EFFECT OF PHOSPHORUS FERTIGATION ON GRAIN YIELD AND PHOSPHORUS USE EFFICIENCY BY MAIZE (*ZEA MAYS* L.)

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ABSTRACT

A field experiment was conducted at Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad, Pakistan for three consecutive years (2009-2010 and 2011) to compare the efficiency of phosphorus fertigation at first and second irrigation with phosphorus broadcasting at sowing time (farmers' conventional practice). The results revealed that application of recommended dose of phosphorus through fertigation at first irrigation and when crop height of 2.5 feet increased number of grains per cob (9.6%), 100-grain weight (18.4%), phosphorus recovery efficiency (70.0%), phosphorus agronomic efficiency (17.3%), phosphorus use efficiency (6.1%) and significantly higher maize grain yield (8.33 mg/ha) as compared to application through broadcast (7.85 mg/ha) before sowing. Higher net income and cost benefit ratio (2.35) by the fertigation of phosphorus was due to more efficient utilization of applied fertilizer.

KEYWORDS: ***Zea mays;*** **maize; phosphate fertilizer; fertigation; P use efficiency; agronomic characters; yield; Pakistan.**

INTRODUCTION

Maize (*Zea mays* L.) ranked third among the cereal crops in the world after wheat and rice. Being a multipurpose crop, it provides food for human beings, feed for poultry and fodder for livestock. It has greater nutritional value as reported (14). It contributes 2.2 percent to the value added in agriculture, 0.5 percent to GDP and cultivated on an area of 1085 thousand hectare (8). In Pakistan despite its higher yield potential, yield per unit area is low as compared to other maize producing countries (7). The majority of soils are phosphorus (P) deficient, containing <10 mg per kg Olsen Phosphorus (27) and hence phosphorus is essential inorganic nutrient for plant growth as it plays a critical role in root development, facilitates greater N uptake and results in higher grain yield as reported by Rehim *et al*. (31), Hayyat and Ali,

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(15), Shah *et al*. (36), Vance *et al*. (39) and Clark (22). Globally being non-renewable resource, the P reserves are being depleted, with half depletion predicted to occur between 2040 and 2060 (22). High prices of P fertilizers and their shortage at the right time of application mostly accounts for low fertilizer usage (3, 37). High calcium carbonate with pH ranging from 7 to 9 favors the formation of relatively insoluble dicalcium phosphate and tricalcium phosphates (17) and availability of applied P depends on the properties of soil being fertilized, fertilizer itself, time and method of its application (5, 19). More than 80% of added P gets fixed in soil by adsorption and precipitation reaction and available to subsequent crops by desorption and dissolution reactions (1, 21, 25, 41). With time, sorbed P becomes difficult to release into soil solution and consequently efficiency of P fertilizer in calcareous soils remains low (11, 18, 34,). Cisse and Amar (9) reported that maize grain yield obtained per kilogram of P application in Pakistan is lower (7.9) than China (9.7) and India (10.3). Maize grain yield and P uptake efficiency can be improved through balanced and timely use of P fertilizers. Time and method of P application is much important in soils because fixation of P increases as the time of contact between soluble P and soil particles increases (6). For sustainable high crop production in calcareous soils, P management is important. The present study was designed to compare the farmers' P application method of broadcasting to soil at the time of sowing with that of fertigation and its effect on growth and P use efficiency of maize.

MATERIALS AND METHODS

A field study was carried out to evaluate the effect of P fertigation in hybrid maize (*Zea mays* L.) during autumn 2009, 2010 and 2011 in Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad, Pakistan. Experiment was laid out in RBCD with three replications and plot size was 5×7m. Before sowing, a composite soil sample was collected from the field and analyzed for physicochemical properties (Table 1). Soil texture was determined by hydrometer method described by Moodie *et al.* (29). Soil pH was measured in a saturated soil paste and electrical conductivity (EC) of the soil extract by method of Mclean (28). Soil organic carbon (SOC) content was estimated by the method described by Ryan *et al.* (33), while phosphorus was measured on spectrophotometer at 880 nm λ using sodium bicarbonate extraction by Rowell, (28). For potassium, soil extraction was made with ammonium acetate (1 N of pH 7.0) and potassium was determined by using PFP-7 Janway Flame photometer designed by Rowell (32).

Table 1. Soil Physical and chemical properties before the start of experiment.

Characteristics	**Value**
Sand (%)	53.91
Silt (%)	21.03
Clay (%)	25.06
Textural class	sandy clay loam
Saturation percentage (%)	35.6
pH_s (%)	8.17
EC_e (%)	1.74
Organic matter (%)	0.67
Total nitrogen (%)	0.03
Available phosphorus (mg/kg)	7.21
Extractable potassium (mg/kg)	204

For seed bed preparation at optimum moisture level land was prepared with a rotavator followed by cultivation. Seed bed preparation was done with a cultivator followed by planking and crop was sown on ridges. The treatments used in this experiment are given below:-

T_1	=	Control
T_2	=	Recommended dose (RD) of P through broadcast before making ridges
T_3	=	½ of RD of P through at sowing and ½ through fertigation at 2nd irrigation
T_4	=	½ of RD of P through fertigation at Ist irrigation
T_5	=	¾ of RD of P through fertigation at Ist irrigation and when crop was and 2.5 feet high
T_6	=	Recommended dose of P through fertigation at Ist irrigation

Half nitrogen (N) and full dose of potassium K was applied before making ridges and remaining half N was applied with second irrigation. Phosphorus (P) as triple super phosphate (TSP) was applied by broadcasting and fertigation. For fertigation the solution of TSP was prepared at 1:5 ratio of fertilizers to water in small plastic drums fitted with water tap at the bottom and placed at inlet of irrigation water flowing from water channel to the sub plots receiving P through fertigation. At the start of irrigation, outlets of plastic drums were regulated in such a manner that the whole solution was delivered just before the termination of irrigation. Overall four irrigations were applied by flooding up to crop maturity. Weeds were controlled by applying a post emergence herbicide atrazine @ 250ml per acre and furadan was applied @ 20 kg per hectare to control various insect pests of crop. Harvesting was done manually and plants were kept in the field for five days and then made into bundles and stacked in the sun for 4 to 5 weeks for drying. After 5 weeks the ears were husked and allowed to dry in the sun for a few days before threshing. Data regarding plant height (cm), number of grains per cob, number of grain rows per cob, 100-grain weight (g), and grain yield (mg/ha) were recorded. Meteorological data regarding total rainfall and mean maximum temperature were collected during the growing period of the crop from observatory of the Crop Physiology Department, Ayub Agricultural Research Institute Faisalabad and is presented in Fig. 1. Grain and stalk samples were taken and dried in an oven at 70^{o}C. The dry grain and stalk samples were grinded and 0.5g sample was digested with tri-acid mixture of HNO_3-H_2SO_4-$HClO_4$ for the determination of phosphorus by method as described by Jackson (20).The absorption of metavandate solution was measured by spectrophotometer (IRMECO Model U 2020) at 410-nm wavelength. From the standard curve, P content in grain and stalk was calculated. P uptake by stalk, grains, P recovery, P agronomic efficiency and phosphorus use efficiency (PUE) was calculated according to formulae given by Rehim *et al.* (31), Dobermann *et al.* (12) and Fageria *et al.* (13).

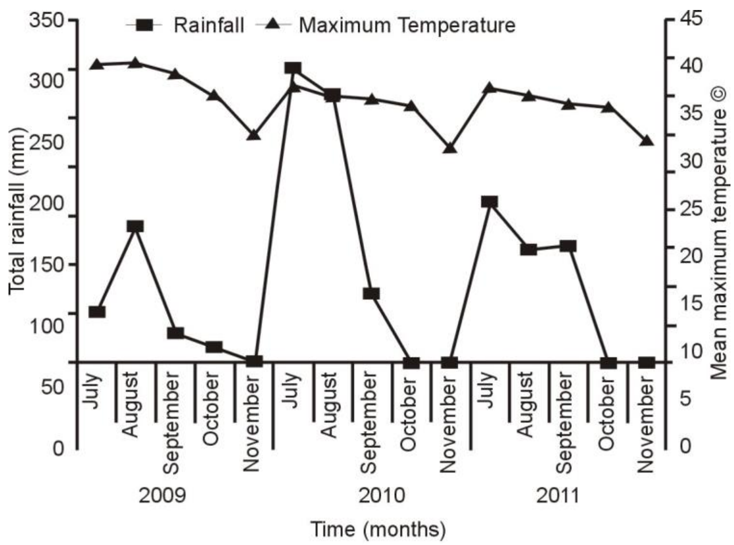

Fig. 1. Meteorological data showing mean monthly maximum temperature and total rainfall during maize growing seasons (2009, 2010 and 2011).

$$\text{P uptake kg/ha} = \frac{\text{P content (\%) in plant part (dry matter)} \times \text{Yield kg/ha}}{100}$$

$$\text{Phosphorus use efficiency (PUE)} = \frac{\text{Maize grain yield kg/ha}}{\text{Fertilizer applied (kg } P_2O_5\text{/ha)}}$$

$$\text{P agronomic efficiency (PAE)} = \frac{\text{Yield in fertilized plot - Yield in control kg/ha}}{\text{Fertilizer applied (kg } P_2O_5 \text{ / ha)}}$$

$$PRE = \frac{\text{[Total P uptake (kg/ha) in fertilized plot]- [Total P uptake (kg/ha) in control plot]}}{\text{Fertilizer applied (kg } P_2O_5 \text{ / ha)}}$$

Three years data was pooled and analyzed by using statistics 8.1 versions and treatment means were compared by using LSD test at 5% probability level (38).

Economic analysis and cost benefit ratio

On the basis of variable and market prices a cost benefit analysis was made (Table 4) and cost benefit ratio was determined by dividing gross income to total expenditure.

RESULTS AND DISCUSSION

Phosphorus levels and application methods showed that fertigation of recommended dose (RD) of P fertilizer at first irrigation and when crop was 2.5 feet high (T_6), increased the plant height, number of grains per cob, number of grain, rows per cob and 100 grains weight (6.9, 9.6, 8.3 and 18.4 % respectively) over T_2, where recommended dose (RD of P fertilizer was applied through broadcast (farmers' practice) before sowing (Fig. 2).

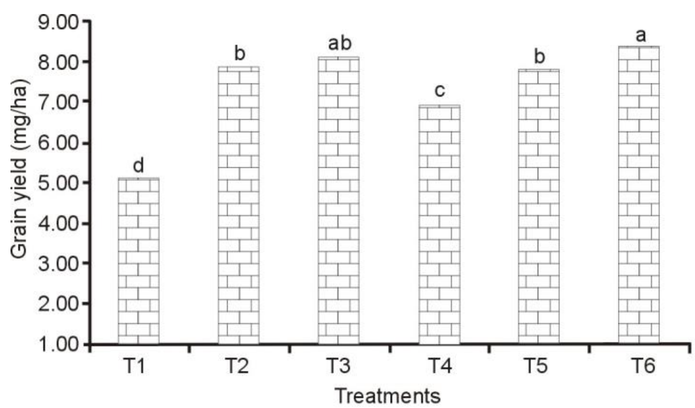

Fig. 2. Effect of phosphorus application methods on grain yield of maize

The maximum grain yield (8.33 mg/ha) was produced by T_6 (8.08 mg/ha) followed by T_3 and grain yield (7.80 mg/ha) produced by T_5 and was applied through fertigation was statistically similar to grain yield produced by T_2. Similar results were explained by Vishandas *et al.* (40) and Alam *et al.* (4), that lower P rates applied through fertigation resulted in equivalent wheat grain yield as compared to higher P rates applied by broadcast method. Minimum grain yield (5.08 mg/ha) was noted in control, followed by the T_4 (6.89 mg/ha) where half of recommended dose (RD) of P was applied through fertigation at first irrigation. The comparison of fertigation and conventional method of P broadcasting showed that relative dose of P application through fertigation T_6 increased the grain yield (6.1), grain P content, P agronomic efficiency (17.3) and PUE (6.1 %) over T_2, where relative dose of P fertilizer was applied through broadcast before sowing. Higher grain yield with fertigation of P is possibly an indication of increased P availability at peak demand period of crop, most probably because of the lesser contacts of fertilizer P with alkaline earth carbonates and soil colloids which are partially responsible for precipitation, fixation and retention of phosphorus fertilizer as reported by Memon *et al*. (27), Amanullah *et al*. (7) and Shah *et al*. (36).

The results (Table 2) revealed that phosphorus (P) uptake by grain, stalk and their total was highest (19.54, 8.81 and 28.35 kg/ha respectively in T_6), where recommended dose of P was applied through fertigation as compared to broadcast method. Improvement in grain and stalk P content seems to be due to readily available P through fertigation to the developing roots and thereby result in improved PUE as reported by Hussein (17).

Table 2. Effect of phosphorus application methods on phosphorus agronomic efficiency (PAE) phosphorous recovery efficiency (PRE) and phosphorus use efficiency (PUE) of maize.

Treatments	Grain P contents (%)	Stalk P contents (%)	P uptake in grain (kg/ha)	P uptake in stalk (kg/ha)	Total P uptake (kg/ha)	PAE (kg/kg) P_2O_5	PRE (kg/kg) P_2O_5	PUE (kg/kg) P_2O_5
T_1	0.09e	0.05d	4.56e	2.34e	6.90e	-	-	-
T_2	0.17c	0.10b	13.18c	6.15c	19.33c	22.17c	0.10c	62.83d
T_3	0.20b	0.12ab	16.52b	7.77b	24.29b	24.03bc	0.14b	64.69cd
T_4	0.14d	0.08c	9.34d	4.15d	13.50d	28.94a	0.10c	110.26a
T_5	0.18c	0.10b	14.13c	6.07c	20.13c	29.00a	0.14b	83.21b
T_6	0.23c	0.13a	19.54a	8.81a	28.35a	26.00b	0.17a	66.66c
LSD	0.02	0.01	1.25	0.75	1.11	2.86	0.01	2.66

Means in a column not sharing the same letters differ significantly from each other at 5% probability level.

Low recovery of broadcast P is an indication of relatively high P fixation and conversion of applied phosphates to less available form owing to alkaline calcareous nature of the soil as founded by Memon *et al.* (27). Similarly, Latif *et al.* (24) and Hussein (16) reported that maize plant receiving P in solution form at first irrigation contained significantly higher P content as compared to P applied by broadcast at sowing. Higher PUE at lower P level might be the result of intense root competition and thereby an efficient exploitation of applied P fertilizer. Similar results were recorded by Rehim *et al.* (30) that P application at higher rates plants used smaller proportion of P fertilizer that resulted in low PUE.

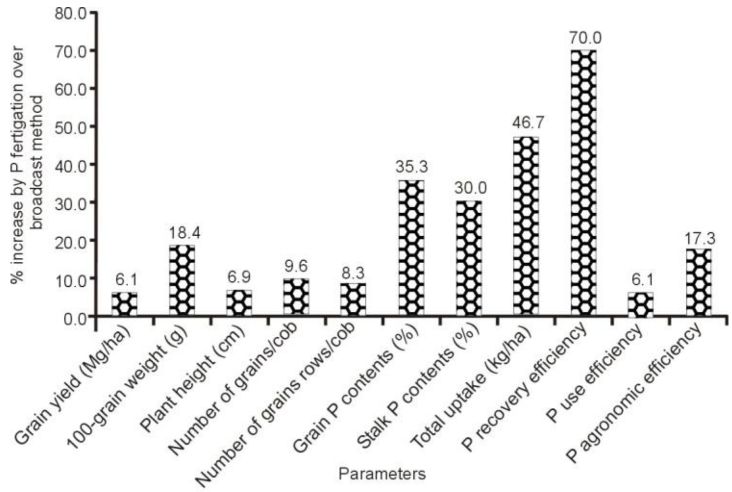

Fig. 3. Percent increase in various growth parameters of maize by application of RD of P through fertigation (T_6) over RD of P (T_2) before sowing.

Correlations were also studied between total P uptake, 100 grain weight, number of grains per cob, stalk P content, grain P content and plant height with grain yield (Table 3). A positive and strong correlation was found between growth attributes and grain yield.

Table 3. Correlation between various growth attributes and grain yield of maize as influenced by P fertigation.

X -variable	Y-variable	Regression equation	Correlation coefficient (r)
Total P uptake	grain yield	y = 0.149x + 4.544	0.94
100 grain weight	grain yield	y = 0.349x - 1.646	0.92
Number of grains/cob	grain yield	y = 0.028x + 0.800	0.99
Number of grain rows/cob	grain yield	y = 0.790x - 1.881	0.98
Stalk P content	grain yield	y = 40.274x + 3.445	0.95
Grain P content	grain yield	y = 23.603x + 3.365	0.95
Plant height	grain yield	y = 0.0621x – 2.4829	0.98

The potential advantages of fertigation include improved fertilizer use efficiency, flexibility in timing of fertilizer use in relation to crops demand, increased crop yield and improved quality of the produce. These findings correlate with the previous findings of Latif and Iqbal (23), Alam *et al.* (2) and

Hussein (16) who observed that phosphorus applied by fertigation resulted in improving the P efficiencies as compared to its soil mixing at sowing.

The cost benefit ratio (CBR) indicates (Table 4) that fertigation of P fertilizer gave maximum return as compared to broadcasting before sowing. Higher net income and CBR by the fertigation of P was the direct result of better grain yield due to more efficient utilization of applied fertilizer.

Table 4. **Effect of phosphorus application methods at varying rates on cost-benefit ratio of maize.**

Treatments	Total expenditure (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Cost-benefit ratio (CBR)
T_1	52447	104144	51697	1.99
T_2	71712	159566	87854	2.23
T_3	72012	164211	92199	2.28
T_4	62230	140322	78092	2.25
T_5	67120	158522	91402	2.36
T_6	72012	169144	97132	2.35

CONCLUSION

It is concluded from the study that maize grain yield and its components increased significantly with the use of P through fertigation as compared to broadcast method. Phosphorus (P) use efficiency and phosphorus agronomic efficiency of fertigated P at lower rates was relatively more than its higher rates and broadcasted P. On overall basis fertigation seemed a more efficient method of P application and is the best option to produce maximum maize grain yield and net economic returns.

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