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**Archives of Applied Science Research, 2011, 3 (2):199-212**

***(http://scholarsresearchlibrary.com/archive.html)***

ISSN 0975-508X
CODEN (USA) AASRC9

# Effect of combining organic materials with inorganic phosphorus sources on growth, yield, energy content and phosphorus uptake in maize at Rawalakot Azad Jammu and Kashmir, Pakistan

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## ABSTRACT

*Phosphorus (P) is a limited resource, and its efficient use is a main task in sustainable agriculture. Due to high costs of imported fertilizers, focus is now shifting to solutions that utilize local resources. We tested the effect of two inorganic phosphorus (P) fertilizer, diammonium phosphate (DAP); triple super phosphate (TSP) and three organic materials farm yard manure (FYM), poultry manure (PM), compost (COM) on growth, yield, energy content and P utilization efficiency (PUE) of maize. DAP and TSP alone or in combination with each of organic materials i. e. FYM, PM and COM in combination (50:50 ratio) were applied to supply 90 kg P ha$^{-1}$. Both inorganic P fertilizers when applied in combination with either organic material significantly increased plant height, leaf area and chlorophyll content over control. Grain, dry matter, biomass yield and protein content increased by 74-101, 43-60, 55-75 and 42-70% over control. P uptake increased from 14 g kg$^{-1}$ in control to 36 g kg$^{-1}$ where DAP and PM was combined while increase in PUE was 10-27%. When applied in combination with organic materials, DAP+PM was the best treatment among P sources to be utilized.*

**Key words:** phosphorus sources, yield, protein, P efficiency, maize.

## INTRODUCTION

The efficient utilization of nutrients with minimum nutrient losses is a main task of sustainable agriculture. This is especially true for phosphorus (P), since P is a limited resource and P-based fertilizers are therefore used routinely in agricultural systems to over-come deficiency of soil P. Some 17.5 million tonnes of P is processed annually from world reserves of rock phosphates, of which approximately 85% is used in the production of fertilizers [7]. However, reserves of rock-P are finite with an estimated depletion of quality sources expected to occur within the next 50–

80 years [27]. Indeed world commodity markets have already faced rapid and sharp increase in the price of phosphate rock in recent years i.e. an approximately 7-fold increase in the period between March 2007 and 2008 [8].

The need to use renewable forms of energy and reduce costs of fertilizing crops has revived the use of organic fertilizers worldwide. A possible way for recovering poor quality soils is to add manure and compost to improve soil health and quality, thereby enhancing biogeochemical nutrient cycles. To evaluate the full benefits of organic fertilization, more knowledge about its effect on nutrient avail-ability is required. This is complicated, since the transformation of organic compounds and nutrient release is a complex process, depending on many factors such as the stability of organic substances [42] and climatic conditions [21].

Organic-matter supply to the soil is one of the most important factors for increasing the productivity in plant, with organic P as a significant part of the soil P cycle contributing to P nutrition of plants [2]. Organic fertilizers have equivalent or even better effects on crop yields than P from mineral sources [3]. Besides serving as a source of nutrients itself, organic fertilization can improve the availability of P in soil, due to the influence on chemical, physical, and biological soil properties. [12, 13] related the reduction of P-sorption capacity induced by organic fertilization to changes of soil chemical properties (e.g., pH and exchangeable Al) and to complexation of P-sorption sites at reactive surfaces. Organic fertilization increases the humus content [47] and enhances the microbiological activity in soil [14, 39, 45].

Maize (*Zea mays* L.) is the single most important crop in the in the state of Azad Jammu and Kashmir (AJK), Pakistan with an area of 104911 hectares under cultivation, contributing more than 80% of the total production in the region [17], but its yield per unit area is very low. The soils of AJK have low organic matter content and low to medium available phosphorus (P). These soils contain high clay content with pH ranging from 6.5 to 8. This high clay contents coupled with high pH favors the formation of relatively insoluble phosphates, hydroxyl apatite, carbonate apatite, and octo calcium phosphate. Soils with high fixation capacity have higher demand for phosphatic fertilizer [33]. Phosphorus deficiency is invariably a common crop growth and yield-limiting factor in unfertilized soils [18].

Grain and biomass yields, number of grains per ear, plant height, chlorophyll contents, energy contents and P uptake efficiency of maize increases at high level of P application. But, previous research has shown no clear-cut superiority of one P fertilizer source over the other when applied at the same dosages of P. For example, in western Nigeria, there were no significant differences in maize yield with application of single super phosphate (SSP), triple super phosphate (TSP), nitrphos (NP), and DAP (diammonium phosphate) [35]. In some cases TSP gave higher yield than DAP, but in other cases it produced lower yield response than DAP [25, 34]. The phosphorus use efficiency (PUE) is often very low and varies from 8–33% depending on crops and soils [16, 40]. One environmentally friendly and economically feasible strategy to maintain high crop productivity without increasing P fertilization rates is the integration of organic and inorganic P sources.

Though information is available on the conjunctive use of organic manures and inorganic fertilizers for improving soil fertility and crop yields, direct quantification of plant-available phosphorus tendered available to the crops from organic manures is scant. The literature suggests that combined application of P fertilizer and poultry manure affect plant growth, grain yield, energy component and P efficiency parameters of maize. However, research information is lacking on the interactive effects of organic materials and inorganic P fertilizers on maize growth and yield in the agro-ecological wheat-maize growing zones of AJK. For sustainable high crop production in AJK, organic materials and P-fertilizers are indispensable. This experiment was, therefore, performed with an objective to investigate the impacts of different P sources on the growth, yield, energy contents and P utilization efficiency of maize.

## MATERIALS AND METHODS

### *The study site*

This study was carried out on an experimental field at the Research farm, Faculty of Agriculture, University of Azad Jammu and Kashmir (UAJK) Rawalakot AJK (33–36$^{o}$ N latitude and 73–75$^{o}$E longitude) during the year 2009. The study area (Rawalakot) lies between the altitude of 1800–2000 m above sea level in the north–east of Pakistan under the foothills of great Himalayas at Poonch district AJK, Pakistan. The study area is characterized by annual rainfall ranging from 500−2000 mm (depending on season), most of which is irregular and falls as intense storms during the monsoon and sometimes in winter. Mean annual temperature is about 28 $^{0}$C (maximum) in summer while winter is fairly cold with temperature ranging even below freezing point. The monthly precipitation and temperature of the experimental area are presented in Figure 1.

### *Field operation, experiment description and treatments*

Before actual experiment, soil samples from the experimental field were collected for physical and chemical characteristics (Table 1). A field of 30 x 16 m$^2$ was selected where maize and wheat were grown previously since the last two years with the addition of organic manures. For proper seed bed preparation, field was ploughed thoroughly twice with tractor and left as such for next two weeks. The individual plots were prepared according to the treatments and the net plot size was 3 × 3 m$^2$ which was kept according to the size of the field. The plot was properly leveled for even and efficient fertilizer and water distribution.

The experiment was laid out in a randomized complete block design (RCB) design with three replications. The treatments comprised of two different sources of P i.e. inorganic fertilizers as i) DAP (diammonium phosphate, $(NH_4)_2$ $HPO_4$, 46% $P_2O_5$ and 18% N); ii) TSP (Triple super phosphate, $Ca(H_2PO_4)2H_2O$, 36% $P_2O_5$) and organic as i) Farmyard manure (FYM); Poultry manure (PM); and Compost (COM) respectively, and a control (no P); altogether a total of nine treatments with three replications were established in the experiment. Phosphorus was applied at recommended rate 90 kg ha$^{-1}$ from either sources at/equivalent basis. The treatments include, $T_1$ = without fertilization ($P_0$); $T_2$ = DAP (alone); $T_3$ = TSP (alone); $T_4$ = DAP × FYM (50:50 ratio); $T_5$ = TSP × FYM (50:50 ratio); $T_6$ = DAP × PM (50:50 ratio); $T_7$ = TSP × PM (50:50 ratio); $T_8$ = DAP × COM (50:50 ratio) and $T_9$ = TSP × COM (50:50 ratio).

Organic manures were applied on the basis of P content 15 days before sowing. The chemical composition of organic materials is presented in Table 2. Urea was used as N source and full dose of N fertilizer 120 kg ha$^{-1}$ was applied by broadcast method at the time of sowing.

Similarly, a basal dose of potassium was applied to all plots including control at the time of sowing at the rate of 60 kg $K_2O$ $ha^{-1}$ as sulphate of potash (SOP), by broadcast method. All the fertilizers were well mixed into the soil. Maize (*Zea mays* L) variety Jalal was used in the experiment. Seeds were collected from maize section, District Agriculture Office, Rawalakot, AJK. Maize was sown in lines on May 08, 2009. After germination the distance between the plants was maintained at 25 cm, while the row to row distance was 50 cm and total of five rows per plot were established. All standard local cultural practices were followed when required throughout the growth period. No irrigation was provided, and anual weeding was carried out on three occasions. There were no major pests or diseases those required chemical control methods.

***Measurements***

***Morphological characteristics***

The morphological characteristics of the crop like plant height, leaf surface area and chlorophyll content were recorded in standing crop.

***Plant Height* (cm)**

Plant height was taken from base to top of the plant for five selected plants per plot in all treatments and then averaged.

***Average Leaf Area* ($cm^2$)**

Five plants were randomly selected from each treatment and leaf area of all leaves of five plants was measured with the help of leaf area machine and averaged.

***Chlorophyll content* (mg $cm^2$)**

Chlorophyll content readings were taken with a handheld dual-wavelength meter (SPAD 502, Chlorophyll meter, Minolta Camera Co., Ltd., Japan). For each plot 30 younger fully expanded leaf blades per plot were used when the plants were at silking stage. The instrument stored and automatically averaged these readings to generate one reading per plot.

***Yield and yield components***

***Dry Matter Yield* (kg $ha^{-1}$)**

For recording dry matter yield, the two middle rows from each plot at maturity were harvested after removing cobs, stacked for uniform drying, weighed and then converted to kg $ha^{-1}$ by using the formula:

$$\text{Dry matter yield (kg ha}^{-1}\text{)} = \text{kg stover yield m}^{-2} \times 10,000\text{m}^2$$

***Shelling Percentage* (%)**

Shelling percentage was calculated by using the following formula:

$$\text{Shelling percentage (\%)} = \frac{\text{Grains weight of five ears}}{\text{Total weight of five ears}} \times 100$$

***Thousand Grain Weight* (g)**

Thousand grain weight was taken at random from the grain lot of each plot using electronic balance. This was repeated three times and then average weight per 1000 grains was calculated and recorded.

***Grain Yield* (kg ha$^{-1}$)**

For recording grain yield data the two middle rows from each plot at maturity were harvested, husked, dried and threshed. Grain yield was recorded and converted to kg ha$^{-1}$ by using the following formula:

$$\text{Grain yield (kg ha}^{-1}) = \text{kg grain yield m}^{-2} \times 10,000\text{m}^2$$

***Harvest Index* (%)**

Harvest index was calculated using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Biological/biomass yield (kg ha}^{-1})} \times 100$$

***Biological Yield* (kg ha$^{-1}$)**

At maturity four central rows in each plot were harvested, dried to constant weight and weighed. Biological yield, in kg ha$^{-1}$, was determined using the formula.

$$\text{Biological yield} = \frac{\text{biological yield per plot}}{\text{plot area harvested}} \times 10\,000.$$

***Biochemical analysis of plant and grain***

Plant material (shoot, leaves and grain) was dried in a forced-draft oven at about 70$^0$C until constant weight and ground to pass a 1-mm sieve with an ED-5 Wiley mill (Arthur H. Thomas Co.). The ground material was analyzed for N and P concentration. Protein concentration in the grain was determined from total N in the grain using the Kjeldhal digestion, distillation and titration method [23]. Grain protein concentration was determined using the formula: protein concentration = %N × 6.25 and then it was converted into g kg$^{-1}$. Phosphorus content in shoot was estimated by wet digestion with a 2:1 mixture of nitric acid ($HNO_3$) and Perchloric acid ($HClO_4$). The P content was then determined by the vanadomolybdate yellow color at 440nm using spectrophotometer [22]. P accumulation (uptake) in plant was calculated from dry matter accumulation and P-concentration in shoot.

***P efficiency Parameters***

The P data of samples were used for calculating the following P efficiency parameters following the methods used by [32].

Agronomic efficiency of applied fertilizer P (PAE) = (Grain yield in plots with fertilizer – grain yield of control plots) / Quantum of applied P fertilizer

P-use efficiency (PUE) = [(P uptake by the fertilized treatment – P uptake in the control)/ Quantum of applied P fertilizer] x100

***Statistical Analysis***

For the determination of significant effect of treatments on the growth and yield of crop and on soil and plant characteristics, analysis of variance (ANOVA) and least significant difference (LSD) tests among means were conducted for each character separately using a MSTAT-C statistical analysis package. Comparison of means for the individual treatments was done at the 5% probability level based on the F-test of the analysis of variance [43].

## RESULTS AND DISCUSSION

***Morphological characteristics***

Statistical analysis i.e. Analysis of Variance (ANOVA) indicated significant difference ($P \leq 0.05$) among differ P fertilizers and their combinations with organic materials for pant height, leaf area and chlorophyll content. Plant height was significantly greater for all the treatments with P fertilizers and their combination with each of manure than those for the control (Table 3). The relative increase in plant height was 15–30% over the control without P addition. Application of DAP+PM resulted in significantly taller plants 242 cm than the plants treated with other treatments. In rest of treatments the combination of inorganic P fertilizers with each of organic material showed greater plant height than their sole application. Growth of maize showed similar response to different inorganic P fertilizers application under climatic conditions of Peshawar, Pakistan [4]. The increase in growth characteristics is attributed to the stronger role of P in cell division, cell expansion and enlargement which ultimately affect the vegetative growth of maize. Ayoola and Adeniyan [38] showed that application of poultry manure and P fertilizers influences plant growth and yield by providing more nutrients. Opala et al. [41] reported that integrated application organic and inorganic phosphorus sources had significant positive role in the growth characteristics of maize. All the treatments showed significant increase in leaf surface area (LSA) compared with the control (Table 3). In general, at equivalent rates of application, DAP+PM resulted in higher LSA followed by plants treated with TSP+PM. The increase in LSA with the P fertilization was 36–51% compared with the control. Similarly, application of DAP and TSP either alone or in combination with PM significantly increased the chlorophyll content of maize plants. Chlorophyll content was significantly increased due to addition of P inputs, ranging from 4.42 mg $cm^2$ in the control to 9.59 mg $cm^2$ DAP+PM. Average across treatments, the increase in chlorophyll content due to application of P fertilizers and manures was 41–118% compared with the control. Integration of DAP and TSP with each of organic source significantly increased the LSA as compared to their sole application. In the present study, chlorophyll content showed a highly significant correlation with P uptake in plant i.e. $r^2$ = 0.88 confirming the findings of Pirdashti et al. [19] who also found that integrated use of half chemical P fertilizer and half organic source significantly increased plant height, leaf area and leaf chlorophyll content in soybean. Averaged across treatments, yield and most of the yield attributes showed higher response to those treatments where integration of different P sources was carried out (Table 4). The results found in the present study were comparable to those reported by [4, 41, 44] for maize.

***Yield and yield components***

Analysis of Variance (ANOVA) for yield and yield components of maize indicated significant differences ($P \leq 0.05$) for inorganic P fertilizer sources and their integration with organic materials for all yield and yield components i. e. 1000-grain weight, shelling percentage, grain yield, dry matter yield, total biomass yield and harvest index(Table 4, 5). Highest 1000 grain weight 332 g was recorded where combine application of DAP+PM was carried out, whereas 1000 grain weight in integrated treatments of TSP with FYM and COM were also higher than their sole application. Average across treatments, the increase in 1000 grain weight due to application of P fertilizers and organic materials was 60–94% compared with the control. Connor, [9] stated that organic agriculture alone cannot feed the world. Similarly, the entire conjunctive nutrient use treatments where half (50%) of either mineral P was applied with half PM (50%) resulted in higher maize grain yields when compared to 100% mineral application of 90 kg P $ha^{-1}$. These results were in accordance to those of Ayoola and Adeniyan [38] who reported that Cassava, maize and melon performed best in terms of growth and yield under poultry manure + NPK fertilizer treatments in both years of the study. Ojo et al. [36] also found similar results of phosphorus in grain amaranth production. A similar trend was observed for the shelling percentage as P fertilizers and integrated use with organic materials. Addition of PM with TSP exhibited highest shelling percentage of 80, followed by DAP+PM with 77%. Average increase in shelling percentage following the application of P fertilizer + organic amendments was 1–13%, respectively over the control. Grain yield recorded for different P treatments was significantly greater than the un-fertilized control (Table 4). Grain yield in DAP+PM was significantly higher 4813 kg $ha^{-1}$ than the rest of treatments but was at par with TSP+PM and DAP+COM with 4715 and 4684 kg $ha^{-1}$ grain yield respectively. Average increase in grain yield following the different P inputs either alone or in combination was 74-101%, respectively over the control. Similarly, application of inorganic P fertilizers and manures alone and in combination significantly increased dry matter yield (Table 4). Dry matter yield in the control was 3974 kg $ha^{-1}$ that significantly increased to 6355 kg $ha^{-1}$ in TSP+COM. On an average, increase in DMY due to P fertilization with organic sources ranged between 43–60%. Likewise the grain yield, biomass yield was also highest 11120 kg $ha^{-1}$ with the combine application of DAP+PM over control. Application of different P inputs did not increased Harvest index (HI) and all the fertilized treatments were at par with each other when compare to control. Dordas, [6] found that combine application of manure and inorganic fertilizers increased dry matter yield 22% than the control. Similarly, Valluru et al. [1] determined 50-105% increase in biomass yield of pear millet with P addition and sholly et al. [11] recorded 29% yield increase with manure application in wheat. Adeniyan and Ojeniyi [37] reported that the highest values were recorded with combined use of 3t $ha^{-1}$ poultry manure and 200 kg $ha^{-1}$ NPK fertilizer with respect to dry matter yield, grain yield and nutrients uptake of maize.

***Grain protein content and P uptake in maize***

Effect of different P treatments on protein content and P-uptake of maize is presented in Table 5. Analysis of Variance (ANOVA) indicated significant difference ($P \leq 0.05$) between DAP and TSP in combination with organic manure for protein content in grain and P uptake of maize. The average increase in protein content following the integrated application i. e. DAP+FYM, TSP+FYM, DAP+PM, TSP+PM, DAP+COM and TSP+COM was 49, 43, 70, 60, 55 and 51%, respectively over the control showing highest content in combine treatments of mineral P fertilizers with organic materials. Increased protein content (N-content) had strong positive correlation ($r^2$ = 0.83) with total P uptake. Grains are most active sink for carbon and N assimilates in cereals. Whereas most of the carbohydrates are provided by current photosynthesis, the major portion of seed N is derived by mobilization of N accumulated in vegetative organs Cartelle, [20]. Similar to our results [5, 6**,** 11] reported that with the addition of inorganic P fertilizers and manure, N contents on whole plant level increased 33-48% over their respective controls.

Similar to protein content, P uptake in plants treated with combination of inorganic and organic P sources was significantly higher than the P content in control and sole P fertilizer treatments. The maximum P uptake was found in the integrated treatments. Maximum P uptake 36 kg $ha^{-1}$ was recorded with DAP+PM, followed by DAP+COM with 32 kg $ha^{-1}$ over rest of treatments. Average across treatments, the increase in P uptake due to P addition was 49–161% over control. Phosphate uptake occurs throughout the life of the plant and it is continuous until physiological maturity Batten, [15]. There is also a significant P remobilization to the developing grains from leaves and stems during grain development Papakosta [10]. In the present study, P uptake showed a highly significant correlation with leaf area, yield, protein and PUE in plant i.e. $r^2$ = 0.71, 0.88, 0.72 and 0.83. Similar results regarding increased P uptake with combine application of inorganic P sources with manure application were reported by Bayu et al. [46] in sorghum, [6, 24, 26] in wheat, [29, 31, 44] in maize. P content of the maize stover is an indicator of the stover feed quality. Thus, the increase in P uptake of the stover with manure application would mean an improvement in the nutritive value of the stover, which in turn would have major implications for resource-poor farmers to whom maize is a major feed source for their animals.

***Phosphorus recovery and efficiency***

Average over P inputs added, phosphorus agronomic efficiency (PAE), and phosphorus use efficiency (PUE) were ranging between 22–27 and 10–27%, respectively (Figure 2). The highest recovery and utilization efficiency of P was recorded in the treatments where P was applied as DAP+PM followed by the combine treatments of DAP+COM. integration of either inorganic P sources with organic sources increased these efficiency in order sources increased these efficiency in order DAP+PM>TSP+PM>DAP+COM>TSP+COM>DAP+FYM>TSP+FYM respectively. Dry matter yield of maize in the present study showed strong relationship with the agronomic efficiency and is confirmed by a strong positive correlation ($r^2$ = 0.81) between the two traits. Meena, [44] reported that the recovery of applied P by maize was 18-27% following the application of organic amendments along with inorganic P sources. Similar findings for PAE and PUE were obtained by [28, 30, 31, 48]. Our results indicated that i) the PUE in our conditions was very low ranging between 10–27%, ii) recovery efficiencies in organic amended treatments with inorganic P sources were markedly higher than the efficiencies recorded for sole application of inorganic P sources indicating that integration of organic sources and manures could save 30 to 40 kg mineral P fertilizer.

***P uptake and correlations***

Many measurements in this study were significantly correlated with each other (Fig. 3). Most of the parameters observed during the study have highly significant correlation (positive) with the P uptake. Leaf area, chlorophyll content, grain yield and protein content all were positively and significantly correlated with P uptake, i.e. r2 = 0.71, 0.88, 0.72 and 0.83 respectively.

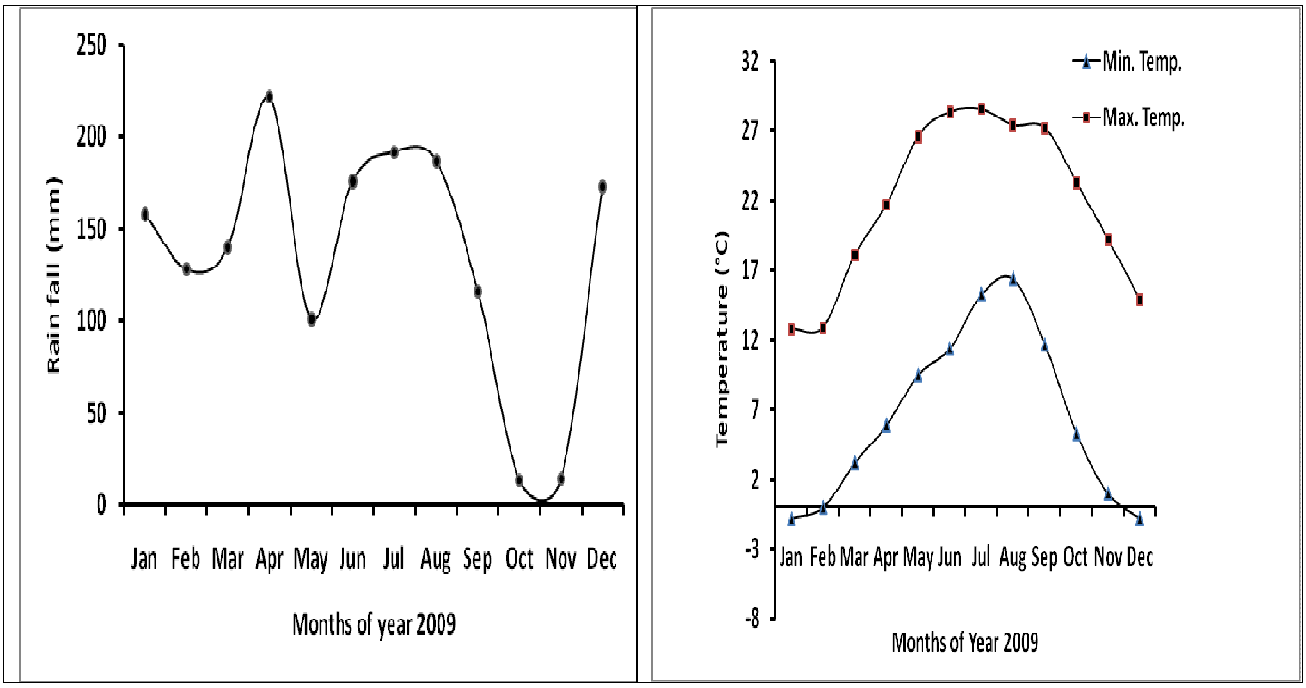


**Fig. 1. Mean annual rainfall, minimum and maximum temperature at Rawalakot during the study year 2009.**

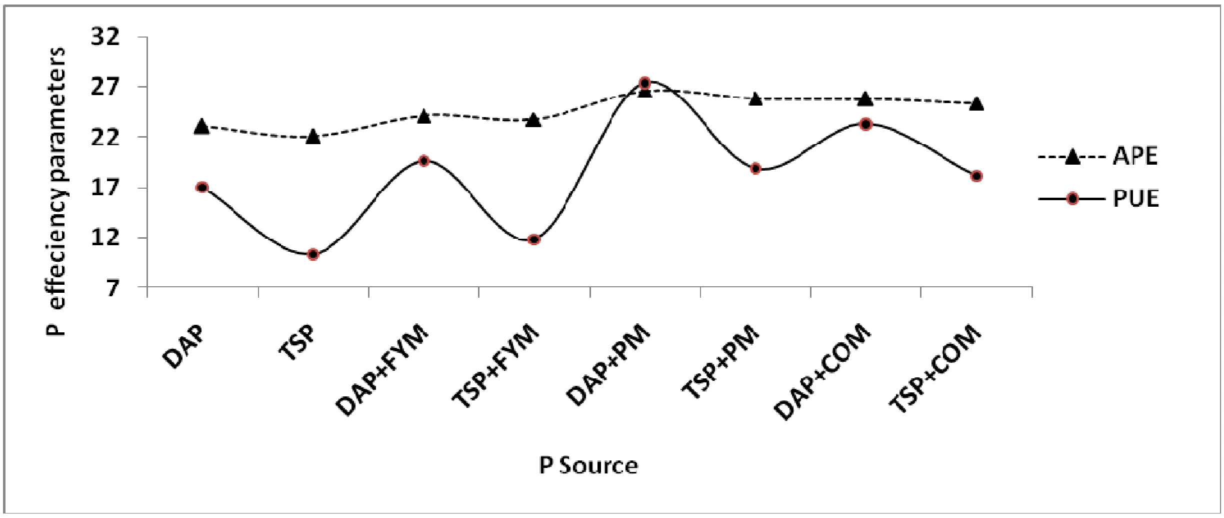


**Fig. 2. Effect of different P sources and their combination on agronomic efficiency of applied P (PAE) and P use efficiency (PUE) in maize.**

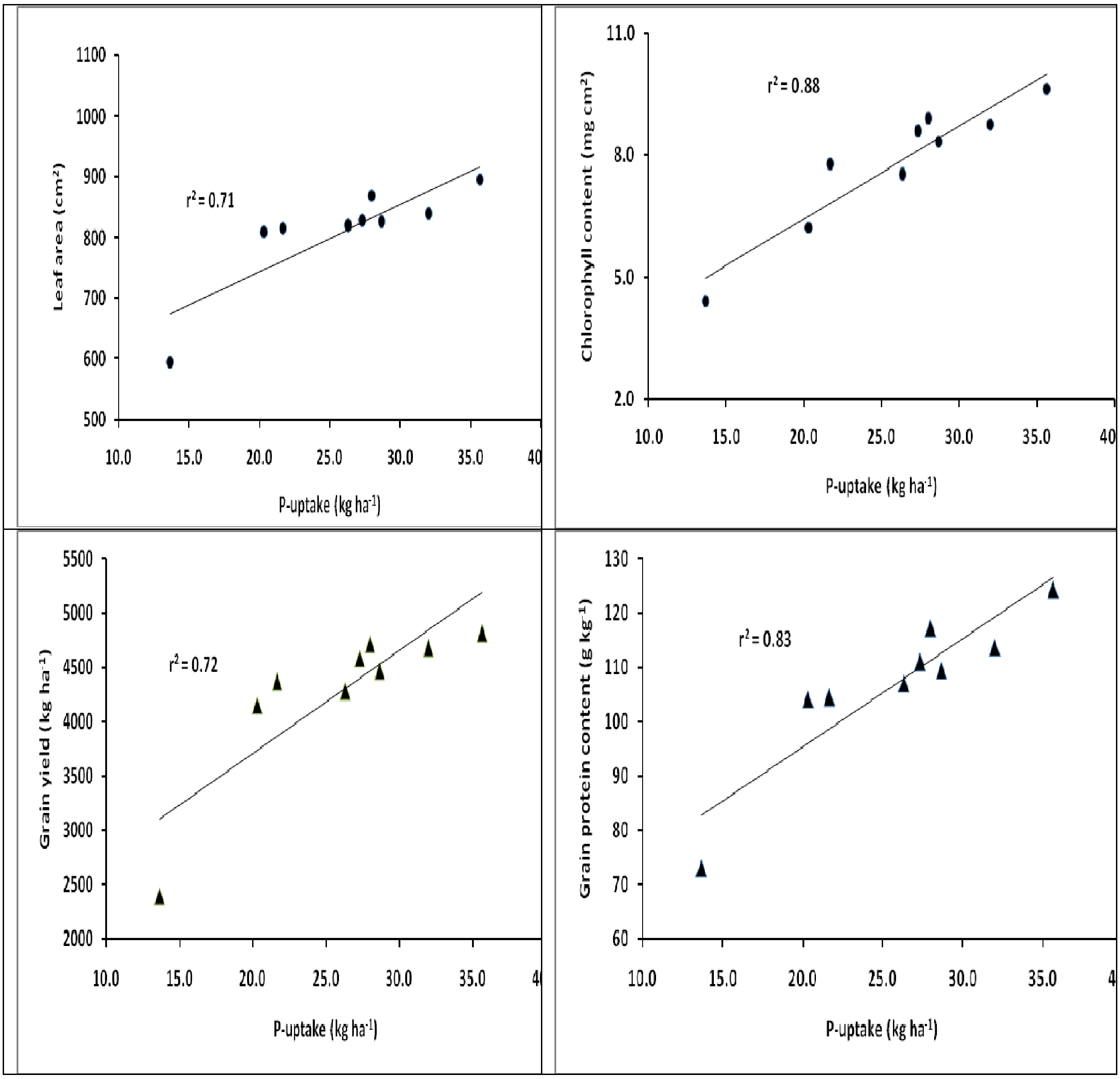


**Fig. 3. Correlation between total (shoot +seed) maize P-uptake vs. maize leaf area, total maize P-uptake vs. maize leaf chlorophyll content, total maize P-uptake vs. maize grain yield and total maize P-uptake vs. maize grain protein content.**

**Table 1. Physical and chemical properties of soil used for cultivation of maize**

| Soil Parameter | Value |
|---|---|
| Organic C (g $Kg^{-1}$) | 4.6 |
| Total N(g $kg^{-1}$) | 0. 32 |
| Available P (mg/kg) | 7.26 |
| K (mg/kg) | 119 |
| ECe ($dSm^{-1}$) | 0.64 |
| CEC (C mol $kg^{-1}$) | 18.4 |
| Sand (g $kg^{-1}$) | 265 |
| Silt (g $kg^{-1}$) | 476 |
| Clay (g $kg^{-1}$) | 263 |
| Bulk density (mg $m^{-3}$) | 1.13 |
| Porosity | 48% |

**Table 2. Chemical characteristics of the organic materials used for the cultivation of maize**

| Nutrients | Organic material | | |
|---|---|---|---|
| | FYM* | PM** | COM*** |
| C (%) | 24.7 | 38.6 | 42.4 |
| N (%) | 1.36 | 2.38 | 2.56 |
| P (%) | 0.48 | 1.14 | 1.26 |
| K (%) | 1.17 | 2.74 | 3.48 |
| pH | 6.92 | 6.88 | 7.2 |
| Dry matter (%) | 42 | 46 | 58 |
| Moisture (%) | 58 | 54 | 42 |

**FYM, Farm yard manure; **PM, Poultry manure; ***COM, Compost*

**Table 3. Effect of different P sources and their combinations on the growth components of maize grown under field conditions at Rawalakot, Azad Jammu and Kashmir**

| Treatments | Plant height (cm) | Leaf area ($cm^2$) | Chlorophyll contents (mg $cm^2$) |
|---|---|---|---|
| $T_1$ | 185.8 e | 594.6 e | 4.42 d |
| $T_2$ | 224.1 bc | 818.3 cd | 7.53 bc |
| $T_3$ | 214.4 d | 810.1 d | 6.22 c |
| $T_4$ | 228.5 bc | 823.6 cd | 8.34 ab |
| $T_5$ | 220.3 d | 815.5 cd | 7.80 b |
| $T_6$ | 242.5 a | 895.2 a | 9.59 a |
| $T_7$ | 231.4 b | 868.7 b | 8.89 ab |
| $T_8$ | 229.8 b | 837.0 c | 8.77 ab |
| $T_9$ | 224.7 bc | 826.1 cd | 8.58 ab |
| LSD ($P \leq 0.05$) | 3.17 | 8.08 | 0.49 |

*$T_1$ = without fertilization ($P_0$); $T_2$ = DAP (alone); $T_3$ = TSP (alone); $T_4$ = DAP × FYM (50:50 ratio); $T_5$ = TSP × FYM (50:50 ratio); $T_6$ = DAP × PM (50:50 ratio); $T_7$ = TSP × PM (50:50 ratio); $T_8$ = DAP × COM (50:50 ratio) and $T_9$ = TSP × COM (50:50 ratio)*
*Means in the same column followed by the same letter do not differ significantly according to the LSD test ($P \leq 0.05$)*

**Table 4. Effect of different P sources and their combinations on the yield and yield components of maize grown under field conditions at Rawalakot, Azad Jammu and Kashmir**

| Treatments | 1000 grain weight (g) | Shelling percentage | Grain yield (kg ha$^{-1}$) | Dry matter yield (kg ha$^{-1}$) | Total biomass yield (kg ha$^{-1}$) |
|---|---|---|---|---|---|
| $T_1$ | 171 f | 70 e | 2393 g | 3974 d | 6367 d |
| $T_2$ | 278 de | 76 c | 4285 ef | 5700 c | 9985 bc |
| $T_3$ | 274 e | 71 e | 4155 f | 5724 c | 9879 c |
| $T_4$ | 299 bcd | 71 de | 4471 cd | 5771 c | 10242 bc |
| $T_5$ | 291 cde | 71 de | 4375 de | 5984 bc | 10359 c |
| $T_6$ | 332 a | 77 b | 4813 a | 6307 ab | 11120 a |
| $T_7$ | 297 bcd | 80 a | 4715 ab | 6252 ab | 10996 ab |
| $T_8$ | 317 ab | 75 c | 4684 ab | 6264 ab | 10881 abc |
| $T_9$ | 304 bc | 73 d | 4590 bc | 6355 a | 10945 bc |
| LSD ($P \leq 0.05$) | 8.32 | 0.52 | 50.07 | 113.37 | 130.82 |

*$T_1$ = without fertilization ($P_0$); $T_2$ = DAP (alone); $T_3$ = TSP (alone); $T_4$ = DAP × FYM (50:50 ratio); $T_5$ = TSP × FYM (50:50 ratio); $T_6$ = DAP × PM (50:50 ratio); $T_7$ = TSP × PM (50:50 ratio); $T_8$ = DAP × COM (50:50 ratio) and $T_9$ = TSP × COM (50:50 ratio)*

*Means in the same column followed by the same letter do not differ significantly according to the LSD test ($P \leq 0.05$)*

**Table 5. Effect of different P sources and their combinations on harvest index, grain protein and P-uptake in maize grown under field conditions at Rawalakot, Azad Jammu and Kashmir**

| Treatments | Harvest Index (%) | Grain protein content (g kg$^{-1}$) | P-uptake (kg ha$^{-1}$) |
|---|---|---|---|
| $T_1$ | 38 b | 73 d | 14 e |
| $T_2$ | 43 a | 107 bc | 26 c |
| $T_3$ | 42 a | 104 c | 20 d |
| $T_4$ | 44 a | 110 bc | 29 bc |
| $T_5$ | 42 a | 105 c | 22 d |
| $T_6$ | 43 a | 124 a | 36 a |
| $T_7$ | 43 a | 117 ab | 28 c |
| $T_8$ | 43 a | 114 abc | 32 b |
| $T_9$ | 42 a | 111 bc | 27 c |
| LSD ($P \leq 0.05$) | 0.63 | 5.11 | 1.69 |

*$T_1$ = without fertilization ($P_0$); $T_2$ = DAP (alone); $T_3$ = TSP (alone); $T_4$ = DAP × FYM (50:50 ratio); $T_5$ = TSP × FYM (50:50 ratio); $T_6$ = DAP × PM (50:50 ratio); $T_7$ = TSP × PM (50:50 ratio); $T_8$ = DAP × COM (50:50 ratio) and $T_9$ = TSP × COM (50:50 ratio)*

*Means in the same column followed by the same letter do not differ significantly according to the LSD test ($P \leq 0.05$)*

## CONCLUSION

The results obtained in the present study indicated that application of organic sources along with mineral P sources increased the yield and yield components and P uptake of maize compared with either sole application of inorganic P sources. Integrated use of P sources not only increased crop yield but also increased nutrient uptake, protein content and P recovery efficiency in maize. The P recovery efficiency and NP uptake by maize following the application of PM with either inorganic P source at 90 kg P ha$^{-1}$ showed higher values to those recorded by applying inorganic P sources alone indicating that integrated use of PM with mineral P sources can save 30 to 40 kg mineral P fertilizer that has potential effects on sustainable agricultural production in soils with higher clay content, greater P fixation and low in organic matter. The results of the present study can be used for better P management practices to improve maize yield, phosphorus use efficiency and nutrient uptake. Poultry manure with reduced levels of mineral P fertilizer is recommended for maize in the hilly and mountain region of Azad Jammu and Kashmir for soil fertility and productivity conservation.

**Acknowledgements**
We thank the University of Azad Jammu and Kashmir, Muzaffarabad, Pakistan for financial support. We also appreciate the help of Mr. Ashfaq during the course of study and lab staff of Department of Soil and Environmental Sciences, Faculty of Agriculture, Rawalakot, UAJK for analytic facilities.

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