Effects of added phosphorus and zinc on yield and its components of corn

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ABSTRACT

Experiments were conducted for two seasons (2000/01 and 2001/02) to study the effects of added phosphorus and zinc fertilizers on yield and its components of corn(*Zea mays* L.) grown on Remaitab soil series, (fine, smectitic, isohyperthermic, Typic Haplusterts) at the Gezira Research Station Farm, Wad Medani, Sudan. Phosphorus was banded in the soil as triple superphosphate at three rates (0, 43 and 86 kg P_2O_5 ha^{-1}). Zinc, as zinc sulphate, was also banded at three rates (0, 5 and 10 kg Zn ha^{-1}). Nitrogen was broadcast as a basal dose in the form of urea at a recommended dose of 86 kg N ha^{-1}. Experiments were arranged in a split-plot design with four replicates. The results indicated that application of both nutrients significantly ($P \leq 0.05$) increased the number of cobs ha^{-1}, the number and weight of grains/cob, 100 grain weight and grain yield. However, doubling the rate of P to 86 kg P_2O_5 ha^{-1} did not result in a significant difference over that of 43 kg P_2O_5 ha^{-1} for most parameters studied. Application of both P rates (43 and 86 kg P_2O_5 ha^{-1}) each in combination with Zn rates (5 and 10 kg Zn ha^{-1}) increased weight of grains per cob, 100 grain weight and grain yield as compared to other treatments. For attaining maximum yield, application of 43 kg P_2O_5 ha^{-1}+ 10 kg Zn ha^{-1} banded in the soil at sowing is recommended, in addition to the recommended rate of nitrogen on the Remaitab soil series.

INTRODUCTION

Continuous cultivation with inorganic fertilizers to supply nitrogen and phosphorus has become a well known practice in many parts of the world. However, many reports in the literature demonstrated that P fertilization may intensify Zn deficiency symptoms in some plant species (Adams, 1980; Xie and Mackenzie, 1989; Olsen, 1991; Marschner, 1995). Zinc–phosphorus interactions are widely reported in crops grown in fields as well as in pots and hydroponics (Adams, 1980; Olsen, 1991).Application of fertilizer P may increase plant growth, but the plants may become deficient in Zn at a later stage of growth and this reduces yields of fruits and grains (Longeragan *et al.*, 1979; Webb and Longeragan, 1990). Rehm and Schmitt (1998) found significantly higher corn yield on adding P with Zn as compared to P alone. Decrease in yield is commonly associated with high application of P to soils when the soil test levels of Zn were low or marginal. Gezira soils, which are calcareous and deficient in Zn (Dawelbeit *et al*., 1995), nitrogen and phosphorus are supplied without zinc fertilization. The present work is undertaken to study the effect of added phosphorus and zinc fertilizers and their interactions on yield and its components of corn (*Zea mays* L.) grown on Remaitab soil series .

MATERIALS AND METHODS

The experiments were conducted in the cropping seasons of 2000/01 and 2001/02 at the Gezira Research Station Farm, Agricultural Research Corporation, Wad Medani, Sudan, latitude 14^0 $24^/$ N, longitude 33^0 $31^/$ E and altitude 411masl.The climate of the study area is classified as arid.The maximum daily air temperature ranges from $32.9C^0$ in January to 41.6 C^0 in May, while the minimum daily air temperature ranges from $14.3C^0$ in January to $24.5C^0$ in June. The rainy season extends from July to October with a peak in August. Average annual rainfall amounts to 306 mm.

The soil of the site is Remaitab soil series, “fine, smectitic, isohyper-thermic, Typic Haplusterts”(Soil Survey Staff,1999).The Soil is invariably calcareous with an average $CaCO_3$ content of about 1.5%. The available phosphorus was 2 μg Pg^{-1} soil. DTPA extractable Zn was 0.23 ppm (Table 1).

The experiments were arranged in a split-plot design with 9 treatments and four replicates .The main plots were assigned to phosphorus fertilizer applied as triple superphosphate as follows: No phosphorus (0P), 43 kg P_2 O_5 ha^{-1} (1P) and 86 kg P_2 O_5 ha^{-1}(2P). The sub plots were assigned to zinc fertilizer applied as zinc sulphate ($Zn SO_4.7H_2O$) as follows: No zinc (0Zn), 5 kg Zn ha^{-1} (1Zn) and10 kg Zn ha^{-1} (2Zn). Fertilizers were banded in the soil on opposite sides of the rows at sowing. Corn seeds were sown in mid July each season at a rate of two seeds per hole, thinned to one plant per hole two weeks after germination. The plants were irrigated at 14 days intervals. The spacing was 30 cm between holes and 80 cm between rows. A basal dose of nitrogen fertilizer was applied as urea at a rate of 86 kg N ha^{-1}. Hand weeding was done when needed. The crop was manually harvested in mid November. Statistical analysis was done by the standard analysis of variance (ANOVA).In the cases of significant F values, Duncan's Multiple Range Test (DMRT) at P= 0.05 was calculated for comparison between treatment means.

RESULTS AND DISCUSSION

Application of phosphorus significantly ($P \leq 0.05$) increased the number of cobs ha^{-1}, the number and weight of grains cob^{-1}, 100 grain weight and grain yield (Table 2). The analysis of variance for both seasons revealed that both rates of phosphorus, 1P and 2P, were significantly ($P<0.05$) superior over the 0P for all parameters studied. However, there was no significant difference between both rates of added P for all parameters studied, except in the first season (2000/01) where the application of IP significantly ($P \leq 0.05$) increased the number of cobs ha^{-1} and grain yield over the higher rate. As for the second season (2001/02), the application of 1P significantly ($P \leq 0.05$) increased the number of cobs ha^{-1}, number and weight of grains cob^{-1} in comparison to the higher rate. These results agreed with the findings of Amon and Adetunji (1970) and Kogbe and Abediran (2003) and in conformity with the approved standard agro-nomic practices of corn made by Agricultural Research Corporation (ARC) recommendations in the Gezira (Ali, 1997) .

Table 1. Some physical and chemical properties of the studied soil.

Depth (cm)	Particle size distribution (%)			Ca CO_3 (%)	O.C (%)	N (%)	Avail.P (mg kg^{-1} soil)	Tot. P (mg kg^{-1} soil)	DTPA Zn (mg kg^{-1} soil)
	Sand	Silt	Clay						
0–30	22	20	58	1.5	0.22	0.034	2.0	340	0.23

Table 1. (continued).

pH		ECe dSm^{-1}	ESP	CEC cmol kg^{-1} soil	Soluble cations and anions Meq l^{-1} in saturation extract					
Paste	1:5 H_2O				K	Na	Ca	Mg	Cl	HCO_3
8.3	9.1	0.50	8	48	0.60	3.6	2.4	1.5	2.3	1.4

Table 2. The main effects of phosphorus on yield and its components of corn.

P level	No. of cobs ha^{-1}	No. of grains cob^{-1}	Wt of grains cob^{-1}(g)	100-grain wt (g)	Grain yield (kg ha^{-1})	Increase in yield (%)
			Season 2000/01			
0P	33262^{c}	310^{b}	65.20^{b}	21.18^{b}	2213^{c}	
1P	38412^{a}	453^{a}	105.04^{a}	23.43^{a}	3766^{a}	70
2P	37578^{b}	459^{a}	105.69^{a}	23.00^{a}	3618^{b}	63
C.V(%)	12.96	16.36	15.83	10.48	14.50	
			Season 2001/02			
0P	31773^{c}	332^{c}	73.71^{c}	21.37^{b}	2308^{b}	
1P	37450^{a}	445^{a}	97.55^{a}	23.18^{a}	3645^{a}	58
2P	37036^{b}	420^{b}	92.42^{b}	23.11^{a}	3623^{a}	57
C.V(%)	10.02	13.91	16.94	11.93	11.59	

Means followed by different letters are significantly different, $P \leq 0.05$.

Zinc application significantly increased the number of cobs ha^{-1}, number and weight of grains cob^{-1}, 100 grain weight and grain yield (Table 3). These results were in accord with those obtained by Frey *et al.* (1992) in that the application of 2Zn gave the highest yield. However, Abunyewa and Mercer–Quarshie (2004) found that soil application of 5 kg Zn ha^{-1} consistently gave higher grain yield and doubling the rate to 10 kg Zn ha^{-1} did not result in a corresponding yield increase. Generally, the response of maize to Zn application is a result of low zinc concentration in the soil (Table 1). Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions (Rehm and Schmitt, 1998).

The present study showed significant difference ($P<0.05$) due to P and Zn interactions for both seasons on number of cobs ha^{-1} at harvest which was an important yield index (Table 4). Khan (1998) found a positive effect of P and Zn interactions on number of cobs ha^{-1}. Noticeable increase in the number of grains per cob was obtained with increasing rate of each nutrient; high rate of applied Zn gave the highest number of grains per cob irrespective of the rate of added P (Table 5).Analysis of variance of P and Zn interaction showed significant difference ($P \leq 0.05$) between treatment means for both seasons.

Application of 2 Zn with both rates of added P gave the highest grain weight without significant difference between both treatments for the two growing seasons. The combination of the higher rate of P and the lower rate of Zn significantly increased ($P \leq 0.05$) the weight of grains per cob more than that of the combination of the lower rates of both of them in season 2000/01, while the data obtained for season 2001/02 showed the reverse (Table 6).One hundred grain weight ranged from 18.98 to 26.17 g and 19.41 to 25.10 g in seasons 2000/01 and 2001/02, respectively (Table7). The highest 100 grain weight was obtained by the lower rate of P and the higher rate of Zn. The least grain weight was obtained by the application of 2Pand 0Zn which reduced the 100 grain weight to a level below that obtained by the control treatment. This clearly indicated that application of Zn enhances grain weight as stated by Pendias and Pendias (1984).

Table 3. The main effects of zinc on yield and its components of corn.

Zn level	No. of cobs ha^{-1}	No of grains cob^{-1}	Wt of grains cob^{-1} (g)	100-grain wt (g)	Grain yield (kg ha^{-1})	Increase in yield(%)
			Season 2000/01			
0Zn	33399[c]	349c[c]	69.82[c]	20.36[c]	2318[c]	
1Zn	37618[b]	416[b]	99.61[b]	23.22[b]	3562[b]	54
2Zn	38234[a]	457[a]	106.51[a]	24.02[a]	3716[a]	60
CV(%)	12.9	16.3	15.8	10.4	14.5	
			Season 2001/02			
0Zn	31997[c]	359[c]	79.52[c]	20.27[c]	2496[c]	
1Zn	36495[b]	402[b]	89.83[b]	23.19[b]	3405[b]	36
2Zn	37767[a]	437[a]	94.33[a]	24.21[a]	3675[a]	47
CV(%)	10	13.9	16.9	11.9	11.5	

Means followed by different letters are significantly different, P<0.05.

Table 4. The effect of P and Zn interactions on number of cobs ha^{-1}.

	0Zn	1Zn	2Zn
		Season 2000/01	
0P	29385[m]	35214[l]	35186[f]
1P	35935[e]	39335[c]	39966[a]
2P	34878[k]	38306[d]	39550[b]
		Season 2001/02	
0P	26114[m]	34133[l]	35072[f]
1P	34569[k]	38197[c]	39584[a]
2P	35307[e]	37156[d]	38644[b]

Means followed by different letters are significantly different, $P \leq 0.05$. CV = 10%.

Table 5. The effect of P and Zn interactions on number of grains cob^{-1}.

	0Zn	1Zn	2Zn
		Season 2000/01	
0P	272[l]	324[k]	333[h]
1P	390[e]	463[c]	506[b]
2P	385[e]	462[c]	531[a]
		Season 2001/02	
0P	332[k]	317[l]	349[h]
1P	391[e]	449[c]	495[a]
2P	354[f]	440[d]	467[b]

Means followed by different letters are significantly different, $P \leq 0.05$.
CV = 13.91%.

Table 6. The effect of P and Zn interactions on weight of grains cob^{-1}.

	0Zn	1Zn	2Zn
	Season 2000/01		
0P	64.26 [f]	69.61 [h]	61.72 [k]
1P	80.01 [d]	106.91 [c]	128.21 [a]
2P	65.17 [e]	122.30 [b]	129.59 [a]
	Season 2001/02		
0P	74.25 [e]	69.32 [f]	77.55 [d]
1P	88.49 [c]	102.01 [a]	102.16 [a]
2P	75.82 [de]	98.15 [b]	103.30 [a]

Means followed by different letters are significantly different, $P \leq 0.05$.
CV = 16.94%.

Table 7. The effect of P and Zn interactions on 100 grain weight (g).

	0Zn	1Zn	2Zn
	Season 2000/01		
0P	20.85 [de]	21.05 [de]	21.64 [cd]
1P	21.26 [de]	22.85 [c]	26.17 [a]
2P	18.98 [f]	25.77 [a]	24.25 [b]
	Season 2001/02		
0P	19.41 [e]	22.22 [c]	22.49 [bc]
1P	20.91 [d]	23.53 [b]	25.10 [ab]
2P	20.48 [de]	23.83 [ab]	25.03 [ab]

Means followed by different letters are significantly different, $P \leq 0.05$.
CV =11.93%.

Table 8. The effect of P and Zn interactions on grain yield (kg)

	0Zn	1Zn	2Zn
	Season 2000/01		
0P	2162 [f]	2307 [e]	2170 [f]
1P	2376 [de]	4295 [b]	4627 [a]
2P	2417 [d]	4084 [c]	4352 [b]
	Season 2001/02		
0P	2124 [l]	2449 [k]	2352 [kl]
1P	2594 [f]	3954 [c]	4388 [a]
2P	2769 [e]	3812 [d]	4287 [b]

Means followed by different letters are significantly different, $P \leq 0.05$.
CV= 11.59%.

There was a significant increase ($P \leq 0.05$) in grain yield with increasing rate of applied Zn irrespective of the rate of P (Table 8). The grain yield obtained by the combination of each rate of added phosphorus with each rate of applied zinc varied between 4084 to 4627 and 3954 to 4388 kg ha^{-1} for season2000/01 and 2001 /02, respectively. Application of 1Pand 2Zn produced the highest grain yield followed by that of 2P and 2Zn without significant difference in yield between both treatment means and both of them were significantly different ($P \leq 0.05$) from that obtained by of 1P and 1Zn or that of 2P and 1Zn. Also, these latter treatments showed no significant difference in yield between their treatment means. The results obtained for grain yield as affected by P and Zn interactions agreed with those obtained by Yilmaz *et al.*, (1997) and Rehm and Schmitt (1998). Moreover, the present results indicated that application of phosphorus with zinc promotes plant growth and ensures better utilization of nutrients.

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أثر إضافة أسمدة الفسفور والزنك على إنتاجية الذرة الشامية ومكوناتها

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الخلاصـة

أجريت هذه الدراسة خلال موسمي 01/2000 و02/2001 بمزرعة محطة بحوث الجزيرة ، واد مدني. نفذت التجربة على نظام القطع المنشقة وقد هدفت التجربة الى معرفة استجابة الذرة الشامية للتسميد بالفوسفات والزنك. شملت المعاملات ثلاث جرعات من الفسفور، الذي أضيف في شكل سيوبر فوسفات ثلاثي عند الزراعة ، وهي صفر ، 43 كجم P_2O_5/هكتار ، 86 كجم P_2O_5/هكتار. وثلاث جرعات من الزنك في شكل ملح كبريتات الزنك مميأة عند الزراعة هي صفـــر، 5 كجم زنك/هكتار و10كجم زنك/هكتار. تم إجراء التحليل الروتيني للتربة في موقع التجربة للموسمين قبل الزراعة. أوضحت نتائج التجربة أن إضافة كلٍ من الفسفور والزنك لها أثر إيجابي في زيادة مكونات الإنتاجية وإنتاجية الحبوب .كما أبانت الدراســة أن إضـــافة جرعتين من الفســفور لم تنجم عنهما فروقات معنوية مقارنة مع إضـــافة جرعة واحدة. أبانت الدراســة أن هنالك اســتجابة موجبة للفسـفور عندما أضـيف الزنك مقارنة للمعاملات التي لم يضـاف فيها الزنك أو تلك لمعاملات التي لم يضف فيها الفسفور في وجود أو عدم وجود الزنك حيث كانت هنالك زيادة معنوية في عدد الكيزان/ هكتار وزن الحبوب/ الكوز وزن المائة حبة وإنتاجية الحبوب، حيث وجد أن أعلى انتاجية كانت بإضافة 43 كجم P_2O_5+ 10 كجم زنك/هكتار للتربة.