*Pak. J. Bot.*, 42(6): 4051-4061, 2010.

# LEVELS AND TIME OF PHOSPHORUS APPLICATION INFLUENCE GROWTH, DRY MATTER PARTITIONING AND HARVEST INDEX IN MAIZE

**AMANULLAH[1*], MUHAMMAD ZAKIRULLAH[1], MUHAMMAD TARIQ[3], KHALID NAWAB[4], AMIR ZAMAN KHAN[1], FARHATULLAH[2], ZAHIR SHAH[3], AMANULLAH JAN[1], SHAD KHAN KHALIL[1], MUHAMMAD TARIQ JAN[1], M. SAJID[5], ZAHID HUSSAIN[1] AND HIDYAT-UR-RAHMAN[2]**

[1]*Department of Agronomy, KPK Agricultural University, Peshawar*
[2]*Department of Plant Breeding and Genetics, KPK Agricultural University, Peshawar*
[3]*Department of Soil & Environmental Sciences, KPK Agricultural University, Peshawar*
[4]*Department of Extension Education and Communication, KPK Agricultural University, Peshawar*
[5]*Department of Horticulture, KPK Agricultural University, Peshawar*
[*]*Corresponding author: draman_agronomist@yahoo.com*
*Cell: +92-3005741363, Fax: +92-91-9216520*

**Abstract**

Phosphorus (P) levels and its time of application is considered some of the most important factor affecting crop growth, dry matter accumulation and harvest index in maize (*Zea mays* L.). Research on the interactive effects of levels into time of P application is lacking in the Khyber Pakhtunkhwa (KPK), Pakistan. A field experiment was therefore conducted to investigate impact of P levels (30, 60 and 90 kg ha$^{-1}$) and time of P application [40, 30, 20 and 10 days before sowing (DBS), at sowing and 15 days after sowing (DAS)] on maize at New Developmental Agricultural Research Farm of KPK Agricultural University Peshawar, during summer 2005. The objective of the experiment was to find out the best level and timing of P application aimed at higher biomass yield and harvest index. The results showed that the highest level of 90 kg P ha$^{-1}$ at 10 DBS and sowing increased plant height, number of leaves per plant, mean leaf area, dry weight of leaf, stem and ear as well as biomass yield and harvest index. It could be concluded from the experiment that P fertilizer application at 90 kg P ha$^{-1}$ at 10 DBS or at sowing time is necessary for profitable maize production in the study area.

## Introduction

Maize (*Zea mays* L.) is the second most important crop after wheat in the Khyber Pakhtunkhwa Province (KPK) of Pakistan, contributing more than 50% of the total production in the country (Chaudhry, 1994), but its yield per unit area is low (Amanullah *et al*., 2008). The soils of KPK are generally low in organic matter and low to medium in available P (Bhatti *et al*., 1998). These soils contain high calcium carbonate with pH ranging from 7 to 9. This high calcium activity coupled with high pH favors the formation of relatively insoluble dicalcium phosphate and tricalcium phosphates. Soils with high fixation capacity have higher demand for phosphatic fertilizer (Hussain & Haq, 2000). Cisse & Amar (2000) reported that in Pakistan additional maize yield obtained per kilogram of P application is low (7.9) than China (9.7) and India (10.3). Phosphorus deficiency is invariably a common crop growth and yield-limiting factor in unfertilized soils, especially in soils high in calcium carbonate, which reduces P solubility (Ibrikci, 2005).

Judicious application of P-fertilizer is a key factor in the cereals based system of Pakistan for sustainable agriculture. Imbalanced fertilizer use, especially in terms of phosphate compared with nitrogen, has created concern as it may affect overall agricultural productivity and economic growth in Pakistan (Anon., 2006). The application of essential plant nutrients in optimum quantity and right proportion, through correct method and time of application is the key to increased and sustained crop production (Cisse & Amar, 2000). Grain and biomass yields, number of grains ear$^{-1}$ and number of rows ear$^{-1}$, plant height and P uptake efficiency (PUE) of maize increases at high level of P application (Okalebo & Probert, 1992; Sahoo & Panda, 2001). Maize yield can be improved through balanced and timely use of P fertilizers (Rasheed & Iqbal, 1995). The time at which P should be applied to a crop is very important because timing affects P efficiency and crop yield. Phosphatic fertilizers should not be applied much in advance of crop sowing since soluble P converts to less available form in the soil and its affectiveness declines with the time between application and the stage at which the crop is in a position to make use of nutrients (Phillips & Webb, 1971). Wheat yield was increased by 16.9% when P fertilizers were applied at first irrigation compared with application at sowing time (Nisar & Bhatti, 1978). Qureshi (1978) reported that P fertilizers should be top dressed with first irrigation rather than applied and incorporated in the soil at sowing time. Another study reported that application of P at planting was more effective than late application and the relative availability of P diminishes as the time between application and planting increases (Malik *et al*., 1978). Rehman *et al*., (1983) reported that application of DAP and NP in full dose at the time of sowing to maize produced maximum yield and VCR and late application of both fertilizers was not profitable. Latif *et al*., (1992) in a field experiment found that application of P fertilizer in solution form to wheat at first irrigation is as effective as P application by broadcast method at sowing time. But P applied to maize in pots by fertigation method 10 days after emergence gave significantly higher dry matter yield as compared to broadcast P at sowing time (Latif *et al*., 1991).

Factors that restrict the availability of P to crops are soil pH, soil texture, amount of P applied to soil, presence of other elements like iron, aluminum, manganese and calcium in the soil, microbial activity and time of P application (Yash *et al*., 1992). Among these factors time of P application is much important in soils with either low or high pH conditions because P applied earlier make it less available to crops than at the time of sowing (Amanullah *et al*., 2010b). Fixation of P increases as the time of contact between soluble P and soil particles increases. Consequently, more efficient utilization of fertilizer P is generally obtained by applying P fertilizer shortly before planting the crop (Griffith, 1983). Small and frequent P applications are needed for plants to get the proper amount of P needed throughout the growing season. Soils that fix the applied P quickly, one large application of P may be adequate at near sowing time to reduce P fixation (Yash *et al*., 1992).

Studies on the proper combination of levels and timings of P in the agro-ecological maize growing zones of the KPK, Pakistan have not been carried out. For sustainable high crop production in KPK, P management is indispensable. The present study was therefore, initiated to determine the best level and timing of P application to maize crop to improve growth, biomass yield, and harvest index of maize.

## Materials and Methods

**Site description:** The experiment was conducted at the Agriculture Research Farm of the KPK Agricultural University, Peshawar, Pakistan during summer 2005. The experimental farm is located at 34.01° N latitude, 71.35° E longitude at an altitude of 350 m above sea level in Peshawar valley. Peshawar is located about 1600 km north of the Indian Ocean and has continental type of climate. The research farm is irrigated by Warsak canal from river Kabul. Soil is clay, low in organic matter (0.87%), extractable P (5.6 mg P $kg^{-1}$), exchangeable potassium (121 mg K $kg^{-1}$), alkaline (pH 8.2) and is calcareous in nature. Soil physiochemical properties such as texture (Gee & Bauder, 1986), organic matter (Nelson & Sommers, 1982), AB-DTPA extractable P and exchangeable K (Soltanpour, 1985) were determined according to standard procedures (Amanullah & Khan, 2010). Mean annual rainfall in the region varies from 300 to 500 mm, of which 70% occurs in summer.

**Experiential description:** A 6 x 3 factorial experiment was conducted in a randomized complete block (RCB) design with split-plot arrangement using four replications. A sub plot size of 19.6 $m^2$ with 7 rows, 4 m long with row to row distance of 70 cm and plant to plant distance of 20 cm was used. Timings of P [40, 30, 20 and 10 days before sowing (DBS), at sowing and 15 days after sowing (DAS)] were allotted to main plots and its levels (30, 60 and 90 kg $ha^{-1}$) were assigned to sub plots. Single super phosphate (18% $P_2O_5$) was used as a source of P. Maize (*cv.* Azam) was sown with a seed rate of 30 kg $ha^{-1}$ and desired plant density of 70,000 plants $ha^{-1}$ was maintained in the different experimental units by thinning one week after emergence. Nitrogen was applied @ 120 kg $ha^{-1}$ as urea in three equal split doses at sowing, at V9 stage (many ear shoots were easily visible upon dissection) and at VT stage (last branch of the tassel was completely visible and the silks were not yet emerged). Potash (SOP, 50% $K_2O$) at the rate of 60 kg K $ha^{-1}$ was applied at the time of sowing. Irrigation, weeding and all other agronomic practices were followed uniformly for all the experimental units. Data were recorded on plant height, number of leaves per plant, mean leaf area, dry leaf, stem and ear weight per plant, stover and biomass yields and harvest index.

Five plants in each sub-plot were randomly selected at physiological maturity (formation of black layer in the seed). Plant height was measured from base to tip of each plant with meter rod and averaged. Number of leaves in each plant was counted and then average number of leaves per plant was determined. Five middle leaves of each plant were removed and leaf areas of each leaf was determined with the help of leaf area machine and then mean leaf area was worked out.

At maturity 10 plants were randomly selected in each plot. Leaves, ears and stem were separated, dried, each part was weighed by electronic balance and then average leaf, ear and stem dry weights per plant was determined.

After harvesting 5 central rows in each sub plot, plants along with cobs were weighed and biomass yield (biological yield) in kg $ha^{-1}$ was determined using the formula:

$$\text{Biological Yield } (\text{kg ha}^{-1}) = \frac{\text{Biological yield per sub plot (kg)}}{\text{No.of rows} \times \text{row length} \times \text{R} - \text{R distance}} \times 10000$$

After removing the ears the stovers of the five central rows in each sub plot was weighed and stover yield in kg $ha^{-1}$ was determined using the formula:

$$\text{Stover Yield } (\text{kg ha}^{-1}) = \frac{\text{Stover yield per sub plot (kg)}}{\text{No.of rows} \times \text{row length} \times \text{R} - \text{R distance}} \times 10000$$

The ears removed were dried, shelled and weighed. Grain yield was expressed in kg $ha^{-1}$. Harvest index (%) was calculated using the formula:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

**Statistical analysis:** Data were subjected to analysis of variance (ANOVA) according to the methods described by Steel & Torrie (1980), and treatment means were compared using the least significant difference (LSD) at $p \leq 0.05$. A brief summery of ANOVA for all parameters is presented in Table 1.

## Results

**Maize growth:** Phosphorus levels, application time and their interaction (P x T) had significant effects on maize height (Table 2). Tallest plants of 181 cm height were attained in the plots applied with the highest level of 90 kg P $ha^{-1}$ and shortest plants of 154.7 cm heights were recorded in the plots which received the lowest level of P (30 kg $ha^{-1}$) being at par with medium level of P (60 kg $ha^{-1}$). Application of P at sowing time of maize resulted in tallest plants of 173.5 cm height being at par with 170.9 cm plants in the plots applied with P 15 DAS, but the plots applied with P 40 DBS produced the shortest plants of 162.9 cm height being at par with 30 DBS (166.3 cm).

Phosphorous levels and application timing had a significant effect on number of leaves $plant^{-1}$ and mean leaf area while their interaction effect was non-significant (Table 3). Number of leaves per plant increased to maximum (14.13) with the highest P level and decreased to minimum (12.79) with the lowest P level. Plots applied with P at sowing time produced maximum of 14.92 of leaves $plant^{-1}$ being at par with 10 DBS and minimum of 12.33 leaves $plant^{-1}$ were noted when P was applied 40 DBS being at par with 30 DBS. The highest mean leaf area (274.7 $cm^2$) was recorded in the plots applied with the highest level of P and the lowest mean leaf area (257.3 $cm^2$) was with the lowest level of P (Table 4). All these levels of P differed significantly from one another. Phosphorus applied 10 DBS produced the highest mean leaf area (272.8 $cm^2$) while the lowest mean leaf area of 259.2 $cm^2$ was noted in the plots which received P 40 DBS being at par with 30 DBS.

**Dry matter partitioning:** Leaf, stem and ear dry weight per plant was significantly affected by levels and time of P application but P x T interaction was non-significant. Highest leaf dry weight of 31.42 g per plant was obtained from those plots applied with the highest level of P being at par with medium P level and minimum leaf dry weight (26.17 g per plant) was recorded in the plots which received the lowest P level (Table 5). Phosphorous applied 10 DBS resulted in maximum leaf dry weight of 36.0 g per plant while the plots which received P 40 DBS produced the minimum leaf dry weight of 23.17 g per plant being comparable with 30 DBS.

Highest ear dry weight of 196.7 g per plant was recorded in the plots that received the highest P level and the lowest ear dry weight of 178.6 g per plant was obtained when applied at the lowest rate of 30 kg P $ha^{-1}$ (Table 6). Highest ear dry weight per plant (199.38 g) was recorded in the plots which received P at 10 DBS being comparable with P applied at sowing (190.5 g) and 15 DAS (190.5 g) but the lowest ear dry weight of 177.7 g per plant was recorded in the plots applied with P at 40 DBS and it was statistically the same when P was applied at 30 and 20 DBS.

**Table 1. Summary of analysis of variance (ANOVA) and coefficient of variation (CV) for various parameters studied in the experiment at Peshawar, Pakistan.**

| Parameter | P Level (P) | P Time (T) | P x T | CV (%) |
|---|---|---|---|---|
| Plant height | *[z] | * | ns | 5.98 |
| Number of leaves per plant | * | * | ns | 9.30 |
| Mean leaf area | * | * | ns | 1.88 |
| Leaf dry weight | * | * | ns | 11.81 |
| Stem dry weight | * | * | ns | 4.32 |
| Ear dry weight | * | * | ns | 4.74 |
| Stover yield | * | * | ns | 6.76 |
| Biomass yield | * | * | ns | 4.44 |
| Harvest index | ns | ns | ns | 10.19 |

[z]* denotes significant at $p \leq 0.05$, and ns refers to not significant.

**Table 2. Plant height (cm) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels (kg ha$^{-1}$) | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 144.75 | 148.50 | 154.00 | 156.00 | 160.50 | 164.25 | 154.70b[y] |
| 60 | 161.50 | 161.50 | 165.7 | 166.25 | 170.75 | 168.25 | 165.70b |
| 90 | 176.50 | 178.75 | 179.00 | 182.50 | 189.25 | 180.25 | 181.00a |
| Mean | 160.9e | 162.9de | 166.3cd | 168.3bc | 173.5a | 170.9ab | |

LSD value for P levels ($p \leq 0.05$) = 12.40

LSD value for P timing ($p \leq 0.05$) = 4.486

[z]DBS and DAS refer to days before sowing and days after sowing, respectively.

[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

**Table 3. Number of leaves plant$^{-1}$ of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels (kg ha$^{-1}$) | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 11.50 | 12.00 | 12.50 | 13.50 | 14.25 | 13.00 | 12.79b[y] |
| 60 | 11.50 | 13.00 | 12.50 | 14.50 | 15.00 | 13.50 | 13.33ab |
| 90 | 14.00 | 13.00 | 14.00 | 14.75 | 15.00 | 13.50 | 14.13a |
| Mean | 12.33c | 12.67bc | 13.00ab | 14.25a | 14.92a | 13.33b | |

LSD value for P levels ($p \leq 0.05$) = 1.549

LSD value for P timing ($p \leq 0.05$) = 0.766

[z]DBS and DAS refer to days before sowing and days after sowing, respectively.

[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

**Table 4. Average leaf area (cm$^2$) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels (kg ha$^{-1}$) | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 252.25 | 252.75 | 256.75 | 262.50 | 261.00 | 258.50 | 257.3c[y] |
| 60 | 256.25 | 259.25 | 264.50 | 272.00 | 268.00 | 264.00 | 264.0b |
| 90 | 269.00 | 271.25 | 272.75 | 284.00 | 276.75 | 274.25 | 274.7a |
| Mean | 259.2e | 261.1de | 264.7cd | 272.8a | 268.6b | 265.6bc | |

LSD value for P levels ($p \leq 0.05$) = 6.200

LSD value for P timing ($p \leq 0.05$) = 3.653

[z]DBS and DAS refer to days before sowing and days after sowing, respectively.

[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

**Table 5. Leaf dry weight (g) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| (kg ha$^{-1}$) | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 19.75 | 21.75 | 22.50 | 34.50 | 30.00 | 28.50 | 26.17b[y] |
| 60 | 23.50 | 26.50 | 29.00 | 38.00 | 35.00 | 31.75 | 30.63a |
| 90 | 26.50 | 28.50 | 29.00 | 35.50 | 35.75 | 33.75 | 31.42a |
| Mean | 23.17d | 25.50cd | 26.83c | 36.00a | 33.58ab | 31.33b | |

LSD value for P levels ($p \leq 0.05$) = 4.313
LSD value for P timing ($p \leq 0.05$) = 2.886
[z]DBS and DAS refer to days before sowing and days after sowing, respectively.
[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

**Table 6. Ear dry weight (g) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| (kg ha$^{-1}$) | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 164.00 | 177.25 | 180.00 | 189.50 | 180.50 | 180.50 | 178.6b[y] |
| 60 | 179.00 | 178.50 | 180.25 | 204.00 | 191.00 | 191.75 | 187.4ab |
| 90 | 190.00 | 192.25 | 195.25 | 205.75 | 200.00 | 196.75 | 196.7a |
| Mean | 177.7b | 182.7b | 185.2b | 199.38a | 190.5ab | 189.7ab | |

LSD value for P levels ($p \leq 0.05$) = 11.05
LSD value for P timing ($p \leq 0.05$) = 13.653
[z]DBS and DAS refer to days before sowing and days after sowing, respectively.
[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

Phosphorous applied @ 90 kg ha$^{-1}$ produced maximum of 113.1 g of stem dry weight while minimum stem dry weight per plant (88.79 g) was recorded in the plots which received the lowest P level (Table 7). All the levels of P differed significantly from one another. In case of application time, maximum stem dry weight per plant (112.2 g) was recorded in the plots which received P 10 DBS, followed by103.93 g stem dry weight per plant in the plots which received P at sowing time being at par with 15 DAS (103.33 g), and the minimum stem dry weight (91.90 g) was recorded in the plots applied with P 40 DBS being comparable with 30 DBS.

**Biomass yield and harvest index:** Phosphorous levels and its application time had a significant effect while their interaction (P x T) had non-significant effect on biomass yield (Table 8). Maize produced the highest biomass yield of 9177 kg ha$^{-1}$ in the plots which received the highest P dose @ 90 kg ha$^{-1}$ and the lowest biomass yield (7662 kg ha$^{-1}$) when applied with the lowest P level (30 kg ha$^{-1}$). All the levels of P differed significantly from one another. In case of application time, the highest biomass yield (8566 kg ha$^{1}$) was recorded in the plots that received P at sowing time of maize crop being at par with 15 DAS as well as 20 & 10 DBS, while the lowest biomass yield (8046 kg ha$^{-1}$) was recorded in the plots where P was applied at 40 DBS being comparable with 30 DBS.

Similarly, P levels and application time had significant while their interaction (P x T) had no significant effect on stover yield (Table 9). Phosphorus applied at the highest rate of 90 kg ha$^{-1}$ produced highest stover yield (3194 kg ha$^{-1}$) while the lowest rate of 30 kg P ha$^{-1}$ produced the lowest stover yield (2696 kg ha$^{-1}$) being comparable with 2879 kg ha$^{-1}$obtained at the medium P level (60 kg ha$^{-1}$). Highest stover yield (3007 kg ha$^{-1}$) was recorded in the plots which received P at sowing time of maize which was statistically the same when P was applied 10 DBS (2971 kg ha$^{-1}$), while those plots which received P at 40 DBS of maize produced the lowest stover yield (2856 kg ha$^{-1}$) being at par with 30 DAS.

**Table 7. Stem dry weight (g) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels (kg ha$^{-1}$) | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 82.25 | 84.75 | 86.00 | 90.75 | 98.00 | 91.00 | 88.79c[y] |
| 60 | 90.25 | 95.75 | 99.25 | 102.25 | 112.25 | 104.0 | 100.60b |
| 90 | 103.25 | 105.0 | 110.5 | 118375 | 126.25 | 115.0 | 113.10a |
| Mean | 91.92d | 95.17cd | 95.58c | 103.90b | 112.20a | 103.30b | |

LSD value for P levels ($p \leq 0.05$) = 5.416
LSD value for P timing ($p \leq 0.05$) = 4.184
[z]DBS and DAS refer to days before sowing and days after sowing, respectively.
[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

**Table 8. Biomass yield (kg ha$^{-1}$) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels (kg ha$^{-1}$) | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 7510 | 7622 | 7622 | 7738 | 7726 | 7726 | 7662 c[y] |
| 60 | 7949 | 8175 | 8238 | 8195 | 8412 | 8473 | 8240 b |
| 90 | 8680 | 8863 | 9240 | 9525 | 9560 | 9196 | 9177 a |
| Mean | 8046 c | 8220 bc | 8367 ab | 8486 ab | 8566 a | 8474 ab | |

LSD value for P levels ($p \leq 0.05$) = 461.2
LSD value for P timing ($p \leq 0.05$) = 305.6
[z]DBS and DAS refer to days before sowing and days after sowing, respectively.
[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

**Table 9. Stover yield (kg ha$^{-1}$) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels (kg ha$^{-1}$) | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 2613 | 2664 | 2642 | 2754 | 2802 | 2698 | 2696b[y] |
| 60 | 2811 | 2826 | 2907 | 2920 | 2941 | 2867 | 2879b |
| 90 | 3144 | 3160 | 3171 | 3238 | 3278 | 3175 | 3194a |
| Mean | 2856c | 2883bc | 2907b | 2971a | 3007a | 2913b | |

LSD value for P levels ($p \leq 0.05$) = 245.50
LSD value for P timing ($p \leq 0.05$) = 37.99
[z]DBS and DAS refer to days before sowing and days after sowing, respectively.
[y]Mean values of the same category followed by different letters are significant at $p \leq 0.05$ using LSD.

**Table 10. Harvest index (%) of maize as affected by P levels and its application time at Peshawar, Pakistan.**

| P levels (kg ha$^{-1}$) | Application timings | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 DBS[z] | 30 DBS | 20 DBS | 10 DBS | At sowing | 15 DAS | Mean |
| 30 | 23.94 | 23.45 | 21.55 | 24.48 | 23.54 | 23.11 | 22.86 |
| 60 | 24.26 | 24.00 | 23.28 | 23.85 | 23.47 | 23.16 | 23.68 |
| 90 | 21.64 | 21.02 | 22.13 | 24.02 | 24.51 | 23.25 | 23.67 |
| Mean | 22.34 | 23.03 | 22.95 | 23.49 | 23.21 | 22.59 | |

[z]DBS and DAS refer to days before sowing and days after sowing, respectively.

Phosphorus levels, application time and interaction of P x T had no significant effect on harvest index (Table 10). However, higher harvest index (23.67%) was recorded in the plots that received the highest rate of 90 P kg ha$^{-1}$ and minimum harvest index (22.86%)

was recorded when P was applied at the lowest rate of 30 kg $ha^{-1}$. Regarding P time, maximum harvest index (23.49%) was noted in the plots that received P 10 DBS, followed by harvest index (23.21%) when P was applied at sowing time but the minimum of 22.34 % was recorded in the plots where P was applied at 40 DBS.

## Discussion

Increase in P levels had positive effect on maize height (Table 2). Taller plants were noted in the plots where P was applied at highest level as compared to shorter plants when applied with lower P levels. The possible reason might be due to that soils low in P will adsorb large amounts of P leaving little for plants, when P was applied at the highest level availability of P was increased that helped maize to attain maximum height. These findings are in agreement with those of Sahoo & Panda (2001) who reported that plant height in maize increased with increase in P level. Rapid plant growth and development with the highest rate of P was reported by Singaram & Kothandaraman (1994). Taller plants were noted in the plots that received P at sowing time while the shortest plants were recorded with the application of P 40 DBS. This might be due to the high soil pH (8.2) of the experimental site that might have increased P fixation in the soil and reduced its availability when applied too earlier from planting. Yash *et al*., (1992) reported that high soil pH decreased P availability applied much before sowing, therefore adequate P should be applied at nearly sowing to reduce P fixation.

Number of leaves per plant and leaf area showed positive association with increase in P levels (Tables 3 & 4). Increase in number of leaves and leaf area per plant at higher P level might be due to the increase in P availability to maize plants that had positive impacts on plant growth which resulted in increase in number of leaves and leaf area per plant. Increase in number of leaves per plant was reported by Arya & Singh (2001), and increase in leaf area was reported by Hamdi & Woodard (1995) that soils low in P will adsorb large amounts of P leaving little for plants and higher P dose increased its availability allowing less adsorption and so improved maize growth. Amanullah *et al*., (2009) reported that leaf area in maize increased with application of P than control, and that the increase in leaf area was more with application of SSP (single super phosphate) as compared to DAP (diammonium phosphate) and NP (nitrophos).

In case of application time, higher number of leaves and leaf area per plant were obtained in the plots which received P at sowing and 10 DBS, respectively but both of them were decreased to minimum when applied with P 40 DBS (Tables 3 & 4). This may be attributed to reduced availability and uptake of P when it was applied much earlier to sowing. Mascagni & Boquet (1998) and Reddy *et al*., (1992) reported that the percentage of P in the crop from fertilizer has been reported highest when moisture availability was optimum than at low moisture level. The high pH (8.2) of the experimental site might also have increased P fixation when P was applied earlier (40 DBS) than applied at sowing and 10 DBS.

Dry matter partitioning to leaf, ear and stem was higher with the highest P level as compared to the lower P levels. The possible reason could be that higher dose of phosphorous (90 kg $ha^{-1}$) enabled the plants to absorb greater amount of the applied P resulting in more assimilate formation and partitioning to leaf, ear and stem. Arya & Singh (2001) found increased dry matter accumulation in maize with increase in P level. Maximum leaf and ear dry weight was noted in the plots that received P 10 DBS and maximum stem dry weight was noted in the plots that received P at sowing time. The possible reason for decrease in dry matter portioning with too earlier (20 to 40 DBS) or too late (15 DAE) application of P might be due to more P fixation and less P availability because of the clay loam texture of the experimental site. Roman & Willium (1993) found that clay loam texture had maximum P fixation and to get proper amount of P availability, P-fertilizers should not be applied much before plantation to minimize P fixation.

Increase in both stover and biomass yields at higher P level than lower P level indicate more P availability at higher P rates. Hussain & Haq (2000) suggested that soils of KPK with high fixation capacity have higher demand for P fertilizer. These results are in line with those of Bhopal & Sing (1989) who reported that stover yield was highest with highest P level; and Singaram & Kothandaraman (1994) reported that P applied at 90 kg $ha^{-1}$ increased biomass yield of maize. The increase in crop growth rate and leaf area index with P application (Amanullah *et al*., 2010a), probably may have resulted in higher biomass in maize. Maximum stover yield and biomass yield were recorded in the plots that had received P at sowing. The decreased yields with too early applied P might be due to the high pH (8.2) of the experimental site increased P fixation and reduced its availability to the plants which is the possible reason for decreased stover and biomass yields. Yash *et al*., (1992) reported that high soil pH decrease P availability and its availability would be adequate if applied nearly at sowing. These findings are in agreement with the finding of Griffith (1983) who reported that fixation of soil P increased with more time of contact between soluble P and soil particles. On the other hand, the decrease in stover and biomass yields of maize with late application of P might be due to the unavailability of P at the growth stage of maize. Rashid *et al*., (1988) suggested two-week time for the establishment of equilibrium after the addition of P fertilizer to the alkaline calcareous soils of Pakistan. Moreover, the higher leaf area and plant heights of maize at elevated P levels and when applied at sowing time or10 DBS is the possible cause of higher maize yields. However, in contrast to our results Latif *et al*., (1991) reported that P applied to maize in pots by fertigation method 10 days after emergence gave significantly higher dry matter yield as compared to broadcast P at sowing time.

Harvest index in maize increased with increase in P levels. The highest harvest index was recorded in the plots that received the highest rate of P and the minimum harvest index was determined when P was applied at the low level. The increase in harvest index with higher P levels might be due to the increase in yield and yield components of maize with higher P rates (Amanullah *et al*., 2010b). Ibrikci *et al*., (2005) found that P deficiency is invariably a common crop growth and yield-limiting factor, especially in soils high in calcium carbonate, which reduces P solubility. Harvest index increased when P was applied 10 DBS or at sowing time than early or late application of P. The decrease in harvest index with too late and too early P application might be due to the decrease in yield and yield components of maize as compared to higher yield and yield components when applied at sowing time or 10 DBS (Part I).

## Conclusion

Our findings suggest that 90 kg P $ha^{-1}$ applied 10 DBS or at sowing significantly improved plant height, number of leaves and leaf area per plant, partitioning dry matter, fodder yield (stover and biomass yields) and harvest index of maize. The farmers of KPK who traditionally apply less than 50 kg P $ha^{-1}$ at sowing time require demonstration of the benefits of the higher level of P that need to be applied about one week before sowing. Further research work for understanding the impacts of levels and timing of P application for high sustainable crop production in different agro-ecological zones of KPK is also suggested.

## Acknowledgements

Financial support from the Department of Agronomy, Faculty of Crop Production Sciences, KPK Agricultural University, Peshawar, is greatly acknowledged.

## References

Amanullah, H. Rahman, Z. Shah and P. Shah. 2008. Effects of plant density and N on growth dynamics, light interception and yield of maize. *Archives of Agron. Soil Sci*., 54: 401-411.

Amanullah, M. Asif, S.S. Malhi and R.A. Khattak. 2009. Effects of P-fertilizer source and plant density on growth and yield of maize in Northwestern Pakistan. *J. Plant Nutr*., 32: 2080-2093.

Amanullah, M. Asif and K. Nawab. 2010a. Impacts of planting density and P-fertilizer source on the growth analysis of maize. *Pakistan J. Bot.*., 42: 2349-2357.

Amanullah, M. Zakirullah and S.K. Khalil. 2010b. Timing and rate of P application influence maize phenology, yield and profitability in Northwest Pakistan. *Int. J. Plant Prod.,* 4: 281-292.

Amanullah, and M.W. Khan. 2010. Interactive effects of potassium and phosphorus application on phenology and grain yield of sunflower in Northwest Pakistan. *Pedos.,* 20: 674-680.

Anonymous. 2006. *Balanced fertilization through phosphate promotion at farm level*: Impact on crop production. World Phosphate Institute, Morocco, FAO and NFDC, Islamabad.

Arya, K.C. and S.N. Singh. 2001. Productivity of maize as influenced by different levels of phosphorus, zinc and irrigation. *Indian J. of Agric. Sci*., 71: 57-59.

Bhopal, S. and B. Singh. 2004. Response of phosphorus on yield of maize and wheat in sequence under rain-fed conditions. *Indian Agri. Res. J*., 23: 184-186.

Chaudhry, I.M. 1994. *Crop Production*. National Book Foundation, Islamabad, Pakistan. pp. 265.

Cisse, L. and B. Amar. 2000. *The importance of Phosphatic fertilizer for increased crop production in developing countries*. In: *Proceedings of the AFA 6$^{th}$ International Annual conference* held on 31 January – 2 February, 2000, Cairo, Egypt.

Griffith, B. 1983. Efficient uses of phosphorus fertilizer in irrigated land. *Soil. Sci. J*., 148: 7-9.

Hamdi, E.L. and H.J. Woodard. 2004. Response of early corn growth to fertilizer phosphorus rates and placement methods. *J. Plant Nutr*., 27: 1103-1120.

Hussain, M.Z. and I.U. Haq. 2000. *P sorption capacities of KPK soils*. In: *Proceedings of symposium on integrated plant nutrient management held at Islamabad* on 8-10 Nov., 1999. pp. 284-296.

Ibrikci, H., J. Ryan, A.C. Ulger, G. Buyuk, B. Cakir, K. Korkmaz, E. Karnez, G. Ozgenturk and O. Konuskan. 2005. Maintenance of P fertilizer and residual P effect on corn production. *Nigerian Journal of Soil Science,* 2: 1279-286.

Latif, A., S.M. Alam, A. Hamid and M. Sharif. 1991. Comparison of P fertilizers and their application methods for maize crop. *Pakistan J. of Soil Science*, 6: 29-30.

Latif, A., S.M. Alam, Z. Iqbal and A. Hamid. 1992. *Effect of rate, time and method of application of phosphorus fertilizer on wheat crop*. In: *Proceedings of fourth national congress of soil science on "Efficient use of plant nutrients*" held on May 24-26, 1992 at Islamabad, Pakistan.

Nisar, A. and H.M. Bhatti. 1978. *Relative efficiency of P sources and time of application to wheat crop*. Paper presented in seminar on "Wheat Research and Production", held on August 1978 at Pakistan Agriculture Research Council, Islamabad.

Okalebo, J.R. and M.E. Probert. 1992. Effects of phosphorus on the growth and development of maize. A search for strategies for sustainable dryland cropping in semi-arid eastern Kenya. *Nairobi Agric. J*., 12(2): 8-20.

Phillips, A.B. and J.R. Webb. 1971. *Production, marketing and use of P fertilizers*. In: *Fertilizer Technology and Use* (2nd Edition) SSSA, Madison, Wisconsin, USA.

Qureshi, S.A. 1978. *Green revolution can be revitalized in Pakistan*. Paper presented in seminar on "Wheat Research and Production", held on August 1978 at Pakistan Agriculture Research Council, Islamabad.

Rasheed, M. and M. Iqbal. 1995. *Factors effecting on the yield of maize*. Progress Report, Agirc. Res. Institute Tarnab, Peshawar. pp. 24-26.

Rashid, A., N. Bughio and M. Salim. 1988. *Calibration of three tests for determining P fertility of soils to support cereals, legumes and oil seeds*. Proceeding of the second regional workshop on soil test calibration in West Asia and North Africa, held on September 1-6, 1987, Ankara, Turkey.

Reddy, S.A., D. Jhon and W. Christie. 1992. Effect of phosphorus on maize under moisture stress condition. *Crop Sci. J*., 33: 212-215.

Rehman, H., A. Bhatti, R. Amin and A.H. Raja. 1983. *Fertilizers experiments on cereal in Swat District*. Soil Science Division, Agriculture Research Institute, Tarnab, Peshawar

Roman, F.D. and T. William. 1993. Studied the effect of phosphorus behavior under different soil texture. *Soil Sci. J.*, 158: 47-49.

Sahoo, S.C. and M. Panda. 2001. Effect of phosphorus and de-tasseling on yield of baby-corn . *Indian J. Agric. Sci*., 71: 21-22.

Singaram, P. and G.V. Kothandaraman. 1994. Studies on residual, direct and cumulative effect of phosphorus sources on the availability, content and uptake of phosphorus and yield of maize. *Madras Agric. J*., 81: 425-429.

Steel, R.G.D. and Torrie. 1980. *Principles and procedures of statistics*. Mc Graw Hill Book Co. Inc., New York.

Yash, S., W. Rakish and K. Sing. 1992. Phosphorus availability under different soil pH. *Indian Agric. J*., 23: 124-128.

(Received for publication 22 September 2008)