**ORIGINAL ARTICLE**

# Effect of fertigated phosphorus on P use efficiency and yield of wheat and maize

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## Abstract

**Iqbal, Z., Latif, A., Ali, S. and Iqbal, M.M.**

**Effect of fertigated phosphorus on P use efficiency and yield of wheat and maize**

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**Field studies were made on wheat and maize crops grown on loam soil to determine the effect of fertigated phosphorus (P) on crop yield and P use efficiency. In case of wheat, rate of P application was 33 and 44 kg P $ha^{-1}$ (not $P_2O_5$) from single supperphosphate (SSP) and diammonium phosphate (DAP), while to maize it was 22 and 33 kg P $ha^{-1}$ from SSP only. The results showed that fertigated SSP enhanced the grain yield of wheat significantly over broadcast, while fertigated DAP did not affect it significantly. Application of lower dose (33 kg P $ha^{-1}$) from DAP by fertigation resulted in almost equivalent wheat yield with higher dose (44 kg P $ha^{-1}$) applied by broadcast method. Phosphorus uptake, P use and agronomic efficiency were higher in fertigation for both the P fertilizers than broadcast method. In case of the maize experiment, application of SSP by fertigation produced significantly higher grain yield as compared to the yield obtained from same dose applied by broadcast method. The lower dose (22 kg P $ha^{-1}$) applied through fertigation resulted in significantly higher grain yield than the full dose (44 kg P $ha^{-1}$) applied by broadcast. The P use efficiency and agronomic efficiency were higher in fertigation than broadcast method. In both studies, fertigated P enhanced the grain yield of the tested crops and improved the P use and agronomic efficiency, indicating the superiority of fertigation technique.**

**Key words :** fertigation, maize, wheat, P use efficiency and P-uptake

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The world's population is expected to double from its current level of 6 billion to 12 billion by the middle of the next century (Hall, 1995). Therefore, if agriculture is to meet the demand for food, the development of soil atmosphere that exhibits higher crop yield, is imperative. The inadequate supply of essential plant nutrients in soil is a growth-limiting factor towards production. Among all the elements required by a plant, phosphorus is one of the most important nutrients for crop production, and emphasis is being given on the efficient use of P fertilizer for sustainable crop production (Ryan, 2002).

The soils of Pakistan having calcareous alkaline nature are generally deficient in phosphorus (P). The P requirement of crops is very high during initial stages of plant growth. An adequate P supply from soil and fertilizer is, therefore, necessary. In general, the uptake of P by plants is almost complete towards the end of the period of maximum growth. The common and recommended practice of P application is to broadcast and incorporate in the soil before sowing. Earlier studies showed little utility of applied P before sowing until first irrigation to wheat crop (Latif *et al.*, 1994). Rapid P uptake took place after irrigation, 3-4 weeks after germination (Ali *et al.*, 1988; Alam *et al.*, 1999). The demand for P at this stage of growth is much higher compared to other stages of growth (Romer and Schilling, 1986). Since the P fertilizers are different from the other nutrient carriers in that they are less mobile, less soluble and highly prone to fixation by the soil constituents, their effectiveness depends on properties of soil being fertilized, fertilizer itself and time and method of application. Broadcast method of fertilizer application may be one of the major causes for low fertilizer efficiency in our soils. Fertigation (the application of fertilizers through irrigation water) seems the best fertilizer management approach for intensive sustainable agriculture, as it is used to increase efficiency of fertilizers, increase yield, protect environment, and sustain irrigated agriculture. Keeping in view the importance of fertigation, the present study was undertaken to evaluate the usefulness of fertigated P on yield, P-uptake, P use efficiency (PUE) and agronomic efficiency (AE) of maize and wheat used as indicator crops.

## Materials and Methods

The experiments were conducted at the institute farm. Physico-chemical properties of the soils of experimental fields determined by the standard methods are given in Table 1. The experiments were performed in a randomized complete block (RCB) design with 4 replications of each treatment. The studies were made on wheat (cv. Inqilab-91) and maize (cv. C-17). In case of wheat, rates of P application were 33 and 44 kg P $ha^{-1}$ from single supperphosphate (SSP) and diammonium phosphate (DAP) in maize, rates was 22 and 33 kg P $ha^{-1}$ from SSP only. Phosphate

**Table 1. Physio-chemical properties of soils.**

| | Wheat field experiment | Maize field experiment |
|---|---|---|
| pH (1:2) | 7.76 | 7.82 |
| Organic matter, % | 0.77 | 0.85 |
| ECe, mS $cm^{-1}$ | 0.39 | 0.33 |
| P Olsen's, $mgkg^{-1}$ | 8.06 | 7.16 |
| Texture | | |
| Clay % | 21.32 | 20.32 |
| Silt % | 27.88 | 30.88 |
| Sand % | 50.80 | 48.80 |
| Class | Loam | Loam |

fertilizer was applied through surface irrigation (flood irrigation). In case of wheat full dose of P (SSP or DAP) was applied through 1st irrigation in wheat while in maize, fertilizer was applied as split in 1st and 2nd irrigations. Wheat was sown in plots (30×20 m) with tractor drill at a seed rate of 120 kg ha$^{-1}$. Areas of 10 m$^2$ in 3 places in the plot were harvested and combined (30 m$^2$) for yield record. Maize was sown in 6×3 m plots having 75 cm distance from row to row and 20 cm from plant to plant. At maturity, 40 plants were harvested from 2 internal lines of each plot. Cobs were removed and grains were separated to estimate grain yield

Phosphorus in the grain was determined by yellow colour methods (Jackson, 1962) for calculating total P uptake in grain. The data were statistically analyzed by analysis of variance in RCB designed as factorial arrangement of treatments (Steel and Torrie, 1960). The comparison among treatment means was made by Duncan's Multiple Range Test (Duncan, 1955). Phosphorus use efficiency (PUE) and agronomic efficiency (AE) were calculated as

$$\text{PUE} = \frac{Pf - Pc}{P} \times 100$$

Pf and Pc are total P uptake from fertigated and check (control) plots respectively and P is the applied P in kgha$^{-1}$.

$$\text{AE} = \frac{GPf - GPc}{P}$$

GPf and GPc are grain yield of P fertigated and check plots respectively and P is the applied P in kgha$^{-1}$.

## Results and Discussion

### Wheat

Fertigated SSP enhanced the grain yield (12.52%) of wheat significantly ($p<0.05$) while fertigated DAP increased it non-significantly over broadcast method. The yield potential was lower (4,882 kgha$^{-1}$) in fertigated DAP than that in fertigated SSP (5,249 kgha$^{-1}$, Table 2). This indicated that fertigation with DAP is less effective than fertigation with SSP. Application of DAP at the lower rate (33 kg P ha$^{-1}$) through fertigation resulted in almost the same wheat yield as obtained by the higher dose (44 kg P ha$^{-1}$) applied by broadcast method (Table 2). A long time reaction (aging)

**Table 2. Effect of application methods on grain yield of wheat and phosphorus uptake in grain under field conditions**

| Fertilizer application | | | | Grain yield | P uptake | PUE* | AE** |
|---|---|---|---|---|---|---|---|
| Source | P Rate (kg ha$^{-1}$) | Method | Time | kg ha$^{-1}$ | kg ha$^{-1}$ | % | kg ha$^{-1}$ |
| Control | - | - | - | 3966 d | 13.88 c | - | - |
| DAP | 44 | Fertigation | 1st irrigation | 4882 ab | 19.78 a | 13.41 | 20.82 |
| DAP | 44 | Broadcast | Sowing | 4516 bc | 17.05 b | 7.20 | 12.50 |
| DAP | 33 | Fertigation | 1st irrigation | 4443 c | 17.38 b | 10.60 | 14.45 |
| SSP | 44 | Fertigation | 1st irrigation | 5249 a | 19.70 a | 13.23 | 29.15 |
| SSP | 44 | Broadcast | Sowing | 4665 bc | 19.00 ab | 11.64 | 15.88 |
| SSP | 33 | Fertigation | 1st irrigation | 4854 abc | 18.99 ab | 15.48 | 26.91 |

**Nitrogen @150 kg ha$^{-1}$ in split application at sowing, Ist and 2nd irrigations through fertigation.**
*** Phosphorus use efficiency**
**** Agronomic efficiency**

of soluble P with soil leads to its reaction with solid phase of soil (Kardos, 1964) and with calcium carbonate and the formation of relatively insoluble reaction products with Ca, Fe and Al leading to P fixation (Brady, 1984). All these processes leading to fixation are delayed when we apply fertilizer through fertigation as plants absorbs this nutrient quickly and directly from solution applied through fertigation. In addition, the positive effect of fertigation may also be due to optimum moisture in the soil at appropriate time along with fertilization, which facilitates maximum utilization of applied P by wheat. Gajbhiye *et al.* (1990) reported that availability of more water for plant absorption and better metabolic activity resulted in higher dry matter yield. Similar results have been also reported by Sharma *et al.* (1990). It was also reported that acid fertilizers like SSP perform very efficiently in calcareous soils; DAP, being alkaline, performed worst in term of yield of some crops (Raun *et al.*, 1987).

Total P uptake by wheat grain increased over control due to P application (Table 2). The increase in P uptake was significantly higher where P was applied as fertigation. Fertigated DAP and SSP had higher P fertilizer efficiency as compared to their broadcast application. The highest P fertilizer efficiency was obtained with the lower rate of fertigated SSP (Table 2). Several workers have studied the efficiency of soil applied with fertigated P (Earl and Jerry, 1977; Mikkelsen and Jarrell, 1987; and Chase, 1985) and in most cases demonstrated greater efficiency with fertigated P as compared to broadcast applied P. The efficiency of fertilizer sources can be calculated in terms of yield and its P uptake per unit of fertilizer application. Generally phosphatic fertilizer sources have been compared with regard to their yield performance (Malik *et al.*, 1992). However, the yield of a crop depends on several other factors, comparison of efficiency of sources may be made on P uptake basis.

It may be observed that between the sources, DAP proved to be inferior to SSP as a P source when applied by fertigation but there was no difference when applied by broadcast method (Table 2). Highest P use efficiency (PUE) was observed with the lower rate 33 kg P $ha^{-1}$ of fertigated SSP application. Agronomic efficiency (AE) was the higher for SSP fertigation at higher rate followed by its lower rate.

**Maize**

In case of maize experiment, application of SSP through fertigation @ 33 kg $Pha^{-1}$ gave significantly higher ($P<0.05$) grain yield and P uptake as compared to the yield and P uptake obtained with the same dose applied by broadcast method. The lower dose (22 kg P $ha^{-1}$) applied by fertigation method resulted in statistically similar grain yield (Table 3) to broadcast at full dose i.e. 33 kg P $ha^{-1}$ (Papadopoulos, 1994). These indicated the relatively higher performance of fertigation at lower rates of P application. Ristimaki and Papadopoulos (unpublished) reported that fertigation at lower rates of urea phosphate provided higher yield than higher dose. The P use efficiency (PUE) by fertigation was higher (31.48%) than broadcast method (16.06%). When both P rates were applied through fertigation along with basal application of 100 kg N $ha^{-1}$, lower rates have given higher fertilizer efficiency than higher rates, indicating better performance of fertigation at lower rate of P application. These effects could be attributed to the direct or indirect acidification pattern produced by SSP like UP (urea phosphate), which after inducing an increases uptake of P hence highest P use efficiency was obtained with lower rate (33 kg $Pha^{-1}$) of fertigated SSP application. Papadopoulos (1994) reported that in calcareous soil having high pH, fertigation was superior to conventional soil P application. Latif *et al.* (2001) also reported similar results. The results further indicated that lower dose of nitrogen (100 kg N $ha^{-1}$) along with full dose of P when applied through fertigation gave equal P uptake to that by full dose of N (150 $kgha^{-1}$) and P (33 $kgha^{-1}$) application. This shows that the crop received maximum benefit from a balanced P supply through fertigation. Rauschkolb *et al.* (1976) also reported similar results.

Agronomic efficiency (AE) was also higher with fertigation than broadcast method. It may be

**Table 3. Effect of application methods on grain yield and phosphorus uptake by maize under field conditions**

| Fertilizer application | | | | Grain yield | P uptake | PUE* | AE** |
|---|---|---|---|---|---|---|---|
| N kg ha$^{-1}$ | P kg ha$^{-1}$ | Method | Time | kg ha$^{-1}$ | kg ha$^{-1}$ | % | kg ha$^{-1}$ |
| Control | | | - | 6746 d | 16.24 d | - | - |
| 150 | - | Fertigation | N: 1st, 2nd & 3rd irrig. | 7701 c | 17.33 d | - | - |
| 150 | 33 | Broadcast | N: 1st, 2nd & 3rd irrig. P: Sowing | 8209 b | 21.54 c | 16.06 | 44.33 |
| 150 | 33 | Fertigation | N: 1st, 2nd & 3rd irrig. P: 1st and 2nd irrig | 9242 a | 26.63 a | 31.48 | 75.63 |
| 100 | 33 | Fertigation | N: 1st, 2nd & 3rd iris. P: 1st and 2nd irrig | 8997 a | 25.14 ab | 26.97 | 68.21 |
| 100 | 22 | Fertigation | N: 1st, 2nd & 3rd irrig. P: 1st and 2nd irrig | 8730 a | 22.72 bc | 29.45 | 90.18 |

*** Phosphorus use efficiency**
**** Agronomic efficiency**

noted that application of P at the rate of 22 kg P ha$^{-1}$ and N at the rate of 100 kg N ha$^{-1}$ applied by fertigation led 50% more agronomic efficiency as compared to full dose of P at the rate of 33 kg P ha$^{-1}$ and N at the rate of 150 kg N ha$^{-1}$ applied by broadcast method. The results of these experiments clearly demonstrate that fertigation was a more efficient method of nutrient management than broadcast method similar results are also reported earlier by Latif *et al.*, 1997 and Alam *et al.*, 1999.

## Conclusion

In both studies, fertigated P enhanced the grain yield of wheat and maize and improved the P use efficiency as well as agronomic efficiency of P fertilizers; fertigation method was relatively more efficient at a lower rate of P application than at its higher rate. On overall basis fertigation seemed a more efficient method of P application and could save considerable amount of P fertilizer as compared to broadcast method of application.

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**References**

Alam, S.M., Zafar, I. and Latif, A. 1999. Fertigation technology for improved phosphorus use efficiency in wheat. Pak. J. Sci. Ind. Res. 42: 380-383.

Ali, A., Ahmad, A.S., Ahmad, M. and Ali, A. 1988. Response of Pak-81 wheat to phosphorus application at Faisalabad. Pak. J. Agric. Res. 9: 593-595.

Brady, N.C. 1984. The nature and properties of soils. Macmillan Publishing Co. NY. pp. 750.

Chase, R.G. 1985. Phosphorus application through a subsurface trickle system. In: Proc. Drip/Trickle Irrigation Congress. Fresno, CA. 18-21 Nov 1985. ASAE, St. Joseph, MI. pp. 393-400.

Duncan, D.B. 1955. Multiple ranges and Multiple F test. Biometrics 11: 1-42.

Earl, K.D and Jury, W.A. 1977. Water movement in bare and cropped soil under isolated trickle emitters. II. Analysis of cropped experiments. Soil Sci. Soc. Am. J. 41: 856-861.

Gajbhiye, K.S., Gajkawad, S.T., Chalia, O., Hazare, T.N. and Deshmukh, S.N. 1990. Evaluation of optimum range of soil moisture stress for establishment of wheat crop in Entisols. J. Ind. Soc. Soil 38: 139-141.

Hall, R. 1995. Challenge and prospects of integrated pest management. In: R. Reuveni (ed.), Novel Approach to Integrated Pest Management. Lewis Publishers, Boca Raton pp. 1-20.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall Inc., Englewood, Califf. NY.

Kardos, L.T. 1964. Soil fixation of plant nutrients. In: Chemistry of the soils, editor F.E. Bear. Reinhold Publishing Corp. NY pp. 369-394.

Latif, A., Alam, S.M., Hamid, A. and Zafar, I. 1997. Relative efficiency of phosphorus applied through broadcast incorporation, top dressing and Fertigation to crops. Pak. J. Soil Sci. 13(1-4): 15-18.

Latif, A., Alam, S.M., Zafar I. and Hamid, A. 1994. Effect of rate, time and method of application of P fertilizer on wheat crop. In: Proc. 4th Nat. Cong. Soil Sci. Islamabad: 299-303.

Latif, A., Alam, S.M., Zafar, I. and Shah, S.A. 2001. Effect of fertigation applied nitrogen and phosphorus on yield and composition of maize. Pak. J. Soil Sci 19: 23-26,

Malik, D.M., Chaudhry, R.A., Sherazi, S.J.A. 1992. Management of phosphorus for wheat production in Punjab. In: Proc. Symp. On the Role of Phosphorus in Crop Production. NFDC, Islamabad: 175-196.

Mikkelsen, R.L. and Jarrell, W.M. 1987. Application of urea phosphate and urea sulphate to drip-irrigated tomatoes grown in calcareous soils. Soil Sci. Soc. Am. J. 51: 464-468.

Papadopoulos, I. 1994. Use of labeled fertilizers in fertigation research. Proceedings of an international symposium on nuclear and related techniques in soil-plant studies, held in Vienna: 399-410.

Rauschkolb, R.S., Rolston, D.E., Miller, R.J., Cariton, A.B. and Burau, R.G. 1976. Phosphorus fertigation with drip irrigation. Soil Sci. Soc. Am. J. 40: 68-72

Raun, W.R., Sander, D.H. and Olsen, R.A. 1987. Phosphorus fertilizer carriers and their placement for minimum till corn under sprinkler irrigation. Soil Sci. Soc. Am. J. 51: 1055-1062.

Romer, W. and Schilling, G. 1986. Phosphorus requirement of wheat plants in various stages of its life cycle. Plant Soil 9: 221-229.

Ryan, I. 2002. Efficient use of phosphate fertilizers for sustainable crop production in WANA. IMPHOS: Phosphate Newsletter: 2-5.

Sharma, B.D., Kar, S. and Cheema, S.S. 1990. Yield, water use and nitrogen uptake for different water and N levels in winter wheat. Fertilizer Research. 22: 119-127.

Steel, R.G.D. and Torrie, J.H. 1960. Principles and Procedures of Statistics. McGraw Hill Book Co. Inc., New York.