Response of improved Moroccan corn cultivars to zinc and phosphorus

J. Ryan[1], M. Abdel monem[1], M. Dafir[1], M. Mergoum[1], and B. Sali[2]

[1] Aridoculture Center, INRA, BP 589, Settat, Maroc

[2] Programme Céréales de printemps, INRA, BP 415, Rabat, Maroc

Abstract

Corn is grown extensively in Morocco's dryland zone, where soils are mainly calcareous and conductive to both P and Zn deficiency. As apparent Zn deficiency in corn has been noted in the field, a greenhouse experiment considered P (0,50, 150 mg/kg) and Zn (0, 12.5 mg/kg) response of six improved corn cultivars grown on two deficient soils : Mollisol and Vertisol. For both soils, applied P increased dry matter yields and plant P concentration, but decreased plant Zn concentration. Zinc increased dry matter yield for both soils as well as plant Zn concentration. There were significant differences among cultivars for dry matter and P concentration for both soils as well as with Zn concentrations for the Vertisol, where values were considerably lower than for the Mollisol. Zinc deficiency symptoms were also more extensive with the Vertisol. Dilution due to increased growth from added P was the apparent reason for the Zn deficiency in the Mollisol.

Key Words : phosphorus, zinc, interaction, dryland corn, deficiency

Résumé

Réponse au zinc et au phosphore de cultivars marocains améliorés de maïs.

Le maïs est cultivé au Maroc sur des sols qui sont généralement calcaires pouvant induire des carences en phosphore et en zinc. Comme les symptômes de carence en zinc sur maïs ont été déjà observés au champ, un essai sous serre a étudié la réponse de six cultivars améliorés aux apports de P (0;50; 150 mg/kg) et de Zn (0; 12,5 mg/kg) sur un sol déficient (Mollisol) et un Vertisol. Dans les deux types de sol, l'apport de P a augmenté le rendement en matière sèche et la concentration en P des plantes mais a diminué la concentration en zinc des plantes. L'apport du zinc a augmenté aussi bien le rendement en matière sèche que la concentration des plantes en zinc. Il y avait une différence significative entre les cultivars pour les rendements en matière sèche et la concentration des plantes en P dans les deux sols et en Zn dans les vertisols. Les concentrations en Zn des cultivars cultivés sur le Vertisol étaient inférieures à celles des cultivars cultivés sur le Mollisol. De même, les symptômes de carence en zinc étaient plus accentués dans le Vertisol. Les déficiences en zinc dans le Mollisol sont dues apparemment aux effets de dilution.

Mots-clés : phosphore, zinc, interaction, maïs en sec, déficience

ملخص

إستجابة أصناف مغربية محسنة من الذرة للزنك والفسفور

ج. ريان1، م. عبد المنعم1، م. ظفير1، م. مرچوم1، ب. سالي2

1 مركز الزراعات الجافة، المعهد الوطني للبحث الزراعي، ص.ب. 589، سطات، المغرب
2 برنامج الحبوب الربيعية، المعهد الوطني للبحث الزراعي، ص.ب. 415، الرباط، المغرب

تزرع الذرة في المغرب في أتربة تحتوي على كميات عالية من الكلس والتي غالبا ما تعوق امتصاص مادتي الزنك (Zn) والفوسفور (P). وبما أنه لوحظت علامات نقص من الزنك في الذرة داخل الحقل، أقيمت تجربة داخل البيوت الزجاجية بهدف دراسة تأثير مادتي الفوسفور (0،5 و 50 و 150 ملج/كلج) والزنك (0 و 5، 12،5 ملج/كلج) على 6 أصناف من الذرة المحسنة زرعت في نوعين من التربة الفقيرة من هاتين المادتين (Mollisol-Vertisol). وفي كلا التربتين، رفعت إضافة الفسفور من مردودية الذرة من المادة الجافة ومن محتوى النبات من الفسفور وقلصت من محتوى النبات من الزنك. ورفع التسميد بالزنك من مردودية الذرة من المادة الجافة ومن محتوى النبات من الزنك. وقد لوحظ أن محتوى الذرة من الزنك في تربة Vertisol كان أقل منه في تربة Mollisol. ويرجع نقصان الزنك في تربة Mollisol إلى مفعول التخفيف.

الكلمات المفتاحية : الفوسفور، الزنك ، الذرة البعلية، تفاعلات، نقص

Introduction

Maize or corn (*Zea mays* L.) is a major cereal both for animal feed and as a human staple, particularly in the semi-arid and sub-humid areas of the world. As with most field crops, fertilization is essential for adequate yields of corn, which has a high nutrient requirement. While yields can be increased by applying nitrogen fertilisers (Karlen *et al.* 1987; Ogunlela *et al.* 1988), fertilization with P is also essential. For instance, Jones *et al.* (1982) showed that 40 kg P/ha quadrupled corn yields while doubling those of legumes. Because of its responsiveness to P, corn has been used as a test crop to evaluate P sources (Hammond *et al.* 1986; Chien *et al.* 1987), to assess soil conservation tillage systems on nutrient uptake (14), and to consider carrier efficiency under irrigation systems (Raun *et al.* 1978)). It is apparent from Cobbina and Miller (1987) that, with respect to P response, corn hybrids differ widely.

As a major cereal, corn is unique in that it is prone to zinc deficiency, especially in calcareous soils. Thus, Zn response of corn has been intensively studied (Shukla *et. al.* 1974; Singh *et al.* 1986). Indeed, Zn deficiency is influenced by preceding crops, while factors other than the soil test level of Zn are involved (Legget and Westerman 1986). Again, as with P response, varietal differences in relation to Zn deficiency are commonly observed (Safaya and Gupta 1979). A frequently observed phenomenon has been a negative effect of P fertlization on Zn deficiency in the field. Various theories have been advanced as to the nature of this aggravating interaction (Olsen 1972). As Morocco is one of the world's major producers of P fertilizers, a logical concern has been the possible effect of high soil P levels on Zn availability for crops.

Corn has been cultivated in Morocco for centuries; currently it ranks third after barley and wheat (Sali 1987). About 80 % of the corn area is under dryland conditions. Though about 400 x 10^3 ha are cultivated annually, yields are low; total production amounts 200-300 10^3 tons, most of which is used for home consumption. A number of reasons for such low yields include : primitive cultural practices, use of unimproved varieties, and the fact that corn production is mainly confined to the marginal rainfall (250-350 mm/year) zones. Futhermore, in this area, there is little evidence of any consistent fertilization of corn; in many cases, corn is grown in rotation with cereals for animal feed indirectly to control weeds.

Despite the antiquity of corn in Morocco, there has been little or no research on its nutritional requirements and fertilization. As most soils in this semi-arid rainfed zone are calcareous, soil conditions are conductive to both P and Zn deficiencies (Lins and Fox 1988). While deficiency symptoms have been observed with rainfed corn, the extent to which they limit corn growth is not clear. The survey of Abdel Monem *et al.* (unpublished data) identified soil areas with extractable Zn levels of less than the 0.6 - 0.8mg/kg range normally considered deficient, and with $NaHCO_3$ - extractable P levels of less than 5 mg/kg. However, some areas, particularly at heavily fertilized research stations, are excessively high in P (Ryan *et al.* 1990) and may induce Zn deficiency where soil Zn level are marginal. In view of efforts to develop new varieties of corn for Moroccan conditions, the comparative responses of these varieties is to be determined under controlled conditions and with soil analyses for both elements.

Materials and methods

Two soil types of widespread agricultural importance in the semi-arid wheat-growing zone in the Chaouia of Morocco were selected for this greenhouse study : Mollisol and Vertisol. Both soils were clayed in texture. The following analyses were made (values for the Mollisol and Vertisol are in parentheses respectively) : pH (8.2, 8.0); $CaCO_3$ (26.2,58.4 g/kg); organic matter (3.2, 1.7 g/kg), NO_3 (9.0, 0 mg/kg). Levels of DTPA-extractable Fe, Zn, Mn, and Cu, for both soils were 5 and 8, 0.7 and 0.6, 10 and 21, and 0.8 mg/kg, respectively. The particular sites were chosen so as to have a low level of P and Zn, and therefore be likely to respond to both elements of concern in this study.

The samples were air-dried and put through a 2 mm sieve, following which 2 kg lots were put in plastic-lined pots (17.5 x 15cm) placed in basins to control drainage. As the analyses indicated that the soils were well supplied with most nutrients, except N, in addition to P and Zn, a basal dressing of 400 mg N as NH_4NO_3 was mixed with the soil; Phosphorus was added at three rates : 0, 50, and 150 mg/kg as NaH_2PO_4. Zinc was added at 0 and 12.5 mg/kg as $ZnSO_4$.

The materials were well mixed with each soil. Treatments were in triplicate, while the design was a split-split plot, with P treatment being the main plot, Zn the sub-plot, and cultivars the sub-sub plot.

Six cultivars were used (Table 1). They were a local forage cultivar (P 586) and five hybrides (Tx 21, DRA 400, INRAM 304, INRAM 305, and INRAM 308). These cultivars vary in adaptation to semi-arid conditions and in yield potential.

Table 1. Moroccan corn cultivar characteristics

Cultivar	Year	Category	Days to maturity	Purpose	Yield potential t/ha
P 586	Old	Variety	160-170	Forage	6-7
Dra 400	1972	Hybrid	125-135	Grain	7-8
Tx 21	Old	Hybrid	115-120	Grain	5-7
INRAM 304	1984	Hybrid	130-140	Grain	7-9
INRAM 305	1986	Hybrid	110-115	Grain	5-7
INRAM 308	1987	Hybrid	115-120	Grain	7-8

The pots were wetted to field capacity with distilled water. Six seed of corn were planted to a depth of 1 cm; after emergence, the stand was thinned to four uniformly spaced seedlings per pot. The pots were watered as necessary to maintain field capacity throughout the growing period of 9 weeks. N was again added with water at 400 mg/pot after 35 days.

At harvest, just at onset of flowering, the plants were cut about 2 cm above ground level and subsequently oven-dried at 70 °C for 72 hours. After weighing, the dried plant material was ground in a Wiley mill to pass a 2 mm sieve. The material was then analyzed for total P using the vanadolybdate procedure of Jackson (Jackson 1964) and for Zn by atomic absorption spectrophotometer. Data were subsequently analyzed by Anova.

Results

Significant soil differences were observed (Table 2). On the Mollisol, only P, Zn, and cultivars had significant effects on dry matter. In contrast, there were significant main effects as well as interactions for the Vertisol. For tissue P concentration, only P fertilizer had a significant effect in the Mollisol. Again, all main effects and interactions, except those involving blocks, were significant for the Vertisol. For tissue Zn concentration, only P and Zn had a significant effect from the Mollisol, while most primary and interactive effects were significant for the Vertisol.

Table 2. Statistical analysis of dry matter yields and P and Zn concentrations of corn grown in two soils

		Dry weight (g/pot)		Tissue P (%)		Tissue Zn (mg/kg)	
Source of variation	df	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2
Block	2	NS	**	NS	NS	NS	NS
P - Fertilizer (P)	2	**	**	**	**	**	**
Px Block	4	NS	**	NS	NS	NS	NS
Zn - Fertilizer (Zn)	1	**	**	NS	NS	**	**
Zn x Block	2	NS	NS	NS	NS	NS	NS
P x Zn	2	*	**	NS	NS	**	**
P x Zn x Block	4	NS	**	NS	NS	NS	*
Cultivar (CVR)	5	**	**	NS	NS	**	**
P x CVR	10	NS	**	NS	NS	**	NS
ZN x CVR	5	NS	NS	NS	NS	*	*
P x ZN x CVR	10	NS	*	NS	NS	*	NS
P x ZN x CVR x Block	60						

*, **, NS = 0.05 and 0.01 levels of probability and non significance, respectively. Soil 1 = Mollisol; Soil 2 = Vertisol.

Despite different initial levels of $NaHCO_3$-P (2 mg/kg for the Vertisol and 10 mg/kg for the Millisol), both soils showed a similar and significant response to added P up to the 150 mg/kg level (Figure 1). Relative dry matter increases were 2.6 to 3.6 times the control. Similarly, plant P concentrations increased with each level of added P; responses tended to be higher for the Vertisol, from less than 0.10 % to about 0.2 %P. These responses confirm visual observations made during the growing period. Without P, all cultivars showed severe P deficiency symptoms. Even at the 50 mg/kg level, mild P deficiency symptoms were evident. For Zn concentration, however, there were distinct differences between the two soils; as P level of the Mollisol increased, plant Zn decreased from 30.7 to 15.5 and 7.3 mg/kg for 0, 50 and 150 mg/kg P, respectively. Corresponding Zn uptake value showed no consistent pattern, being 0.18, 0.24, and 0.15 mg/pot, respectively. Plant zinc value of the Vertisol showed no particular pattern with applied P, i. e., 13.9, 7.3, and 10.2 mg/kg, respectively. However, Zn uptake from the Vertisol increased with applied P, i. e., 0.09, 0.12, and 0.18 mg/pot, respectively.

For both soils, the mean effect of the added 12.5mg/kg Zn, averaged over all P rates and cultivars, significantly increased dry matter yields (Table 3). Differences in plant Zn concentration were also significant. In the Vertisol, Zn concentration was more than trebled. However, Zn had either no effect on plant P (Mollisol) or reduced it (Vertisol). Decreases in plant Zn at the 50 and 150 mg/kg P levels, where Zn was not added, coincided with widespread symptoms of Zn deficiency. Where Zn was added, no such symptoms appeared.

With dry matter yield, there were little differences between cultivars, except the local forage cultivar (P 586), which was significantly less than the others (Figure 2). There were little differences between soils. However, for Zn concentration there were no cultivar differences for the Mollisol, with values for each cultivar being higher than corresponding values for the Vertisol. The mean P content of all six cultivars was consistent, i. e., about 0.16 %, with values for the Vertisol being slightly higher than those of the Mollisol.

As P x Zn cultivar interaction was significant for the Vertisol responses of dry matter were presented. While the trend was for yields to increase with added P and Zn, there were some exceptions (Table 4). Not surprisingly, the addition of Zn alone had no consistent effect on cultivars. However, Zn increased yield at the 50 and 150 mg/kg P rates, extent of which varied with the cultivar. Though the improved local forage cultivar (P 586) tented to have lower yields at any P level, there were no obvious differences between different hybrids.

Table 3. Dry matter yield (g/pot), P (%) and Zn (mg/kg) concentrations of corn in relation to applied Zn

	Dry weight		Plant P		Plant Zn	
Applied Zn (mg/kg)	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2
0	13.3	11.5	0.13	0.18	15.85	4.63
12.5	14.7	15.6	0.13	0.14	19.74	16.32
LSD 0.05	0.9	0.8	0.01	0.01	1.60	1.21

Table 4. Dry matter yield (g/pot) response of six corn cultivars to added P and Zn in a Vertisol

P mg/kg	0		50		150	
Zinc mg/kg	0	12,5	0	12,5	0	12,5
P 586	4.4	5.2	15.6	17.1	12.0	17.1
Dra 400	6.1	5.8	13.3	21.0	15.5	18.9
Tx 21	4.8	6.3	12.8	21.4	17.7	22.1
INRAM 304	7.7	8.0	9.7	18.3	17.3	18.7
INRAM 305	5.5	8.0	13.5	20.2	20.4	25.8
INRAM 308	7.5	5.2	12.9	23.2	9.6	19.1

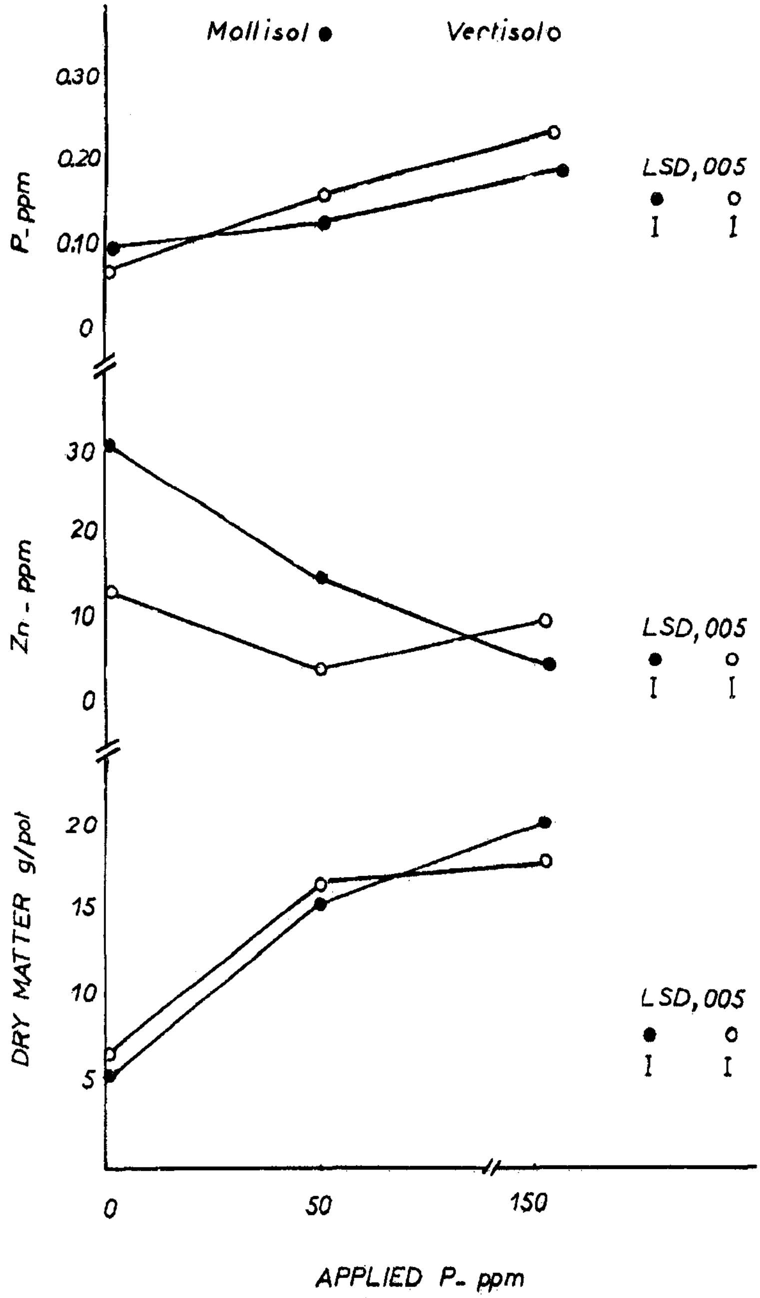

Figure 1. Overall mean effect of applied P on dry matter yield, P and Zn concentrations of corn

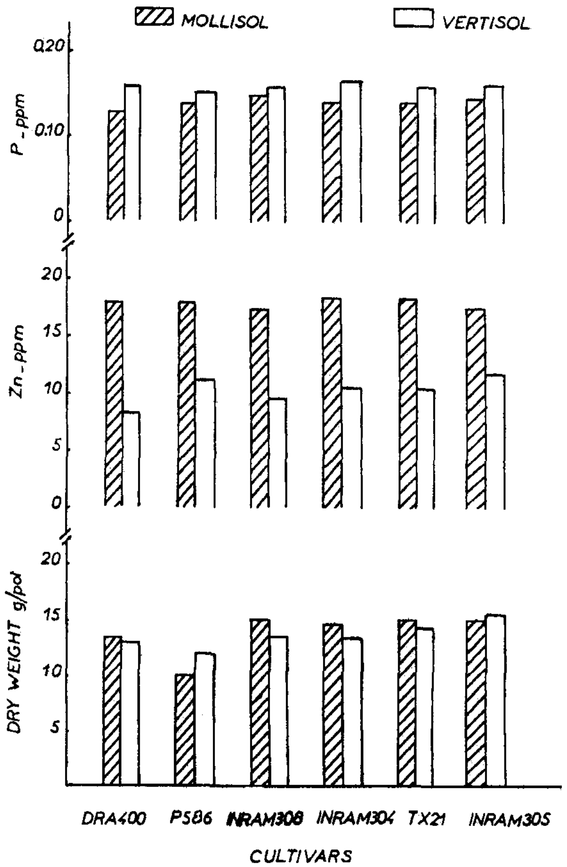

Figure 2. Overall mean effect of corn cultivars on dry matter yield and P and Zn tissue concentrations

Discussion

This study demonstrated the importance of adequate P and Zn fertilization of corn in Morocco. Added P not only increased yields but also enhanced forage quality due to the increased plant P concentration. While crop response to P is dependent on the initial level of available soil P, it was apparent that the P levels in this study, i. e., 10 (Mollisol) and 2 (Vertisol) mg/kg, were less than the critical level. Similarly, the tissue P concentrations of the unfertilized controls, i. e., about 0.10 %, indicated P deficiency, as they were less than the critical concentration of 0.14 % established by Terman *et al.* (1972). Though no criteria have been established for dryland corn in Morocco, established critical soil P levels for field and greenhouse were of about 6 (Abdel Monem *et al.* 1988) and 12 mg/kg (Azzaoui *et al.* 1989), respectively, served as guidelines for corn. As corn is mainly grown in the semi-arid 250 to 400 mm rainfall zone and generally without fertilization (Sali 1987), and as a significant proportion of the soils in that zone are marginal or deficient (Abdel Monem *et al.* 1990), adoption of routine P fertilization would have a considerable impact on corn forage or grain output.

The consistent responses to applied Zn observed here suggest that lack of Zn may severely limit crop yields in the field. Though no field studies have been conducted with Zn, some apparent deficiency symptoms of Zn deficiency in corn have been observed, especially in Vertisols where corn is frequently spring-planted. Using the criterion of 0.8 mg/kg (Lindsay and Norvell 1978) as a critical value, the fertility survey of Chaouia province in the northern more favorable part of Morocco's semi-arid zone (Abdel Monem *et al.* 1990) indicated that a sizable percentage of fields are Zn-deficient.

A surprising aspect of this study was the absence of a differential response of the six cultivars to either P or Zn. The local grain and forage cultivars responded in a similar manner to the improved cultivars, at least for the Mollisol. While significant interactions occurred with the Vertisol, there were no consistent differences between the local and improved cultivars. All cultivars showed severe P deficiency symptoms without P fertilization, and Zn deficiency symptoms at the 50 and 150 mg/kg P level without Zn. Wile P induced Zn deficiency has been attributed to several mechanisms, i. e., precipitation of insoluble P - Zn compounds in the soil or plant interference with translocation, or dilution in a greater volume of plant material (Olsen 1972), it is apparent from yield and plant Zn concentration and uptake data that the latter explanation is more plausible. Terman *et al.* (Terman *et al.* 1972) similarly attributed the observed Zn deficiency to dilution of Zn in near Zn-deficient plants by growth response to P. Most treatments in this study which were less than 14 mg/kg - the critical plant concentration for corn of similar age - exhibited Zn deficiency symptoms.

This experiment highlighted the need for field evaluation of P and Zn for corn in Morocco's dryland zone. Under such conditions, where grain and total dry matter yields can be measured, differences between local and improved cultivars may be evident. While P deficiency can be easily rectified, the problem of Zn is more difficult. Micronutrient fertilization of field crops in Morocco is essentially absent, and is unlikely to be adopted under low input rainfed farming conditions in the foreseeable future. If Zn efficiency is found to be a significant limiting factor in corn, efforts should be made to incroporate tolerance in future corn breeding programs in Morocco by crossing with cultivars shown to be tolerant to low soil Zn levels elsewhere.

References

Abdel Monem M., Azzaoui A., El Gharous M., Ryan and Soltanpour P.N. (1988). Response of dryland wheat to nitrogen and phosphorus in some Moroccan soils. *In* J. Ryan and A. Mater (ed). Proc. Third Regional Soil Test Calibration Workshop. Amman, Jordan, Sept. 3-9. ICARDA, Aleppo, Syria.

Azzaoui A., Hanson R.G., and Soltanpour P.N. (1989). Wheat P requirements on calcareous Moroccan soils. I. A comparison of Olsen, Soltanpour and $CaCl_2$ soil tests. Commun. *Soil Sci. Plan Anal.* **20** : 869-91.

Chien S. H., Adams F., Khasawueh F.E., and Henao J. (1987). Effects of combinations of triple superphosphate and a reactive phosphate rock on yield and phosphorus uptake by corn. *Soil Sci. Am. J.* **51** : 656-8.

Cobbina J., and Miller M.H. (1987). Purpling in maize hybrids as influenced by temperature and soil phosphorus. *Agron. J.* **79** : 576-82.

Hammond L.L., Chien S.H., and Easterwood G.W. (1986). Agronomic effectiveness of Bayover phosphate rock in soil with induced phosphorus retention. *Soil. Sci. Soc. Am. J.* **50** : 1601 - 6.

Jackson M.L. (1964). Soil chemical analysis. Prentice Hall, Engelwood Cliffs, New Jersey, U. S. A.

Jones V. S., Samonte H.P., and Jariel D.M. (1982). Response of corn and inoculated legumes to urea, lime, phosphorus and sulfur on a Guadalupe clay. *Soil Sci. Soc. Am. J.* **46** : 328-31.

Karlen D.L., Sadler E.J., and Camp C.H. (1987). Dry matter, nitrogen, phosphorus, and potassium accumulation rates by corn on Norfolk loamy sand. *Agron. J.* **79** : 649-56.

Leggett G.E., and Westeman D.T. (1986). Effect of corn, sugarbeets, and fallow on zinc availability to subsequent crops. *Soil Sci. Soc. Amer. J.* **50** : 963-8.

Lindsay W. L., and Norvell W.A. (1978). Development of a DTPA test for zinc, corn, manganese, and copper. *Soi Sci. Soc. Amer. J.* **42** : 421-8.

Lins I.D.G., and Cox F.R. (1988). Effect of soil pH and clay content on the zinc soil test interpretation for corn. *Soil Sci. Soc. Amer. J.* **52** : 1681-5.

Mackay A.D., Kladivido E.J., Barber S.A., and Griffith, D.R. (1987). Phosphorus and potassium uptake in conservation tillage systems. *Soil Sci. Am. J.* **51** : 970-4.

Ogunlela V.B., Amoruwa G.M., and Oglogunde, O.O. (1988). Growth, yield components and micronutrient nutrition of field-grown maize. (*Zea mays* L.) as affected by nitrogen fertlization and plant density. *Fert. Res.* **17** : 189-96.

Olsen S.R. (1972). Micronutrient interactions. *In* J. Mortvedt, P.M. Giordano, and W.L. Lindzay (edS). pp.243-64. *Soil Sci. Soc. Am.*, Madison, Wisc.

Sali B. (1987). Amélioration génétique du maïs au Maroc depuis 1980. Institut national de la recherche agronomique. Rabat, Morocco.

Raun W.R., Sander D.H. and Olsen, R.A. (1978). Phosphorus fertilizer carriers and their placement for minimum till corn under sprinkler irrigation. *Soil Sci. Soc. Amer. J.* **51** : 1055-62.

Ryan J., Keith D., Abdel Monem M. and Christiansen, S. (1989). MidAmerica International Agricultural Consortium's Dryland Agricultural Project in Morocco. *Agron. Abst.* p. 48.

Ryan J., Abdel Monem M. and El Gharous M. (1990). Soil fertility assessment at agricultural experimental stations in Chaouia, Abda, and Doukkala. *Al Awamia* **74** : 1-47.

Safaya N.M., and Gupta A.P. (1979). Differential susceptibility of corn cultivars to zinc deficiency. *Agron. J.* **71** : 132-6.

Shukla U.C., and Prasad K.G. (1974). Ameliorative role of Zn on maize growth under alkaline soil conditions. *Agron. J.* **66** : 804-6.

Singh K.K., and Banerjee N.K. (1986). Growth and zinc content of maize (*Zea mays* L.) as related to soil-applied zinc. *Field Crops Res.* **13** : 56-61.

Soltanpour P.N., El Gharous M., Azzaoui A., and Abdel Monem M. (1989). Response of dryland wheat to P rates and placement methods. Common. *Soil Sci. Anal.* **20** : 597-605.

Terman G.L., Giordano P.M., and Allen S.E. (1972). Relationship between dry matter yields and concentrations of Zn and P in young corn plants. *Agron. J.* **64** : 684-7.