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Effect of P and Zn application by fertigation on P use efficiency and yield of wheat

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ABSTRACT

Balanced application of fertilizer at appropriate time by proper method is important to improve P uptake efficiency in wheat. Due to widespread deficiency of Zn in Pakistan soil, Zn was applied along with P by fertigation to determine its effect, in comparison with other methods of P application, on P use efficiency and yield of wheat. Application of P and Zn by fertigation at first irrigation increased grain yield of Pak-81 wheat compared to other methods of P application in a pot experiment. Concentration of Zn in seeds also increased significantly due to Zn application along with N and N+P. Under field conditions, Zn application by fertigation increased grain yield by 9% and improved agronomic efficiency, P fertilizer efficiency and the physiological nutrient efficiency by 35, 20 and 12% respectively over N and P applied by the same methods.

Key words: Fertigation phosphorus, P efficiency, wheat, zinc.

INTRODUCTION

Due to alkaline and calcareous nature of Pakistan soils, the amounts of nutrients available for plant growth are relatively low. For sustainable agriculture, judicious use of fertilizer is necessary (Ahmad *et al.* 1992; Rasher 1992). Although the over all fertilizer use has grown by 40% over the past decade, major increase has been in N use resulting in a wider N: P ratio. The type of phosphatic fertilizer used in the country do not differ much in their efficiency, measured in terms of yield response. However, time and method of application have some influence on improving P uptake and efficiency (Ahmad *et al.* 1992). Balanced application of fertilizer at appropriate time by a proper method may further improve the efficiency of P fertilizer (Rashid 1994). Earlier studies indicated that efficiency of P uptake improved considerably when applied by fertigation at first irrigation compared to broadcasting and incorporation at seeding, and when applied as top dressing (Latin *et al.* 1997). Zinc deficiency is the most widespread micronutrient problem and about 30% of the agriculture soils of the world are Zn deficient (Sillanpaa 1982). In general, cereals and particularly wheat, suffer from Zn deficiency, limiting yield in many parts of the world (Graham *et al.* 1992; Cakmak *et al.* 1996). In Pakistan, Zn has also been identified to be a limiting nutrient in most of the soils (Kausar *et al.* 1979; NFDC 1998). In a recent survey Rafique *et al* (1996) reported N, P and Zn deficiency in 70-80% field of rapeseed mustard, 62-80% of groundnut, 60-67% each of wheat and sorghum in the rainfed area of Pother Plateau. Wheat being the staple food in Pakistan accounts for 48% of total fertilizer used. Yet the per acre yield remained quite low compare to other wheat growing countries of the world (Twyford 1994). The stagnation in crop yield may largely be attributed to inadequate and imbalanced application of fertilizer. This study was therefore conducted to assess the effect of Zn and P application by fertigation in comparison with other methods of P application on P use efficiency and yield of wheat.

Abbreviations: AE - Agronomic efficiency, DM -Dry matter, DMY - Dry matter yield, PFE -Phosphorus fertilizer efficiency, PNE - Physiological Nutrient efficiency, PUtE - Phosphorus utilization efficiency, SSP - Single super phosphate.

MATERIALS AND METHODS

Pot experiment

A bulk soil sample was collected form NIAB farm area. A sample of this soil was crushed to pass through 2 mm sieve and analyzed for some physicochemical properties (Table 1). Four and a half kg soil was packed in python line plastic pots. Nitrogen as urea was applied to all the pots except control in three equal splits; at the rate of 50 mg N kg^{-1} soil mixed before sowing and as urea solution each at first and third irrigation (42 and 70 days after sowing of wheat). Zinc was applied as $ZnSO_4$ solution at first irrigation while P as single superphosphate was applied by different methods (Table 2). All or half of P was either mixed with the soil before sowing or was applied as solution along with first or second irrigation 42 and 56 days after sowing. The eight treatments were replicated four times and the pots

Table 1. Soil characteristics of the experimental site at Faisalabad, Pakistan

Soil series	Lyallpur
Sub group	Typic Ustocrept
PH	7.45
Ece	1.01 dSm^{-1}
Organic matter	0.83%
Free lime	4.52%
Texture	Silt loam
$NaHCO_3$-P	4.98 mg kg^{-1}
DTPA Zn	0.45 mg kg^{-1}
DTPA Cu	0.97 mg kg^{-1}

were arranged in a completely randomized design in a net house. Seven seeds of wheat (Cv.Pak-81) were sown in each pot and after germination they were thinned to three uniform plants. Deionized water was used to maintain moisture at field capacity. At maturity, the number of tillers per plant were counted. The plants were harvested and grains were separated from straw and both were dried in oven at 70^0C for three days and dry weight was recorded. Phosphorus in straw and grain was determined after digestion in triacid mixture using Bartons' reagent (Jackson 1962) and Zn in grain by atomic absorption spectrophotometer. Analysis of variance of the data was performed using MSTAT software in a personal computer. P fertilizer efficiency (PFE) was calculated as[$(P_f-P_c)/P$] 100 where P_f and P_c are total P uptake form fertilized and the check pots respectively, and P is applied P in mg pot^{-1}. P utilization efficiency (PUtE) was calculated by dividing the weight of grain by total P uptake, both in mg $plant^{-1}$ (Sanders *et al.* 1990).

Field experiment

A field experiment was conducted on the site where soil for the pot experiment was collected. Pak81 wheat was sown at the rate of 120 kg ha^{-1} by a tractor operated drill in 7x3 m plots. Nitrogen as urea was top dressed in 2 equal split of 75 kg ha^{-1} at 25and 55 days after sowing with first and second irrigation. P and Zn were applied at the rate of 44 and 10 kg ha^{-1} respectively as commercial SSP and $ZnSO_4$ by fertigation at first irrigation. The experiment was laid out in a randomized complete block design with four replicates. Plant samples were taken form $0.5m^2$ area at 25,55 and 87 days after sowing for crop biomass (DMY) and P uptake determinations. Grain and straw yields were measured from 5x2 m area at crop maturity. The number of bearing heads were also counted in 1 m^2. P and Zn in plant dry matter, straw and grain were determined by the method used for the pot experiment. Agronomic efficiency (AE),P fertilizer efficiency (PFE)and the physiological nutrient efficiency was calculated according to method described by Saleem (1994).

RESULTS AND DISCUSSION

Pot experiment

Grain and straw yield

Application of N alone (T2) or with Zn (T3) did not significantly increase grain and straw yield of wheat over the control (Table 2). Application of P by either method (T4 and T5) along with N increased grain and straw weight significantly over the control as well as N application alone. Split application of P, half at sowing and half at first irrigation by fertigation (T7) produced significantly higher grain and straw yield than splitting P between first and second irrigation (T6) or its single application at sowing (T4). The increase grain and straw yield could be attributed to P effect on tiller production. Application of Zn with N alone (T3) had no significant effect on the tiller number but with N+P (T8) it significantly increase the productive tiller number over P applied only at sowing (T4) or at first irrigation (T5) and thereby increased the grain yield significantly (Table 2). The highest grain yield was recorded when half of P was incorporated before sowing and half as solution by fertigation at first irrigation (T7). Equivalent grain yield was also obtained when Zn was applied by fertigation along with full P dose at first irrigation (T8). This treatment resulted in significantly higher Zn concentration in grain compared to treatment where Zn was not applied (Table 2).

Nutrient content in plants and total uptake

Nitrogen application alone increased P content in grains and the total P uptake but application of Zn alone with N did not increase the total P uptake significantly over the control (Tables 2 & 3). Similarly application of P along with N did not always increase P content over N alone. Method and time of application have same influence on increasing P content. Splitting P dose between sowing and first irrigation (T7) increased P content and P uptake in grain as compared to P application at sowing (T4) or at first irrigation (T5). Similarly spilt application of P at first and second irrigation by fertigation (T6) significantly increased the P content and P uptake than the single application at sowing (T4). Application of P at first irrigation by fertigation (T5) resulted in equivalent P content and P uptake by grains compared to its application at sowing (T4).

Table 2. Grain and straw yields, tiller nos. and total P uptake in wheat as affected by N, P and Zn application.

Nutrient application, yield, Mg kg^{-1} soil g pot^{-1}	Grain yield, g pot^{-1}	Straw of tillers, $plant^{-1}$	Number uptake, mg pot^{-1}	Total P
T1-Control	4.54D	7.25C	5.25C	9.85E
T2-N150	5.54D	7.29C	5.25C	14.87D
T3-T2+Zn10(S)*	5.08D	6.96C	5.25C	13.35DE
T4-T2+P44(IBS)	14.98C	21.26B	10.25B	40.88C
T5-T2+P44(S)	15.32BC	20.37B	10.75B	44.98BC
T6-T2+P44(SS)	15.35BC	21.90AB	11.00B	48.63B
T7-T2+P44(IS)	16.45A	22.95A	11.50AB	53.90A
T8-T2+P44+Zn10(S)	16.43A	21.17B	12.50A	41.63C

Figures with similar letters within each column are not significantly different at P<0.05, according to DMRT.

* (S) - all P or Zn as solution at 1st irrigation; (IBS) - incorporated in soil before sowing; (SS) - split application of at 1st and 2nd irrigation; (IS) - half P incorporated before sowing and half as solution at 1st irrigation.

Table3. Concentration and uptake of P and Zn in wheat as influenced by N, P and Zn application.

Nutrient Application, mg kg^{-1} soil	P in straw		P in grain		Zn in grain	
	Conc., mg kg^{-1}	Uptake, mg pot^{-1}	Conc., mg kg^{-1}	Uptake, mg pot^{-1}	Conc., mg kg^{-1}	Uptake, µg pot^{-1}
T1-Control	188AB	1.36C	1864F	8.48E	25.16C	155.6D
T2-N150	178BC	1.30C	2450CD	13.57D	32.76B	182.7C
T3-T2+Zn10(S)*	160BC	1.11C	2415D	12.24DE	47.64A	238.5B
T4-T2+P44(IBS)	190AB	4.03AB	2467CD	36.85C	13.20D	197.2C
T5-T2+P44(S)	189AB	3.85B	2683BC	41.12BC	14.67D	224.9BC
T6-T2+P44(SS)	191AB	4.40AB	2855AB	43.89B	12.16D	186.8C
T7-T2+P44(IS)	214AB	4.74A	3009A	49.51A	13.68D	225.0BC
T8-T2+P44+Zn10(S)	174BC	3.67B	2310DE	37.95C	27.26C	447.9A

Figures with similar letters within each column are not significantly different at P<0.05, according to DMRT.
* Please see table 2 for details.

Application of Zn significantly increased Zn content and total Zn uptake in grain over N or N+P. Zinc when applied with N (T3) did not decrease P uptake but with N+P (T8), it decreased P content and P uptake compared to split P application (T6, 7) but not when applied fully at sowing (T4) or at first irrigation (T5). On the other hand, application of P by either method decreased (P<0.05) Zn concentration over N alone but had little depressive effect on Zn uptake in grain and could be attributed to dilution effect resulting from increased grain yield (Alam *et al.* 1998)

P use efficiency (PUE)

Application of P in the form of a solution or as a split dose at different times resulted in higher agronomic efficiency and P fertilizer efficiency (PFE) than its application at sowing. Incorporation of half of P dose before sowing and remaining half as solution at first irrigation also resulted in 15% higher AE and 50% higher PFE than its application at sowing but the absorbed P could not be utilized for grain production which was evident in lower P utilization efficiency in these treatments. This could partially be attributed to late application of P (Ali *et al.* 1998). Application of Zn along with P at first irrigation improved P utilization efficiency ranging from 7.9 to 29.5% compared to P applied alone by different methods.

Field Experiment

Growth

There were no significant differences in dry matter production among treatments at 25 days after sowing (Table 4). Similar results are been obtained in an earlier study (Letif *et al.* 1994). At 55 days after sowing the dry matter production was significantly (P<0.05) higher over control where P was applied along with N or N+Zn. The effect of P on DM production was very clear at 87 days after sowing. Application of P not only increased DMY over control, but increased it over N and N+Zn treatments too and this trend was continued until crop maturity. Between 25 and 87 days, the increase in growth rate due to N alone was 4.19 kg ha^{-1} day^{-1} while it was 26.88 kg ha^{-1} day^{-1} due to combined effect of N and P application. Further increase in growth rate to 37.93kg $ha^{-1}day^{-1}$ was observed when Zn was applied alone with N and P. Thus combined application of (N, P, Zn) at first irrigation enhanced growth. Ali *et al.* (1998) reported increased number of tillers per meter length and highest grain yield of wheat when P was applied at first irrigation. They observed that this occurred due to more efficient absorption of P by the wheat roots that are very active at this stage. Late application of P at 2^{nd} and 3^{rd} irrigation was not so useful and resulted in lower grain yield.

Table 4. Effect of N, P and Zn applications on the total dry matter yield (t ha^{-1}) of wheat at different times of growth.

Nutrient application Kg ha^{-1}			Days after sowing			
			25	55	87	136
N	P	Zn				
0	0	0	0.11A	0.42C	2.43B	5.64C
150	0	0	0.13A	0.51BC	2.69B	6.51BC
150	0	10	0.12A	0.62ABC	2.70B	6.70B
150	44	0	0.12A	0.72AB	4.08A	8.54A
150	44	10	0.12A	0.83A	4.77A	8.77A

Figures with similar letters within each column are not significantly different at P<0.05, according to DMRT.

Grain and straw yield

Application of N significantly increased the grain yield over control (Table 5). Application of P alone with N further increased the grain yield over control and N application. The increase in grain yield may partially be attributed to increase number of heads m^{-2}. Application of Zn did not result in an increase in

Table 5. **Effect of N, P and Zn application on grain yield, number of heads m^{-2}, total N and P uptake and P use efficiency in wheat.**

Nutrient application, kg ha^{-1}			Grain yield, kg ha^{-1}	No. of heads m^{-2}	N-uptake, kg ha^{-1}	P-uptake, kg ha^{-1}	AE, kg kg^{-1}	PFE, %	PNE, kg kg^{-1}
N	P	Zn							
0	0	0	3182C	265D	54.4D	9.40C	-	-	-
150	0	0	4016B	326BC	90.7BC	11.60B	-	-	-
150	0	10	4068B	310C	85.5C	11.64B	-	-	-
150	44	0	5221A	362AB	122.3A	20.35A	27.4	19.9	138
150	44	10	5695A	389A	117.6AB	22.14A	37.0	23.9	155

AE, agronomic efficiency; PFE, P fertilizer efficiency and PNE, physiological nutrient efficiency.

grain yield significantly over N+P but it increased the agronomic efficiency (AE), P fertilizer efficiency (PFE) and the physiological nutrient efficiency (PNE) by 35,20 and 12% respectively.

Application of P along with N or N+Zn increased both N and P uptake over N alone (Table 5) but showed depressive effect on Zn content and Zn uptake by grain (Fig. 1). Application of P along with N also decreased Zn content over N alone treatment in plants harvested at 55 and 87 days of growth as well as in straw at maturity (fig. 2). Moustaoui *et al.* (1991) reported similar P and Zn interaction in wheat and noted that Zn content of wheat shoots and roots decreased up to 53 and 52% respectively as the supply of soil phosphorus was increased. The origin of this interaction, whether due to lower translocation of Zn from roots to shoots or due to its dilution within the plants was not clear. Alam *et al.* (1998) on the other hand found that Zn content in tops of both wheat and maize plants were reduced mainly due to dilution effect since higher P rate applied did not affect absorption of Zn in the roots of both the species but partially reduced the

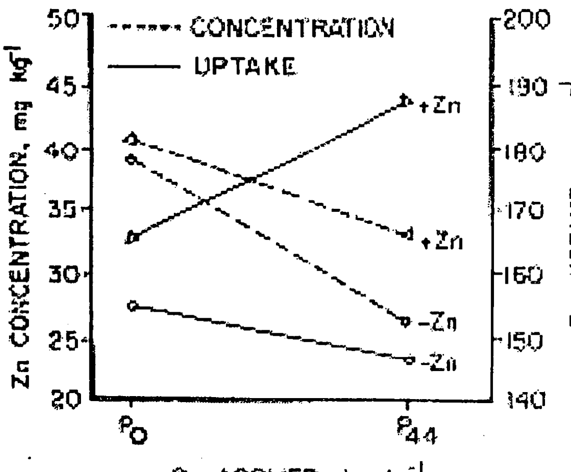

Fig 1. **Influence of P and Zn application on Zn uptake by the crop and on Zn concentration in wheat grain**

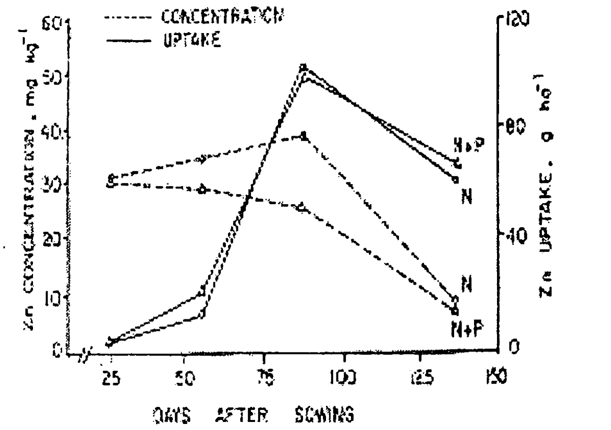

Fig 2. **Influence of N and P application on Zn concentration and crop uptake at different stages of growth in wheat.**

translocation of Zn from roots to the tops. Wheat is considered relatively insensitive compared to other species to low Zn levels in soils (Rashid and Fox 1992) and varietal differences in Zn absorption from soil has also been reported (Graham *et al.* 1992; Alam *et al.* 1983; Kausar and Tahir 1994). Growing wheat on Zn deficient soil leads not only to depression in plant growth and yield but also to low Zn concentration in grain. When seeds of low Zn concentration are resown on Zn deficient soils, poor seeding vigour and low yield at harvest could be expected. The current stagnation and low per acre yield of wheat grain in Pakistan may partially be attributed to cultivation of wheat varieties of low Zn content as well as to imbalanced fertilizer use particularly with respect of P and Zn. Application of Zn fertilizer may not only improve yield but would also result in higher seed Zn content (Rengel and Graham 1995). Resowing of seeds of higher Zn content would partially overcome problems of insufficient Zn fertilization as well as spatial and temporal variability in Zn availability which are typically patchy even in a single field.

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