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EFFECT OF APPLIED P AND Zn FERTILIZERS ON WHEAT AND THEIR RESIDUAL EFFECT ON THE GROWTH AND COMPOSITION OF MAIZE

S. M. Alam, M. Sharif and A. Latif

Nuclear Institute for Agriculture and Biology, Faisalabad

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The effect of applied P and Zn fertilizers on wheat and their residual effect on the growth and composition of maize was studied under pot culture conditions. P application increased the dry matter yield of wheat tops and roots but Zn application increased top growth only. Application of P decreased Zn concentration in tops but not in roots. The critical Zn concentration in 62 days old wheat tops appeared to be 10 $\mu g/g$.

Residual P and Zn was most effective at P_{100} Zn_3 mg/kg level of application for the growth of maize plant. P x Zn interaction was positive in producing dry matter yield of leaf, stem or roots. Higher level of residual P affected the distribution of Zn in different plant parts.

Soil P content showed significant correlation with plant growth of both wheat and maize while soil Zn content had no such relationship. The ratio of P to Zn in soil showed no correlation with crop yield, Zn concentration or Zn uptake and appeared to be less reliable parameter to predict p-Zn disorder in the plant.

Key words: Phosphorus, Zinc, Wheat, Maize.

INTRODUCTION

The soils of Pakistan are generally alkaline and calcareous and possess high P "fixing" capacity [1]. Application of repeated or heavy phosphatic fertilizer is therefore, necessary to get increased crop yields. Recently these soils have also been recognised to be widely deficient in Zn [1,3]. However, application of Zn fertilizer to field crops, in general, resulted in variable responses. In field trials Zn usually showed a positive response in terms of increased grain yield for rice and wheat whereas it showed little or slight depressive effect for maize [4,5]. Some workers from NWFP reported little effect of P and Zn on maize growth or yield whereas others reported a positive and significant effect on the yield of maize grain [6-8]. These studies usually lack information on the concentration of Zn in soils or plants. On the contrary in pot experiments Rashid *et al.* [9] reported a good response (in terms of increased dry matter yield) of maize to Zn application on 17 out of 23 soils, while Kausar *et al.* [3] in their studies reported response of rice to Zn on 14 out of 20 soils but that of wheat on only 4 out of 21 soils. In pot experiments we also observed (unpublished data) that wheat responded to P and Zn application in terms of increased grain yield only on light textured soils. In view of these conflicting reports, it was thought necessary to evaluate P and Zn effect on wheat and maize crop under pot and field grown conditions. The study reported here describes the effects of applied P and Zn on wheat and their residual effect on the growth and composition of maize under pot culture conditions.

MATERIALS AND METHODS

The soil used for this study was a sandy loam, of slightly alkaline pH (8.0), low organic matter (0.5 %) and low in extractable P and Zn concentration (Table 3). The soil was crushed, passed through a 2 mm sieve and 4 kg portions weighed in polyethelene lined plastic pots. Phosphorus was applied at the rate of 0, 20 and 100 mg/kg P from KH_2PO_4 and Zn at the rate of 0, 3 and 9 mg/kg Zn as Zn SO_4 alongwith the basal N at the rate of 100 mg/kg as urea. Potassium content of the soil was raised in respective pots upto the level attained due to highest application of phosphorus by applying K_2SO_4 solution. The soil was saturated with deionized water and allowed to equilibrate for about 10 days. When it attained field capacity, ten seeds of wheat (CV. Lyallpur-73) were sown. A week after germination only five plants per pot were allowed to grow. Pots were irrigated to field capacity as and when required. The tops were harvested when the plants were 62 days old. The roots were separated from the soil by gentle sieving and washed successively with deionized water. Soil samples were collected for analyses of P and Zn. The soil was replaced in the same pot and irrigated alongwith the application of 50 mg/kg N as urea. Seven seeds of maize (Cv. Akbar) were sown when pots attained field capacity condition. After 10 days of germination four plants per pot were maintained and 25 mg/kg N was applied to each pot. The plants were allowed to grow for 28 days, then harvested and separated into leaf, stem and roots, dried in oven at 70° and their weights recorded.

Portions of ground plant material from wheat and maize were digested in diacid mixture (HNO_3: $HClO_4$, 5:1). Phosphorus was determined by metavanadate yellow colour method and Zn by atomic absorption spectrophotometer. Soil Zn was estimated by extraction with DTPA (10) and soil P by extraction with $NaHCO_3$ [11] and was determined colorimetrically using ascorbic acid.

RESULTS

Effect of P and Zn application on dry matter production of wheat. Application of phosphorus stimulated wheat growth, producing large number of tillers and green leaf as compared to the control. The plants did not show any adverse effect of heavy P application on plant leaf [12,13]. Applied P significantly ($P < .05$) increased dry matter yield of tops and roots (Table 1). Zinc application increased top growth only and it had little effect on root growth resulting in a wider top/root ratio at all P levels. However, Zn application higher than 3 mg/kg had no additional effect on dry matter production of tops. Phosphorus and Zn interaction was non-significant for the growth of wheat plants.

Table 1. Dry matter yield of 62 days old wheat tops and roots as affected by P and Zn application.

Treatment		Dry matter yield		
P	Zn	Tops	Roots	Top/root
(mg/kg)		(g/pot)		
0	0	0.69	0.29	2.38
0	3	1.36	0.53	2.57
0	9	1.61	0.64	2.52
20	0	7.28	2.37	3.07
20	3	7.67	1.94	3.44
20	9	7.77	2.20	3.53
100	0	8.40	2.88	2.92
100	3	9.63	2.80	3.44
100	9	9.73	2.74	3.55
L.S.D. ($P < .05$)	P	0.62	0.23	
	Zn	0.62	n.s.	
	P x Zn	n.s.	n.s.	
Overall		1.08	0.40	

Nutrient concentration in plant tops and roots. Application of Zn significantly ($P < .05$) increased Zn concentration in plant tops (Table 2). It had no effect on P concentration or its uptake in tops and roots. Application of P increased P concentration both in tops and roots. It had a depressing effect on Zn concentration in tops at all levels of Zn but not so in roots. However, the total Zn uptake in plant tops increased due to growth promotion by applied phosphorus. So the apparent depression in Zn concentration in plant tops is due to dilution effect. A true antagonisum of P on Zn absorption is apparent only at highest Zn level where P_{100} has depressed Zn concentration and total Zn uptake as compared to P_{20} treatment.

The critical Zn concentration in wheat leaves below which Zn application would respond in dry matter production has been reported to be 15 μg/g [14]. Application of 100 mg P/kg though depressed Zn concentration to as low a level as 10 μg/g, but there was no reduction in plant dry matter yield. So it appears that deficiency limit for Zn in wheat (Cv. Lyallpur-73) would be around 10 μg/g. Application of Zn at 3 mg/kg significantly ($P < 0.05$) increased the dry matter as well as Zn concentration in the plant tops. The P/Zn concentration ratio in 62 days old wheat tops varied from 21 to 544 and the highest dry matter yield was obtained at a P/Zn concentration ratio around 144 (Table 2). Gattani *et al.* [15] reported similar results.

The analysis of the soil (Table 3) after the harvest of wheat plants revealed that P application had no detrimental effect on Zn availability in soil although Zn application increased Zn concentration in soil. This agrees with earlier reports [16,17] and supports the hypothesis that the site of P-Zn interaction is not the soil but within the plant itself. Table 2 reveals that P application has not affected the absorption of Zn in the roots but has impaired the translocation of Zn from roots to tops. Zinc application without P has slightly decreased P translocation from roots to tops but not in the presence of phosphorus.

Effect of residual P and Zn on growth and dry matter yield of maize. Significant differences in general appearance of the plant at 3 weeks after sowing was evident. The plants in the control treatment were stunted, lower leaves purple in colour and the oldest leaves dry. In P_{100} treatment, growth was stunted, internodes short and leaves appeared papery and lost the green colour. Margins of fully developed leaves were purplish, having dry tips. In P_{100} Zn_3 or P_{100} Zn_9 treatments the growth was normal.

The residual P and Zn was most effective at P_{100} Zn_3 level of application for the growth of maize plants (Table 4). Higher Zn had no additional effect on the dry matter yield. The plants had a positive P-Zn interaction in the dry matter production of leaves, stems or roots. It should be observed that the growth and the dry matter production was not significantly better in the residual P_{100} treatment

Table 2. Nutrient concentration and uptake in wheat tops and roots as affected by P and Zn application.

Treatment		Zn Concentration	Zn uptake	P concentration	P uptake	P/Zn	Changes in distribution	
P	Zn							
(mg/kg)		(ug/g)	(ug/pot)	(%)	(mg/pot)		P	Zn
				Tops				
0	0	35.31	25.25	0.154	1.09	43	1.40	0.34
0	3	61.06	79.28	0.144	1.85	24	0.90	0.55
0	9	62.42	98.68	0.133	2.04	21	0.89	0.51
20	0	15.17	109.10	0.218	15.81	144	1.15	0.15
20	3	41.67	320.05	0.216	16.54	52	1.11	0.39
20	9	54.58	422.05	0.229	17.74	42	1.14	0.45
100	0	10.00	83.75	0.544	45.82	544	1.66	0.10
100	3	27.08	260.92	0.482	46.52	178	1.62	0.26
100	9	34.17	332.47	0.491	47.73	143	1.62	0.32
L.S.D.	($P < .05$)							
	P	6.34	32.30	0.32	2.48	—	—	—
	Zn	6.34	32.30	n.s.	n.s.	—	—	—
	PxZn	n.s.	79.17	n.s.	n.s.	—	—	—
			Roots					
0	0	104.11	30.46	0.110	0.32	10		
0	3	110.16	56.18	0.160	0.81	14		
0	9	123.35	78.27	0.150	0.92	12		
20	0	101.25	241.75	0.190	4.58	19		
20	3	105.83	205.78	0.194	3.75	18		
20	9	121.67	267.95	0.201	4.42	16		
100	0	97.50	281.38	0.327	9.44	33		
100	0	104.17	291.91	0.297	8.34	29		
100	9	107.50	294.67	0.304	8.32	28		
L.S.D.	($P < .05$)							
	P	n.s.	26.88	0.020	0.52	—		
	Zn	n.s.	n.s.	n.s.	n.s.	—		—
	PxZn	n.s.	n.s.	0.050	n.s.	—		

Table 3. P and Zn content and their ratio in soil after the harvest of wheat plants as affected by different treatments.

Treatment		Soil content*		
P	Zn	P	Zn	P/Zn
(mg/kg)		(μg/g	(μg/g)	
0	0	6.1	0.21	29.0
0	3	6.5	1.79	3.6
0	9	6.3	5.36	1.2
20	0	9.7	0.18	53.9
20	3	10.3	1.79	5.7
20	9	11.0	5.44	2.0
100	0	59.1	0.18	328.3
100	3	59.8	1.85	32.3
100	9	64.8	6.64	9.7

*Extractable P by $NaHCO_3$ and Zn by DTPA methods.

as compared to control or P_{20} but it greatly improved ($P < .01$) where small amount of Zn was also present with it.

Nutrient composition and their distribution within plant parts. It is evident from Table 5 that residual P and Zn has increased their respective concentrations and total uptake as well as their ratio in the stem or leaves. In treatments having higher P, the concentration of Zn in leaves and stem was significantly reduced. The critical Zn concentration in leaves appear to be around 13 μg/g. The plants in P_{20} treatment suffered with both P and Zn deficiency while in P_{100} treatments the plants were not deficient in P but suffered from Zn deficiency. Presence of a small amount of Zn increased the concentration of Zn in the plant above the

Table 4. Effect of residual P and Zn fertilizer on the growth of maize plant.

Treatment		Dry matter yield			
P	Zn	Leaf	Stem	Roots	Total
mg/kg		g/pot	g/pot	g/pot	g/pot
0	0	1.12	0.42	1.21	2.75
0	3	1.08	0.37	1.24	2.69
0	9	1.12	0.43	1.23	2.78
20	0	1.47	0.62	1.61	3.70
20	3	1.64	0.78	1.58	4.00
20	9	1.55	0.63	1.41	3.59
100	0	1.58	1.06	2.23	4.87
100	3	5.81	3.78	4.51	14.10
100	9	6.18	3.69	4.76	14.65
LSD (P<.01)					
P:		0.42	0.41	0.35	
Zn:		0.42	0.41	0.35	
PxZn		1.03	1.02	0.87	
Overall		0.73	0.72	0.46	

critical level and the plants responded to higher P level. P/Zn ratio varied from 9 to 359 in leaves and 11 to 455 in stems. Optimum dry matter yield were obtained when the P/Zn ratio was 123 in leaves and 111 in stem.

Unlike leaves and stem, higher residual P has not depressed Zn concentration in the roots rather increased total Zn uptake due to increased root dry matter. Phosphorus tended to impair the movement of Zn from roots to stem and to leaves at all leavels of Zn (Table 5) as could be judged by the change in Zn distribution. The average percentage distribution of Zn in different plant parts of the P_O plants were 23 % in roots, 36 % in stem and 41 % in leaves, but at P_{100} level the distribution pattern changed and the roots retained highest Zn 46 %, followed by stem 28 %, and then leaves 26 %.

Residual Zn had little effect on P concentration in leaf, stem or roots at P_O or P_{20} level but at P_{100} level, it decreased P concentration, which may be due to dilution effect, since the total P uptake at this level increased signi-

Table 5. Effect of residual P and Zn on the concentration and uptake of these nutrients in 28 days old maize plants.

Treatments		Zn concentration	Zn uptake	P concentration	P uptake	P/Zn	Changes in distribution	
P	Zn						P	Zn
(mg/kg)		(μg/g)	(μg/pot)	(%)	(mg/pot)			
				Leaf				
0	0	17.35	19.28	0.10	1.11	57.00	1.13	1.15
0	3	51.25	55.35	0.10	1.01	19.00	0.98	2.02
0	9	107.36	119.53	0.10	1.11	9.00	1.11	1.86
20	0	11.69	17.33	0.09	1.42	82.00	1.17	0.81
20	3	36.74	66.28	0.09	1.56	26.00	1.03	1.65
20	9	88.75	140.05	0.09	1.47	10.00	1.02	1.48
100	0	8.63	13.38	0.31	4.93	359.00	1.29	0.82
100	3	15.03	87.48	0.18	10.82	123.00	1.06	0.61
100	9	30.61	190.07	0.21	13.04	69.00	1.03	1.03
L.S.D. (P<.01)								
	P	6.95	20.27	0.020	1.18			
	Zn	6.95	20.27	0.020	1.18			
	PxZn	17.03	49.65	0.049	2.89			
				Stem				
0	0	12.38	5.19	0.11	0.47	90.00	1.28	0.82
0	3	43.31	16.00	0.11	0.41	26.00	1.08	1.71
0	9	101.10	44.91	0.11	0.49	11.00	1.24	1.75
0	0	8.76	5.50	0.10	0.66	119.00	1.27	0.61
20	3	38.13	30.48	0.11	0.86	28.00	1.18	1.71
20	9	101.25	64.85	0.11	0.71	11.00	1.25	1.69
100	0	0.07	8.40	0.37	3.91	455.00	1.53	0.76

(Continued . . . . .)

(Table 5, continued)

100	3	17.25	64.11	0.19	7.00	111.00	1.10	0.70
100	9	32.29	119.29	0.24	8.77	73.00	1.17	0.71
L.S.D. (P < .01)								
	P	9.67	14.94	0.039	1.97			
	Zn	9.67	14.94	0.039	n.s.			
	PxZn	23.69	36.60	0.096	n.s.			
				Roots				
0	0	15.03	18.22	0.09	1.06	58		
0	3	25.33	31.15	0.10	1.26	40		
0	9	57.69	71.13	0.09	1.10	15		
20	0	14.47	23.11	0.08	1.31	57		
20	3	22.26	35.27	0.09	1.46	41		
20	9	60.00	84.65	0.09	1.29	15		
100	0	10.57	23.68	0.24	5.41	228		
100	3	24.77	111.54	0.17	7.88	70		
100	9	58.75	280.78	0.20	9.73	35		
L.S.D. (P < .01)								
	P	n.s.	23.72	.013	0.99			
	Zn	5.16	23.72	–	0.99			
	PxZn	n.s.	58.11	.033	2.44			

ficantly in all the three plant parts. The 'lock up" process of P in roots as suggested by Nair and Babu [21] was not evident in this experiment.

DISCUSSION

Maize appeared to be more sensitive than wheat in responding to P and Zn deficiency in soil [18]. Soil P showed significant correlation with dry matter yield of wheat (r = 0.707*) and maize (r = 0.822**). Soil Zn had no such relationship with dry matter yield of either crop. It also had little correlation with Zn concentration or its uptake by wheat plants, but showed significant relationship with maize leaf Zn concentration (r = 0.692*) and its total uptake (r = 0.970**). The ratio of P to Zn in soil however, showed little relationship with crop yield, Zn concentration or total Zn uptake by the plant and appeared to be less reliable parameter to predict P-Zn disorder [19]. On the contrary plant P/Zn concentration ratio was a better index as suggested by others [15,20].

Increasing rates of P application had little effect on extractable Zn of the soil. It also showed little effect on the absorption of Zn into the roots but appeared to impair translocation of Zn from roots to the tops. Nair and Babu [21] reported similar results for 42 days old maize plants. However, irrespective of the mechanism that could be involved in P induced Zn deficiency, application of P fertilizers generally reduce Zn concentration in the plant. It, therefore, appears to be logical to apply small amount of Zn alongwith P in order to avoid P-induced Zn deficiency and obtain increased dry matter yield wherever Zn may be marginal to deficient in the soil.

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