Fertilizer Research **43**: 127–130, 1996.

Optimisation of nitrogen fertilisation

Relationship between precipitation and expected yields

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Key words: nitrogen fertilisation, precipitation, yield potential, wheat varieties

Abstract

The optimisation of nitrogen fertilisation for cereals in Mediterranean regions is very difficult, because yields and leaching losses are depending on winter rainfall. In this article five years of nitrogen fertilisation trials are analysed in order to get a model which relates winter rainfall, nitrogen fertilisation and wheat yields. A highly significant model obtained, in which soil type and the cultivar were taken into account. In order to improve nitrogen use efficiency and to avoid unnecessary nitrogen fertilisation, information on the minimum amount of nitrogen at seeding time and for how long the first top dressing can be delayed without yield losses will be necessary.

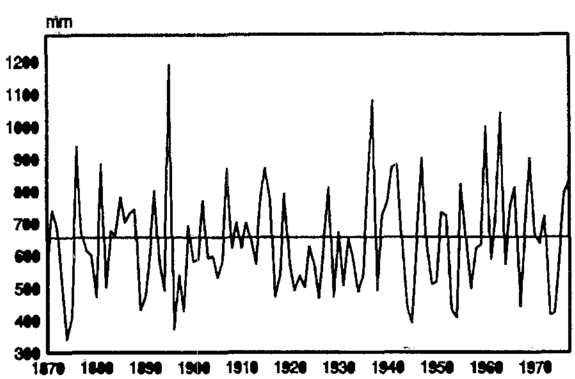

Fig. 1. Total yearly precipitation in Évora between 1870 and 1978

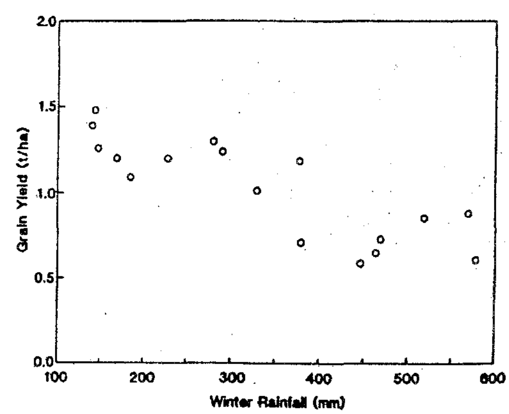

Fig. 2. Influence of winter rainfall on the yield of wheat in Évora district

Introduction

The variation of annual precipitation in Mediterranean regions is very high (Fig. 1). As rainfall can influence cereals yield potential and nitrogen losses, the optimisation of nitrogen fertilisation is therefore a very difficult task. Usually the farmers aim at the highest yield, but this behaviour leads frequently to an excessive application of nitrogen. Having in mind that winter nitrogen applications are necessary in this regions for good wheat production, the potential for N leaching losses is quite high. Therefore the development of a model relating winter rainfall, nitrogen level and expected wheat yield could help to rationalise the application of nitrogen fertiliser. Several authors have tried to establish relationships between climatic parameters, mainly rainfall, and the wheat yields in Portugal. (Carvalho, 1978; Figueiredo, 1919; Frazão, 1943; Oliveira, 1955; Oliveira and Sousa, 1969). Authors using average yields on a regional basis generally obtained negative relationships between rainfall and yields (Fig. 2). However, when the soil type is taken into account, the results can change (Fig. 3) (Goss and Carvalho, 1988). In field trials similar results were obtained for the Eutric Cambisol, however for the Pelic Vertisol

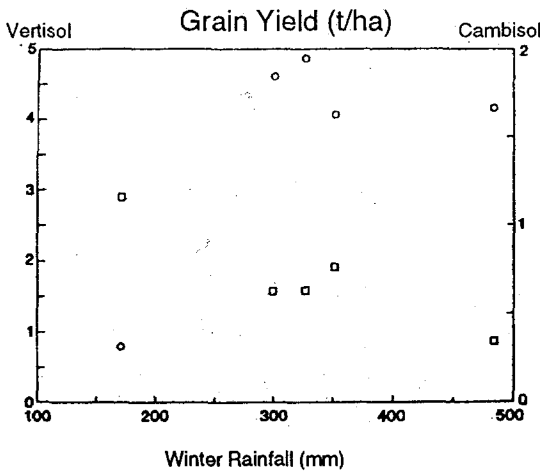

Fig. 3. Contrasting influences of winter rainfall on the yield of wheat on two different soils: circles - Pelic Vertisol; squares - Eutric Cambisol

Table 1. Precipitation (mm) - Long term averages (1941/70) and actual values during the experimental period

	1981	1982	1983	1984	1985	1986	1941-70
Jan	-	83	0	34	143	67	83
Feb	-	58	22	14	113	136	72
Mar	-	43	7	53	14	30	92
Apr	-	57	74	121	76	68	51
May	-	6	22	62	28	22	36
Jun	-	1	13	29	8	0	19
Jul	-	8	0	0	6	0	2
Aug	-	13	1	1	0	-	2
Sep	23	40	24	8	3	-	22
Oct	32	10	56	61	0	-	56
Nov	2	108	180	109	41	-	79
Dec	162	31	85	58	58	-	83

wheat grain yields were almost the same when winter rainfall exceeded 300 mm but much reduced with rainfall amounts below 200 mm.

Yield losses caused by water excess can have various reasons, but the most frequent one referred in literature is nitrogen deficiency (Fisher, 1924; Gales, 1983;. Leyshon and Sheard 1974; Millington, 1961; Van Horn, 1958; Van der Paauw, 1972). The nitrogen losses caused by leaching due to excess of rainfall during the winter months in Mediterranean regions can be very high. Almeida (1965) measured losses up to 90 kg ha^{-1} $year^{-1}$ at Tapada da Ajuda (Lisbon), and this is certainly one of tbe explanations for the low nitrogen use efficiency in cereal crops in Mediterranean regions (Alves, 1979).

Materials and methods

Field trials were conducted between 1981/82 and 1985/86, on a Pelic Vertisol at the University of Évora on the Experimental Farm of Almocreva. Precipitation and soil parameters are given in the Tables 1 and 2. The levels of nitrogen used were 0, 100 and 200 kg N ha^{-1} as ammonium nitrate. Half of the fertiliser was applied at seeding time and the other half at the end of tillering. Two wheat varieties were sown: Mara and Etoile de Choisy. The first one is an alternative variety, with shorter cycle and straw; Etoile is a winter type, taller and a longer cycle. Two seeding times were used every year (Nov 20th ± 3 days; Dec 1Oth ± 3 days) and the average of the two seeding dates for each one of the cultivars was used for the model. The layout of the trial was a randomised block design with a split and 4 replications. Seeding time and nitrogen levels were the main plots and varieties the secondary ones.

Table 2. Soil characteristics of the experimental

Horizon	Depth (cm)	Clay (%)	O.M. (%)	C.E.C. mep 100 g^{-1}	pH (water)
Ap	0–35	40.6	0.94	20.22	7.0
B	35–65	44.2	0.87	29.99	7.5

In order to obtain the model only the variables presenting a significant effect were considered, which was the reason for not taking into account the linear effect of nitrogen. Only the precipitation from November to the end of February was used as rainfall variable for the elaboration of the model as the values for this period showed the highest correlation with the yield. The programme used to fit the model was MSTAT (Michigan State University, 1986).

Results and discussion

Table 3 shows the results of wheat grain yield for each one of the varieties (average of the two seeding times) and nitrogen level, and the rainfall from November to the end of February. In the models obtained from the results given in Table 3, for each one of the wheat cultivars, Y represents the grain yield (kg ha^{-1}), R the rainfall from the beginning of November to the end of

Table 3. Wheat grain yields (kg ha^{-1}) and precipitation from beginning of November to the end of February

	Nitrogen level (kg of N ha^{-1})	Mara (kg ha^{-1})	Etoile de Choisy (kg ha^{-1})	Rainfall (Nov to Feb)
1981/82	0	2618	2740	
	100	3480	3830	305
	200	4862	3070	
1982/83	0	916	999	
	100	1003	906	161
	200	880	741	
1983/84	0	1747	1712	
	100	3691	3254	313
	200	3760	3234	
1984/1985	0	1600	2015	
	100	2967	3588	422
	200	3760	3969	
1985/86	0	1342	1728	
	100	3534	3620	302
	200	4146	3074	

February (mm), and N the amount of applied nitrogen (kg N ha^{-1}).

$$MARA: Y = -4879 + 46.4R - 0.076R2 - 0.030N2 + 0.05NR$$
$$(r = 0.948 p < 0.1\%)$$

$$ETOILE: Y = -2621 + 29.5R - 0.045R2 - 0.057N2 + 0.05NR$$
$$(r = 0.956 p < 0.1\%)$$

The partial derivatives $\delta Y/\delta N$; $\delta Y/\delta R$ of each one of the equations are equal to:

	$MARA:$	$ETOILE:$
$(\delta Y/\delta N):$	$N = 0.833R$	$N = 0.465R$
$(\delta Y/\delta R):$	$R = 305 + 0.392N$	$R = 328 + 0.59N$

For both of the cultivars the models are highly signiificant. Therefore it is possible to calculate the nitrogen fertilisation taking into account the amount of rainfall of the winter (Nov. to Feb.), considering, however, the different lodging resistance of the varieties used. Etoile is a tall cultivar and lodging problems were clearly visible with 200 kg of N ha^{-1} while no lodging happened

Table 4. Values of rainfall and corresponding nitrogen level for maximum yield for each one of the wheat cultivars according to the models

	R (rainfall mm)	N (kg N ha^{-1})	Y max. (kg ha^{-1})
Mara	420	350	4878
Etoile	452	210	4036

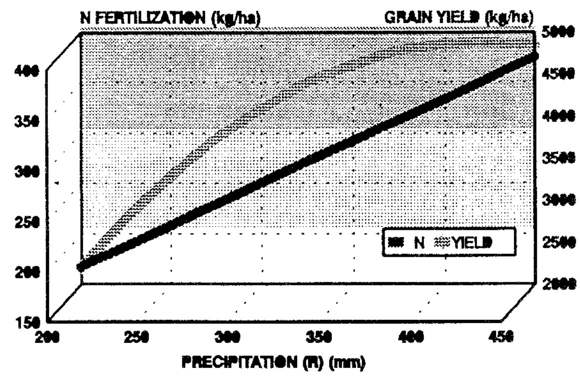

Fig. 4. Influence of winter rainfall on the nitrogen fertilisation for maximum yield and on achieved yield for Mara variety

with Mara during the field trials, thus explaining the differences shown in Table 4. The amount of nitrogen to be applied increases with the rainfall during November to February because of an increase of the yield potential (Figures 4 and 5) and of nitrogen losses (Table 5).

To reach high wheat yields during wet winters the nitrogen fertilisation has to be increased and the potential for nitrogen leaching losses is very high. Although

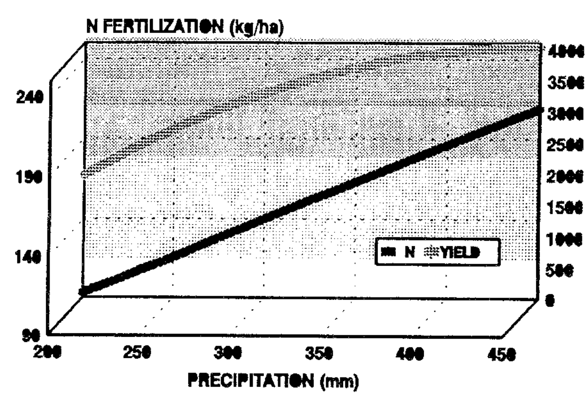

Fig. 5. Influence of winter rainfall on the nitrogen fertilisation for maximum yield and on achieved yield for Etoile variety.

Table 5. Rainfall (Nov-Feb) and calculated N fertilisation (kg N ha^{-1}) maximum yield (kg ha^{-1}), nitrogen uptake (kg N ha^{-1}) and nitrogen losses (kg N ha^{-1}) according to the models

	Rainfall (mm)	Fertilisation (kg N ha^{-1})	Grain yield (kg ha^{-1})	N uptake (kg N ha^{-1})	N losses (kg N ha^{-1})
Mara	200	167	2194	56.9	110.1
	300	250	4076	105.6	144.4
	400	333	4854	125.8	207.2
Etoile	200	93	1972	50.5	42.5
	300	140	3288	85.2	54.8
	400	186	3950	102.4	83.6

this type of model can help the farmers to adjust nitrogen fertilisation to the yield expectation according to actual rainfall, it will be necessary to improve the system in order to reduce nitrogen leaching losses. The next steps will be to know the minimum nitrogen level at the seeding time and how long the first nitrogen top dressing can be delayed without decreasing yield. The benefits of these informations would be:

- Reducing the risk of leaching losses would increase nitrogen use efficiency and reduce nitrogen use efficiency and reduce nitrogen fertilisation;
- Possible delay of the decision on the nitrogen application will reduce the amount of nitrogen applied until the end of February, and the decision on total nitrogen application can be taken based on an already secure estimation of the expected yield, thus avoiding unnecessary nitrogen fertilisation.

Conclusions

In Mediterranean regions nitrogen fertilisation can be managed taking into account winter rainfall, once it affects crop yield and nitrogen losses. As the relationship winter rainfall and crop yield depends on the soil type, and the crop response to high levels of nitrogen depends on the cultivar, both factors affect the model. To avoid high nitrogen leachinglosses during wet winter, the nitrogen fertilisation management system has still to include the information on the minimum nitrogen application at seeding time and on the period during which the first top dressing can be delayed.

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