Pak J Sci Ind Res 1999 42 (5) 253-256

IMPROVING PHOSPHORUS FERTILIZER USE EFFICIENCY IN WHEAT THROUGH METHOD OF APPLICATION

S M Alam*, A Latif and Zafar Iqbal

Nuclear Institute for Agriculture and Biology (NIAB), P O Box No 128, Faisalabad, Pakistan

(Received 24 April 1997; accepted 19 June 99)

The recommended method of "broadcasting and incorporation" of solid P fertilizer before sowing was compared and evaluated against "top dressing" of P after plant emergance and as "solution application" along with irrigation water (termed fertigation) by growing wheat in pot and field experiments. The lower P rate applied by fertigation at first irrigation resulted in equivalent wheat yield and 25-30% higher P fertilizer efficiency compared to higher rate applied broadcast and incorporated at sowing, indicating the possibility of substantial saving in P fertilizer input.

Key words: Fertigation, Phosphorus fertilizer, Fertilizer efficiency, Wheat.

Introduction

Improvement in fertilizer use efficiency has been a subject of interest for the farmers and the agronomist not only for economic reasons but for environmental protection as well (Saleem 1992). In Pakistan the increasing cost of phosphatic fertilizer emphasises the need to find some methodology for improving the efficiency of added fertilizer (Twyford 1994). In the past, the time and the method of phosphorus placement had been more intensely studied (Dibb *et al* 1990; Ahmad *et al* 1992; Malik 1992). In general, phosphatic fertilizers are recommended to be broadcast and incorporated (soil mixing) before sowing of crop (Malik 1992). Banding P along the rows before sowing has been reported to increase wheat grain yield (Khalid and Abu Khalid 1994). Few studies, however, indicate that top dressing P at crown root stage or at the first irrigation also increased wheat yield (Ali *et al* 1988; Rashid 1994). More recently, Latif *et al* (1994) reported that solution of P fertilizer applied alongwith the first irrigation (fertigation) produced wheat grain yield equivalent to conventional soil mixing before sowing or top dressing after plant emergance. They further observed that P uptake by plants were also higher when P was applied by fertigation as compared to soil mixing (Latif *et al* 1997). Fertigation, therefore, appeared to be a simple and practical method for P application to the standing crop. The objectives of the study were (i) to compare "fertigation" with conventional "soil mixing" and "top dressing" methods of P application for wheat yield and also (ii) to evaluate it for P use efficiency as affected by rate of application.

Materials and Methods

Pot experiment. Soil from 0-15 cm depth was collected from NIAB farm (Hafizabad series, Typic Ustochrept), air dried, passed through 2 mm sieve and analyzed for some physico-chemical properties (Table 2). Five kg soil was placed in polyethylene lined plastic pots. Phosphorus was applied at 0, 22 and 44 mg P kg^{-1} soil as single super phosphate (SSP, 16% P_2O_5) to the respective pots with the following methods:

Broadcast and incorporation (soil mixing). Weighed quantity of the powdered SSP fertilizer (40 mesh sieved material) was thoroughly mixed with the entire soil mass (5 kg pot^{-1}) before sowing of seeds.

Top dressing. Weighed quantity of the fertilizer was uniformly spread on the surface of the pot soil and gently mixed with the top soil just before the first irrigation.

Solution application with irrigation water (fertigation). Calculated amounts of the SSP fertilizer for 22 and 44 mg P kg^{-1} soil were weighed in plastic beakers and 50 ml of deionized water was added with intermittent shaking, 24 h before application. The stirred suspension was applied alongwith the irrigation water to the respective treatments as outlined in Table 1.

Nitrogen as urea solution @ 150 mg N kg^{-1} was applied to all pots in two equal split doses at the first and the second irrigation, 30 and 65 days after sowing, respectively. Each treatment was replicated four times in a completely randomized design. Seven seeds of wheat (cv Pak-81) was sown in each pot and after emergence thinned to 4 uniform plants per pot. Deionized water was used to bring the soil near to field capacity as and when required. Two plants were harvested 75 days after sowing and the remaining two plants after crop maturity. At harvest, the plant samples, straw and grain were dried in oven at 70°C and dry weights were recorded. One gram portions of the ground material was digested in HNO_3-H_2SO_4-$HClO_4$ (10:4:1) ternary acid mixture and the concentration of P was determined colorimetrically using Barton's

* Corresponding author.

Table 1
Method of application of SSP fertilizer

P rate applied mg per kg soil	Broadcast (at sowing)	Top dressing (at 1st irrigation)	Fertigation (at 1st irrigation)
0	T1	--	--
22	T2	--	T7 (All P at 30 DAS)*
44	T3	T4	T5 (All P at 30 DAS)
44 Split	--	--	T6 (half of P dose at 30 DAS, remaining half at 65 DAS)

* DAS, days after sowing.

reagent (Jackson 1962). Total P uptake was calculated by multiplying the yields with respective concentrations. Statistical analysis of the data was performed using MSTAT computer programme. The rate of plant growth as influenced by P application was calculated by $(Y_f-Y_c)/(t_2-t_1)$ where Y_f and Y_c are the dry matter yields of the fertilized and the control pots and t_1 and t_2 are times (in days) of P application and of plant harvest. Phosphorus utilization efficiency (PUtE) was calculated by dividing the weight of grains by total P uptake, both in mg plant^{-1} (Sanders *et al* 1990).

Field experiment. A field experiment was simultaneously conducted at NIAB Farm to evaluate "fertigation" method of P application against the conventional "soil mixing" and "top dressing" with respect to yield and P use efficiency as affected by rate of application. Wheat cultivar Pak-81 was sown using seed rate of 120 kg ha^{-1} with single row hand drill. Row to row distance was 25 cm and plot size of 6 x 4 m^2 was established having 17 rows in all plots. The treatments comprised P rates of 0, 22 and 44 kg ha^{-1} as single superphosphate (SSP, 16% P_2O_5). The low P rate (22 kg ha^{-1}) was applied by fertigation at first irrigation while the higher amount (44 kg P ha^{-1}) was mixed with the soil before sowing, top dressed, as well as applied by fertigation at the first irrigation. Phosphorus was also applied by fertigation as a split dose, half at first and remaining half at the second irrigation, 25 and 45 days after sowing. Each treatment was replicated four times in a randomized complete block design. Nitrogen as urea was applied @ 75 kg ha^{-1} to all plots at the first and the second irrigation. Normal agronomic practices were followed. At maturity 5 x 3 m^2 area (12 plant rows) was harvested to estimate grain and straw yield. The P concentration in straw and grain was determined colorimetrically after wet digestion. Agronomic efficiency (AE) was calculated as follows:

$$AE = \frac{\text{Grain yield (fertilized) - Grain yield (control)}}{\text{P applied kg h}^{-1}}$$

P fertilizer efficiency (PFE) was calculated by the formula:

$$PFE = \frac{(P_f-P_c)}{P} 100$$

where P_f and P_c are total P uptake from fertilized and check plots respectively and P is applied in kg ha^{-1}.

Results and Discussion

Pot experiment: Growth and yield. Application of P fertilizer increased the dry matter yield (DMY) of wheat plants harvested at 75 days of growth (Table 3). Rate and method of application, however, affected the effectiveness of the applied P for dry matter (DM) production. Application of higher P rate by either method resulted in significantly ($P<0.05$) higher DMY compared to the lower rate. At lower P rate, the DMY was significantly ($P<0.05$) higher where P was applied by fertigation compared to soil mixing. Whereas at higher P rate, DMY was significantly higher where P was applied by soil mixing compared to other methods studied. The lower DMY in fertigation applied higher P rate may be attributed to late application (30 days in full and 30 and 65 days in split application) and short time between P application and plant harvest as compared to soil mixing where 75 days were given for utilization of P from added fertilizer. However, it is evident that fertigation applied P was more efficiently taken up and utilized by wheat plants for vegetative growth. The plant

Table 2
Physico-chemical properties of the soil used for pot and field experiment

pH	7.80
ECe	0.94 d S m^{-1}
Organic matter	0.62%
Free $CaCO_3$	3.1%
Texture	Silt loam
Clay	25%
Silt	48%
Sand	27%
$NaHCO_3$-P	7.34 mg kg^{-1}

growth rate induced by P application was higher in fertigation (26.44 and 39.33 mg plant^{-1} day^{-1}) compared to soil mixing (7.47 and 30.80 mg plant^{-1} day^{-1}) at 22 and 44 mg P kg^{-1} rate of application, respectively. This accelerated growth rate was maintained throughout the growth period.

At maturity, the straw yield was similar in all treatments including control, while the grain yield increased significantly due to P application. Lower P rate applied by either method did not increase grain yield over control. The higher P rate applied by soil mixing before sowing or top dressing after plant emergence also did not increase grain yield significantly over control. When the same high P rate was applied by fertigation, the grain yield increased significantly ($P<0.05$) over control. The lower P rate applied by fertigation also resulted in grain yield equivalent to that obtained by higher P rate applied by other methods, indicating improved utilization of P due to fertigation.

Phosphorus uptake. Rate and method of application significantly ($P<0.05$) increased P concentration and total P uptake in plants harvested at 75 days of growth as well as in straw and grain at maturity (Table 3). Application of P at lower rate by soil mixing before sowing or by "fertigation" after plant emer-

Table 3

Effect of rate and method of P application on yield and total P uptake by wheat plants

Treatment		Vegetative Stage			Maturity		
Rate (mg kg^{-1})	Method	DMY* (g plant^{-1})	P conc. %	P uptake (mg plant^{-1})	Grain yield (g plant^{-1})	Straw yield (g plant^{-1})	P uptake (mg plant^{-1})
Pre-emergence							
T1-0	--	1.79 e	0.22 c	3.85 d	5.76 b	12.02 a	17.26 c
T2-22	Soil mixing	2.35 d	0.27 a	6.33 c	5.89 b	12.67 a	21.28 ab
T3-44	Soil mixing	4.10 a	0.23 bc	9.53 a	6.43 ab	12.24 a	22.63 a
Post-emergence							
T4-44	Top dressing	3.35 bc	0.24 abc	8.08 ab	6.33 ab	13.09 a	21.86 ab
T5-44	Solution**	3.56 b	0.25 abc	8.72 a	7.11 a	13.42 a	22.66 a
T6-44	Solution split**	3.43 bc	0.26 ab	9.02 a	7.00 a	13.10 a	23.14 a
T7-22	Solution	2.98 c	0.22 c	6.53 bc	6.46 ab	12.52 a	19.72 b

* Dry matter yield was taken as whole plant 75 days after sowing (DAS); ** Applied as full or split at dose first (30 DAS) and second (65 DAS) irrigation. (Figures with similar letters within a column are not significantly different at $P<0.05$ as determined by Duncan's multiple range test).

Table 4

Effect of rate and method of P application on wheat yield, P uptake and P use efficiency

Treatment		Yield		P uptake	Agronomic efficiency	P fertilizer efficiency
Rate (kg ha^{-1})	Method	Grain (kg ha^{-1})	Straw (kg ha^{-1})	(kg ha^{-1})	(kg kg^{-1})	%
Pre-emergence						
0	--	2309 B	3462 B	6.71 C	--	--
44	Soil mixing	2614 AB	3695 AB	9.19 AB	6.93	5.63
Post-emergence						
44	Top dressing	2605 AB	4171 A	9.25 AB	6.73	5.77
22	Fertigation	2509 AB	4276 A	8.32 B	9.09	7.32
44	Fertigation	2625 AB	3943 AB	9.24 AB	7.18	5.75
44	Fertigation split*	2709 A	4090 AB	9.81 A	9.09	7.04

* One half of P dose at first and another half dose at second irrigation.

Figures with common letter(s) within a column are not significantly different at $P<0.05$ as determined by Duncans multiple range test).

gence resulted in similar P uptake by wheat plants. The lower P concentration in plant dry matter in fertigation applied low P rate compared to soil mixing may be attributed to shorter duration between P application and plant harvest. However, rapid P absorption by the active roots and their effective utilization for optimum growth (Ali *et al* 1988) indicates that P concentration was maintained near or above the critical level throughout the growth period (Sanders *et al* 1990). Hence at maturity the P utilization efficiency (PUtE) in fertigation applied low P rate was higher (328 mg mg^{-1}) compared to soil mixing (277 mg mg^{-1}). At higher rate, irrespective of method of application, P uptake by plants were similar in all treatments both at vegetative stage and at maturity. Similar results were reported by (Latif *et al* 1994, 1997).

Field experiment. Broadcast and incorporation of P fertilizer before sowing, or "top dressing" and "fertigation" of P after plant emergence resulted in equivalent wheat grain and straw yield and they were not significantly higher than control (Table 4). But application of the same P rate (44 kg P ha^{-1}) in two equal split doses, at the first and the second irrigation by fertigation significantly ($P<0.05$) increased the grain yield over control. This indicates that split application of P fertilizer may be more effective than its single application at sowing. The agronomic efficiency (AE) and P fertilizer efficiency (PFE) both were higher where P was applied by fertigation compared to soil mixing and top dressing (Table 4). Comparatively more P was absorbed where P was applied as a split dose. The percentage increase in AE and PFE due to fertigation over soil mixing was 31 and 30% at lower rate while it was 31 and 25% at higher rate applied as split dose respectively. Higher efficiency of P fertilizer at lower rate applied by band placement was also reported by Randall and Hoeft (1988) and Sanders *et al* (1990). Moreover, it may be observed that fertigation applied lower P rate resulted in equivalent wheat yield and improved AE and PFE compared to higher P rate applied by other methods. Therefore, in case of shortages in supply or other economic constrains, if the amount of phosphatic fertilizer available is small, it should preferably be applied at the first irrigation by fertigation.

References

Ahmad N, Saleem M T, Twyford I T 1992 Phosphorus research in Pakistan: a review. In: *Proc Symp On the Role of Phosphorus in Crop Production,* NFDC, Islamabad, pp 59-92.

Ali A, Ahmad S, Ahmad M, Ali I 1988 Response of Pak-81 wheat to phosphorus application at Faisalabad. *Pak J Agric Res* **9**(4), 593-595.

Dibb D W, Fixen F E, Murphy L S 1990 Balanced fertilization with particular reference to phosphate: interaction of P with other inputs and management practices. *Fert Res* **26**, 29-52.

Jackson M L 1962 *Soil Chemical Analysis.* Prentice-Hall Inc, Englewood, Cliffs, NJ, pp 151-153.

Khalid B Y, Abu Khalid S 1994 Efficient use of fertilizers on wheat and maize crops. In: *Pro 4th Nat Cong Soil Sci,* Islamabad, pp 215-218.

Latif A, Alam S M, Hamid A, Iqbal Z 1997 Relative efficiency of phosphorus applied through broadcast incorporation, top dressing and fertigation to crops. *Pak J Soil Sci* **13** 15-18.

Latif A, Alam S M, Iqbal Z, Hamid A 1994 Effect of rate, time and method of application of phosphorus fertilizer on wheat crop. In: *Proc 4th Nat Crop Soil Sci,* Islamabad, pp 299-303.

Malik D M 1992 Phosphorus management for wheat production in Punjab. In: *Proc Symp On the Role of Phosphorus in Crop Production,* NFDC, Islamabad, pp 175-196.

Randall G W, Hoeft R G 1988 Placement methods for improved efficiency of P and K fertilizers: a review. *J Prod Agric* **1**(1) 70-79.

Rashid A 1994 Phosphorus use efficiency in soils of Pakistan In: *Proc 4th Nat Cong Soil Sci,* Islamabad, pp 115-128.

Saleem M T 1992 An overview of phosphatic fertilizer in Pakistan. In: *Proc Symp On the Role of Phosphorus in Crop Production,* NFDC, Islamabad, pp 9-38.

Sanders D H, Penas EJ, Eghball B 1990 Residual effects of various phosphorus application methods on winter wheat and grain sorghum. *Soil Sci Soc Am J* **54** 1473-1478.

Steel R G D, Torrie J H 1960 *Principles and Procedures of Statistics.* MaGraw-Hill Book Co Inc, NY, p 481.

Twyford I T 1994 Fertilizer use and crop yields In: *Proc 4th Nat Congr Soil Sci,* Islamabad, pp 47-71.