Impact of phosphorus fertiliser on barley, wheat and triticale in phosphorus deficient dryland zone soil

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Abstract

An on-farm trial was conducted in a semi arid zone of Morocco (375 mm rainfall) to compare responses of four cereals crops to applied phosphorus (0, 10, 20 and 40 kg/ha) on a Petrocalcic Palexeroll P-deficient (4.0 mg/kg $NaHCO_3$-P). The four cereal crops were barley cv. Arig 8, bread wheat cv. Saada, durum wheat cv. Cocorit and triticale cv. Juanillio. Biomass and grain yield increased with increasing P. Yields of durum wheat were lower than the other cereals, probably due to Hessian fly (*Mayetiola destructor* Say.) damage. Relative responses were highest for barley. Soil P values changed throughout the season. The site was used to demonstrate P response of cereals to extension agents and local farmers. These results are applicable to the rainfall areas of the dryland zone between 300 and 450 mm/yr.

Key words : phosphorus, barley, wheat, triticale, fertilization, deficient soil

Résumé

Impact de la fertilisation phosphatée sur l'orge, le blé et le triticale dans les sols deficients en phosphore de la zone d'agriculture pluviale.

Un essai a été conduit chez les agriculteurs dans une zone semi-aride du Maroc (375 mm de pluie) pour comparer la réponse de quatre céréales à l'apport de l'engrais phosphaté (0, 10, 20 et 40 kg P/ha) sur un sol calcimagnésique (Petrocalcic Palexeroll) pauvre en P (4,0 mg/kg P extrait au $NaHCO_3$). Les quatre céréales étaient l'orge cv. Arig 8, le blé tendre cv. Saada, blé dur cv. Cocorit et le triticale cv. Juanillio. La biomasse et le rendement en grain ont augmenté avec l'augmentation de la dose de P. Les rendements du blé dur étaient inférieurs à ceux des autres céréales, probablement à cause des dégâts causés par la cécidomyie (*Mayetiola destructor* Say.). Les orges ont relativement donné les meilleurs rendements. La teneur en phosphore du sol a subi des variations durant la saison. Cette étude a été utilisée comme un essai de démonstration sur la réponse des céréales au phosphore pour les vulgarisateurs et les agriculteurs de la région. Les résultats de cette étude peuvent être applicables aux zones bour favorable recevant des précipitations annuelles de 300 à 450 mm.

Mots-clés : phosphore, orge, blé, triticale, fertilisation, sol pauvre

ملخص

مفعول الأسمدة الفسفورية على الشعير ، القمح والتريتكال في تربة المناطق الجافة ذات نسب ضعيفة من الفسفور

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أقيمت هذه التجربة عند المزارعين في منطقة شبه جافة من المغرب (375 مم من الأمطار في السنة) لمقارنة استجابة أربعة أنواع من الحبوب لأربع كميات من الفسفاط (0، 10، 20 و 40 كلغ في الهكتار) على تربة بتركلسيك بلكسيرول (Petrocalcic Palexeroll) فقيرة من الفسفور(4 ملغ في كل كيلو من التربة). في هذه التجربة استعملت 4 أصناف من الحبوب : الشعير صنف آريكو 8، القمح الطري صنف السعادة، القمح الصلب صنف كوكوريت و التريتكال صنف خوانيليو. بينت النتائج أن الإنتاج الكلي قد ارتفع مع ارتفاع كمية الفسفور. مردودية القمح الصلب كانت أقل من مردودية الحبوب الأخرى، وربما يرجع هذا إلى الإصابة بدودة الهس. في حين كانت مردودية الشعير هي الأعلى على الإطلاق. أما بالنسبة لكمية الفسفور الموجودة في التربة فقد لوحظت عليها تغيرات خلال الموسم. كانت هذه التجربة نموذجية بالنسبة للمزارعين والمرشدين ويمكن استعمال نتائجها في المناطق البورية التي تتلقى ما بين 300 و 450 مم من الأمطار سنويا

الكلمات المفتاحية : الفوسفور، الشعير، القمح، التريتكال، التسميد، تربة فقيرة من الفسفور

Introduction

Much attention is now being focused on the agricultural and socio-economic problems of dryland areas (Steiner *et al.* 1988). While drought is the obvious limiting factor for crop/yields in such areas, lack of available nutrients is almost universal. Despite improvements in management techniques to improve water-use efficiency and breeding for drought tolerance, lack of adequate moisture will continue to be practically insurmountable for most of the world's dryland farmers. Nevertheless, lack of nutrients can easily be overcome by fertilization. However, because of lower yield potential, dryland crops are as well fertilzed as irrigated or temperate zone crops.

Morocco's semi-arid cereal belt typifies this disparity (crawford and purvis, 1986). In view of the importance of rainfed cereals in Morocco-similar to most countries of the middle east (Shroyer *et al.* 1990 a), concerted interational efforts have been made in the last decade to improve the output through intensified applied research (Ryan *et al.* 1990 a). The drive to increase fertilizer use and efficiency has been a major thrust of these endeavors. While N is the most commonly deficient element (Shroyer *et al.* 1990b), the importance of P cannot be ignored.

As soil fertility studies in the relatively poor dryland zone are of recent origin, initial greenhouse work showed that while most soils of the Chaouia region are P deficient, others are well supplied with P (Azzaoui *et al.* 1989). However, where levels of $NaHCO_3$-P exceed about 6 to 7 mg/kg, field responses to P are unlikely (Abdel Monem *et al.* 1990a; Soltanpour *et al.* 1989) a critical value that coincides with research on rainfed cereals in the mediterranean zone (Ryan and Matar) cereals at several agricultural research stations in Morocco have consistently found no response to applied P. This may be due to accumulations of P as a result of yearly applications (Ryan *et al.* 1990). Mineralization of organic P may account for a recent observation of apparent P growth response for a wheat variety at a low-P site in the early growth stage and the absence of any P effect at harvest time. However, at the same site, we observed singificant P responses for triticale.

Therefore, in view of the scarcity of crops, P response data and importance of cereals in Morocco, a field trial compared responses of major cereals-barley breadwheat, durum wheat, and a novel cereal, triticale, at a site with a P level less than the assumed critical value.

Materials and methods

The site chosen was adjacent to Settat in the Chaouia region of central Morocco. Mean annual rainfall is 380 mm/yr, mainly from November to April with considerable inter-annual variation (Watts and El Mourid 1989). The area is devoted to cereals, with barley dominant as well as some fallow and food legumes. The soil is a dominant type in Morocco's semi-arid zone : Petrocalcic Palexeroll (30 - 35 cm) with a low soil test level of P (4.0 mg/kg Olsen) and 3.0 mg/kg nitrate N. The field was cropped the previous year to cereals.

The soil was prepared by two runs of a tractor-drawn offset disc, the most common means of land preparation in the area. Plots were 4 x 5 m with three replications in a split-plot design, with cereals being the main plots and P the sub-plots. The cereals, applied at 120 kg/ha, were barley (Arig 8) breadwheat (Saada), durum wheat (Cocorit), and triticale (Juanillo). The P treatments were 0, 10, 20 and 40 kg/ha as triple superphosphate hand-broadcasted and raked in with the seeds; a blanket N rate of 150 kg/ha as ammonium nitrate was also applied at that time. A fifth replicated block was uncropped and kept free of weeds and reserved for periodic sampling for P analysis.

Following tillering, the plots were sprayed with "certrol H" at 4l/ha a.i. to control broad leaved weeds. During the growing period (Nov. 25 to may 28), the uncropped incubation plots were sampled three times (Dec.20, March 25, June 4), taking three samples per plot, each consisting of 10 sub-samples to a depth of 0-20 cm. At maturity, the entire plots were hand-harvested and weighed in bundles at the site; grain yield data were estimated from sub-samples taken for threshing.

As the main emphasis of the Mid-America international agricultural consortium's Dryland Applied Agricultural Research Project, which established the Aridoculture Center in Settat, is towards technology transfer, this field trial was demonstrated to local extension personnel in April, when differences between P treatments were evident. Following harvest, the straw bundles from all four cereals were stacked in large piles adjacent to the road side, representing increasing P levels. One of the local farmer-guardians for the site remained there for a week to explain the effect P fertilizer in producing the larger piles to farmers passing by and attending weekly markets or "souks".

Results

Statistical analysis of biomass and grain yield indicated significant effects of applied P and differences between cereals, but no singificant interaction between the two of them at the 5 % probability level. However, interaction effects were apparent at the 10 % level. Thus, mean effects are presented along with response data for individual cereals.

Overall biomass and grain yield were significantly increased by each increment of added P; biomass yield was increased by 32, 60, and 69 %, while grain yield increased by 37, 52, and 76 %, respectively (Table 1). Mean biomass yield data showed little differences between the four cereals, with durum wheat yielding lower than bread wheat and barley and triticale (Table 2). The differences were reflected in grain yield data; however, triticale yielded higher than breadwheat or barley, with durum wheat being lowest.

Though the effect of P followed a similar pattern for yields of both wheat and triticale, the response of barley was relatively higher than the other cereals (Fig. 1). While actual yields of barley fertilized at 10, 20, and 40 kg P/ha were similar to those of fertilized triticale and breadwheat, unfertilized barley yields were much lower and similar to those of durum wheat, i.e., 2.3 t/ha compared to around 3.1 t/ha for triticale and breadwheat.

While the $NaHCO_3$-P data reflected the increasing P application rates (Table 3), these data did, however, change throughout the growing season. Compared with the December sampling, values in March were lower; however, all values at the end of the season were higher than at any other time. Nevertheless, added P values relative to the unfertilized controls tended to decrease with time.

Table 1. Mean effect of P fertilization on cereal biomass (kg/ha) and grain yields (kg/ha)

Parameter	P levels (kg/ha)				LSD (5 %)
	0	10	20	40	
Total Biomass	2687 D	3556 C	3933 B	4566 A	312
grain	1062 D	1654 C	1617 B	1871 A	134

Means with same letters are not significantly in any row

Tableau 2. Mean yields of cereals over all P treatments

Parameter	Cereal type				LSD (5 %)
	Saada	Cocorit	Arig 8	Juanillio	
Total Biomass	4081 A	2950 B	3866 A	3865 A	312
Grain	1439 B	1097 C	1504 B	1964 A	134

Means with same letters are not significantly different in any row

Tableau 3. Extractable P (mg/kg) during the growing season

Treatement	Sampling date			Mean
P (kg/ha)	12/90	3/91	6/91	
0	4.8	4.1	7.1	5.3 A
10	11.9	7.0	16.7	11.2 B
20	12.9	11.3	16.5	14.1 C
40	20.5	16.9	21.3	19.5 D
Mean	12.5 A	9.8 B	15.3 C	

Means with different letters are significantly different (5 %) for row and column.

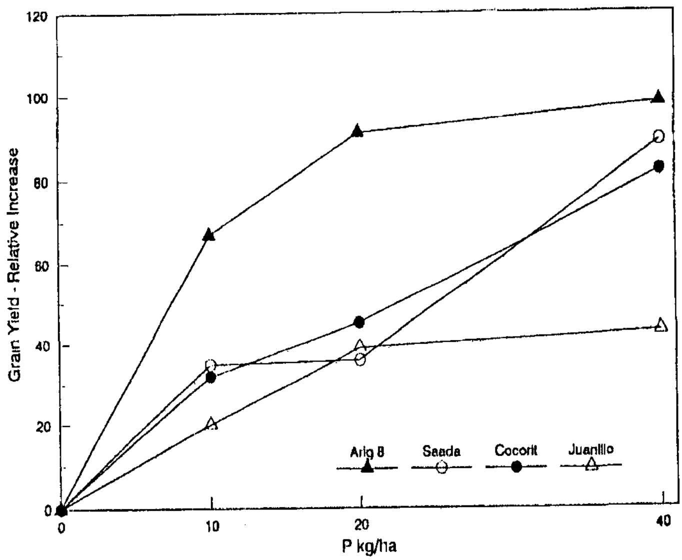

Figure 1. Cereal biomass yields as a function of P fertilizer application

Discussion

In marked contrast to previous P fertilzation studies in Morocco's semi-arid (250-450/yr), this trial demonstrated that all the major cereals grown in the region respond unequivocally to applied P fertilizer when soil tests indicate deficiency. While the concept of soil testing is an integral part of modern agriculture, it is only now being introduced in Morocco. With only a few commercial laboratories in operation, soil testing as a basis for fertilizer use is confined to high value cash crops, such as citrus. Even among researchers, soil testing was rarely used for on-station or on-farm fertilizer trials. The absence of such selection criteria led inevitably to erroneous conclusions about the needs in the Chaouia region where P is deficient (Abdel Monem *et al.* 1990b). Given the yield increase achieved here, adequate fertilization would not only be economically attractive for individual farmers, but also for national cereal output.

Differences in yields between the four cereals highlight the deleterious effect of hessian fly infestation - a problem P fertilization can mitigate but not overcome. While there was evidence of damage to triticale, barley or the newly developed resistant variety - Saada, the durum wheat Cocorit was infested; however, P fertilization increased Cocorit yields by up to 50 %. Our experience in Morocco, and work elsewhere (Buntin and bruckner 1990b) indicates that triticale is naturally more resistant to Hessian fly than wheat. While barley in Morocco is also relatively resistant to Hessian fly (Shroyer et al. 1990a), it is seldom fertlized, though it is the main cereal in the semi-arid zone. Combined with such resistance, the relative response of barley to applied P was striking, being higher at all three P levels than the other cereals, which followed a similar response pattern. As cereals differ in response to P fertilizer (Gardiner and Christensen 1990), the greater P responses of barley, and the factors involved in it, will be studied later.

The soil P data revealed an interesting anomaly : an increase in native P availability at the end of the season. This was probably due to mineralization of native P due to higher temperatures during late spring and early summer, especially with soil high in organic matter as in this trial, i.e., 3.5 g/kg. Such factors should be taken into account when interpreting soil P test values. As anticipated, the analysis detected the soil enrichment due to P fertilization and the slight and gradual decline with time. Based on these data, a modest P fertilizer dressing would have a residual effect for a few years.

In summary, this on-farm trial clearly showed the importance of P fertilization for cereals when soil P levels are deficient. As the rainfall for the year (370 mm) approached the norm for the region in both amount (386 mm/yr) and distribution, these data would have widespread applicability. As a large portion of the dryland project area have less than 300 mm/yr, future trials in the drier areas are planned. While P fertilizer efficiency could be increased by band application, broadcasting is the common farmer practice and will be for the foreseeable future, thus justifying its use in our studies. Given the reliability of the $NaHCO_3$ test as an index of availability, the soil test survey already completed in Chaouia will be extended to the entire project zone in order to identify these areas wich are P deficient, thus combining crop response and soil test data for fertilizer recommendations.

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