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Zinc and Phosphorus Nutrition of Wheat Grown on a Highly Calcareous Soil

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Abstract A pot culture experiment was conducted to study the effect of different levels of P(0, 25, 50, and 100 ppm) and Zn (0, 5, 10 and 20 ppm) on their concentration and uptake by wheat biomass in a highly calcareous soil. P application decreased the concentration but increased the uptake of Zn in grain and straw parts of the plant. Zn availability in soil after crop harvest was also enhanced with application. However, Zn application did not affect either P concentration in the plant or in the soil significantly.

Key words wheat, zinc, phosphorus, uptake of Zn and P, Calcareous soil

In view of the widespread deficiencies of some micronutrients particularly Zn and thereby its periodical application in several soils is bound to interact with some of the major nutrients like nitrogen and phosphorus. Zn and P are reported to interact either antagonistically or synergistically depending upon a number of physico-chemical characteristics of the soil (Barrow 1987). Application of higher doses or presence of higher levels of either of them in soil may reduce or enhance the availability of the other (Chahal & Randhawa 1980, Yadav & Shukla 1982 and Orabi *et al*. 1985). Various hypotheses have been suggested in this regard right from soil (Kalyanasundaram & Mehta 1970) to above ground plant parts (Takkar *et al*. 1976). Dilution of Zn and P in plant tissues due to increased growth seems to be more plausible (Takkar *et al*. 1976 , Verma & Minhas 1987). However, Zn and P interaction in calcareous soils which are usually deficient in these nutrients due to their adsorption on $CaCO_3$ surfaces and precipitation as insoluble species is more complex and different from the normal soils. Comprehensive information on Zn and P interaction in whole soil-plant system particularly under calcareous soils is still lacking. Keeping this in view present study was undertaken with different Zn and P levels applied to a highly calcareous soil using wheat as a test crop.

Materials and Methods

A calcareous soil (Typic Calciorthents) collected from *Bhatt* region of eastern U.P. (Distt. Deoria) was used for the present study. The soil was silty loam (14.3, 53.2 and 32.5% clay, silt and sand, respectively) and contained 42.8% free amorphous $CaCO_3$, 0.41% organic carbon, 0.54 mg kg^{-1} DTPA extractable zinc and 0.3 mg kg^{-1} available (Olsen's) phosphorus.

A pot experiment using wheat as a test crop was conducted during *rabi* 1989 at Water Technology Centre, IARI, New Delhi. The treatments comprised all possible combinations of four levels both of zinc (Zn_0, Zn_5, Zn_{10} and Zn_{20} ppm) as zinc sulphate ($ZnSO_4 . 7H_2O$) and phosphorus (P_0, P_{25}, P_{50} and P_{100} ppm) as ammonium dihydrogen orthophosphate ($NH_4H_2PO_4$). All the treatments were replicated thrice. These amounts of Zn and P along with basal dose of 100 ppm N as $(NH_4)_2SO_4$ (N supplied as $NH_4H_2PO_4$ was taken into account) and 50 ppm K as KCl were mixed thoroughly with the soil. Other micronutrients were not added due to their adequate available amounts. The treated soil was transferred into plastic pots of 3 kg capacity in which a thin layer of prewashed gravel + sand was placed at the bottom. Eight healthy seeds of wheat (var. HD 2285) were sown in each pot and after germination six plants per pot were allowed to grow till maturity. Deionized water was used for watering the plants as and when required. At maturity, the plants along with roots were harvested, washed carefully with deionized water and dried at $65^o \pm 1^oC$. The plants were separated into straw, grain and roots and weight of straw and grain was recorded. The dried plant samples of straw, grain and root were digested in tri-acid mixture of HNO_3:$HClO_4$:H_2SO_4 in 9:4:1 ratio and analysed for Zn and P. After harvest, soil samples

Table 1 *Effect of zinc and phosphorus levels on grain and straw yields of wheat*

Zn level (ppm)	Grain yield (g pot^{-1}) P levels (ppm)					Straw yield (g pot^{-1}) P levels (ppm)				
	0	25	50	100	Mean	0	25	50	100	Mean
0	1.1	2.9	3.2	3.1	2.6	2.1	4.9	5.3	5.1	4.4
5	1.9	3.3	3.5	3.8	2.1	3.1	5.8	6.0	6.9	5.4
10	1.8	3.2	3.8	4.2	3.2	3.1	5.6	6.4	7.4	5.6
20	1.5	3.1	3.5	3.9	3.0	2.6	5.3	6.0	6.9	5.2
Mean	1.6	1.6	3.5	3.7		2.7	5.4	5.9	6.6	
C.D. (5%) Zn	= 0.14					Zn = 0.23				
P	= 0.14					P = 0.23				
Zn x P	= 0.29					Zn x P = 0.46				

were collected and analysed for DTPA extractable Zn (Lindsay & Norvell 1978) and $NaHCO_3$ extractable P (Olsen *et al.* 1954). Zinc estimations were carried out using atomic absorption spectrophotometry and P was determined colorimetrically.

Results and Discussion

Grain and straw yields

Grain and straw yields of wheat (Table 1) were increased significantly with increasing levels of Zn and P. Application of P increased the mean grain and straw yields from 1.6 to 3.7 and 2.7 to 6.6 g pot^{-1} whereas Zn increased it from 2.6 to 3.2 and 5.1 to 5.6 g pot^{-1}, respectively. Interactive effect of Zn and P on grain and straw yield was also significant. Treatment $P_{100}+Zn_{10}$ gave highest grain (4.16 g pot^{-1}) and straw (7.38 g pot^{-1}) yield over control (P_0 Zn_0). Significant response of wheat to Zn and P in highly calcareous soil may be attributed to their initial deficient levels in the experimental soil.

Zinc concentration and uptake

With increasing levels of Zn application the Zn concentration in different parts of the wheat plant enhanced significantly (Table 2). The mean Zn concentrations in straw, grain and root in-

Table 2 *Effect of different levels of Zn and P application on their mean concentration in different wheat plant parts*

Levels (ppm)	Straw Zn (ppm)	Straw P (%)	Grain Zn (ppm)	Grain P (%)	Root Zn (ppm)	Root P (%)
Zn levels						
Zn_0	16.60	0.12	24.60	0.63	52.50	0.16
Zn_5	35.00	0.11	37.10	0.62	70.40	0.17
Zn_{10}	50.70	0.11	50.70	0.61	90.40	0.18
Zn_{20}	82.40	0.11	68.30	0.62	123.30	0.18
P levels						
P_0	66.90	0.06	57.60	0.44	71.90	0.09
P_{25}	46.00	0.09	44.90	0.62	77.90	0.14
P_{50}	38.20	0.13	40.30	0.69	86.60	0.21
P_{100}	33.60	0.16	37.90	0.73	100.20	0.26
C.D. at 5%						
Zn	5.10	–	2.83	–	4.08	0.009
P	5.10	0.012	2.83	0.011	8.16	0.009
Zn x P	10.2	–	5.66	–	–	–

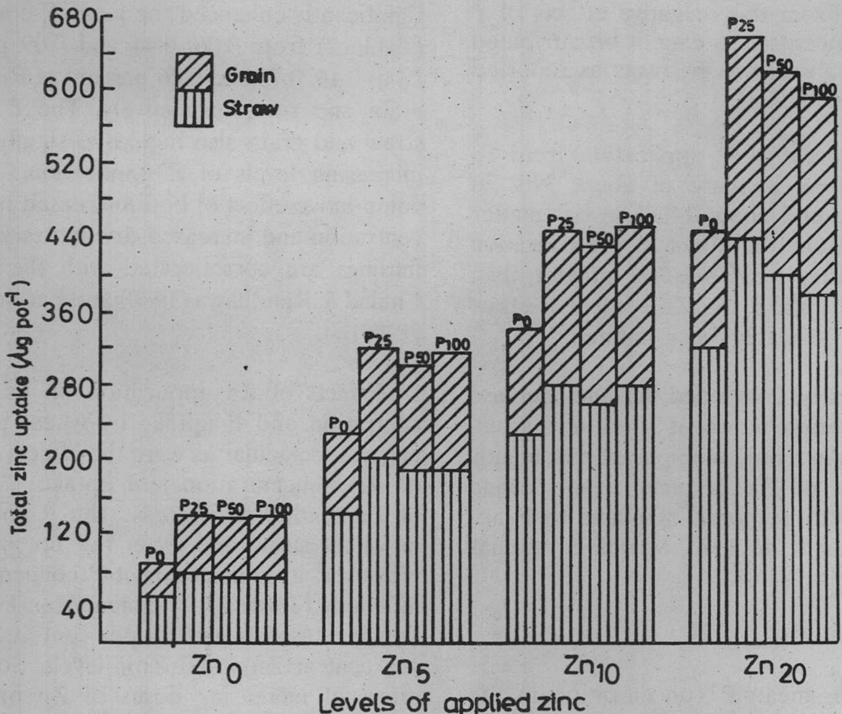

Fig 1 Effect of applied Zn and P on Zn uptake by wheat

creased from 16.6, 24.6 and 52.5 ppm at Zn_0 to 82.4, 68.3 and 123.3 ppm at Zn_{20} level, respectively. The mean Zn uptake by straw and grain also increased from 67.0 and 58.8 $\mu g\ pot^{-1}$ to 387.0 and 193.8 $\mu g\ pot^{-1}$, respectively, as the Zn application was increased from Zn_0 to Zn_{20} (Fig.1). Increased uptake of Zn by wheat parts was due to cumulative effect of increased Zn concentration and increased dry matter yield. However, the magnitude of increase in Zn uptake due to increased Zn application from Zn_0 to Zn_{20} was larger in straw (67.0 to 387.0 $\mu g\ pot^{-1}$) as compared to that in grain (58.8 to 193.8 $\mu g\ pot^{-1}$) which can be attributed to higher accumulation of Zn in straw as compared to that in grains probably due to selective upward translocation (Fig. 1).

Increasing rate of P application caused a significant decrease in Zn concentration of straw and grain while root Zn concentration was significantly increased (Table 2).With increasing levels of P application, the mean Zn concentration decreased from 66.9 and 57.6 ppm at P_0 to 33.6 and 37.9 at P_{100} in straw and grain, respectively, while in roots, it increased from 71.9 ppm at P_0 to 100.2 ppm at P_{100}. However, no visual symptoms of Zn deficiency were observed in the present study. This may be explained by the fact that even at its highest level applied, P might not have reduced plant Zn concentration below its critical level. Despite its depressing effect on plant Zn concentration, applied P significantly enhanced the mean Zn uptake by straw and grain (Fig. 1), which was due to increased dry matter production. Depressing effects of P application on Zn concentration, in straw and grain, are critically examined and compared with possible mechanisms of Zn-P antagonism reported earlier.

The availability of Zn in the soil, after crop harvest, increased with increasing levels of P application (Table 3). Therefore, the possibility of a precipitation of Zn into insoluble $Zn_3(PO_4)_2$ as a mechanism responsible for the depressing effect of P on the plant Zn concentration, as reported by Kalyanasundram & Mehta (1970) can be ruled out. Besides, an increasing effect on the Zn concentration in roots (Table 2), applied

P also enhanced the Zn uptake by straw and grain (Fig. 1). From this, negative effects of P on plant Zn concentration cannot be attributed to reduced Zn absorption by roots as reported by Reddy *et al.* (1973).

Increasing levels of P application from P_0 to P_{100} caused an increase of about 39% in total Zn uptake and about 140% in dry matter yield (Fig. 1). Since the effect of P fertilization on the dry matter yield was far greater than its effect on Zn uptake, the Zn content in straw and grain has probably been diluted.

Hence, it can be concluded that the decrease in Zn concentration in wheat straw and grain, after P application is only an apparent one, mainly due to dilution of Zn in plant tissues owing to positive growth response of plants to P application (Takkar *et al.* 1976, Verma & Minhas 1987).

Phosphorus uptake

The data on mean P concentration in the various wheat plant parts and its uptake by straw and grain are presented in Table 3 and Fig. 2, respectively. Increasing levels of P application significantly enhanced the mean P concentration (Table 2) from 0.06, 0.44 and 0.09 per cent at P_0 to 0.16, 0.73 and 0.26 percent at P_{100} in straw, grain and root, respectively. The P uptake by straw and grain also increased significantly with increasing levels of P application, due to the cumu-lative effect of both increased plant P concentration and increased dry matter yield. These findings are corroborated with the reports of Chahal & Randhawa (1980) and Farah & Soliman (1986).

Effects of Zn application on tissue P concentration and P uptake by wheat plants were not as spectacular as were the effects of P supply on Zn concentration and uptake. Applications of Zn tended to decrease the P concentration in wheat straw and grain but not significantly. However, it enhanced root P concentration significantly (Table 2). The mean root P concentration increased from 0.16 per cent at Zn_0 to 0.18 per cent at Zn_{10} and Zn_{20} levels. So far as the effect of increasing doses of Zn on P uptake is concerned, this could primarily be due to an increase in dry matter production as a conse-

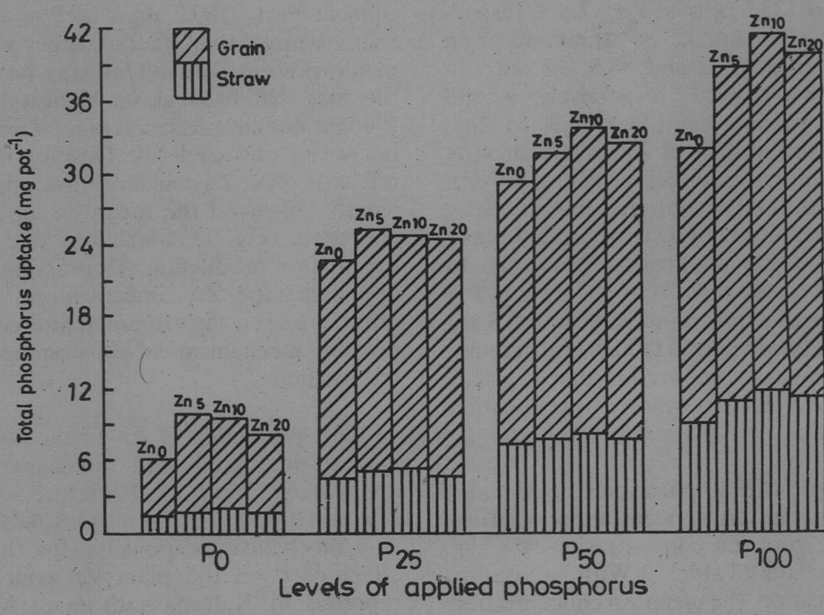

Fig 2 Effect of applied Zn and P on P uptake by wheat

Table 3 Effect of different levels of Zn and P application on mean concentration of available Zn and P of soil after crop harvest

Level (ppm)	Available Zn (ppm)	Available P (%)
Zn levels		
Zn_0	0.56	10.75
Zn_5	2.16	11.30
Zn_{10}	4.61	11.00
Zn_{20}	6.74	11.95
P levels		
P_0	3.28	3.20
P_{25}	3.71	5.45
P_{50}	4.59	13.87
P_{100}	3.50	22.50
C.D. at 5%		
Zn	0.309	–
P	0.309	2.00
Zn x P	–	–

quence of Zn applications. Orabi *et al.* (1985) also reported a similar positive effect of Zn application on P uptake in maize grown on calcareous soil.

Zn and P availability in soil after crop harvest

With increasing levels of Zn and P application their respective availability was increased in soil after crop harvest (Table 3).The mean Zn availability increased from 0.56 ppm at Zn_0 to 6.74 ppm at Zn_{20}. Similarly, mean P availability increased from 3.2 ppm at P_0 to 22.5 ppm at P_{100}. Application of Zn had no significant effect on soil P availability while P application significantly increased Zn availability in soil after crop harvest. Saeed (1977) attributed similar observations of phosphorus induced increase in Zn availability in a calcareous soil to the depressing effect of P on Zn adsorption at $CaCO_3$ surface.

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