3. The relative SMD_{max} will increase in the future because soils will deplete more frequently (Fig. 1). The probability of exceeding thresholds for reduced growth rate (0.5 *AWC*) or increased senescence (0.7 *AWC*) will increase by about 10 % by 2050.

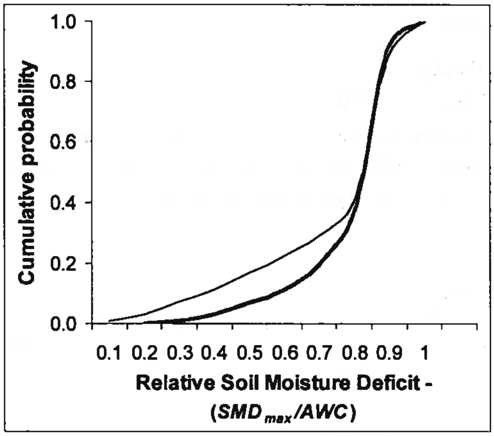

Figure 1: Cumulative probability of relative SMD_{max} (— past; ▯ future); East Midlands.

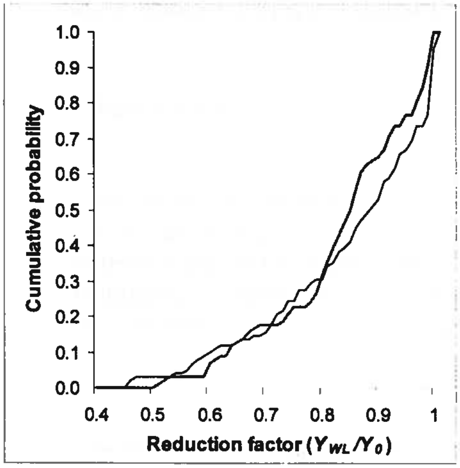

Figure 2: Yield reduction factor (Y_{WL}/Y_0) in the past (□) and future ( ) for shallow soils

The impact of drought on wheat yields is less noticeable than for maximum *SMD*. Distribution of yield reduction factor (Y_{WL}/Y_0) for all East Midland soils is similar for past and future. For shallow soils small yield reductions (10-20 %) are likely to increase in the future (Fig 2). In other regions drought-related yield reduction may change more.

Yields in all regions are likely to increase in the future because of increased *RUE* due to rising CO_2-concentration (Fig. 3). Regional yield distributions are predicted to be more negatively skewed indicating the relative increase of lower yields in the future. For the 2050s we can expect regional wheat yields to increase by 1-2 t/ha. With respect to the dynamics of change (2020s – 2050s) simulations suggest that yield gains are going to slow down (+1 vs. +0.6 t/ha). The relative gains (15-23%) are likely to be higher in the East, provided our weather scenarios and selected soil properties correctly reflect the spatial variation.

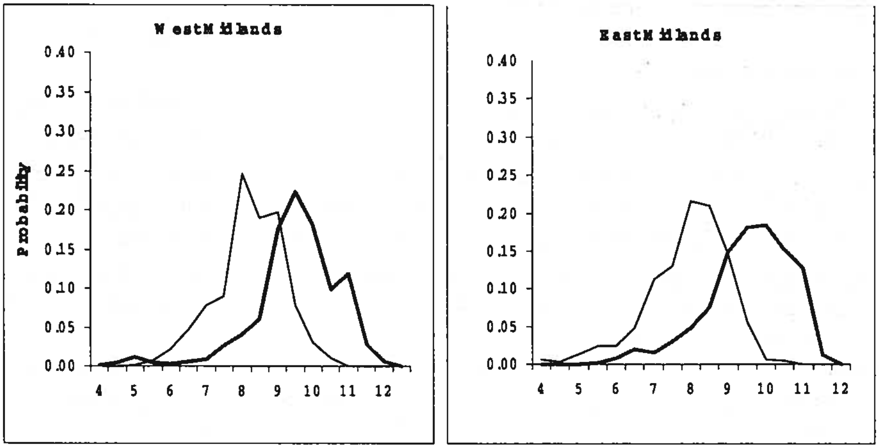

Figure 3: Simulated wheat yield distributions in the Midlands in the past (□) and future ( )

Conclusions

- Maximum SMD is likely to increase in Eastern England until the 2050s (20 mm, 10%).
- Drought-related yield reduction is likely to be similar but shallow soils could suffer more.
- Actual yields are increasing by 1-2 t/ha because *RUE* rises due to higher CO_2-concentration.
- Relative yield increase for winter wheat (15-25 %) is larger in East than in West England.

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ESTIMATES OF 1990 CARBON STOCK CHANGES IN BELGIAN CROPLAND

Sleutel S.[1], De Neve S.[1], Hofman G.[1]

[1] Ghent University, Dep. of Soil Management and Soil Care – Coupure Links 653 -9000 Gent (Belgium)

Introduction

By ratifying the Kyoto protocol Belgium has agreed carbon stock changes and resulting net anthropogenic CO_2-emissions from agricultural management activities are to be accounted under a net-net approach (i.e. carbon stock changes in the commitment period (2008-2012) minus five times the carbon stock changes in the base year 1990). The use of this system poses a problem of data availability and quality with respect to 1990 carbon stock changes: the level of accuracy of data is a criterion for eligibility of the net-net approach. Few countries have actually measured the 1990 baseline (including Belgium) and the question is then if it is possible to make estimates retrospectively. Using a large historic dataset of soil organic carbon (SOC) in Belgian cropland (1989-1999), first estimates of 1990 carbon stock levels and stock changes up till 1997 were made. This dataset may be used to tangle the problem of data-availability. Bulk density and SOC-depth distribution were estimated for each Belgian agro-pedological region individually.

Methods

Calculations of the 1990 baseline SOC-levels in Belgian cropland and their further evolution till 1999 were based on reports published by the Belgian Pedological Service. These reports provide figures based on almost 750 000 SOC-measurements made on Belgian cropland, which were grouped per 3 years in 7 classes and per agro-pedological region (Polders:PO, Sandy region:S, Campines:CA, Sandy-Loam region:SL, Loam region:L, Pasture area Liege:PL, Condroz:CO, High Ardennes:HAR, Pasture area Fagnes:PF, Famenne:FA, Ardennes:AR and Jura:JU). Data on the total area of Belgian cropland in each of these regions was obtained from the NIS (National Institute for Statistics). Bulk density was approximated for 4 main textural classes (sand, sandy loam, loam and clay) from 943 bulk density measurements made in 1990 in the province of West-Flanders by Van Meirvenne et al. (1996). An exponential C-density distribution equation (Hilinski, 2001) was fitted using non-linear regression for each agro-pedological region on the 'aardewerk' database (Van Orshoven et al., 1988): $C(z) = C_b + (C_o - C_b).e^{-K.z}$, being C(z), C_o and C_b the carbon density (g C g^{-1}dry soil) at depth z (cm), at the surface layer and the bottom of the profile respectively, and K a scale constant (cm^{-1}). The 'aardewerk' database constitutes about 13000 profiles for which information is divided per horizon. Only those profiles with a land-use as cropland, temporary pasture or orchard were included when fitting the equation.

Results

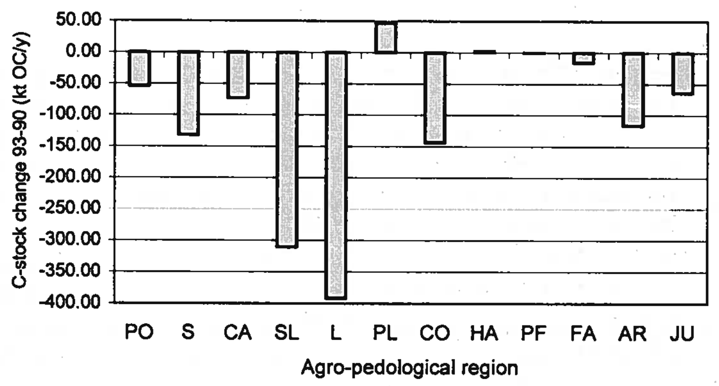
The density distribution function fitted poorly for CO, CA, PO, S and SL. This was due to the presence of horizons with high OC-content below the upper horizon (podsols and peat layers). Excluding those specific profiles from the database (2.5, 5.4, 8.5, 1.8, 0.6% of total number of profiles for each region resp.) drastically improved model fit. Integrating the fitted density equation and multiplying with the bulk density (ρb) then gives a function for the total profile OC (till depth z): profile $C = (1-e^{-K.z}).(C_0-C_b) + z.C_b$. In order to use the model for each agro-pedological region it was necessary to state that the carbon density at the profile bottom (1.25 m on average) remained the same between the time of measuring the profiles (1947-1962) and 1990. For each other depth OC-content was stated to change proportional to the measured difference in C_0 between above mentioned dates. Values for cropland area, K and C_b for the six main agro-pedological regions are shown in Table1. Total 1990 stock changes were approximated as 1/3 of the difference between calculated carbon stocks for 1993 and 1990 (Fig. 1).

Region	Cropland area (ha)	1990 stock (kt OC)	K (cm^{-1})	C_b (%OC)	β_0 (%OC)	β_1 (%OC y^{-1})
S	114575	16444.2	0.022098	0.0567	2.457	-0.03075
CA	79297	14059.7	0.022310	0.0655	2.873	-0.03879
SL	196864	19090.1	0.025214	0.0796	1.708	-0.02349
L	267969	27408.9	0.025104	0.1310	1.722	-0.02292
PO	51697	4861.1	0.053748	0.2801	2.599	-0.04425
CO	86913	6983.4	0.029051	0.1160	1.504	-0.01548

Table 1 cropland area, depth distribution coefficients and estimated regression parameters per region

Carbon-stock changes were evaluated by linearly regressing the carbon-stock data provided by the Pedological service for 3 dates: 1990, 1993 and 1997. The regression coefficient was significant (P=0.05) for all regions except for AR, PL and PF. Estimated regression parameters (intercept β_0, slope β_1) for the six main regions are shown in Table 1.

Fig. 1 Carbon stock changes per region



Discussion

A depth distribution model could be well fitted when leaving out a small fraction of the measured profiles that had organic matter rich horizons at greater depths. To obtain better results while including these profiles, a finer spatial grouping would have to be applied. Since OC-data was only available per region, doing this was irrelevant. The low amount of measurements made in AR, PL and PF may explain the inability to find a significant relationship in their case. The sum of stock changes per region yields, after conversion, a total CO_2-flux for Belgium for the baseline year 1990: -4580.1 kt CO_2. This means that based on this mean data Belgian cropland showed to be a net source. If we take the measurements of 1997 into account however, SOC is diminishing in Belgian cropland since 1990 by –4174.3 kt CO_2 y^{-1}, as is also indicated in the values of regression slopes (Table 1). This difference illustrates that the net-net approach in this case may be a bad system, since it based completely on data from one year only. It also shows the controversy of the approach not to take into account the period since the baseline year up till the commitment period.

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:OMPARING SIMULATED GROWTH OF MANAGED GRASSLANDS UNDER 'RESENT AND CLIMATE CHANGE SCENARIOS

ılexandre Vaz Correia[a], José Paulo Melo e Abreu[b] and Pedro Aguiar Pinto[c]
Departamento de Engenharia Florestal, Instituto Superior de Agronomia, Tapada da Ajuda, 349.017 Lisboa, Portugal. e-mail: alexcorreia@isa.utl.pt
Department of Environmental Sciences, Instituto Superior de Agronomia, Apart. 3381, 301 Lisboa Codex, Portugal. e-mail: jpabreu@isa.utl.pt
[c]
)epartment of Plant and Animal Production, Instituto Superior de Agronomia, Tapada da Ajuda, 349-017 Lisboa, Portugal e-mail: papinto@isa.utl.pt

ntroduction

'he aim of this report was to compare the growth and productivity of permanent and temporary ıastures in mainland Portugal under present and climate change scenarios. Climate data was ;enerated by the Hadley Center's Regional Climate Model (HadRM). An object-oriented growth ıodel was used to simulate potential growth and yield, under water-limited conditions. /ianagement options consisted of biomass removal either through grazing or harvesting.

/Iethods

:limate data was supplied by the LINK project (Viner, 1996). It consists of a grid of 46 cells vith about 50 km of horizontal resolution. Two data sets were used, a control data set, epresenting current climate, consisting of 29 years of daily data with an atmospheric CO_2 :oncentration of 350 µmol mol^{-1}, and a climate change data set consisting of 19 years daily data vith an atmospheric CO_2 concentration of 697 µmol mol^{-1}. The variables used to drive the model vere maximum and minimum daily temperatures, rainfall, relative humidity and global adiation. The control climate set was found to be reasonably close to the observed climate luring the 1961-1990 period (Santos *et al.*, 2001). The climate change scenario predicts ncreases range from 4 °C in the minimum average winter temperature and up to 9 °C in the naximum summer temperature. Annual rainfall is reduced by up to 15%, with an increase of 20-50% during winter and a decrease in all other seasons.

The model consists of a main program that controls three objects dealing with weather variables, soil processes and crop processes (Abreu and Campbell, 1998). Sensitivity to CO2 atmospheric concentration was added (Goudriaan and van Laar, 1994). An input file contains crop parameters (thermal time for phenological events, maximum rooting depth, specific leaf area (SLA), atmospheric CO_2 concentration, physiological parameters and radiative proprieties of canopy and soil) and management options. In the grazing option dry matter is constantly cut when the Green Area Index (GAI) reaches a threshold value of 1.5, and in the cutting option, dry matter is cut when GAI reaches 4, reducing GAI to 0.5 (Aslyng and Hansen, 1985). With the cutting option, total yield is somewhat larger, because a greater GAI is maintained for a longer period of time period than in the grazing option.

We simulated water-limited yearly growth of pastures under these two management options. Results are presented as yearly averages of total dry matter produced.

Results

Dry matter production simulated with the control climate set (figures 1-a and 1-c) reproduces real data from these agricultural systems reasonably well. In the wetter regions there are two growth periods: i) from early spring until the onset of summer drought and ii) in autumn, after the first rains. Autumn growth can represent as much as 40% of total growth. In contrast, in lower productivity regions, autumn growth is much smaller, representing as little as 10% of total growth, due to lower water availability.

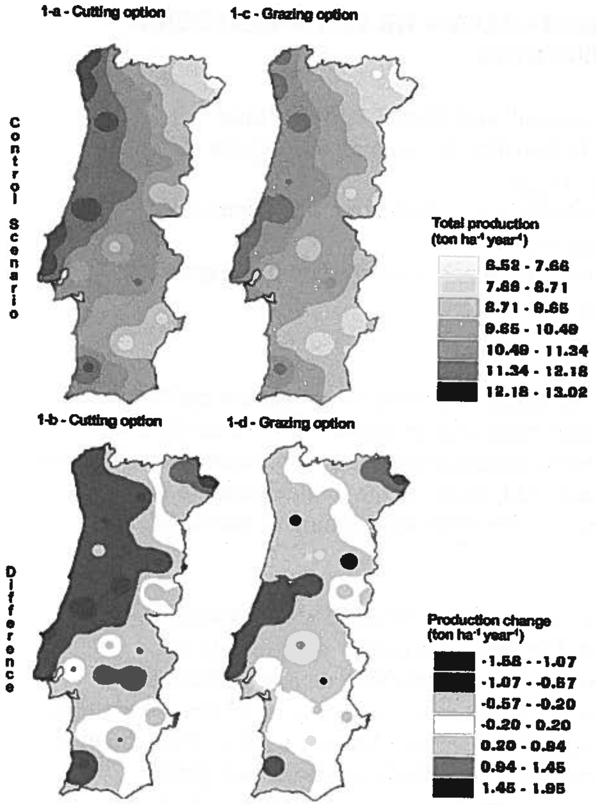

Figure 1. Predicted dry matter production (ton ha^{-1} $year^{-1}$) in Portugal. Figures 1-a and 1-c show the average annual yield under present climate in the grazing and the cutting options, respectively. Figures 1-b and 1-d show yield variation (ton ha^{-1} $year^{-1}$) due to climate change.

With climate change, there is an earlier start of the growing season that results from temperature increase, extending active growth into the period of higher water availability. Higher GAIs are attained sooner, resulting in increased productivity during this part of the year, in spite of an earlier onset of the drought period. The drought period is extended also into autumn, delaying the start of the later growth season towards winter and reducing severely productivity. In the interior regions, where production is low during autumn, the increased productivity during spring is sufficient to sustain total yield, or even increase it. In the coastal regions, however, autumn growth represents an important fraction of the annual production, and its decrease reduces total yield.

Conclusions

Climate change can decrease productivity in most of the country's grassland type communities, especially in the more productive regions. Seasonality is also affected, with growth concentrating in the earlier part of the year.

Acknowledgements

Climate data was supplied by the Climate Impacts LINK project (DEFRA Contract ETG 1/1/124) on behalf of the Hadley Centre and U.K. Meteorological Office.

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THE BRAUNSCHWEIG CARBON PROJECT: FREE AIR CARBON DIOXIDE ENRICHMENT (FACE) AND ATMOSPHERIC FLUX MONITORING IN ARABLE CROP ROTATION SYSTEMS

Weigel, H.J., Frühauf, C., Burkart, S., Dämmgen, U.

Institute of Agroecology, Federal Agricultural Research Centre (FAL), Bundesallee 50, 38116 Braunschweig, Germany

Introduction

Concern about the rapid increase of the global atmospheric carbon dioxide concentration ([CO_2]) along with uncertainties of the global carbon (C) balance requires a better understanding of the C cycle in agroecosystems. More information is needed on the spatial location and strength of CO_2 sources and sinks in relation to management and to changes in climate (e.g. elevated [CO_2]).
Open questions concern the atmosphere-biosphere exchange of CO_2, the control of this exchange by plant and soil processes and the feedbacks between C fluxes and fluxes of water and other elements. Currently there is unsatisfactory information on CO_2 fluxes in arable agricultural land as one of the major European types of land use. Although a stimulation of photosynthesis and plant growth and a reduction of stomatal conductance by elevated [CO_2] has been observed in the vast majority of CO_2 enrichment experiments done so far, it still remains open to what extent agricultural plants and soils will respond to increasing [CO_2] under real field conditions, i.e. under the influence of various other growth constraints, and how this might be related to energy, water and nutrient fluxes in agroecosystems. Additional field experiments with suitable CO_2 enrichment and flux measurement techniques are needed to address these issues. A field experiment has therefore been installed at Braunschweig/Germany which aims to study atmosphere-biosphere interactions under current and simulated future [CO_2] conditions (Weigel and Dämmgen 2000). A brief description of the experiment is given here.

Methods

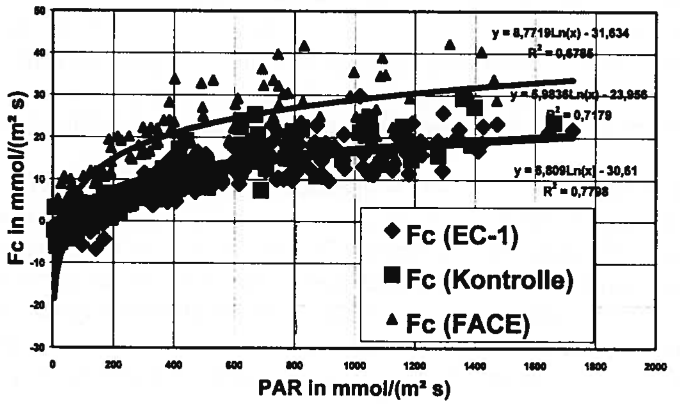
A free air carbon dioxide enrichment (FACE) technique and continuous, long-term micrometeorological flux measurements of CO_2 as well as measurements of atmospheric-biospheric fluxes of other air constituents are applied to the same ecosystem, i.e. a uniform arable field plot (22 ha) with sufficient fetch under otherwise identical atmospheric, soil, vegetation and management conditions. The experiment is included into a local crop rotation including winter barley (1999/2000) -> cover crop (ryegrass mixture) -> sugar beet (2001) -> winter wheat (2001/2002) -> winter barley (2002/2002) etc. Soil, nutrient and pesticide management is carried out according to current local farm practices including field irrigation if necessary.
A FACE system (BNL type; Brookhaven NY/USA) is operated to simulate future [CO_2]. 2 rings (20 m diameter each) equipped with blowers are enriched with CO_2 and 2 rings operated with blowers and ambient air only (controls). The target CO_2 concentration in the enriched rings is 550 μmol mol^{-1} during daylight hours. No enrichment criteria for CO_2 are set to wind speeds > 6.0 – 6.5 m s^{-1} and air temperatures < 5° C. C-turnover in the plant-soil system is specifically addressed by applying a stable C isotope signature as a C tracer to the enriched plots using CO_2 with a certified $^{12}C/^{13}C$ ratio. Nitrogen supply (organic and mineral N) is restricted to 50% of adequate N in half of each of the FACE and control rings resulting in a CO_2 x N split-plot design.
Flux measurements of energy, gases, aerosols and sedimenting particles are performed at the field plot with different resolutions in space and time. At a 10 m micrometeorological tower

large scale (ca. 10 ha) fluxes of sensible heat and momentum and of CO_2 and H_2O vapour are carried out using eddy covariance. Small scale (0.8 m^2) fluxes of CO_2 and H_2O vapour at ambient and elevated CO_2 concentrations are determined using a chamber technique. Fluxes of other air constituents (gases like SO_2, O_3, NH_3; NH_3, HNO_2, HNO_3, SO_2, HCl and NH_4, SO_4, NO_3 and Cl in aerosols; sedimenting particles like Na, K, Mg, Ca, Al, NH_4-N, NO_3-N, PO_4-P, SO_4-S, Cl, heavy metals) are determined by various other methods. To characterize the water and energy budget of the experimental field as a whole and of the FACE ring areas, respectively, relative humidity, evapotranspiration, volumetric soil water content, global and net radiation, PAR, albedo, canopy temperature and humidity, soil temperature, soil heat flux, wind speed and wind direction are also measured.
Biological measurements to assess effects of elevated [CO_2] include leaf area index, canopy height, total above ground biomass, yield, grain and tissue quality, plant phenology and chlorophyll content, leaf soluble carbohydrate content, root biomass, soil organic C content, concentrations of NH_4^+/NO_3^- in the soil solution, soil basal respiration and soil microbial biomass, fungal/bacterial ratio of the microbial biomass and abundance of soil invertebrates (collembola and enchytraeidea). Air, plant and soil samples are analysed for their ^{12}C / ^{13}C stable isotope ratio.

Results

One of the objectives of the FACE experiment is to assess possible feedback effects of plant physiological responses to elevated [CO_2] for the CO_2 fluxes at the field scale. This objective is an example of where the FACE approach and the flux monitoring are closely interrelated. While CO_2 flux measurements within FACE rings can only be carried out with chamber techniques which do not reflect "real" fluxes in turbulent air, extrapolation to ambient conditions can be achieved by calibration procedures using e.g. eddy covariance techniques. As shown in Fig. 1 CO_2 fluxes measured in ambient air with the EC method did hardly differ from corresponding chamber measurements. Elevated [CO_2] significantly enhanced CO_2 fluxes into the canopy at a given radiation level.

Fig. 1: Canopy CO_2 flux (Fc) above a sugar beet canopy as a function of photosynthetic active radiation (PAR) measured by eddy covariance (EC-1) at the field scale and by a H_2O/CO_2 gas exchange chamber technique in FACE (Fc-FACE) and control rings (Fc-Kontrolle) between 17 – 20 August 2001 (10 min a. half hour means)



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Special session on heavy metals pollution

FFECT OF POLLUTANTS ON PLANT AND SOIL LEAD LEVELS

ogdanovic Darinka, Cuvardic Maja, Agoston Mariana

aculty of Agriculture, Institute of Field and Vegetable Crops, Trg D. Obradovica 8, 21000 Novi ad, Yugoslavia

ntroduction

n conditions of intensive urbanization and industrialization, soils receive not only the elements ecessary for plants but also those that are not desirable, such as heavy metals. Lead is found in aces in rocks and soil. Soil contamination with lead is invariably anthropogenous. The most nportant anthropogenous sources of soil contamination with heavy metals are motorized ehicles, mines, foundries, solid and liquid urban waste, etc. According to VETTER *et al.*(1994), oils and plants around mines and zinc, copper and lead smelteries contain high amounts of Cd nd Pb. Motorized vehicles are principal lead polluters. Soil contamination with lead decreases ith distance from roads. Compared with other heavy metals, Pb is less mobile in soil. It reacts ith soil organic matter to form insoluble Pb chelates, thus reducing its chance of being taken up y plants and entering a food chain.

he objectives of this study were to assess the effect of the distance from pollution source on the ontents of total and mobile Pb in soil and plants, and to estimate possibilities of contamination f soil and plants with this element.

ethods

he Pb pollution sources selected for the study of the effect of distance on Pb concentration in oil and plants were "Black Horse" car battery factory in Sombor and the heavily trafficked road ombor - Novi Sad.

amples of soils and plants [wheat (*Triticum vulgare*), grasses: meadow fescue (*Festuca ratensis)*, Italian ryegrass (*Lolium italicum*) and plum (*Prunus domestica*)] were taken at andom from: factory yard (soil), 50, 100 and 2000 m away from the factory (soil and plants), nd 3, 50 and and 100 m away from the road (soil).

seudo-total Pb in soil was determined after boiling in HNO_3 and H_2O_2 on an AAS. Available ead was determined in 0.05 MDTPA + 0.1M TEA + 0.01M $CaCl_2$ and in 0.05M Na_2EDTA + .1M KCl. Total Pb in leaves of wheat, grasses and plum trees was determined by the method of rganic matter destruction with HNO_3 and $HClO_4$ (PAGE ET AL., 1974).

esults

n our study, an enormously high contamination with pseudo total lead was detected in the actory yard (6,297.5 mg kg^{-1} on the average), which may be extremely hazardous for human ealth (Table 1). Only 50 m away from the factory, however, Pb concentration was below the ermitted level, 93.6 mg kg^{-1}. At the distance of 2,000 m from the factory, Pb content in the soil was 30.3 mg Pb kg^{-1}. Three meters away from the road Sombor-Novi Sad, the concentration of pseudo total Pb was above the maximum allowed concentration (MAC). Further away from the roadside, however, Pb concentration was far below the control value. In an earlier study, BOGDANOVI□ (1995) found that Pb concentrations in the soil under corn and soybean were significantly lower 100 m away from a road than 10 and 3 m away. Lead is not very mobile and its accumulation in topsoil has been noted (WRIGHT *et al.*, 1955; FRIEDLAND *et al.*, 1984; BOGDANOVI□, 1995). Our results show that exceptionally high concentrations of available Pb were present in the factory yard, in both DTPA and Na_2EDTA extract (2486.67 mg Pb kg^{-1} and 1685.0 mg Pb kg^{-1}, respectively). These concentrations are sufficiently high to become concerned about the health of workers in the factory (Table 1). The concentrations found in the other samples, taken at different distances from the contamination sources, are not alarming.

Table 1- Contents of pseudo-total and available Pb in the soil depending on the distance from pollution source (mg kg^{-1})

Location	Pseudo-total Pb	Available Pb		
		Na_2EDTA	DTPA	Average
Factory yard	6.297.5	1685.0	2486.67	2085.83
50 m away from the factory	93.6	40.04	51.13	45.58
100 m away from the factory	33.68	9.74	16.30	13.02
2000 m away from the factory	30.3	11.50	18.72	15.11
3 m away from the road	100.9	24.8	35.32	30.26
50 m away from the road	18.7	3.24	6.25	4.75
100 m away from the road	18.1	3.16	6.50	4.83
LSD t 0.05	44.25	19.60	34.05	48.16
LSD t 0.01	60.03	26.64	46.14	62.26

Pb concentrations found in dry matter of leaves of all examined plants were within the permitted values, ranging from 3.70 to 13.69 mg Pb kg^{-1} (Table 2). According to KASTORI *et al.* (1998), toxic Pb level is reached with the concentration of 20 mg per of kg dry plant mass. In the factory yard, however, due to toxic action of heavy metals including Pb, there are no plants at all. The highest Pb concentration in leaf, regardless of plant species and height, was found 50 m away from the plant. The concentration decreased with distance from the contamination source. Most of the tested plants accumulated more Pb in their roots than in the aboveground parts. This is good, since such plants may be used within the food chain.

Table 2– Total Pb content in plant dry matter (mg kg^{-1})

Location	Plant species			
	Grasses	Plum	Wheat	Average
Factory yard	-	-	-	-
50 m away from the factory	9.31	13.69	13.29	12.10
100 m away from the factory	8.78	3.70	5.79	6.09
130 m away from the factory	9.03	5.19	5.48	6.57
2000 m away from the factory	9.00	-	6.52	7.76
Average	9.03	7.53	7.77	
LSD t 0.05	1.56	1.56	1.56	
LSD t 0.01	2.14	2.14	2.14	

Grasses- *Lolium italicum, Festuca pratensis;* Plum- *Prunus domestica;* Wheat- *Triticum vulgare*

Conclusions

The soil in the factory yard was heavily contaminated, the Pb concentration being 6,297.5 mg Pb kg^{-1} of soil. Pb concentration in the soil 3 m away from the heavily trafficked road was slightly above the maximum allowed concentration (100.9 mg Pb kg^{-1} of soil). This is not alarming, but calls for caution. Plants growing next to road shoulders should be excluded from the food chain.

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EFFECTS OF CADMIUM AND CHROMIUM ON SEED GERMINATION AND EARLY GROWTH IN *BRASSICACEAE* SPECIES.

Bona S., Ganis A., Vamerali T. & Mosca G.
Dipartimento di Agronomia Ambientale e Produzioni Vegetali, Università di Padova, Agripolis, Via Romea 16, 35020 Legnaro – Padova (Italy).

Introduction

Recent Italian laws impose strict limitations on the soil and water contents of various organic and inorganic pollutants. For heavy metals in particular, reduction in soil concentrations to permitted levels may be very difficult and expensive, especially if cases of moderate or low pollution are handled with current technologies based on physical or chemical treatments. In such cases, given the known ability of many plants and other organisms to assimilate or immobilize metals in soils, its contribution may become critical. Therefore, one basic task in developing phytoextraction techniques (i.e., direct assimilation of heavy metals by plants from the soil) is to gain wider knowledge of the genetic potential for metal accumulation through botanic taxa. In this view, the simplest approach is preliminary screening of plants based on tolerance to toxic metals and metal uptake during the most critical stages of germination and their early growth.
Of the heavy metals found in Italy, those causing the greatest concern – due to their high concentrations and the possible damage they may cause when they enter the food chain - are cadmium and chromium, the presence of which in water and soil is due almost exclusively to industry. Cd does not appear to play any useful biological role. However, it is toxic for plants, animals, and thus humans (Yang et al., 1995) and in some cases it is extremely dangerous. Hexavalent Cr (Cr VI) is generally highly toxic and carcinogenic.
In this paper, attention focuses on the germination and early growth of various accessions of the family *Brassicaceae*, known to include various metal-accumulators. Some preliminary results are presented about plant tolerance and metal uptake in the presence of Cd or Cr in nutrient solutions.

Methods

Seeds of six species (Table 1) were placed in Petri dishes on filter paper soaked in nutrient solution, in a growth chamber (25°C, dark). Germinability of seeds with 1:10 Hoagland solution plus Cd, added as $Cd(NO_3)_2$, or Cr (as $K_2Cr_2O_7$) at 3 concentrations (10, 100 and 1000 μM), was tested after 7 days in comparison with pure (control) solution. Germinated and non-germinated seeds were collected and oven-dried at 65°C until constant weight. The above species, plus six rapeseed cultivars, were grown hydroponically (16-h photoperiod, 15-20°C night-day temperature, 70% RH) with half-strength Hoagland solution, with and without the addition of Cd at two concentrations (10 or 100 μM) or Cr at three (10, 50 or 100 μM). In the case of Cd, more accessions and two species, *Brassica oleracea* and *Lepidium sativum*, were added. Cultivation used the floating system technique on 10-l vessels, and the solutions were maintained at pH 6 and kept at constant volume by periodical addition of deionized water. Plants were collected 2 weeks after sowing, split into shoots and roots, and oven-dried at 65°C until constant weight. After determination of biomass, all plant parts were analysed for heavy metal concentrations by an inductively-coupled plasma emission spectrometer, after digestion under pressure in a microwave oven with HNO_3/H_2O_2. Both the above experiments were replicated 4 times.

Species	*Sinapis alba*	*Raphanus sativus*	*Raphanus maritimus*	*Brassica oleracea**	*Brassica rapa*	*Brassica juncea*	*Brassica napus*	*Brassica carinata*	*Lepidium sativum**
Accessions	6	7	1	1	4	7	6	1	4

Table 1 – Studied species of *Brassicaceae* and respective number of accessions.
* hydroponic culture with Cd only.

Results

In all examined accessions, the presence of cadmium or chromium in nutrient solutions did not affect the rate of seed germination. However, a greater dry weight of seedlings was observed on day 7 after sowing (+5% on average, $P \leq 0.05$), when seeds were treated with 10 to 1000 µmol/l Cd or Cr, without significant differences among concentrations or between the two toxic metals. Since the seeds had germinated in the dark, heavy metals reduced the exploitation of cotyledon reserves by embryos. This interpretation is supported by visual evaluations of radicles, the elongation of which appeared to be greatly reduced, particularly at the highest metal concentrations. Plants grown hydroponically showed better tolerance to Cr (mean loss of shoot biomass at 100 µmol/l: 17%; minimum loss in *B. juncea*: 5%) than to Cd (mean: 53%; minimum: *L. sativum*, 49%). Most Cd toxicity was noticeable at 10 µmol/l (53% DM loss, with a slight further loss - 3% - at 100 µmol/l), whereas the toxicity of Cr was only significant starting from 50 µmol/l (13% DM loss, $P \leq 0.05$). In comparison with the other species studied, higher tolerance of *L. sativum* to Cd was combined with greater concentration of this metal (Fig. 1) in the shoot biomass, in both Cd treatments. On average, a 10-fold increase of Cd in the nutrient solution led to a 6.4-fold increase in shoots, with great differences among species (Fig. 1). Vice versa, accumulation of Cr was fairly proportional to solution concentration in all species (average: 7.2-fold increase in shoots vs. 10-fold in solution); the highest contents in shoots were found in *B. juncea* and *B. rapa* (Fig. 1).

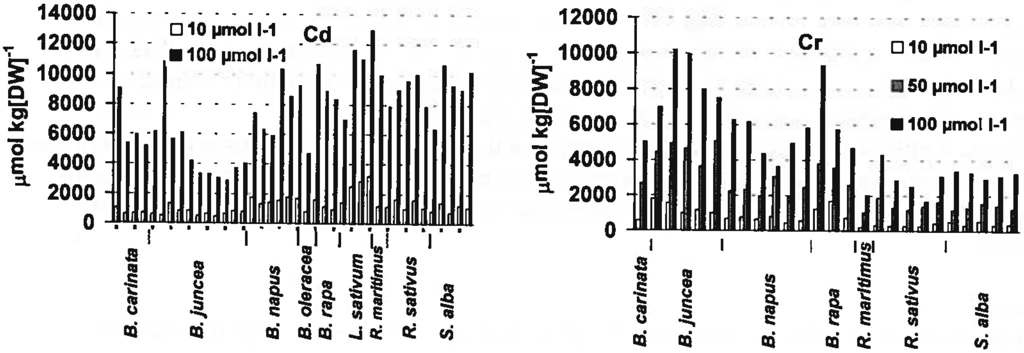

Fig. 1 - Concentrations of Cd and Cr in shoot biomass. LSD for accession×treatment interactions ($P \leq 0.05$): 2400 (Cd) and 1520 (Cr).

Discussion and conclusions

Although acquired data refer to very early growth stages and need further verification, all tested accessions were found to tolerate concentrations of toxic metals which are very high in the range of known soil pollution. Features of tolerance and accumulation capacity were associated in *B. juncea* and *L. sativum*. For the latter in particular, Cd found in shoots was double that indicated as a criterion for identifying hyperaccumulators (Baker et al., 2000). Cd content in rapeseed, considering the easy availability (commercial source) of the tested accessions, means that attention to this crop is worthwhile, in view of its possible use in phytoremediation projects. For all features examined here, within-species variability was very high compared with inter-specific variability – for example, for Cd accumulation, the within-species coefficient of variation (C.V.) ranged from 11% to 35%, versus 24% of inter-specific C.V. – a fact which confirms the usefulness of more extensive exploration of germplasm resources.

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HYTOEXTRACTION OF HEAVY METALS WITH *BRASSICACEAE* SPECIES IN :ONTAMINATED SOIL.

ona S., Ganis A., Vamerali T. & Mosca G.
)ipartimento di Agronomia Ambientale e Produzioni Vegetali, Università di Padova, Agripolis, 'ia Romea 16, 35020 Legnaro – Padova (Italy).

ntroduction

'he technique which makes use of plants to remove heavy metals from contaminated soils 'phytoextraction") has attracted increasing attention from researchers in the last few years, as iese pollutants spread and low-cost and ecologically sustainable solutions become necessary. Of ie heavy metals found in Italy, those causing the greatest concern are cadmium and chromium, ie presence of which in water and soil is due almost exclusively to industry. Cadmium is toxic or plants, animals, and thus humans; concentrations ranging between 0.01 and 1.34 ppm were ieasured in foods more than 20 years ago (Cantoni et al., 1979). Chromium reaches oncentrations which depend on the type of plant in question, from 5.8 ppm in lettuce to 18 ppm i cauliflower, grown in heavily contaminated soils (Gianquinto and Pimpini, pers.comm.). lexavalent Cr (Cr VI) is extremely toxic and carcinogenic. From reports in the literature, *'hlaspi caerulescens* appears to be a species able to accumulate very high concentrations of Cd nd other heavy metals (Ebbs et al., 1997), although decontamination possibilities are limited, ue to its very low biomass. The *Brassicaceae* family, however, is known to include various ietal-accumulators, some of which are species of agricultural interest. Among these, *Brassica incea* has been found to absorb large quantities of Cd. Moreover, its bio-accumulation oefficient (concentration of Cd in plant tissues with respect to the concentration in nutrient olutions) is up to 1100 in aerial parts and 6700 in roots (Salt et al., 1995). This species can ccumulate quantities of Cr VI 100-250 times greater than those occurring in the soil (Salt et al., 997). The results presented here come from a greenhouse experiment, in which *B. juncea* and ther *Brassicaceae* were cultivated in a metal-contaminated soil with the aim of assessing their olerance to toxic concentrations of metals and their ability to accumulate Cd and Cr.

lethods

\ first test (test 1) was carried out during winter 1999-2000. Twenty-six rapeseed cultivars and !6 more accessions of six *Brassicaceae* species (*Sinapis alba*, *Raphanus sativus*, *Raphanus naritimus*, *Brassica rapa*, *Brassica juncea*, *Brassica carinata*) were grown for 80 days in a ieated glasshouse, in 2.5-l plastic pots filled with three different soil mixtures: 1) 25% soil from he experimental farm + 75% river sand (L), used as control (heavy metal concentrations far elow toxicity threshold); 2) a highly metal-polluted organic soil (M100) sampled from top-soil (25 cm deep) situated in the urban fringe of a densely populated industrialized area, and irrigated vith urban waste water. Among other metals (Cu, Pb, W, Zn), it contained 0.8 and 8.7 $\mu mol\ g^{-1}$ Cd and Cr, respectively; 3) soil M100 diluted with 75% (weight) river sand (M25). Plants were collected on 3 dates (35, 50 and 80 days after sowing, before stem elongation), split into shoots and roots and oven-dried at 105°C until constant weight. On the basis of biomass determinations, the most tolerant accessions from each species were identified and cultivated (test 2) for 9 weeks during spring 2000, until flowering, on the same soils as in test 1 plus M100 half diluted with sand (M50). All plant shoots were analysed for heavy metal contents by an ICP emission spectrometer (CIROS^{CCD}, Spectro Italia S.r.l., Lainate, Italy) after pressurized digestion in a microwave oven (Ethos 1600, Milestone Inc., Monroe, USA) with HNO_3/H_2O_2. Trial design was of randomized-complete block type, with three replications.

Results and discussion

In test 1, none of the accessions survived the stage of 2 true leaves in treatment M100, whereas they showed variable tolerance to the lower toxicity of treatment M25 (all accessions were able to complete this growth period). In this treatment, although a more appropriate control soil with physical and chemical properties identical to the polluted soil was not available, the toxic effect of metals on shoot growth was evident for most of the tested accessions, with a variability that was greater within-species and lower among species (C.V. = 1300 % vs. 500 %). Treatment M25 had very little effect on the seven most tolerant accessions, so that in some cases (*B. rapa*, *R. sativus*) biomass at day 80 after sowing was even greater in M25 with respect to the control; in *B. napus*, biomass loss was relatively low (11%). It is probably that the low toxic effect of metal contamination on these species was masked by other soil features relevant to fertility (e.g., organic matter). In test 2, treatment M50 confirmed good tolerance to heavy metals in *R. sativus*, *B. rapa* and *B. napus* (below 64% loss in shoot biomass compared with the control, vs. 85-98% loss of other species). This tolerance was of greater interest in *R. sativus*, given its capacity for accumulating cadmium and chromium (Fig. 1) in M50. For Cd only, this observation can be extended to *B. napus*, thus confirming previous findings on this species grown hydroponically (data not published). The greatest concentrations of Cd and Cr found in the above three species grown in M100 led to the death of plants and were of no interest, like *B. juncea* plants grown in M50, whereas at lower pollution levels this species did not show any great ability as a metal accumulator. Regression analysis applied to plant biomass and concentrations of toxic metals in shoots did not reveal one relationship for these variables in all accessions, but showed close relations (R^2>0.85) between contents of some metals, such as Cd-Zn or Pb-Cr, thus suggesting a chance of success of combined remediation for more than one pollutant.

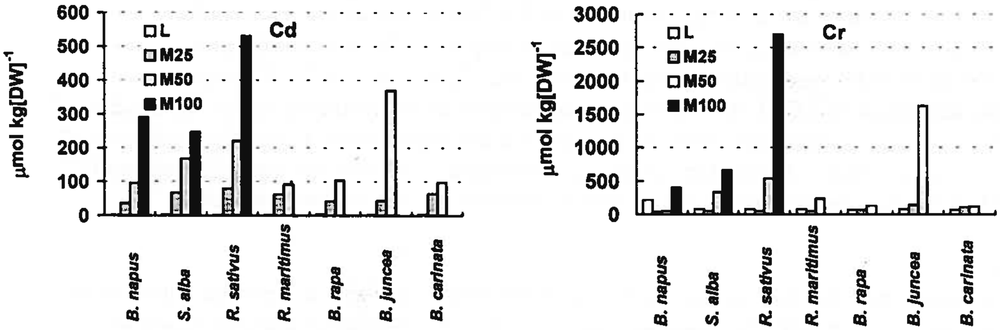

Fig. 1 – Concentrations of Cd and Cr in shoot biomass. LSD for accession×soil interactions (P≤ 0.05): 20.2 (Cd) and 282 (Cr).

Conclusions

Soil contamination, like the most severe level examined here, exceeded the range of pollution for agricultural soils in Italy, and its toxicity was critical for the *Brassicaceae* examined. Even in the absence of this difficulty, remediation times calculated on the basis of the uptake would last for several decades. After partial recovery of the soil by current physical or chemical technologies, some of the tested species (*R. sativus*, *B. napus*) may be of interest in view of the low-cost refinement of the remediation process, whereas further research on their genetic potential may bring operational times within sustainable limits.

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ACTORS AFFECTING TOTAL AND AVAILABLE SELENIUM CONTENTS IN THE OILS OF THE VOJVODINA PROVINCE

uvardic Maja, Ubavic M., Bogdanovic Darinka, Hadzic V.

aculty of Agriculture and Institute of Field and Vegetable Crops, Trg D. Obradovica 8, 21000 ovi Sad, Yugoslavia

ntroduction

Vhile selenium is an essential element for humans and animals, this is not the case with plants. e level in soil affects Se levels in humans and animals through the food chain. Se level in plants epends on its amount in soil, solubility and availability to plants (Elrashidi et al., 1987; ayaweera et al., 1996). Consequently, the objectives of this study were to determine Se levels nd availability in the soils of the Vojvodina Province and factors that affect its solubility and vailability to plants, in order to remedy its eventual shortages in soils and plants used for food nd feed.

lethods

oil profiles were opened in the following soil types: chernozem, humogley, distric cambisol. luvisol, solonetz, solonchak and arenosol. Profile morphology was described, physical and hemical soil properties analyzed, and contents of total and available Se determined in soil amples taken from the profiles.

n order to determine total Se content, the soil was treated with a mixture of strong acids HNO_3:$HClO_4$) (Gelman, 1985). Water-soluble selenium was extracted using boiling water for five ninutes. In both cases the extraction was followed by the reduction of selenate with 6M HCl, after vhich total and water-soluble Se were determined using the hydride system on AAS (Varian).

esults

Dur study has shown the soils under investigation to be poorly supplied with selenium. In the urface layer of the soil, the total Se content ranged from 0.024 to 0.194 μg Se g^{-1} , while the vater-soluble Se levels varied from 0.003 to 0.010 μg g^{-1}. Therefore, water-soluble Se accounted or 1.75-9.43% of total Se.

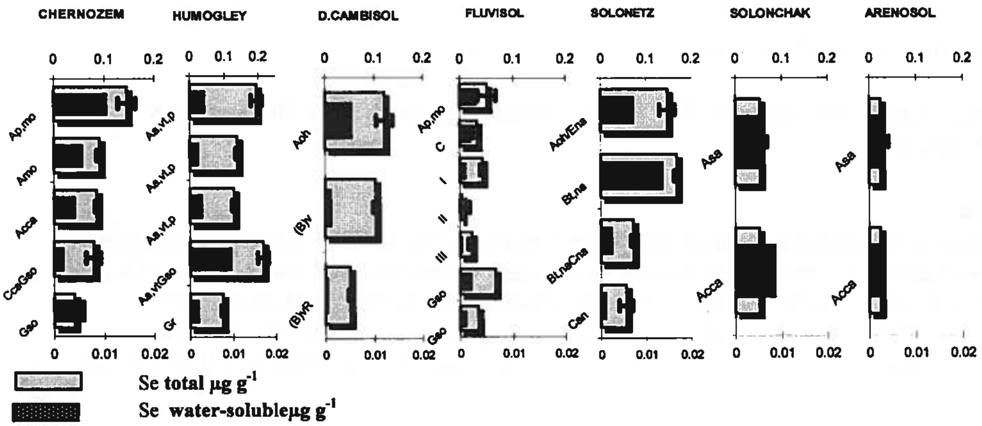
n the profiles of the studied soils, total Se content decreased with soil depth. This indicates that he bedrock that these soils formed on (loess, serpentinite, alluvial deposits of the rivers Tisa and Danube, aeolian sand) has a low Se supply as well as that the Se is bound to humic substances nd together with them distributed across the profile. In parallel with the decline of Se and umus levels along the profile, we observed a decrease in total N and AL-K_2O contents as well. A positive exponential dependence was found between these soil properties and total Se content humus/Se r=0.81**; total N/Se r=0.81**; AL-K_2O /Se r=0.74**).

The mechanical soil composition also affected Se content. Thus, we found a significant positive lependence between clay content (r=0.72**), powder content (r=0.68**) and total Se as well as a significant negative dependence between small- and large-grained sand (r=-0.61** and r=-0.54**, respectively), on the one hand, and total Se content, on the other. Notably, as the contribution of the smaller fractions in the soil increased, so did the contribution of total Se.

A significant positive exponential dependence was found between the DTPA-extracted Pb (r=0.74**), Ni (r=0.72**), Cu (r=0.77**), Cd (r=0.73**), Fe (r=0.53**), and Mn (r=0.62**), on the one hand, and total Se, on the other, which confirmed that Se enters the soil together with heavy metal sulphides.

Just like total Se, water-soluble Se follow the distribution of humus, total N and readily available K_2O along the profile and was found to be bound to clay and powder fractions. An exponential

Figure 1. The contents of the total and water-soluble Se in the soils of the Vojvodina province



regression dependence was determined between these soil properties and water-soluble Se (humus/Se r=0.67**; N/Se r=0.69**; AL-K_2O/Se r=0.57**).
No dependence between soil reaction and water-soluble Se concentration was determined in the soil profile samples, although according to the literature soil reaction should have the greatest influence on Se solubility (Johnsson, 1991). This dependence was determined in the surface soil layer, where soil reaction/pH value determined in water had the largest effect on water-soluble Se concentration. In this layer of the soil, pH value determined in KCl (r=0.60**) and $CaCO_3$ content (r=0.59**) also had a positive influence on water-soluble Se concentration.

Conclusions

The contents of total and water-soluble Se were generally low. Se had to be added in order to achieve its appropriate concentration in grain and vegetative mass.
Se solubility, therefore its availability, varied in the different soil types under the effect of several factors (soil reaction, humus content, soil texture, etc.). Consequently, the effectiveness of added Se varied from one soil type to another.

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UPTAKE AND DISTRIBUTION OF ZN IN *BRASSICA JUNCEA* PLANTS GROWING ON ARTIFICIALLY CONTAMINATED SOILS

Del Río, M., Font, R., De Haro, A.
Instituto de Agricultura Sostenible, Alameda del Obispo s/n-14080. Córdoba (Spain).

Introduction

The remediation of large volumes of contaminated soil by conventional technologies results very expensive. Recently, phytoremediation has emerged as an alternative to the engineering-based methods. Species of the genus *Brassica* have been shown to accumulate moderate levels of heavy metals and variation in the ability to accumulate metals has been observed (Nanda-Kumar et al., 1995; Ebbs et al., 1997). In this sense, *Brassica juncea* has shown greater capacity for uptaking heavy metals than *Brassica carinata* in a field trial performed on contaminated soils of Aználcollar, although all plants had low biomass because of the unfavorable agronomic conditions during the growing period (Del Río et al., 2000).

The objective of this work was to determine the potential for phytoremediation of several genotypes of *Brassica juncea* to clean up contaminated soils, based on their growth responses and Zn uptake when they are grown in pots with artificially contaminated soil.

Methods

Three genotypes of *Brassica juncea* (BJ552, BJ1019 and BJ121) were investigated for their ability to accumulate Zn. Seeds were germinated in Petri dishes, and when the plants had reached adequate height (8-12 cm) were transplanted to plastic pots containing 3 Kg dry matter commercial potting mixture. After 10 weeks of plant growth, treatment started adding Zn as a $SO_4Zn\ 7H_2O$ solution to the surface of soil. In each treatment all pots received 0.5 mmols of Zn as 250 ml of a 2 m*M* $SO_4Zn\ 7H_2O$. The solution was added every 7 days since 10 week until 17 week of development of the plants. At 12, 14, 17 and 21 weeks of development four plants were collected, as well as one plant more used as control, which received only tap water during the development.

Each specimen was divided into leaves, stem, roots and pods. The samples were washed with tap water, rinsed several times with distilled water and weighed. For the determination of Pb, Zn, Cu and Cd the method described by Del Río et al. (2000) was used.

The design of the pot experiment was a two factorial replicated in four completely randomized blocks. Data were subjected to ANOVA with samplings (12, 14, 17 and 21 weeks of development of plants) and *B. juncea* genotypes (BJ552, BJ121, BJ1019), as the two experimental factors. The differences in Zn accumulation between treatments were compared with least significant difference test ($p<0.01$).

Results

The effect of soil treatment on shoot biomass is shown in Figure 1.

Genotype 1019 had a significantly higher shoot biomass than genotypes 121 and 552 (Fig.1). There was no significant difference between the controls and any of the genotypes of *B. juncea* at all the samplings used in this experiment for shoot biomass.

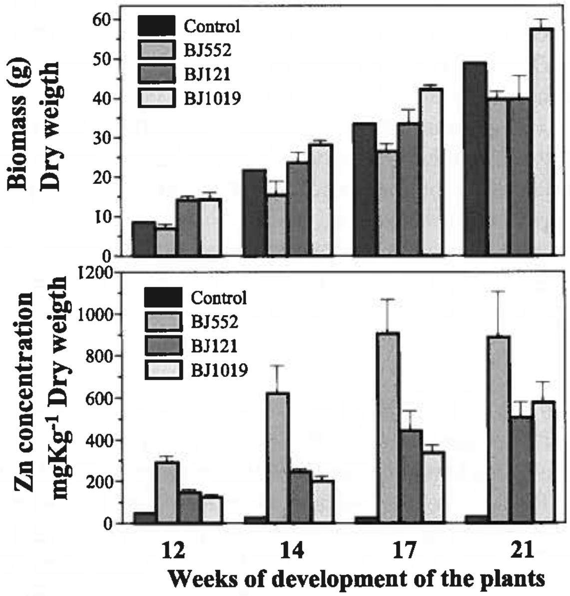
The Zn concentrations in shoots of *B. juncea* plants at the 12, 14 and 17 weeks of development for 552 genotype was significantly higher than the others. At the 21 weeks, Zn concentrations in shoots of *B. juncea* plants were not statistically significant and mean concentrations ranged from 575.4 to 681.9 mg Kg^{-1} (Fig.1).

The highest Zn concentration was found at the 17 weeks for genotype 552, which reached a mean value of 853 mg Kg^{-1} of Zn.

This genotype removed similar amount of Zn than 21-weeks old plants of any of the genotypes.

The distribution of Zn concentration in all the parts of the plants of *B. juncea* followed the trend: leaf>root>stem>pod. When the biomass values were considered, the total amount of Zn taken by plants followed the trend: leaf>stem>pod>root.

Fig 1. Biomass and Zn concentration (mg Kg^{-1}) in shoots of plants grown in Zn-treated soil



Conclusions

These results suggest that the genotype 552 of *Brassica juncea* could be used to clean up soils contaminated with Zn and its efficiency in accumulating Zn in a short period of time will allow us to grow and harvest several crops by year.

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TRACE METAL ANALYSIS OF AGRICULTURAL SOILS BY NEAR INFRA-RED SPECTROSCOPY

Font, R.[1], Del Río, M.[1], Simón, M.[2], Aguilar, J.[2], De Haro, A.[1]

[1]IAS-CSIC. Alameda del Obispo s/n. 14080 Córdoba. Spain

[2]Departamento de Edafología y Química Agrícola. Universidad de Granada. Spain.

Introduction

After the toxic spill occurred in Aznalcóllar (Seville, Spain) on April 1998, more than 4000 Ha of the adjacent agricultural lands along the Guadiamar and Agrio rivers were affected. After physically removing the upper sediments, soils have remained polluted by heavy metals as Pb, Cu, Zn, Cd, Tl, Sb, and metalloids as As. For the last 30 years, Near Infra-Red Spectroscopy (NIRS) has been widely used as a rapid and accurate method for qualitative and quantitative analysis of organic matter in the fields of agriculture, food, textiles, petrochemicals and pharmaceuticals (Williams et al., 1987). More recently, this technique has been applied to the determination of heavy metal and arsenic in plant tissues (Clark et al., 1987; Font et al., 2000; Font et al., 2001), analysis of heavy metals in sediments of lake (Malley et al.,1997), and to study some properties of soils (Krischenko et al. 1992; Confalonieri et al. 2001).

The objective of this work was to investigate if NIRS technique is useful for evaluating the content of As, Pb, Zn and Cu in polluted agricultural soils from the Aznalcóllar area.

Methods

About one-hundred samples of soil were collected along the affected area, and at different depths from the soil surface (tailings, 0-10 cm, 10-30 cm). Samples were digested with nitric and perchloric acids and analised for trace metals by inductively coupled plasma (ICP) in a spectrophotometer Perkin Elmer mod. SCIEX-Elan-5000A in the Departamento de Edafología y Química Agrícola (Universidad de Granada, Spain). A subsample (about 6 cm^3) of each one was analysed at the IAS-CSIC in a Near Infra-Red Spectrophotometer (NIRSystems mod. 6500, Foss-NIRSystems, Inc., Silver Spring, MD, USA) in the reflectance mode, acquiring their spectra over a wavelength range from 400 to 2500 nm (VIS + NIR regions). NIR calibration equations were computed using the raw optical data (log 1/R), or first or second derivatives of the log 1/R data, with several combinations of segment (smoothing) and derivative (gap) sizes. Each of the equations obtained was validated on an external validation group. The predictive ability of each equation obtained was determined by its coefficient of determination (r^2), ratio of the standard deviation to standard error of prediction (RPD) and ratio of the range to standard error of prediction (RER) (Williams et al., 1993).

Results

For all the elements studied in this work the transformation of the original spectra (log 1/R) to their first derivative (1, 4, 4, 1) prior to calibrate, gave slightly better results than any other combination. Tables 1 and 2 show the composition of the calibration and external validation sets, respectively. The As and Pb equations showed the highest coefficients of determination (R^2= 0.93), followed by Zn (0.87) and Cu (0.76), in the calibration (Table 1).Performances of the different equations were tested on independent sets of samples for each metal (Table 2), resulting in r^2 between reference and predicted element concentration from 0.67 (Cu) to 0.82 (As). The RPDs for As, Pb and Zn were close to 2.0, and their respective RERs between 8.0 and 9.0. Copper was the worst predicted element, presenting the r^2, RPD and RER statistics lower than desirable.

Conclusions

NIR equation performances for As, Pb, and Zn in soil samples from the Aznalcóllar area resulted in RPD and RER ratios indicative of acceptable accuracy for screening purposes. On the basis of the r^2 and RPD statistics, the accuracy of the prediction equations was as follow: As>Pb>Zn>Cu, while when RER was considered, Pb was better predicted than As. The way used by NIR for detecting and measuring the metals in soil is unknown. Probably associations established between metal and soil ligands (organic or minerals), can be detected by NIR, and indirectly correlated with the metal content. Different soil variables such as mineral composition or pH, or the metal affinity by a particular type of soil, could explain the differences detected in the accuracy of the equations for each element.

Table 1. Calibration statistics for the elements studied. Values are expressed in mg/kg dry weight (n=70).

	Calibration				
Element	range	mean	sd	SEC	R^2
As	16.30-225.40	65.44	46.37	12.32	0.93
Pb	28.20-598.10	167.54	131.07	35.09	0.93
Cu	19.40-483.80	156.36	101.91	50.07	0.76
Zn	70.50-1784.80	601.90	461.85	163.30	0.87

sd: standard deviation; SEC: standard error of calibration; R^2: coefficient of determination in the calibration.

Table 2. External validation statistics for the elements studied. Values are expressed in mg/kg dry weight (n=30).

	External validation						
Element	range	mean	sd	SEP	r^2	RPD	RER
As	22.90-199.50	74.49	47.66	21.17	0.82	2.25	8.34
Pb	32.50-430.90	147.67	96.82	45.38	0.80	2.13	8.77
Cu	26.90-436.40	169.22	95.33	59.62	0.67	1.59	6.86
Zn	78.60-2112.30	637.67	484.14	246.97	0.76	1.96	8.23

sd: standard deviation; SEP: standard error of performance; r^2: coefficient of determination; RPD: ratio of the standard deviation to SEP; RER: ratio of the range to SEP.

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PHYTOSTABILIZATION OF HEAVY METAL POLLUTED SOILS AS A TOOL FOR AVOIDING RISKS IN SUBSIDIARY AGRICULTURAL LANDS

García, G., Conesa, H. M. & Faz, Á.
*Dpto. Producción Agraria. Universidad Politécnica de Cartagena. 30203 Cartagena, España.
Tf. 34 968 325755, Fax 34 968 325435, E-mail: gregorio.garcia@upct.es

Introduction

The agricultural district known as "Campo de Cartagena-Mar Menor" is a very important agriculture area with a great variety of intensive crops (vegetables, citric trees, greenhouse crops, etc.). This agricultural lands are located in the proximity of a traditional mining area, exploited since more than two millenniums ago, but actually abandoned. As a result of that, piles from huge scale exploitations, and enriched in various metals such as Pb, Fe and Zn, can be found close to agricultural lands. As these sites are environmentally dangerous, especially for agricultural and fisheries of the surrounding areas, they should be cleaned up, or at least stabilized. One suitable way is the stabilization of these polluted soils by plants.
On this respect, some plant species endemic to metalliferous soils have been demonstrated to tolerate exceptionally high metal concentrations (Morrey *et al.*, 1992). An *in situ* metal inactivation by means of vegetation –phytostabilization-, reduces the risk presented of a contaminated soil by using a combination of plants and soil amendments (Mench *et al.*, 1994).

Methods

During 2001 and 2002 experiments related to phytoremediation were focused on comparison of lead and zinc tolerance tolerance by several Mediterranean wild plants from polluted soils in order to search for the most suitable species for phytostabilization purposes. Data on this topic are still rare. Samples were collected from an old mining area on the east side of Murcia province in SE Spain, a typical semiarid Mediterranean zone. Samples of the whole plants - above ground part, rhizomes and roots- were harvested in the full maturity stage (5 repetitions), for Zn and Pb content in plant parts and in the below-plant soil. Extraction of bioavailable zinc and lead in the selected soil samples was determined by a DTPA extraction solution (Lindsay and Norvell, 1978). Final concentrations of Zn and Pb in the solution were determined by flame atomic absorption spectroscopy (UNICAM 969 AA spectrometer). Plants were incinerated in a muffle furnace to 600 °C, metals extracted with nitric acid (Kabata-Pendias and Pendias, 1992) and the digests analysed by inductively coupled plasma atomic mass spectroscopy (ICP-MS 4500 Agilent Technologies).

Results

For mining areas phytostabilization, plants species should be highly tolerant to heavy metals and they also should be highly adapted to specific climatic conditions of the treated area because of the difficulties to grow them under common agricultural procedures. To resolve this problem, powerful heavy metals tolerant autochthonous plant species are being selecting after screening a large number of contaminated soils in a SE Spain Mediterranean area. We must take in account that in response to heavy metals, some studied plants can reduce their growth rate or even die at medium heavy metal pollution (Gawronski *et al.*, 1999). In relation to this topic, toxic levels of zinc and lead in soils are not easy to evaluate, and range from 70 to 300 for Zn and from 100 to 500 ppm for Pb (Kabata-Pendias and Pendias, 1992).
Under these conditions, several interesting species such as the *gramineae Sporobolus pungens* (Schreber) Kunth, *Piptatherum miliaceum* (L.) Cosson, *Hyparrhenia hirta* (L.) Stapf. and *Lygeum spartum* L., the *caryophyllaceae Paronychia suffruticosa* (L.) Lam., the *cruciferae Brassica fruticulosa* Cyr., the *compositae Helichrysum decumbens* (Lag.) Camb. and the *zygophyllaceace Zygophyllum fabago* L. has been found. Based on field observations and the

results of our preliminary study with these wild species and soil data, collected from heavy contaminated sites, five taxa were chosen for further studies.

Plant / parameter	Pm [a]	Pm [g]	Hd [a]	Hd [g]	Ls [a]	Ls [g]	Zf [a]	Zf [g]	Hh [a]	Hh [g]
Zn in soil	346,7	346,7	278.89	278.89	185.56	185.56	273.33	273.33	170.03	170.03
(bioavailable)*	(251,5)	(251,5)	(87.53)	(87.53)	(131.25)	(131.25)	(27.54)	(27.54)	(66.14)	(66.14)
Pb in soil	1678,0	1678,0	1020,7	1020,7	202.96	202.96	655,4	655,4	165.88	165.88
(bioavailable)*	(1129,2)	(1129,2)	(217,3)	(217,3)	(15.87)	(15.87)	(71,3)	(71,3)	(50.5)	(50.5)
Zn in plant *	10,5	187,5	84.83	49.56	15.17	40.28	755.01	525.67	203.67	585.50
	(5,57)	(123,38)	(34.66)	(16.09)	(8.52)	(18.01)	(48.218)	(40.70)	(142.58)	(102.20)
Pb in plant *	5,7	332,7	44,2	24,8	10.00	70.00	59,2	81,7	139.67	161.5
	(1,53)	(228,45)	(10,60)	(8,25)	(0.72)	(5.24)	(28,15)	(25,26)	(41.56)	(81.56)

Table 1: Zn and Pb concentration (mg kg^{-1}) in five selected Mediterranean autochthonous plant species ([a] = aerial -stems and leaves- and [g] = ground -roots and rhizomes- part) and below-plant contaminated soil samples (bioavailable). *Pm = Piptatherum miliaceum, Hd = Helichrysum decumbens, Ls = Lygeum spartum, Zf = Zygophyllum fabago, Hh = Hyparrhenia hirta.* *Values are means from 5 samplings of each soil and plant; values in parentheses are standard error.

Data of Table 1 indicate that differences exist between various species as well as between different parts (ground part/shoot) of the same species. For phytostabilization purposes, species with high specific tolerance and low transport to the shoot of the metal from the soil that should be stabilized are needed. In relation to zinc, most of the considered plant taxa showed a very similar tolerance range. Nevertheless, the minor accumulator plants were *Helichrysum decumbens* and *Lygeum spartum*. Because of *Lygeum spartum* good growth and high soil canopy rate, and a moderate accumulating capacity, mainly in ground parts, this species must be taken into account for this purpose in Zn polluted soils. With regard to lead, the best Pb tolerant plant that has been found, *Piptatherum miliaceum*, has the inconvenient of accumulate big amounts of lead ions. On the other hand, the second better plant tolerant to lead, *Helichrysum decumbens*, has a minor accumulation rate. By this reason, this *compositae* must be considered the best taxa for phytostabilization of lead polluted soils.

Conclusions

Two taxa of autochthonous plant species should be considered for further studies in order to phytostabilize semiarid Mediterranean mining sites polluted by lead and zinc: *Lygeum spartum* and *Helichrysum decumbens*

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INFLUENCE OF HEAVY METAL SOIL POLLUTION ON TOXICITY OF *SILENE VULGARIS*, AN AGRONOMICAL PLANT SPECIES

García, G. [1]; Batista[2], R.S. and Faz, Á.[1]

1 *Dpto. Producción Agraria. Universidad Politécnica de Cartagena. 30203 Cartagena, España. Tf. 34 968 325755, Fax 34 968 325435, E-mail: gregorio.garcia@upct.es
2 Faculdade de Ciências da Universidade do Porto. Portugal.

Introduction

A great number of autochthonous species from SE Spain can be used as food. Among these, bladder campion (*Silene vulgaris* (Moench) Garcke), a perennial herb native to Eurasia and one of the 500 species of the genus belonging the family *Caryophyllaceae*, is an outstanding example. Nevertheless, most of the agronomic aspects of this species have not been studied yet. In Central Europe and the Mediterranean Region, people have traditionally used bladder campion as a vegetable, in particular when the shoots are tender (Laghetti and Perrino, 1994).

The possibility of cultivating this species as a leafy vegetable led us understates a series of experiments to assess its heavy metal accumulation rate in relation with soil pollution. It is well known the bladder campion heavy metal accumulation ability (Brown *et al.*, 1994). The present study was carried out with the aim of ascertaining the range of pollution that can be held by soils to avoid any toxicity effect due to *Silene vulgaris* consumption.

Methods

During fall of 2001 and winter of 2002 experiments related to influence of lead and zinc soil pollution were focused on comparison of these heavy metal tolerance and uptake effectiveness by bladder campion in order to search for this species useful for agronomical purposes. Seeds were collected between 2000 and 2001 from wild plants in Murcia province (Lomas del Espartero, Sierra de las Victorias, Cartagena), in a typical semiarid area.

Up to 9 different treatments have been used, with 3 replicates per each. For Pb, pollution ranged from 300, 900 and 1500 ppm respectively, applied as lead acetate. For Zn, metal applications varied from 100, 300 and 600 ppm respectively, applied as zinc acetate. Besides, 3 mixed treatments have been tested. One series without any metal addition was also prepared as control. One-liter capacity pots, filled up with vermiculite and sand (1:2) as soil substrate, were used for the experiments. Four weeks after seeds germination, heavy metals were added to substrate. Twenty-one days later plants were harvested, processed and metals extracted with nitric acid (Kabata-Pendias and Pendias, 1992). Final concentrations of Zn and Pb in the solution were determined by flame atomic absorption spectroscopy (UNICAM 969 AA spectrometer) and by inductively coupled plasma atomic mass spectroscopy (ICP-MS 4500 Agilent Technologies).

Results

The presence of metals in the environment and in the food chain poses a risk for human health and for ecosystems. The presence in agricultural soils of metals deriving from amendments, mining or industrial activities can be a potential source of food contamination. The transfer coefficient of lead and zinc into edible and non-edible parts of a bladder campion crop was evaluated. The results indicate that metal concentrations in the plant are directly correlated to metal concentrations in the soil, and for some of the treatments these concentrations do not remain within the limits prescribed by legislation.

The bladder campion was found to hyper-accumulate lead from contaminated soil, with approximately up to 10.000 mg per kg of root dry weight (transfer coefficient of 6.7), and up to 4.600 mg per kg of shoot dry weight (transfer coefficient of 3.0), during the first 21 days after soil contamination (Figure 1). Some deleterious effects were observed in plants at maximum soil contamination level (1500 ppm of lead). Nevertheless, even for minor treatments (300 ppm), the lead was accumulated in plants at concentrations that would exceed the recommended acceptable daily intake if it were to be consumed.

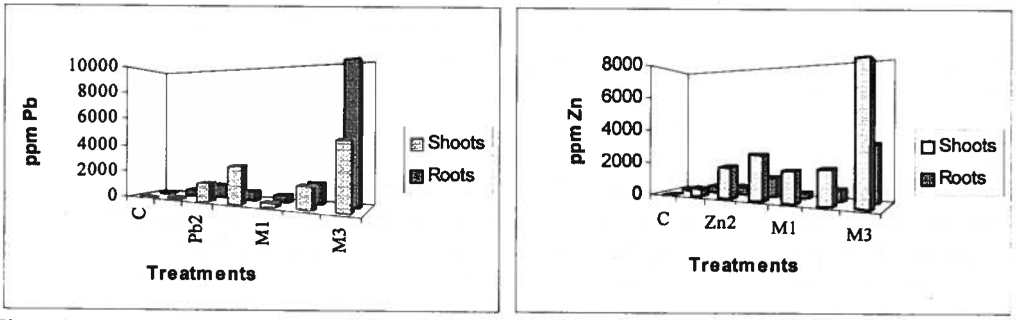

Figure 1: Pb and Zn accumulation by *Silene vulgaris* in different treatments (C = control, Pb1= 300 ppm Pb, Pb2= 900 ppm Pb, Pb3= 1.500 ppm Pb, Zn1= 100 ppm Zn, Zn2= 300 ppm Zn, Zn3= 600 ppm Zn, M1= 300 ppm Pb and 100 ppm Zn, M2= 900 ppm Pb and 300 ppm Zn, M3= 1.500 ppm Pb and 600 ppm Zn). Values are means from 3 samplings.

For zinc, bladder campion also showed great accumulation ability, approximately up to 7.700 mg per kg of shoot dry weight (transfer coefficient of 12.9), and up to 3.300 mg per kg of root dry weight (transfer coefficient of 5.5), during the first 21 days after soil contamination (Figure 1). Leaf damage and significantly restricted growth occurs only in plants at maximum mixed soil contamination level (600 ppm of zinc plus 1.500 ppm of lead). For medium and major treatments (300 and 600 ppm of zinc), and mainly for mixed treatments with lead, the zinc was accumulated in the leaves at concentrations that would exceed the recommended toxicity critical values.
The knowledge of the precise localization of metals is of great interest, for example in edible parts of crops, or in other portions of the plant such as roots or rhizomes. Bladder campion accumulated lead mainly in roots, while zinc was located mainly in shoots.

Conclusions

Bladder campion (*Silene vulgaris*) is a caryophyllaceous species of agronomical interest with a great ability to accumulate and hiperaccumulate heavy metals, such as lead and zinc. That property points towards the potential of phytoremediation of soils affected by these contaminants. Nevertheless, the toxicity that this process has for human health should have into account when heavy metal level of soils is high. Further work is recommended to investigate the potential toxicity of these polluted crops. More research into the uptake by different species and the possibility of food chain transfer of lead and zinc is also recommended.

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CADMIUM UPTAKE DEPENDS ON GRAIN WHEAT QUALITY

Grabiński J[1]., Stuczyński T.[2]

Institute of Soil Science and Plant Cultivation, Department of Cereal Crop Production [1], Department of Soil Science, Erosion and Land Conservation[2], 24-100 Pulawy, Czartoryskich 8, Poland

Introduction

The speciation of the cadmium in tissue of food plants is an important factor in determining its accumulation in the human body. This trace element is readily translocated to plant tops after absorption through the roots and cumulated in stems, leaves and grain (Chaney et al.,1977). Amount of cadmium accumulation in grain of wheat depends on cultivar (Grabiński et al.,1998). The objective of the research was to examine the effect of some wheat grain quality measures decisive on its usefulness for bakery, on mentioned differences among cultivars. The investigations, which show that cadmium has been bounded by the proteins, collectively called phytochelatins, gave the base of the assumptions that grain quality measures might be correlated with cadmium uptake. These proteins identified in wheat have been found also in other species (Spivey et al.,1988).

Methods

The analysis were done on the base of spring and winter wheat grain from pot-experiments which aimed to determine the differences between cultivars in cadmium uptake. Taken under consideration spring cultivars were sown into soils with two types of contamination: natural (very low) and artificial (by addition of 4 mg Cd kg^{-1}in $CdSO_4$). Winter cultivars were sown only into soil with natural Cd content. Concentration of Cd in grain was analyzed using flame atomic absorption spectroscopy (AAS). Protein content was analyzed by Kjeldahl method with conversion factor 5.7. Wet and dry gluten and gluten index were analyzed according to ICC 137 (gluten amount) and ICC No 155 (gluten index) on Glutomatic 2200 apparatus.

Results

The accumulation of cadmium in grain of spring wheat grown on uncontaminated soil did not depend on both protein and wet and dry gluten content. Relation between the grain quality measures and cadmium uptake on contaminated soil defines significant positive correlation (Tab. 1). In the case of winter wheat sown into uncontaminated soil positive correlation between cadmium accumulation and protein and gluten content was found (Tab. 2). Gluten index of spring wheat from uncontaminated soil was not correlated with cadmium uptake. But in spring wheat from contaminated soil and in winter wheat from uncontaminated soil significant increase of cadmium accumulation in grain with higher gluten quality (higher gluten index) was confirmed (Tab. 1, 2). For significant correlations the regression equations were defined (fig. 1-4).

Soil cadmium content	Grain protein content	Wet gluten content	Dry gluten content	Gluten index
Natural	-0,064	-0,225	-0,203	0,242
Polluted soil	0,457	0,637	0,6760	-0,526

Table 1. Simple correlation coefficients between cadmium content and some grain quality features of spring wheat according to cadmium content in the soil

Soil cadmium content	Grain protein content	Wet gluten content	Dry gluten content	Gluten index
Natural	0,72	0,468	0,535	-0,516

Table 2. Simple correlation coefficients between cadmium content and some grain quality features of winter wheat (soil with natural low cadmium content)

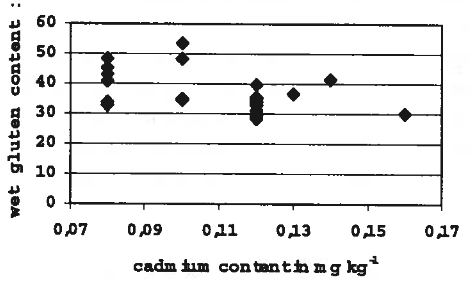

Fig.1. Relationship between cadmium uptake and gluten content in grain of spring wheat (soil not contaminated with Cd) (n=26, r^2=0,05)

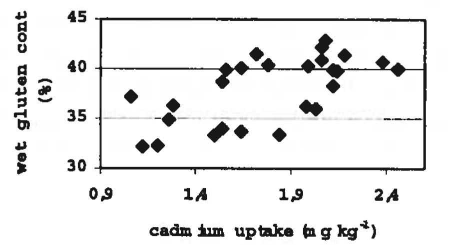

Fig.2. Relationship between cadmium uptake and wet gluten conta in grain of spring wheat (soil contaminated with 4 mg Cd kg^{-1}) (n=26, r^2=0,41; y=0,075638*x-1,08278)

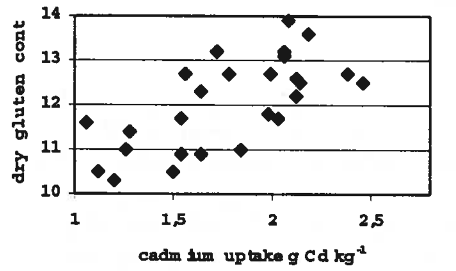

Fig.3. Relationship between cadmium uptake and dry gluten content in grain of spring wheat (soil contaminated with 4 mg Cd kg^{-1}) (n=26, r^2=0,46; y=0,264868*x-1,39956)

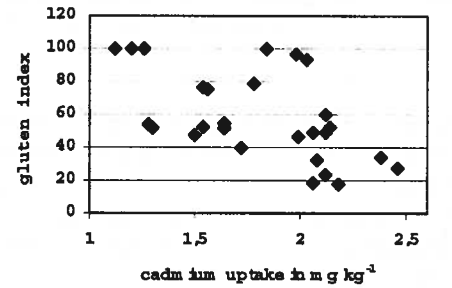

Fig.4. Relationship between cadmium uptake and gluten index of spring wheat (soil contaminated with 4 mg kg^{-1}) (r^2=0,28; y=-0,00782*x+2,260245)

Discussion

The investigations confirmed the assumption that wheat grain with higher protein content accumulates more cadmium than that with smaller level of protein. Both grain quality measures protein content and gluten amount are determined mostly by production technology, especially by nitrogen fertilization, so it might be said that intensive fertilization of wheat caused high cadmium uptake. But what is interesting that gluten index which defines gluten quality was negatively correlated with cadmium uptake. Usually cultivars with higher gluten index were better for bakery.

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PHYSIOLOGICAL EFFECTS OF TITANIUM LEAF SPRAYS ON PLANTS. INTERFERENCE WITH MINERAL NUTRIENTS

S. Kužel[1], M. Hrubý[2], P. Cígler[3], P. Tlustoš[4] and Phu Nguyen Van[4]

1. South Bohemian University, Faculty of Agriculture, Department of General Plant Production, Studentská 13, 370 05 Ceské Budvjovice, Czech Republic. E-mail: kuzel@zf.jcu.cz. Corresponding author.
2. Institute of Macromolecular Chemistry, Heyrovského nám. 2, 162 02 Prague 6, Czech Republic. E-mail: mhruby@centrum.cz
3. Institute of Chemical Technology, Department of Analytical Chemistry, Technická 5, 166 28 Prague 6, Czech Republic. E-mail: cigler@natur.cuni.cz
4. Czech University of Agriculture, Department of Agrochemistry and Plant Nutrition, Kamýcká 129, 165 21 Prague 6, Czech Republic. e-mail: tlustos@af.czu.cz

Introduction

Titanium (Ti) has significant biological effects on plants, being beneficial at low concentrations and toxic at higher ones. The beneficial effects comprise mainly the effects on biomass yield (Pais 1983), essential elements' contents (Wojcik et al. 2001) and chlorophylls' contents (Simon et al. 1988) and are summarized in a review (Carvajal and Alcaraz ,1998). Although Ti is beneficial, it is not essential – Ti deficiency does not exist. These effects are often exploited in the meaning that Ti is being added to various complex micronutrient fertilizers. We have followed in our recent hydroponical experiments the influence of the addition of Ti ascorbate to the nutrient solution on some physiological parameters (Hrubý et al. 2000, Hrubý et al. 2002). We have proposed a hypothesis about the mechanism of Ti beneficial effects on the basis of our research and recent state of art what is based on the effect usually called "hormesis". The results seem to have wider consequences so we decided to run a similar experimental scheme on plants grown on different soil types where Ti was applied on leaves. Considering the different entry pathway and generally low Ti mobility within the plant (Hrubý et al. 2000) could be expected different effects on the physiological parameters and on some metabolic and organ specific physiological functions in plant. Ti was applied in the form of organic acid complex to obtain results comparable with our hydroponical experiments done also with the identical complexed form of Ti. The application of complexed Ti(IV) is necessary due to complete hydrolysis of uncomplexed compounds of Ti(IV) under usual acidity conditions.

Methods

Plants of oats (*Avena sativa* L. cv. Zlakák) were grown in pots (20 plants per pot) on two different soil types (chernozem and cambisol) containing 100 and 164 $mg.kg^{-1}$ of available Mg. More, the concentration of Mg in each soil was adjusted by the addition of magnesium acetate solution respectively by dilution of soil with quartz sand to obtain three different Mg concentrations (2/3 of original concentration, original concentration, two fold original concentration). Four replicates per each experimental treatment were used. All treatments were fertilized by NPK identically 0.2 g N, 0.03 g P, and 0.08g K per kg of soil. The first spray [30 ml Ti(IV) citrate solution per pot] was applied after four weeks of growth, the second one (the same dose) after next two weeks. Blank alternative and two concentrations of Ti in spray (30 and 50 $mg.kg^{-1}$) were used. The oats were harvested one week after second foliar application in stage of flowering.

Following parameters were determined: the top raw weights (TRW); stated in grams per pot, Top dry weights (TDW), by drying in oven (10 hours at 105°C); stated in grams per pot, the Mg (MgC), Fe (FeC), Zn (ZnC) and Mn (MnC) concentrations in top dry mass, using AAS (Varian, SpectrAA-200 spectrometer) after mineralization in concentrated HNO_3 in microwave mineralizator (CEM MDS 2000); stated in $mg.kg^{-1}$, the chlorophylls' content (CH), by spectrophotometry after extraction of homogenized raw material with ethanol; stated in $mg.g^{-1}$ of raw leaf.

Results

The strength of influence (how much is the parameter influenced by the factor) is stated in text as the ratio of maximal and minimal value in the trend.

Ti slightly increases the TRW on the Mg-malsupplied soil, has almost no effect on TRW on Mg-normal soil and most strongly increases (up to 1.19-times increase) TRW on the Mg-overloaded soil. The effect of Ti on TDW follows similar trends as the effect on TRW. Ti has almost no effect on the Mg-malsupplied and Mg-normal soil but is beneficial on the Mg-overloaded soil (up to 1.32-times increase of TDW caused by Ti). CH is increased at low Mg concentrations in soil (up to 1.28-times). Ti has almost no effect on CH at medium Mg concentrations in soil and slightly decreases it at high Mg concentrations in soil. Ti increases (up to 1.16-times increase) the MgC at Mg-malsupplied soil but does not have any effect at higher Mg concentrations in soil. Ti strongly decreases the FeC (up to 1,76-times decrease). This effect is the stronger the higher is the concentration of Mg in soil. Ti strongly increases (up to 3.01-times increase) the ZnC at low and medium Mg concentrations in soil, but decreases it at Mg-overloaded soil (up to 2.72-times decrease). Ti strongly decreases (up to 1,52-times decrease) the MnC. The effect is obvious at any Mg concentration of Mg in soil, but being the strongest at low one.

Discussion

The interactions of Ti with other elements and the influence of Ti on physiological parameters well correspond with our previous hydroponical experiment (Hrubý et al. 2002) except the reversed trend in Fe content – it's decreased by leaf sprays of Ti. Differences among two different soil types used are only in the strength of the effect of Ti, the trends remained unchanged. Generally the effect of Ti is considerably weaker if Ti is applied on leaves than if being added to the nutrient solution. The results well correspond with proposed mechanism.

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EVALUATING THE USE OF *LUPINUS ALBUS* FOR THE PHYTOREMEDIATION OF SOILS POLLUTED WITH Zn AND Pb

Pastor J.[1], Prieto N.[1] and Hernández A.J.[2]

1 Centro Ciencias Medioambientales, CSIC, Madrid. E-mail: j.pastor@ccma.es
2 Dto. Interuniversitario de Ecología, Universidad de Alcalá. E.mail: anaj.hernandez@uah.es

Introduction

The soil of several areas of central Spain is polluted with heavy metals (Zn, Cu, Pb and Cd among others) due to past industrial and mining activities, and the presence of abandoned landfills of rubble, industrial and urban waste. In an attempt to find suitable native plants for the recovery of these soils, an evaluation was performed on the forage leguminous species *Lupinus albus* Cv. Multolupa. The behaviour of this species towards heavy metals is currently being explored by several authors.

Material and methods

Five soils of acid pH were selected from the central Spanish zone. According to FAO classification, the first of these soils is a chromic luvisol; an abandoned agricultural soil previously subjected to cereal-legume rotation, with an extremely low Zn content and an absence of Pb (soil 1). Soils 2, 3 and 4 are pasture soils with total Zn and Pb contents in the range 90 to 550 ppm and 106 to 327 ppm respectively. Soil 2 shows similar Zn and Pb levels to those found in the covering soils of mixed waste landfills (Pastor and Hernández, 2002). Soil 5 is a distric leptosol with a high total and extractable Zn and Pb content. Soils 3, 4 and 5 were sampled in the immediate surroundings of past mines. With the exception of soil 1, these soils can be considered toxic (especially soils 4 and 5). Besides Zn and Pb the following elements were also determined in soil samples by atomic absorption spectroscopy: Cu, Al, Ba, Cd, Cr, Fe and Ni. Only high extractable Zn and Pb contents were recorded. Concentrations in the soil extracts were analysed according to the method of Lakanen (1967).

Once the total and extractable Zn and Pb soil contents had been established, 5 top soil samples were obtained. Three kilogram samples of each (in quadruplicate) were placed in 22 x 15 x 8 cm containers with a lower draining grid to collect excess water. The bioassay was performed under controlled green-house conditions seeding *Lupinus albus* cv Multolupa until the start of flowering (12 weeks). Three seeds of *Lupinus albus cv.* Multolupa were planted in each container. Each specimen was then subjected to determination of the following non-invasive quantitative agronomic variables: dry weight (grs), plant height (cm), leaf diameter (cm), length and width of the foliole (mm). Middle-aged leaves were used for this purpose. Other semiquantitative character was also taken into account: vigour (plants of scarce to highly vigorous growth graded according to a 7-point scale).

ANOVA was performed on log-transformed data to determine differences among treatments. We used the least-significant difference (LSD) option with the ANOVA as a post-hoc test of significance of differences among means for the different treatments. The software used was the SPSS version 10 package.

Results and discussion

This lupin was able to grow well and flower in even the most polluted soils. Analysis of variance revealed that the soil Zn content affected plant Zn levels. The table 1 show Zn and Pb levels as absolute means ± SE rather than log values to aid comprehension. The LSD of the groupings are also provided. Treatments sharing the same letter in a column did not differ significantly at a $p = 0.05$. The mean Lupinus content of this metal, in the most polluted soil, was 850 ppm, although levels up to 1300 ppm were recorded. These Zn concentrations are higher than those observed in other species spontaneously growing in these soils (Pastor and Hernández, unpublished data). The Zn contents shown by lupins growing in the 5 soils were significantly different. The Pb levels of the soils only affected lupin in the case of soil 5.

	SOIL					PLANT	
		Zn		Pb			
	pH	Extract.	Total	Extract.	Total	Zn	Pb
Soil 1	5.0	0.1	30	0.0	0	18.4±5.2 a	0
Soil 2	5.5	5	90	7.4	106	31.8±7.2 b	0
Soil 3	5.8	70	200	70.5	224	99.0±7.3 c	0
Soil 4	6.0	166	550	183.5	327	150.3±33.0 c	0
Soil 5	5.6	700	2600	1348.3	2388	850±376 d	25.5±49.8

Tabla 1: Soil and plant Zn and Pb contents

Tables 2 shows the results of the analysis of variance and provide mean values (±SE) for the 6 agronomic variables estimated for lupins growing in the five soils. Low or very low soil heavy metal levels showed scarce effects on plant variables. Significantly different plant variables were, however, noted when the lupins were grown in soils 1 and 2 compared to soils 3, 4 and 5. Plants growing in soils 1 and 2 only showed significantly different dry weights. Those growing in soils with total Zn and Pb contents above 200 ppm (extractable contents 70 ppm), showed practically no significant morphological differences but the variables height, dry weight and vigour barely reached 50% of those shown by controls growing in non-polluted soil (soil 1). Hernández *et al.*(1995) observed that the use of high Zn concentrations in the nutrient solution significantly impaired aerial growth, weight and number of nodules in only 18 days.

	Plant				Foliole	
Soil	Vigour	Height (cms)	Dry Weight (grs)	Leaf Diameter (cms)	Length (mm)	Width (mm)
Soil 1	6.6±0.5 a	39.3±5.6 a	2.3±0.3 a	6.0±0.7 a	30±4 a	134±23 a
Soil 2	6.0±0.9 a	32.0±5.2 a	1.6±1.2 b	5.3±0.6 a	26±4 a	112±21 a
Soil 3	3.1±1.5 b	23.2±6.7 b	0.8±0.2 c	3.7±0.6 b	17±3 b	73±13 b
Soil 4	3.4±2.6 b	22.8±11.2 b	0.7±0.4 c	4.1±1.6 b	21±7 c	83±26 b
Soil 5	2.8±1.5 b	19.1±9.1 b	0.9±0.2 c	4.0±0.8 b	20±2 c	82±18 b

Tabla 2: Mean values ±SE of different agronomic characteristics of *Lupinus albus* cv. Multolupa

We also noted that the leaf diameter, and the length and width of the foliole barely reached 75% of those recorded for plants grown in non-contaminated soil (soil).

Conclusions

L. albus Cv. Multolupa would appear to be appropriate for the phytoremediation of acid soils of intermediate Zn levels. In contrast, soil Pb was not taken up by the aerial parts of this species. In general, high soil levels of both these metals affect the growth and diminish the productive capacity of this lupin.

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PHYTOEXTRACTION OF AS AND ZN BY CROPS GROWING ON A POLLUTED SOIL IN SOUTHERN SPAIN.

Soriano[1], M.A. and E. Fereres[1,2]
1 Departamento de Agronomía, Universidad de Córdoba, Menéndez Pidal s/n, Córdoba (Spain).
2 Instituto de Agricultura Sostenible, Alameda del Obispo s/n, 14004 Córdoba (Spain).

Introduction

On April 25, 1998, an accident in a pyrite mine near Aznalcóllar (Sevilla), Southern Spain, caused a toxic spill over a 4500 ha area, most of it devoted to agriculture. Following mechanical removal of toxic waste, affected soils remained contaminated with heavy metals (CSIC, 1999), particularly with Zn and As. Phytoremediation is considered one of the more promising, and environmentally sound techniques for decreasing soil pollution by heavy metals (Salt *et al.*, 1995). Use of crops for *in situ* phytoremediation is considered to have advantages over the use of *hyperaccumulator* plants (Brooks *et. al.,* 1977) due to their higher capacity for biomass production. We present here results of experiments conducted to evaluate the removal potential of Zn and As by three crops grown in the polluted area.

Matherial and Methods

The experiments were carried out between 1999 and 2000 on three experimental plots located in the affected zone, at 850 m (C1), 1700 m (C2) y 2,5 km (C3) away from the source of the spill. Outside the affected zone a plot of the same size was planted as a control (CT). Three crops were planted on each experimental plot: a winter crop (barley), a summer crop (sunflower) and a root crop (sugar beet), all under rainfed conditions. Each main plot was 50 m x 100 m and within it, subplots 16 m x 100 m were planted to each crop. Planting took place on 13 November for sugar beet and barley and on 18 February for sunflower, all at commercial densities. Following emergence, we observed significant spatial variability in plant symptoms to heavy metal toxicity; thus, we mapped homogeneous areas within each plot to carry out plant measurements and subsequent soil and plant analyses on each of the mapped areas. On each crop subplot, we identified five homogenous areas for sampling; such areas ranged from lack of symptoms and normal growth to severe symptoms and stunted growth. Intermediate areas with limited growth and moderate symptoms were also present among all the subplots. Sampling took place at three developmental stages: seedling, flowering and physiological maturity for barley and sunflower, and at the seedling stage and at harvest for sugar beet. Plants were oven dried at 70 °C to determine biomass. Subsequently, plants were milled on a metal-free mill and were analyzed for As and Zn. Element concentrations were analyzed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) according to US EPA methodology (USEPA, 1994). Sample digestion was carried out with high purity concentrated nitric acid in closed Teflon vessels in a microwave system (Jones *et al.*, 1991).

Results

Substantial variability was found in accumulation of Zn and As in plant tissues at all sampling dates. Table 1 presents results for sunflower as a representative example of the results. The variability was associated with the spatial variation in heavy metal concentration in the soil. The removal process of the toxic waste generated sources of secondary contamination at smaller scales, from container or truck spills to many other forms of contamination that soon became hidden from sight and therefore were not fully removed. The spatial variations in contaminant concentration caused a large degree of heterogeneity in Zn and As concentration in plant samples within each plot (Table 1) caused by variations in soil concentration, as it has been found previously (Soriano *et al.*, 2000). Maximum extraction values (g m^{-2}) for each crop were observed at maturity even though maximum plant concentrations were observed at the seedling stage. This is due to the overwhelming effect of biomass production relative to the acquisition of heavy metals by the root system. We did not detect major differences among species in the accumulation of either Zn or As. At harvest, the three species behaved similarly in terms of extraction amounts relative to tissue concentration of heavy metals. The maximum levels of extraction observed in this experiment were 14 mg m^{-2} of As and 500 mg m^{-2} of Zn at plant concentrations of about 300-500 ppm of Zn. Figure 1 presents the extraction amounts for the three crops as a function of tissue concentration. Extraction increased rapidly as tissue concentration increased until a maximum value was reached for Zn in sugar beet with a tissue concentration of less than 300 ppm (Fig. 1). At very high tissue concentrations, total extraction decreased in barley for Zn and reached a plateau for As (Fig. 1).

Table 1. Concentration (minimum and maximum values, mg kg^{-1}) of As and Zn in plant tissues (above ground biomass) and aerial biomass (g $plant^{-1}$) of sunflower, at the seedling stage and at maturity, growin in affected (C1, C2 and C3) and unaffected (CT) soils.

Plot	Seedling stage			Maturity		
	As	Zn	Biomass	As	Zn	Biomass
CT	0.188-0.316	36.7-59.1	2.61	0.159-0.171	20.5-24.1	215
C1	0.962-14.8	208-1519	1.25	0.047-0.791	211-308	97
C2	1.73-2.72	124-142	2.29	0.0-0.179	58.7-108	189
C3	4.10-47.8	190-348	1.26	0.487-10.8	102-335	112

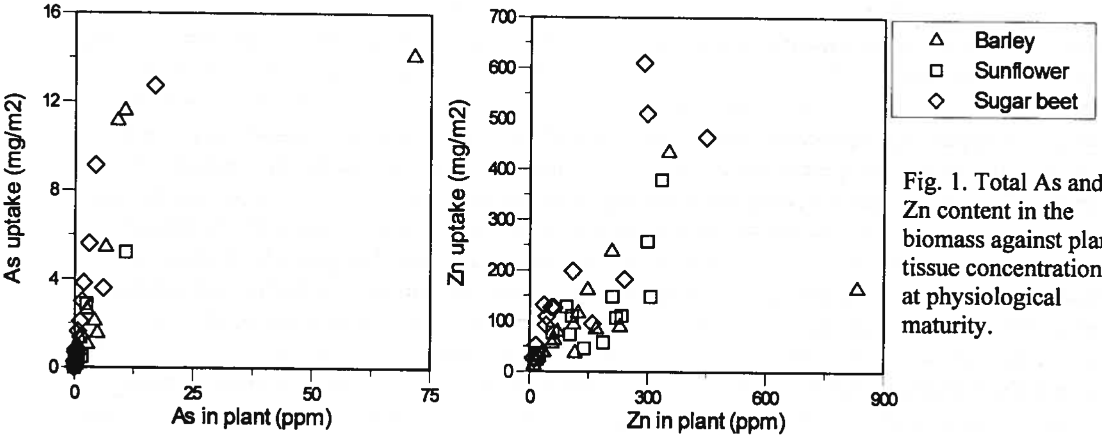

Fig. 1. Total As and Zn content in the biomass against plant tissue concentration at physiological maturity.

Conclusions

Measurements of the extractive capacity de As y Zn by various crops at different phenological stages demonstrated that, for phytoremediation purposes, the major factor governing the amount of heavy metals extraction was biomass production. No major differences in extraction capability were observed among crops for As and Zn, despite the large differences among the three crops tested.

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UPTAKE OF HEAVY METALS BY AGRICULTURAL CROPS PLANTED ON NINE DIFFERENT SOILS TREATED BY SEWAGE SLUDGE

P. Tlustoš, J. Balík, J. Száková, D. Pavlíková, A. Hank, P. Dvoák, and S. Kužel#

Czech University of Agriculture, Department of Agrochemistry and Plant Nutrition, Kamýcká 129, 165 21 Prague 6, Czech Republic. e-mail: tlustos@af.czu.cz
South Bohemian University, Faculty of Agriculture, Department of General Plant Production, Studentská 13, 370 05 Zeské Budjovice, Czech Republic.
E-mail: kuzel@zf.jcu.cz.

Introduction

Sewage sludge is a source of potentially toxic elements differing in their content due to the source of waste material and location, (Smith, 1996). Sludge of low content of potentially toxic elements is suitable for field application (Balík et al., 1998). Organic matter content, content of clay particles and sesquioxides, and soil pH are main parameters affecting adsorption of elements in soils (McBride, 1989). Binding capacity of elements on surfaces of different materials significantly differed from material and element tested. The rate of element uptake by plant biomass is also substantially affected by crop species grown on different soils (Tlustoš et al., 1997). Total content of elements in plant biomass is also affected by the yield increase at soils treated by sewage sludge.

The main objective of our study was focused on the accumulation of four potentially toxic elements Cd, Ni, Zn and Pb by above ground biomass of spinach, oat, and maize grown on nine soils with substantially different soil properties treated by processed fresh sewage sludge and on the changes of availability of both elements in soil when sewage sludge was applied.

Methods

The accumulation of elements was investigated in a three year pot experiment. Nine soils taken from surface layer (0 - 20 cm) of arable land covering Fluvisols, Cambisols, Luvisols, and Chernozems was used each year. Only one soil (Fluvisols - Píš□any) showed higher content of elements exceeding Czech limit values which restricted waste application on land. Other soils did not substantially exceed average content of investigated elements in Czech soils.

Fresh homogenous sewage sludge with 26 - 28 % of dry matter and the mean total content of Cd 3.68 $\pm$ 1.03 $mg.kg^{-1}$, Ni 44.74 $\pm$ 2.86 $mg.kg^{-1}$, Pb 172.4 $\pm$ 2.86 $mg.kg^{-1}$ and Zn 1437 $\pm$ 10.3 $mg.kg^{-1}$ from one waste water plant was used in the experiment.

Soils taken each year in the same plot were air-dried, and 5 kg of each soil was thoroughly mixed with N, P, K applied in NH_4NO_3 and K_2HPO_4 at control treatments and with the same amount of nutrients plus processed fresh sewage sludge in equivalent to 20 Mg. ha^{-1} at observed treatments. Prepared mixture was filled into plastic pots, sown by seeds of different crops and planted up to harvest. Spinach (*Spinacia oleracea L.*) var. Monores, (*Avena sativa L.*) var. Pan, Maize (*Zea mays L.*) hybrid DK 254 were planted at each designed treatment. After harvest, above ground biomass was checked for fresh and dry biomass, grounded and analyzed.

Plant material was decomposed by modified dry ashing procedure, total soil content was determined after two step decomposition using HF acid, and available portion of elements in soil was determined in the extract of 0.01 $mol.l^{-1}$ of $CaCl_2$ solution. Content of elements was determined by atomic absorption spectrometry using flame and flameless techniques on VARIAN SpectrAA-40 equipment. Quality of analyses was controlled by reference materials.

Results and Discussion

The results of the experiment showed positive effect of sludge application on the mean yield of all three crops. The addition of sludge increased an average yield of all three crops, but the effect of sludge application differed by the soil used as well as crop planted. Spinach introduced highest yield increment among all crops at acid Cambisols. The rest of soils treated by sludge improved spinach yield, too. Completely opposite effect of sludge addition was found in the case of maize. Soils of higher clay content negatively affected the growth of maize and the addition of sludge improved soil properties and the yield of maize on Luvisols and Chernozems. The lowest yield differences among soils used in the experiment were found when oat was planted. The lowest relative yield effect of sludge application was found on Fluvisols and significantly higher at Luvisols and at Chernozems. Cambisols also introduced very similar average yield effect of sludge application, but the standard error of yield at Cambisols was so high. Spinach showed the highest accumulation of Cd in biomass among crops at all soils. Oat accumulated lower amount of Cd and the lowest Cd content was found in maize. Majority of sludge treatments introduced plants with lower Cd content mostly due to „their dilution effect“. High differences were found at soils of higher Cd availability at Fluvisols and Cambisols in the case of Cd probably due to improvement of binding capacity by addition of sludge organic matter.
Mean content of Ni in plant biomass was higher than Cd one and showed the same order. The sludge treatment contained less Ni in majority of spinach treatments and at five soils at maize experiment. Only oat biomass accumulated more Ni at sludge treatments than control ones. The accumulation of Ni in plants was not significantly correlated with any of determined soil properties.
Spinach also showed the highest accumulation potential for lead in above ground biomass confirming its high accumulation potential for cations. Maize contained about half amount of lead compare to spinach, but showed higher mean concentration (0.288 $mg.kg^{-1}$) than oat (0.093 $mg.kg^{-1}$). The addition of sludge did not increase lead content in plant biomass in majority of treatments, even at one Fluvisols containing significantly higher amount of Pb.
Spinach confirming the highest accumulation ability in case of Zn as well. Oat accumulated lower amount of zinc and the lowest Zn content was found in maize. The yield improvement at sludge treatments did not lead to decrease of Zn content as in the case of Cd. Planted crops mainly introduced higher Zn content at sludge treatment, except partly contaminated Fluvisols.
Mean binding capacity of all elements at individual soils was determined by soil extraction using calcium chloride. Available portion of Cd fluctuated from 0.3 % at Chernozems up to 15.2 % at Fluvisols. Higher fluctuation in Cd extractability at sludge treatments showed soils with very low content of total Cd in soil. The application of sludge increased total Cd content from 1 to 16 % with no consistent effect on Cd mobility in soil. Extractability of Ni was lower than Cd and fluctuated from 0.14 % to 2.51 %. The sludge addition increased Ni mobility in soil and showed lower binding capacity than in the case of Cd. Higher effect of sludge application was found in the case of Zn, and the majority of treated soils showed higher Zn mobility. On the other hand very firm bounds of Pb did not allow to extract its high portion when sludge was applied.
Results of the experiment showed significant effect of investigated element as well as soil type and growing plant on the element availability and accumulation.

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Workshop on research for development

AGRICULTURE RESEARCH AND FOOD SECURITY: THE ROAD AHEAD

Isabel Alvarez
FAO - Servicio de Fomento de la Investigación y la Tecnología, Viale delle Terme di Caracalla, Rome, Italy

Food security may be considered at the individual, household, national, regional and global level. At the household level, it describes a situation in which all households have both physical and economic access to adequate food for all members and the access is stable. This implies: accessibility, availability and stability. Accessibility refers to the fact that many people suffer from hunger because they do not have the means to produce or purchase the food they need. Adequate food availability means that on average, sufficient food supplies should be available to meet consumption needs. Stability refers to minimising the probability that, in difficult years or seasons, food supplies might fall below consumption requirements.

During the last decades, per capita food supplies increased in three regions (Near East and North Africa, East Asia and Latin America and the Caribbean), but stagnated at low levels in South Asia and actually declined in sub-Saharan Africa. The incidence of chronic undernutrition in developing countries declined from 35 to 27 percent of the total population although it remained high in absolute numbers because of population increases (FAO, 1996a). At present, there are 86 countries defined as low-income food-deficit countries. The majority is in Africa (43), followed by Asia (21), Latin America (9) and Oceania (7). The European Region includes six (Albania, Armenia, Azerbaijan, Bosnia-Herzegovina, Georgia and The Former Yugoslav Republic of Macedonia).

Global food security depends on maintaining and conserving the natural resource base for food production in both developed and developing countries. There is increasing evidence that as agricultural production becomes more intensive, the natural resource base can become degraded unless specific conservation measures are put in place (FAO, 1996b). During the period 1960-1995, yields of the major cereals, rice, wheat and maize, more than doubled in many regions of the world as a result of the introduction of improved varieties with matching technological packages in what have been called the green revolution (FAO, 1996c). Some of the most frequent criticisms to the green revolution are: a) its impact on the poor has been less than expected; b) it has not reduced, and in some cases it has encouraged, natural resources degradation and environmental problems; c) its geographical impact has been limited; and d) there are signs of diminishing returns (Conway, 1998).

Future research themes

Research investments in the natural and social sciences for agriculture and rural development are declining in most countries in spite of clear indications of their large returns to society. There is real concern that past advances in agricultural productivity cannot be maintained and that agriculture in developing countries will be by-passed in new scientific advances that do not relate to the needs of food-insecure people (FAO 1996d).

The research agenda must respond to the problems of food insecurity, poverty and resource and environmental degradation. Much of the agriculture research being carried out is currently focused on crops and issues of concern to the developed countries and provides little support to the production of tropical food crops with the exception of the research being carried out at some centres of the CGIAR (Consultative Group on International Agricultural Research). A major challenge is to ensure that the global community does not develop policies and procedures that will exclude issues relevant to farmers and herders in tropical and marginal areas. Additionally, a determined world-wide effort should be made to encourage the rapid transfer of safe and appropriate technology to those in greatest need. Research on soil degradation is needed in many areas of developed and developing countries. Crop breeding for tolerance to abiotic stresses, crop rotations to improve soil characteristics and fertility and new techniques to reduce input applications and water use are potential areas for international cooperation. There is further scope for exploring the use of plant genetic resources to increase productivity and diversification and the reduction of post-harvest losses. Particular attention should be paid to the conservation of local breeds and the genetic resources they represent which will enable farmers to respond to changing environmental conditions as well as to consumer preferences. Genetic improvement of local breeds must also receive attention to attain better animal nutrition and husbandry to exploit the yield potential of established breeds (FAO, 1996c).Most farmers in food insecure conditions spread risks by integrating a multitude of crops, livestock and tree crops into smallholder production systems. Research efforts need to be promoted to make mixed farming systems more productive, particularly in those situations where external inputs are not available (FAO, 1999d). The experiences accumulated through general development studies suggest that science and technology are essential but cannot by themselves solve the food security problems of developing countries. Appropriate social, economic and institutional factors must also be present in order to maintain what has been accomplished. Further advances need to consider:

- restructuring the linkages between international and national research and extension services in order to have greater involvement of stakeholders and sensitivity to food security priorities;
- continued advances in research and technology to produce the basic foods that people need but with stronger emphasis on mixed farming systems staple crops, livestock, poultry and fish;
- policy reform that addresses access to capital, incentives for investment in research and productivity-enhancing farming systems;
- Promotion of more equitable distribution of benefits by devising productivity-enhancing strategies that exploit the comparative advantage of different gender groups and benefit lower-income food-insecure groups (FAO, 1996c).

The World Food Summit Plan of Action contains seven commitments to promote food security (FAO, 1996e). FAO has an important role to monitor the implementation of these commitments and to analyse the factors that favour or hinder the attempts to put the commitments into practice. The commitments will require national action as well as international efforts to supplement and reinforce the national action.

The case of the agricultural research systems of Central and Eastern European (CEE) countries and Commonwealth of Independent States (CIS) needs special attention within Europe. Many countries have solid scientific communities in need of reinforcing alliances with the international scientific community. They are also in need of improving extension services that will provide technical assistance to an emerging rural private sector.

The success of the global agricultural research system is dependent upon a strong national research capacity, complemented by effective technology transfer mechanisms. The two-way linkages between research and extension need to be strengthened and particular emphasis placed in giving extension assistance to the poor and food-insecure, including women.

A carefully drafted and delivered agricultural research agenda for food security with determined backing from all developing and industrialised countries, government and private sectors alike is one of the best tools that the global community can devise for contributing to food security during the next two or three decades.

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EU/INTERNATIONAL CO-OPERATION FOR RESEARCH IN AGRICULTURE: FACING THE 6TH FRAMEWORK PROGRAM

EUROPEAN COMMISSION. RESEARCH DIRECTORATE-GENERAL
Unit 06 - INCO: International scientific cooperation projects
Presented by **J.L. Araus Ortega.**Prof. Plant Physiology, University of Barcelona. Seconded National Expert EC Commission - DG Research. SDME 1/149 Unit 06 – INCO. Brussels

Introduction

In order to insure the increase of the international dimension of the European Research Area (ERA), bi-regional dialogues have been established, in coordination with Member States, and instruments offering are:

- The possibility for Third countries to participate in the seven priority thematic areas defined in the specific programme "Integrating and Strenghtening the ERA". That will help the European, and associated, researchers to have access to knowledge and expertise existing elsewhere in the world. In addition it will also facilitate a Europe's stronger and coherent participation in the research initiatives related to global issues.
- The support of Specific Activities on S&T cooperation contributing to the fair and sustainable development and socio-economic progress of some groups of countries (NIS, MPC and DCs) in coordination to Community's foreign policy and development aid policy.
- The opportunity for more mobility of scientists between Europe and Third countries which will facilitate the implentation of the two above mentioned.

1. International Scientific & Technological Cooperation integration into the seven priorities
The seven priority thematic areas of research range from 'genomics and biotechnology for health' through 'citizens and governance in a knowledge-based society'.
2. International S & T Cooperation. Priorities for Specific Measures in support of international co-operation with developing countries (ACP, Latin America and Asia)

In addition, a limited number of research priorities have been identified through this international dialogue over recent years as requiring scientific cooperation on more specific areas. The development and application of knowledge, which is specific to the partner regions' physical, ecological, socio-economic and cultural environments is the main objective of international EU S&T Co-operation. This takes into account the fact that in the international "knowledge & learning continuum", the role of *Research for Development* based on equitable and performing international scientific partnerships is irreplaceable. The production and use of public knowledge goods requires the involvement and firm commitment of the public sector in close articulation with private sector and society's institutions. Sustainable and equitable development in developing economies has priorities, which can be clustered in three major global thrusts with cross-cutting issues betweem them like the rural-urban interface for sustainable settlements: 1) Health and Public health; 2) Food Security; 3) Rational Resource Use.

For all three thrusts would be naturally, five main "horizontal components to be tackled, namely: a) a genuine and equitable partnership; b) an emphasis on interdisciplinary approaches concomitantly addressing the ecological, economic, social and institutional dimensions; c) the use of ICTs underscoring the Information Society and its role in Development; d) investments in human capital, with emphasis on functional linkages with Higher Education and with Training activities for organisational and technological innovation; and e) effective communication with economic and political decision makers and stakeholders in society at large.

Research should also focus on policy analysis opening new opportunities for harnessing economic globalisation and trade for empowering local communities to make full use of natural resource endowment and strengthening local quality of life

1. Health and Public health: Promoting healthy societies. Research to address crossectoral policy which promotes societal commitment and participation in order to ensure the sustainability of measures for disease prevention and control. This implies a health systems approach. Evidence-based research into the organisation and management of functional and cost-effective health services that are socially equitable and financially sustainable. Development of strategies to prevent and control through health systems of regionally relevant poverty related diseases in rural and urban communities, including sanitation and nutrition aspects. Research into diseases will be limited to tropical and specific diseases and conditions encountered in the partner regions.

2. Food Security. Food security has to be treated on a broader front than only through thechnology. Therefore the approach should include policy research, not only agricultural policy but also the interactions of all policies which could affect food security, system research in order to insure the sustainability of the process as well as research on tehnologies. It will concern as well as the quantitative aspects than the qualitative (nutritional, safety and market value). It concerns plant , animal and fish production and processing.

Biodiverse, biosafe and value added crop: Research for increasing production of biosafe and value added crops of local or regional importance, others than the five main crops coverded by the CGIAR centers (maize, wheat, rice, potato, and cassava), to increase market-oriented products, which are environmentally friendly and safe for consumption. This will be achieved through integrated crop managment based on Good Agricultural Practices, crop breeding for biotic and abiotic stress, appropriate post-harvest technologies and quality standards and quality assurance systems according to subjects of regional ad international agreements

*The new frontier - managing aquatic farming:*Development of integrated management approaches based on suitable source populations safeguarding aquatic biodiversity, disease prevention and control, safe and sustainable aquafeeds and supporting energy efficient 'farming down aquatic food webs'. The economic context created by international food safety standards and the need for internalising environmental costs and demand for environmental sustainability at local and wider scales will need to be addressed.

Health Security of Livestock Populations: Meeting the various and diverse pressures put on animals by production systems of present day societies with emphasis on ensuring public health through the control of zoonoses and food safety; the sustainable management of animal populations in accordance with the requirements of the national and international trade; enhancing animal productivity to reach the economic goals while preventing negative impacts of animals on terrestrial and aquatic environments.

3. Rational Resource Use

Managing arid and semi-arid ecosystems: Researching opportunities for responsible resource management and 'valorisation' of renewable resources and related knowledge, including traditional one, through an enabling policy environment which promotes restoration, conservation and sustainable use of resources and which provides support for stable livelihoods, through diversifying sources of income and exploring innovative use of biological diversity in arid and semi-arid environments.

Conserving humid and semi-humid ecosystems: Responsible renewable resource management through an enabling policy environment, which promotes restoration, conservation and sustainable use of resources of humid and semi-humid ecosystems, including forests. Bio-prospecting for value-added products from genetic resources and 'valorisation' of related knowledge, including traditional one, which provide support for stable livelihoods, through diversifying sources of income and exploring innovative use of biological diversity.

Integrated Strategies for reconciling multiple demands on coastal zones: Increasing understanding of coastal zone complexity, including through structured analysis of empirical evidence with a view to extract new knowledge and meta-rules, which can contribute to reconciling multiple demands on limited coastal resources and serve as decision support with a view to mitigate degradation and find equitable and innovative solutions taking into account the social, institutional, environmental and economic context.

VALUATION OF AGRICULTURAL PRACTICES TO IMPROVE EFFICIENCY AND NVIRONMENT CONSERVATION IN MEDITERRANEAN ARID AND SEMI-ARID RODUCTION SYSTEMS. (MEDRATE): AN EXAMPLE FOR CONSERVATION ILLAGE.

[10] Cantero-Martinez C., [2]Ameziane T.,[3] Karrou M., [4] Benbelkacem A., [5] Sghaeir M.B.A., El-Shaer H., [7] Avci M., [8] De Pau E., [9] Pisante M., [10] Angas P., [1,10] Romagosa.

Universitat de Lleida-IRTA. Rovira Roure, 191. 25198. Lleida. Spain;
. IAVHassan II. Morocco; 3. INRA. Morocco; 4. ITGC. Algerie; 5. IRA.Tunisia; 6. DRC. gypt; 7. FCCRI. Turkey; 8. ICARDA. Siria: 9. COTIR. Italy; 10. CIHEAM-IAMZ. Zaragoza. pain.

NTRODUCTION

.ainfed agriculture is practised over the largest arable crop surface area in the Mediterranean. he arable and livestock production that accompanies rainfed agriculture in the south and east of ie Mediterranean have been and continue to be the main and often only base of economic ctivity in these areas. The maintenance and efficacy of the agricultural systems in these areas is ierefore an indispensable condition for the livelihood of the rural population and for a decline ı their migration and concentration in the urban areas.

he MEDRATE project is part of the activities within EC (EuropeAid) – CIHEAM Cooperation roject, 1998-2002 Regional Action Programme "Rainfed agriculture"
AP-RAG. MEDRATE project aims to evaluate and assess the impact and adoption of gricultural technologies specially adapted to rainfed agriculture within the framework of well escribed and defined farming systems. The evaluation and the assessment of impact will be arried out at three levels: 1. Research, 2. On-farm trials / demonstration and 3. At farm level, ısing quantitative and qualitative data. Data collection is done by using experimental data and hrough surveys. The following countries participate: Algeria, Egypt, Italy, Morocco, Spain, yria, Tunisia and Turkey. This project is being carried out until February 2003. In this paper he preliminary results are presented taking Conservation Tillage as an example of evaluated echnology in the selected farming systems of the represented areas.

METHODOLOGY

The project has been developed in the following phases:

Selection of a set of the main Mediterranean Rainfed Farming Systems in which the study **is** going to be carried out. This selection has been made taking as reference those published by ICARDA. The systems selected are Wheat based system; Barley based system, Rangeland-Pastures-Livestock system and Horticultural/Trees system.

Selection of representative pilot areas of the main Mediterranean Rainfed Farming Systems in Algeria (2), Egypt, Italy, Morocco (2), Spain, Syria, Tunisia and Turkey.
These areas have been selected in such a form that it covers all range of farming systems with different rainfall levels from 100 mm up to 500 mm.

Characterization and Evaluation of the Farming systems of each selected area. This was done following a specific guideline for all the groups.

Selection of the techniques to be evaluated. A total of 15 technologies were selected for evaluation covering Land and Water management (Reduced and no-tillage, water harvesting, supplementary irrigation); Crop Production (soil test calibration & fertilizer recommendation, seeding & planting techniques, improved plant material, weed control, new crops and cropping systems); Animal Production (Alternative and non conventional feed resources, control of reproduction, breeding [selection and crossing], processing of animal products [dairy, wool & hair, pelt], forage conservation, range management and preservation) and technical and technical-economic management programmes.

Selection of criteria for the evaluation of the technologies. Evaluation has been carried out at the three levels and different criteria for assessment were chosen taking into account mainly aspects such as yield level and stability, quality of the obtained products, cost and margins, technical feasibility and need for training, gender impact, environmental impact and social acceptance. Questionnaires specific for research and farm level evaluation were tailored.

Evaluation on research and on trial experimentation has been done through an intensive review of the available data and literature in the selected areas, following the specific questionnaire. On farm technology adoption is being actually evaluated by specific inquiries to the farmers, advisers and technical experts of the selected areas.

RESULTS

The presentation in the Workshop will explain all the methodology process carried out. Also the results of the evaluation on research level for conservation tillage technology will be shown as an example.

Specific deliverables of this project are: 1. The document that will include all the methodological aspects of the project and the main results obtained in the evaluation, adoption and further recommendation of these technologies, 2. A data base with all the obtained results; and 3. A website with all the main information obtained and the further recommendations for the development and adoption of these technologies in the area.

For further information of the Regional Action Programme "Rainfed agriculture" RAP-RAG and MEDRATE project see www.iamz.ciheam.org/RAP-RAG

XPLORE ON-FARM FOR RAINFED CEREAL-BASED CROPPING SYSTEMS IN HE MAGHREB

ómez Macpherson, H[1], Rawson, HM[2] and El-Mourid, M[3]
FAO, Crop and Grassland Service, Viale delle Terme di Caracalla, 00100 Rome, Italy
UTC Bombala, Australia
ICARDA Regional Office, Tunisia

'ater shortage is the major abiotic factor limiting growth and yield of cultivated rainfed crops in lediterranean environments. The damaging effect of a drought period will depend on its ıration, on how much water is stored in the soil and the proportion that the crop can access, ›w fast it is used or lost, and on the crop phenological stage at that time. Crop management ıould make as much of the rainfall available to the crop as possible and at the right times in ıenological development to form the best combination of yield components to maximize yield. ther factors that may reduce yield significantly are late frosts, high temperatures and any 'edominant damaging pest, disease or weed. Understanding the relationship between all these ıctors and crop growth and yield is the first critical step towards intelligent crop management nder the prevailing environment.

XPLORE ON-FARM is a methodology aimed at improving understanding of the crop and local ıvironment through on-farm agronomic trials. It is a dynamic process in which local reference alues are obtained through on-farm research and are used to detect potential areas for nprovement. This methodology requires full participation and interaction of farmers and ıcilitators (researchers, extensionists, NGOs).

XPLORE ON-FARM methodology is proposed to improve sustainable productivity of cereal-ased rainfed systems. A set of agronomic trials is proposed that address major yield-etermining crop management issues. The trials are not fixed recipes with fixed ingredients but onceptual recipes that encourage the use of locally available ingredients and encourage ıodification in order to address local needs and circumstances. The set is not complete. Further ompletely new experiments will be required to address problems not contemplated here.

'he general objective of the approach is to improve sustainable productivity of rainfed cereal-ased systems by: i) increasing understanding of the local environment and how it, the crop and ther yield-determining factors interact; ii) improving management of cropping systems and hus, sustainable yield; and iii) increasing diversification.

Methodology

On-farm trials are proposed using guidelines prepared by the Crop and Grassland Service of FAO (Rawson *et al.*, 2002). The guidelines are a set of pamphlets each addressing an agronomic ıspect of rainfed cereal-based systems:

- optimum cereal adaptation to growing season (how to choose sowing date and variety);
- cereals crop establishment (optimising sowing rates and methods and dealing with weeds);
- crop rotation (the need for and use of break crops);
- conservation tillage (which tillage system is right for the farm); and
- wheat nitrogen fertilizer use

Each pamphlet is independent, containing its own experiment and background material, but the series is linked and addresses the same farming system . The thinking behind all pamphlets is that there is no farming package that will fulfil the requirements of a whole region; thus, each pamphlet provides options and explains when these options should be tried and why.

The methodologies can only be tested in the field. Thus, an Evaluation Project is proposed to fine-tune the pamphlets. The resulting product and the experience gained during the tuning process will set the basis of an Implementation Project.

The following activities are contemplated in the Evaluation Project (Figure 1):

1. Identify the zone/region within the country in collaboration with the Ministry of Agriculture (MoA) and ICARDA.
2. National and international (ICARDA and FAO) agronomists identify required adaptation trials and adapt FAO material to local needs during a workshop:
   - first review of pamphlets and identify other critical topics;
   - participants develop, with FAO technical assistance, new pamphlets on identified topics.
3. Discuss and define workplan with local communities:
   - identify key adaptation trials and do second review of pamphlets with farmers;
   - identify collaborating farmers;
   - define workplan for conducting trials and training needs.
4. Training activities, for example:
   - participatory methods (how to improve communication between farmers and facilitators
   - sustainability concepts, sustainability indexes;
   - methodologies for conducting demonstration trials;
   - local manufacturers (making and adapting reduced tillage machinery);
   - diversification: market opportunities, farmers organizations, livestock integration (farm planification for including livestock production);
   - specific training for women.
5. Conduct trials.
6. Evaluation of the project. Lessons learned. With tested and improved methodology available, formulate the Implementation Phase (Up-scaling phase).

Expected outputs:

– increased understanding of the local environment and of interaction of major factors affecting yield (participating farmers, researchers and extensionists);
– tuned technology adopted by farmers;
– sustainable farm productivity increased;
– non-cereals crops adopted;
– methodology improved and adapted to local needs;
– implementation (up-scaling) project formulated.

Figure 1. Diagram showing activities, collaborators and expected outputs in the evaluation project.

Evaluation Phase		outputs	
1^{st} Review of material	MoA (researchers + extensionists) +ICARDA + FAO	material (pamphlets) adapted; researchers and extensionists committed to project	EVALUATION OF METHODOLOGY
⇓			
Define activities & 2^{nd} Review of material	community + researchers + extensionists	plan of activities defined; collaborating farmers identified; pamphlets adapted to address major local needs	
⇓			
Conducting trials Training	collaborating farmers + researchers + extensionists + ICARDA	optimum management identified and adopted by farmers	
⇓			⇓
Final evaluation	community + researchers + extensionists + ICARDA + FAO	methodology ready for up-scaling	⇐
⇓			
Formulation of Implementing Project	MoA (researchers + extensionists) + ICARDA + FAO	implementation project formulated	

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ıANAGEMENT OF ORGANIC RESIDUES IN AGRICULTURE: AN EUROPEAN 'ERSPECTIVE

osé Martinez[1]
Head Livestock and Municipal Waste Management Research Unit, Cemagref, 17 avenue de :ucillé, CS 64427, F-35044 Rennes Cedex. E-mail : jose.martinez@cemagref.fr
 Co-ordinator of Ramiran, Research Network on Recycling of Agricultural Municipal and ndustrial Residues in Agriculture (Fao European Cooperative research network).

ntroduction

Basically, one could state that there is no possible animal life without a production of organic esidues (Fardeau, 1999). Among this residues, animal manures are by far the more important low. In the very, very recent past in the West, we have built a new type of urban lifestyle from vhich animals are physically excluded (Hodges, 1999). In these new societies, our contact with nimals is limited to buying animals products in shops and supermarkets where there is virtually ıo evidence of the animal itself. Basically, animal production is a biological transformation process with an influx of feed, water and air, the production of meat, milk and eggs and the generation and release of large amounts of liquid and solid manure and air pollutants such as gases into the environment. Recycling the wastes of domesticated animals, either via natural ecosystems or actively by man, is now considered an important and, in many cases, the rate letermining step in the development of the Livestock sector.

Animal manure and the environment

Animal agriculture can contribute to pollution in three ways. First soil pollution can be caused by applying extremely high rates of nutrients to the land (through manure) and creating an mbalance of nutrients that can cause poor plant growth. Second, water pollution can be caused by direct runoff after field application of manure or by leaching caused by excessive nutrient applications or leaking earthen manure storages; and by direct runoff into poorly sealed wellheads. Third, air pollution can be caused within the buildings and during land application from odours and gases created by manure decomposition, microbial agents, and dust from feed systems and the animals (figure 1).

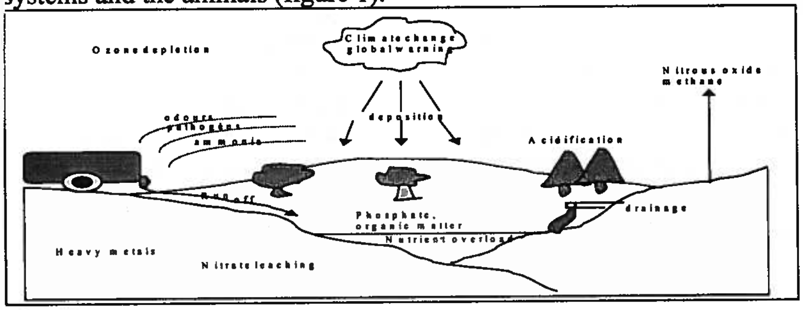

Figure 1. Soil, water and air pollution resulting from agricultural activity.

Nitrogen flows in animal production

Nitrogen plays an important role in animal production because it is essential for the production of animal tissue, milk, eggs and wool. Based on N contents in meat (2.5%), milk (0.5%) and eggs (2%) the global livestock production contains roughly 12 Tg N. The global N excretion by animals is about 102 Tg N per year. Therefore, the global N intake by animals is 114 Tg N per year, yielding an efficiency of N use of about 10%. If we consider the global agricultural sector as a big farm, N budget (figure 2) shows that the quantity of animal manure N generated is much higher than the amount of fertiliser used, while that removed in products for human consumption is only 20 Tg. An additional 30 Tg is exported, primary as grain and animal feed. Although animal manure is recycled to cropland, up to half of the manure N may be volatilised to the atmosphere as NH_3 prior to it's incorporation into soil.

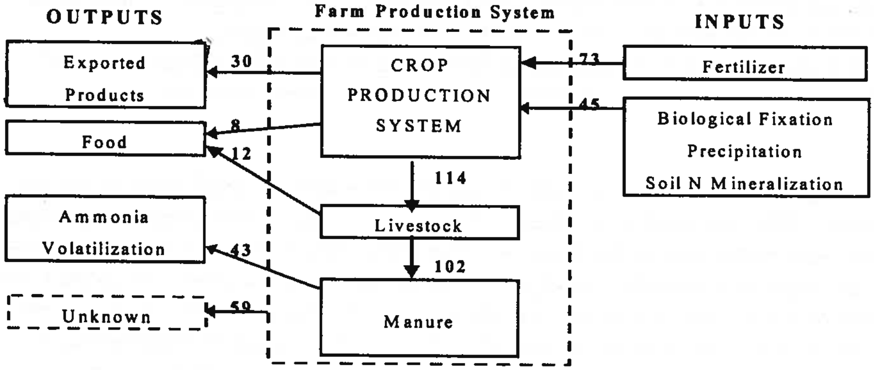

Figure 2. Annual N budget (T g N) for global agriculture (modified from van der Hoek, 1998).

Major environmental problems arise from the excessive use of nitrogen compounds. Among these are (i) acidification of forests and natural ecosystems through atmospheric deposition of ammonia (NH_3), (ii) eutrophication of inland waters and costal seas mainly by organic N and nitrates, (iii) contamination of groundwater by nitrates and (iv) a contribution to the global warming problem by nitrous oxide, N_2O.

Regulations for organic residues utilisation

Most European countries have similar regulations regarding livestock farming including (i), licensing required for housing animals, (ii), storage of manures and slurries to enable a better agronomic utilization and (iii), prohibited periods for land spreading (usually the winter months of November to February). There are however some differences between countries (and even between regions of the same country) as a consequence of the local situations. A common pollution concern is nitrate contamination of water, but in most countries there are other pollution issues as well eg, ammonia emission (in the Netherlands) and odour nuisance (in UK and Greece). Integrated pollution control (IPC), as a principle of environmental protection and management, aims to minimise the overall environmental impact of human activities by taking into account pollution of air, water, land and the human environment, and identifying the action that causes on balance the least damage potential disadvantages, necessary follow-on action, and cost.

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CONTRIBUTION OF CZECH WINTER WHEAT BREEDING TO PROFITABILITY OF CURRENT AGRICULTURAL SYSTEMS AND ENVIRONMENTAL QUALITY

Sip V.[1], Bobkova L.[2], Chrpova J.[1], Skorpik M.[1],

1 Research Institute of Crop Production, 161 06 Prague – Ruzyne (Czech Republic)
2 SELGEN a.s., Breeding Station Uhretice, 538 32 Uhretice (Czech Republic)

Introduction

Wheat is the most widely grown and consumed food crop. Both better crop management and improved cultivars are needed to meet the challenge: one billion tons of wheat by 2020. In any case wheat production need to be economical and satisfy the requirements for sustainable development of agriculture enhancing environmental quality and the resource base on which agriculture depends. It is obvious that wheat breeding can highly contribute to the fulfilment of these requirements.
The objective of this contribution was to show the progress in wheat breeding oriented to the development of cultivars meeting the requirements for high productivity and effective response to different environmental conditions and cultural practices.

Material and methods

The study is based on two types of experiments. The first experiment included seven relatively older winter wheat cultivars (1 – Table 1) in which the effects of cultivar and cultural practices (N nutrition, application of growth regulator Retacel and fungicide Tango) on grain yield and grain quality characters was studied in different environmental conditions (Sip et al., 2000). The second trial performed at the location Uhretice for three years (1999-2001) included six winter wheat cultivars bred in the Breeding Station Uhretice, SELGEN a.s. (three of them in cooperation with RICP Prague-Ruzyne). This experiment (2) had seven variants: 1- control variant (without application of pesticides and additional N nutrition and with the recommended sowing rates and dates) and combinations of 2- high/low intensity (high intensity consisting in additional application of 40 kg of N ha^{-1}, two fungicide applications and 1 l ha^{-1} of Stabilan regulator), 3- sowing rate (recommended/ lowered by 1 mil. of sprouting seeds), 3- sowing date (recommended- end of September/ sowing date postponed till the beginning of November).

Table 1. Characteristics of the examined winter wheat cultivars

Cultivar	Year of registration	Breeder	Earliness*	Plant height (cm)	Bread-making quality **	Experiment
Regina	1982	SELGEN a.s.	2	93	A	1
Samanta	1993	SELGEN a.s.	0	95	A	1
Bruta	1994	Monsanto com.,Branisovice	1	97	A	1
Siria	1994	SELGEN a.s.	3	97	B	1
Alka	1995	SELGEN a.s.	0	97	A	2
Alana	1997	SELGEN a.s.	2	98	A	2
Sarka***	1997	SELGEN a.s., RICP Prague	0	84 *(Rht2)*	B	1and 2
RU51A	tested 1994-7	SELGEN a.s., RICP Prague	0	88	A	1
Vlasta	1999	SELGEN a.s., RICP Prague	2	89 *(Rht2)*	B	1and 2
Mladka***	2002	SELGEN a.s.	0	85 *(Rht2)*	C	2
Rheia	2002	SELGEN a.s.,RICP Prague	-2	90 *(Rht1)*	B	2

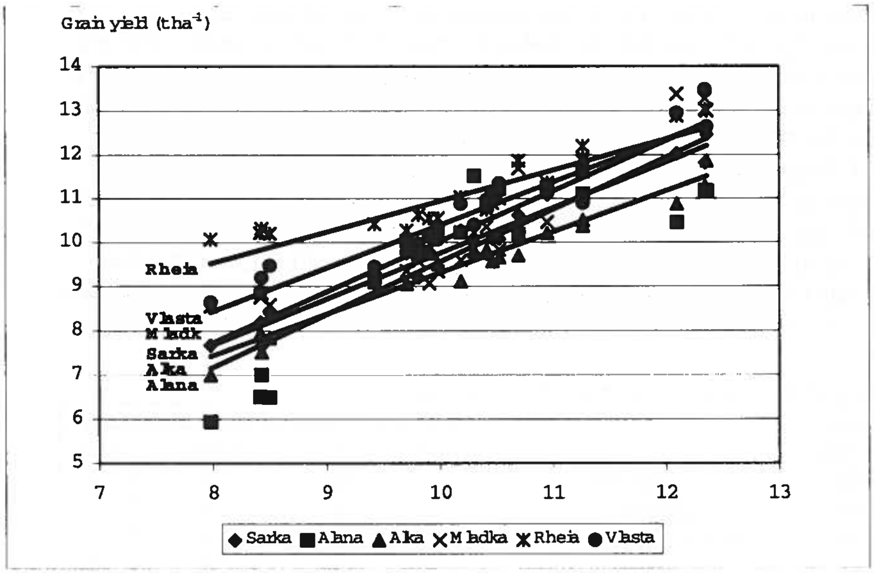
* Differences in days to heading
** C=not suitable for bread-making
*** feeding quality

Results

Results of the first type of experiment with relatively older cultivars (Table 1), available in publication of Sip et al. (2000), showed the effective response of the cultivar Vlasta (included also in experiments 2) to the examined variants of treatments. The cultivar Vlasta, registered in 1999, had in comparison with the older cultivar Regina (grown on large area) significantly higher protein yield (by 11 %), which documents better utilization of N nutrients. With short straw cultivars (carrying effective *Rht* genes) the application of growth regulator had positive effect on grain yield only when combined with additional N nutrition.

The experiments (2) included also the latest cultivars of the Breeding Station Uhretice (SELGEN a.s.) Mladka and Rheia that in the Official Trials of Czech Republic lasting three years (1999-2001) outyielded standards in different regions (maize, sugar beet, cereal, potato) by 4.0-15.2%. Fig. 1 shows the results of cultivar response to different treatments (seven combinations of inputs, sowing rates and sowing dates in three years at the Breeding Station Uhretice). It is evident that the cultivars registered earlier (Alka, Alana, Sarka) were on average lower yielding than Vlasta, Mladka and Rheia, and it is particularly important that the cultivar Rheia showed the regression coefficient ′b′ significantly lower than 1 (more stable performance) and high average yield level, which indicates effective response to ′low yielding′ (low input) environments (the best adaptation to low intensity and occurring alterations in sowing rates and dates).

Fig. 1. Response of examined winter wheat cultivars (2) to different types of environment



Conclusions

The results document the progress of wheat breeding consisting not only in yield improvement but also in better utilization of natural resources and effectivity of response to different types of environment (different combinations of treatments occurring in agricultural practice), which can be a substantial contribution to the sustainability of agriculture.

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