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RESPONSE OF MAIZE (*ZEA MAYS* L.) TO ZINC AND PHOSPHORUS APPLICATION

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Pot and field experiments were conducted to assess the response of maize (*Zea mays* L.) to Zinc application and the effect of Phosphorus on Zinc distribution in plants. It was observed that maize responded significantly ($P < 0.01$) to Zn application and showed positive P x Zn interaction for growth as well as grain yield depending on soil Zn level and maize variety. Application of Zn increased Zn concentration in all plant parts including grain while application of P tended to decrease Zn concentration in plants. The results suggest that only small amount of Zn should be applied to soils containing marginal soil Zn in order to obtain better maize growth and yield.

Key words: Maize, Interaction, Phosphorus, Zinc.

Introduction

Maize is an important cereal and is widely grown in all four provinces of Pakistan both as a spring and summer crop. It is also grown as a fodder crop for farm animals. During the last decade there was a steady increase in maize yields globally, but the yields were lowest in Pakistan as compared to those obtained by the major maize growing countries of the world (1). Beside other factors, low and imbalanced application of fertilizers may be one of the major cause of this low yield. It has been reported that maize consumes only 5% of the total fertilizer used in Pakistan [2]. It has also been estimated that among the maize growers, 39% use only N fertilizer and 60% use both N and P fertilizer while none use micronutrients. Widespread deficiency of Zn has been recognized on many important soil series of Pakistan [3] and response to its application has been obtained in some crop species,[2,4,5]; Application of N and P fertilizers increased grain yield of maize under field condition (2,6,7) but application of Zn alongwith N and P has increased grain yield only at some places in North West Frontier Province [8-11] while in the Punjab only marginal response has been reported (4,5). In contrast, good response of maize to Zn application in terms of increased dry matter yield has been obtained under pot culture conditions [12,13]. Rashid *et al.* [14], observed response of maize to Zn application on 17 out of 23 soils collected from different area of the Punjab. The soils of Pakistan are generally alkaline and calcareous and low in available N and P content. They normally require repeated and liberal application of N and P fertilizers for better growth and yield. This study was therefore, undertaken to determine the response of maize to Zn application as affected by P fertilization in pot culture and under field conditions. The distribution of Zn in different plant parts as affected by P fertilization was also determined.

Experimental

Experiment 1. In order to determine the extent of maize response to Zn application at different levels of P, a pot culture experiment was conducted using a sandy loam soil (Hafizabad series, typic Ustochrepts) collected from NIAB farm area. The soil was sampled, crushed, sieved and analyzed for some physico-chemical properties,: pH 8.0; organic matter, 0.4%; $NaHCO_3$-P, 6.4 mg kg^{-1}; and DTPA-Zn and -Cu, 0.40 and 0.70 mg kg^{-1}. Five kg soil per pot was prepared by applying 3 rates of P (0,22 and 88 mg Pkg^{-1} soil as reagent grade KH_2PO_4) and 2 rates of Zn (0 and 5 mg Kg^{-1} as reagent grade $ZnSO_4$) in a factorial combination. All the reagent grade chemicals were applied in solution form and mixed with the soil of respective treatments. There were 3 replications per treatment. Pots were arranged in a completely randomized design. A basal dose of nitrogen was applied to each pot at 100 mg Nkg^{-1} as urea. Enough water was added to the pots to saturate the soil at or near field capacity. Seven seeds of maize (cv. Akbar) were sown and after germination plants were thinned to 4 pot. Another dose of nitrogen at 50 mg Nkg^{-1} as urea was applied to the soil after 25 days of growth.The soil moisture in the pots was maintained near field capacity throughout the plant growth period. Plants were harvested after 40 days, separated into leaves, stems and roots and dried in oven at 70°C to record dry weights. One gram portions of the ground material was digested in a diacid mixture (HNO_3: $HC10_4$, 5:1). Phosphorus was determined by metavanadate yellow colour method [15] and Zn by atomic absorption spectrophotometer. The data were subjected to analysis of variance and L.S.D. worked out to compare the means [16].

*Experiment 2.*The effect of P and Zn application on the yield of maize was also assessed under field condition. The physico-chemical properties of soils of the two experimental sites (Thikriwala; Faisalabad and Chimbranwali, Jhang) are given in Table 4. The experimental layout was a randomized complete block design with 3 rates of P (0,33 and 66 kg P ha^{-1} as single super phosphate) and 2 rates of Zn (O and 10 kg Zn ha^{-1} as zinc sulphate), and replicated four times. A basal dose of nitrogen at 100 kg N ha^{-1} as urea was applied at the time of sowing and a second dose of 50 kg N ha^{-1} was applied when the plants were about half meter high. The 5 x 3.75 m plots contained five rows having plants at 20 cm apart. At tasseling stage of growth 6 fully developed leaves were harvested and at maturity cobs were collected from the three central rows. The cobs were dried and weighed for estimating grain yield. Grain and leaf samples were analyzed for P and Zn content as given above.

Results and Discussion

Experiment 1. Effect of P and Zn application on dry matter yield. Application of P progressively increased the dry matter yield (DMY) of maize plants (Table 1). Similarly, application of Zn increased the DMY of all plant parts. The interaction effect was also significant (P < 0.01) in increasing DMY of all plant parts. In the absence of Zn, highest rate of P application produced approximately 50% of the highest yield. Shukla and Morris [17] have shown that visual symptoms need not be present for corn to be deficient in zinc. Growth may be restricted by lack of Zn before plants show other symptoms of deficiency. Although there was no symptoms apparent on plants from 88 mg P kg^{-1} treatment, application of Zn along with 88 mg P kg^{-1} increased top growth much more than root growth. The increase in top growth being more than 129% as compared to root growth that was only 40% (Table 1). The results are in agreement to earlier study on wheat [12].

TABLE 1. EFFECT OF P AND ZN APPLICATION ON THE DMY OF MAIZE GROWN IN POTS (EXPERIMENT 1).

Treatment		DMY, g pot^{-1}			
P	Zn mg kg^{-1}	Leaf	Stem	Root	Top/Root
0	0	1.84	0.52	1.29	1.83
22	0	4.32	1.96	4.04	1.55
88	0	5.41	3.57	7.44	1.21
0	5	1.88	0.54	1.05	2.30
22	5	4.51	1.94	4.07	1.58
88	5	12.32	8.28	10.37	1.99
LSD (P < 0.01)					
	P	1.39	1.05	1.24	-
	Zn	1.13	0.86	1.02	-
	P x Zn	2.78	2.10	2.49	-

Nutrient composition and their distribution within plants. Application of Zn significantly (P < 0.01) increased Zn concentration in plants at all levels of P, but to a lower extent in roots as compared to stems and leaves (Table 2). Application of phosphorus significantly (P < 0.01) increased P concentration in plants while Zn x P interaction significantly (P < 0.01) decreased P concentration in all plant parts, which may be attributed to dilution of P in plants caused by growth acceleration at the highest rate of P application, since total P uptake (yield multiplied by its concentration) increased in all plant parts due to Zn application (data not shown).

TABLE 2. PHOSPHORUS AND ZN CONCENTRATION IN MAIZE LEAVES, STEMS AND ROOTS AS AFFECTED BY P AND ZN APPLICATION (EXPERIMENT 1).

Teatment		Leaves		Stems		Roots	
P	Zn	P	Zn	P	Zn	P	Zn
		(mg kg^{-1})					
0	0	933	22.1	1179	12.3	592	35
22	0	864	12.9	804	10.0	1137	44
88	0	2634	9.6	3164	13.7	2041	44
0	5	947	37.1	1185	31.9	881	40
22	5	1085	25.4	1192	43.7	1128	49
88	5	1278	17.1	1731	12.9	1536	52
LSD (P < 0.01)							
	P	702	6.5	414	3.2	213	7.9
	Zn	ns	5.3	ns	2.6	ns	4.56*
	PxZn	403*	ns	828	6.4	426	ns

*Significant at (P < 0.05), ns : non-significant.

Application of P significantly (P < 0.01) decreased Zn concentration in leaves and stems. Total Zn uptake, however, increased in all plant parts due to P application (data not shown). Thus the decrease in Zn concentration was again due to dilution effect. The highest rate of P application decreased Zn concentration in stems and leaves upto 9.6 µgg^{-1} but the dry matter yield was still higher than the control. The plants contained enough P but suffered from Zn starvation. Application of Zn along with 88 mg P kg^{-1} increased Zn concentration and the dry matter yield of both leaves and stems about two fold over that obtained without Zn. This indicates that for better utilization of P, plants must contain sufficient Zn which would be around 13 µgg^{-1} [12]. The critical Zn and P concentration in maizze plants has been reported to vary greatly depending on crop requirement, plant age and soil types [13,18].

Contrary to stems and leaves, higher rate of P application significantly (P < 0.01) increased Zn concentration in the roots. Phosphorus, therefore, appeared to restrict the movement of Zn from roots to tops which is evident from the changes in Zn distribution between tops and roots (Table 3). The average percentage distribution of Zn in different parts of the plant at zero P were 50% in leaves, 11% in stems and 39% in roots but at 88 mg P kg^{-1} the distribution pattern changed and the roots retained the highest Zn 68% followed by leaves 20% and then stems 12% similar results were obtained in an earlier study [12].

Experiment 2. At Thikriwala site of the field study, application of P increased the grain yield significantly ($P < 0.05$). Application of Zn alone or in combination with P had little effect on the production of maize grain (Table 5). This may be attributed to the native soil Zn which may be adequate for the variety used (Table 4). At Chimbranwali site, application of P at lower rates increased grain yield of maize but higher P rate reduced it below that at lower rate. Application of Zn along with increasing P rates progressively increased ($P < 0.05$) grain yield over that of P and Zn alone, showing a positive P x Zn interaction.

Analyses of grain indicated that application of P and Zn fertilizers increased their respective concentrations and uptake in grain at the Chimbranwali site (Table 5). However, P application at both sites tended to decrease Zn concentration in plant leaves at tasseling as well as in the grain at maturity. Bhatti *et al.* [9] reported 36 mg Zn kg^{-1} as the critical level in leaves at tasseling stage of growth, which is at variance with

TABLE 3. TOP/ROOT RATIO* FOR Zn IN MAIZE AS AFFECTED BY P AND Zn APPLICATION IN POTS.

Treatment	Leaf/root			Stem/root			Mean
mg kg	Zn0	Zn5	Mean	Zn0	Zn5	Mean	
P O	0.90	1.64	1.27	0.14	0.41	0.27	0.77
P 22	0.31	0.49	0.40	0.11	0.36	0.23	0.31
P 88	0.16	0.38	0.27	0.15	0.19	0.17	0.22
Mean	0.46	0.84	-	0.13	0.32	-	-

*Expressed on per plant basis.

TABLE 4. SOME PHYSICO-CHEMICAL PROPERTIES OF THE SOILS OF THE EXPERIMENTAL SITES AND MAIZE VARIETY GROWN.

Soil property/maize variety	Thikriwala soil	Chimbranwali soil
pH (saturated paste)	7.55	7.70
EC (saturated extract),dS m^{-1}	2.20	0.66
Organic matter, %	0.54	0.50
Free lime, %	4.15	n.d.
Texture	Clay loam	Sandy loam
$NaHCO_3$ -P, mg kg^{-1}	7.13	2.43
DTPA-Zn, mg kg^{-1}	0.71	0.37
Variety	Neelum	Sultan

n.d. = not determined.

TABLE 5. GRAIN YIELD AND COMPOSITION OF MAIZE AS AFFECTED BY P AND ZN APPLICATION IN THE FIELD.

Treatment		Grain Yield	Leaves at tasselling		Grain at maturity	
P	Zn		P	Zn	P	Zn
kg ha^{-1}		kg ha^{-1}	%	mg kg^{-1}	%	mg kg^{-1}
(Thikriwala site)						
0	0	7368	0.31	27.5	0.27	19.3
33	0	8089	0.32	27.2	0.28	18.5
66	0	8368	0.31	27.1	0.29	18.4
0	10	7675	0.30	32.2	0.23	20.7
33	10	7768	0.31	31.3	0.28	20.1
66	10	8268	0.31	27.2	0.27	20.0
LDS ($P < 0.05$)						
	P	560	ns	ns	ns	ns
	Zn	ns	ns	2.28	ns	ns
(Chimbranwali site)						
0	0	5382	0.21	41.5	0.20	29.2
33	0	6997	0.24	32.9	0.22	28.5
66	0	6479	0.24	32.5	0.22	27.3
0	10	5431	0.20	48.6	0.19	34.1
33	10	7506	0.23	47.8	0.21	32.4
66	10	8563	0.26	43.5	0.22	32.1
LSD ($P < 0.05$)						
	P	755	0.013	ns	0.011	ns
	Zn	616	ns	5.02	ns	2.08
	PxZn	1511	ns	ns	ns	ns

ns = Non significant

the values reported in Table 5. This could be attributed to differences in type of soil and variety used [13]. It, therefore, appears necessary to evaluate the existing varieties of maize against Zn and P applications and find out the critical level for both plants and soils so that response to Zn application could be precisely determined. In the present experiments maize responded significantly to Zn application in terms of growth as well as grain yield only at Chimbranwali site. It can therefore, be concluded that small amount of Zn may be applied along with higher rates of P in order to avoid P induced Zn deficiency particularly on soils that may be marginal to deficient in Zn content.

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