Pak J Sci Ind Res 2002 ***45*** *(2) 117-119*

Wheat Yield and Phosphorus use Efficiency as Influenced by Method of Phosphorus and Zinc Application

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(Received 26 May 1999; accepted 31 May 2001)

Phosphatic fertilizers are recommended to be applied as broadcast and incorporated into the soil before sowing. More recently application of fertilizer with irrigation water as solution, termed "Fertigation", has been found equally effective for wheat production. Fertilizer zinc whose requirement is small and is commonly deficient in soils, was tried as fertigation in order to determine its effect on yield and P use efficiency by wheat. Single superphosphate fertilizer was applied at 22 and 44 kg P ha^{-1} either alone or with 10 kg Zn ha^{-1}. The method of application employed was broadcast at sowing and fertigation at first irrigation. It was found that rate of P application increased wheat grain yield over control and P applied @ 44 kg ha^{-1} by fertigation proved significantly better than broadcast application. Addition of Zn as broadcast or as fertigation showed no difference in yield compared to P alone. Application of Zn by fertigation, however, improved agronomic and P fertilizer efficiency compared to its broadcast application at sowing.

Key words: Fertigation, Phosphorus, Wheat, Zinc.

Introduction

Over 90% of Pakistan soils are regarded poor in available phosphorus (Ahmad *et al* 1992). Factors responsible for low Pare mostly high pH, high $CaCO_3$ content, variable P fixation capacity and low organic matter content of these soils (Ahmad *et al* 1992). Sustainable agriculture necessitates P fertilizer application in amounts ranging from 44-66 kg P ha^{-1} for optimum wheat yield (Malik *et al* 1992). But due to shortage in supply or other economic constrains, the farmers are some times compelled to add reduced amounts of P fertilizer. They usually top dress their crops with N fertilizer that adversely effects the N:P ratio and generally result in low P use efficiency and crop yield (Ahmad *et al* 1992, Malik *et al* 1992). Placement of P at proper time by appropriate methods and in balanced proportion with N may lead to improved P use efficiency (Ahmad *et al* 1992, Khalid and Khalid 1994). More recently, application of P fertilizer by fertigation at first irrigation or split P application at first and second irrigation by fertigation has shown some advantage in P use efficiency over conventional method of broadcast and incorporation at sowing or top dressing at first irrigation (Latif *et al* 1997; Alam *et al* 1999 a & 99 b). Deficiency of Zn has been recognised as widespread nutritional problem in almost all types of soil in the world (Sillanpaa 1982; Rengel and Graham 1995). In Pakistan, Zn is considered the third most common deficient nutrient after N and P (NFDC 1998). The response of wheat to Zn application has, however, been found to be inconsistant over time and locations (Rashid *et al* 1988) but improvement in wheat grain yield has been obtained on many locations (NFDC 1998, Suhag *et al* 1988). Present studies were conducted to determine the effectiveness of fertigation technology for improved yield also to assess the effect of Zn application on P use efficiency and yield of wheat.

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Materials and Methods

A field experiment was conducted at NIAB Farm, Faisalabad during 1992-93 on a normal, alkaline loam soil, moderate in free lime content, low in organic matter and available phosphorus and marginally deficient in zinc (Table 1). The experiment was laidout in a randomized complete block design having net plot size of 3x6 m^2 and replicated four times. All the plot received urea-N at 20 kg ha^{-1} as a basal dose at sowing and also 50 kg N ha^{-1} top dressed each at first and the second irrigation. Single superphosphate (SSP, 16% P_2O_5) was applied at 22 and 44 kg P ha^{-1} by broadcast and incorporation at sowing or by fertigation at first irrigation (4 weeks after sowing). Zinc oxide was applied at the rate of 10 kg ha^{-1} either at sowing by broadcast method or at first irrigation by fertigation. Wheat (*Triticun aestivum* L. Cv. Pak-81) was sown by single hand row drill at a seed rate of 120 kg ha^{-1} in 30 cm apart rows (eleven rows per plot). Four irrigations were given to the crop besides initial soaking dose and normal agronomic practices were followed. At maturity seven central rows 4m in length, were harvested to estimate grain and straw yield. Phosphorus content in grain was estimated by metavandate yellow colour method after digestion of ground material in triacid mixture (Jackson 1962). The data were analyzed using MSTAT software on a personal

computer and pairwise means separated by DMR test. Agronomic efficiency (AE) was calculated as grain yield (fertilized)-grain yield (control) divided by amount of P applied, in kg ha^{-1}. P fertilizer efficiency (PFE) was calculated as [(P_f-P_c)/ P]100 where P_f and P_c are total P uptake in grain from fertilized and check plots, respectively and P is applied P in kg ha^{-1}.

Results and Discussion

Grain yield and P uptake. Application of P either by rate and by method significantly increased ($P<0.05$) grain and straw yield of wheat (Table 2). Higher P rate applied by fertigation significantly increased ($P<0.05$) grain yield over the lower P rate applied by the same method as well as the conventional method of broadcast and incorporation at sowing. The lower P rate applied by fertigation also produced statistically similar grain yield as obtained by higher P rate applied by broadcast method. These results support earlier reports (Latif *et al* 1997, Alam *et al* 1999 a, 99 b). In one of these studies (Latif *et al* 1997) half of recommended P rate applied by broadcast method at sowing gave significantly less grain yield compared to those obtained by the recommended P rate applied as broadcast. Applying half of P rate by fertigation, however; improved grain yield and it was statistically equivalent to grain yield where full P was applied by broadcast at sowing or by fertigation at first irrigation. This showed improved efficiency of P when applied by fertigation. Application of Zn by either method alongwith P did not increase grain yield significantly over respective P alone treatment. However, lower P rate and Zn when applied by fertigation, produced grain yield statistically similar to that obtained by applying higher P rate by either method. This indicates a synergistic effect of Zn on increasing P efficiency and causing yield improvement due to fertigation.

Total P uptake increased significantly ($P<0.05$) over control due to rate and method of application. Highest P uptake was obtained where higher P rate was applied by fertigation and applying the same P rate by broadcast and incorporation at sowing resulted in significantly lower ($P<0.05$) P uptake by wheat. Application of Zn did not increae total P uptake significantly at either rate and method of P application over the corresponding rates of P application alone.

P use efficiency. Rate and method of application positively influenced P use efficiency in wheat. Agronomic efficiency (AE) and P fertilizer efficiency (PFE) both improved when P was applied by fertigation (Table 2). At equivalent P rate of 44 kg P ha^{-1}, AE and PFE was 70.1 and 81.6% higher over its broadcast application at sowing, respectively. Ranjha and Mehdi (1992) also reported that top dressing of 20 kg p_2O_5 ha^{-1} at first irrigation resulted in equivalent wheat grain yield obtained by broadcasting and incorporating 60 kg P_2O_5 ha^{-1} at seeding. They noted that immediate use of irrigation water after P application was the key factor in improving P fertilizer use efficiency. Water is helpful in the formation of hydrated phosphate compounds such as mono calcium phosphate dihydrate which are more mobile and remain available for a longer period of time (Ranjha and Mehdi, 1992). Application of "fertilizer solution" alongwith first irrigation water (4 weeks after sowing) might also carry P to lower depths in soil be-

Table 1.
Some physico-chemical properties of the experimental site

Soil series	Lyallpur
Sub group	Typic Ustochrept
Texture	Loam
Soil pH	7.87
ECe	0.31 dSm^{-1}
Organic matter	0.65 %
Free lime	1.63 %
Total N	0.03 %
NH_4OAc K	150 mg kg^{-1}
AB-DTPA P	3.87 mg kg^{-1}
AB-DTPA Zn	0.92 mg kg^{-1}
AB-DTPA Cu	2.73 mg kg^{-1}

Table 2
Effect of rate and method of P and Zn application on P use efficiency and yield of wheat.

Treatment			Grain yield	Straw yield	P Uptake (grain)	Agronomic efficiency	P Fertilizer efficiency
Rate* P kg ha^{-1}	Zn	Method**	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	%
0	0	-	3008 C	5897 B	9.10 C	-	-
44	0	Broadcast	3687 B	7500 A	12.13 B	15.4 B	8.70 C
44	10	Broadcast	3884 AB	8609 A	13. 90 B	19.9 B	10.90 BC
44	0	Fertigation	4161 A	8217 A	16.05 A	26.2 AB	15.80 AB
22	0	Fertigation	3458 B	8058 A	12.15 B	26.3 AB	13.83 ABC
22	10	Fertigation	3817 AB	7642 A	13.34 B	36.7 A	19.23 A*

*Fertilizer P as SSP and Zn as Zn0; Fertilizer N as urea @ 20,50,50 kg ha^{-1} at sowing, Ist and 2nd irrigation as a basal dose,** Broadcast and incorporation at sowing and fertigation at first irrigation (4 weeks after sowing); Figures not sharing a common letter within a column are significantly different at $P<0.05$ as determined by DMR test.

cause the soil still remains loose by that time. At this stage the high P demand for growth could be met rapidly through the active growing roots due to prolonged P availability (Ali *et al* 1988, Barber 1984, Romer and Schilling 1986, Hajabbasi and Schumacher 1994).

Application of Zn with higher P rate at sowing increased AE and PFE by 29.2 and 25.4% only while application of Zn along with lower P rate by fertigation increased AE and PFE by 80.4 and 39.0% over P alone treatment, respectively (Table 2). It may be noted that fertigation applied Zn alongwith lower P rate increased AE by 40% and PFE by 22% over the higher P rate applied also by fertigation, indicating increased P efficiency caused by combined Zn and P effect on grain yield. Thus Zn application by fertigation alongwith reduced P rate was much more effective in increasing the efficiency of P fertilizer and resulted in equivalent wheat yield compared to full P rate applied by broadcast method. Therefore, under situations of marginal Zn deficiency in soils, application of reduced P rate, either due to shortages of P availability or some other economic constrains, may be supplemented with small amount of Zn and should be applied at first irrigation by fertigation. Application of Zn has been reported to increase vegetative yield and also to result in improved yield with higher seed Zn content (Rengel and Graham 1995, Alam *et al* 2000).

Conclusion

It may be concluded from this study that fertigation is a better method over broadcast for applying P fertilizer to wheat. Fertigation applied P and Zn resulted in improved agronomic and P fertilizer efficiency. Therefore, on soils of marginal to deficient Zn content, if P fertilizer availability is also limited, it should be supplemented with Zn and applied at first irrigation by fertigation.

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