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IMPACT OF COMPOST, INORGANIC PHOSPHORUS FERTILIZERS AND THEIR COMBINATION ON MAIZE GROWTH, YIELD, NUTRIENT UPTAKE AND SOIL PROPERTIES

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ABSTRACT

Effect of compost (COM) and four inorganic phosphorus (P) sources, diammonium phosphate (DAP), single super phosphate (SSP), nitrophos (NP) and triple super phosphate (TSP) either alone or in combination on growth, yield and nutrient uptake of maize and their effect on soil properties was studied. Each of the inorganic P source and COM either alone or in combination (50:50 ratio) were applied to supply 90 kg P ha^{-1}. The results indicated that conjunctive use of inorganic P sources and COM significantly ($P < 0.05$) increased plant height, leaf area and chlorophyll content. Grain, dry matter, biomass yield and protein content increased by 10-61, 40-67, 30-67 and 17-46% over control. P uptake increased 17 g kg^{-1} in control to 29 g kg^{-1} where DAP and COM was combined. The results also indicated that combine use of inorganic P with COM resulted in significant increase in total N (13−75%), available P (7−57%) and available K (7−20%) compared to control. In addition, increase in plant N accumulation and P uptake associated with combined treatments would help to minimize the use of high cost inorganic P fertilizers for sustainable agro ecosystem.

Key words: phosphorus sources, yield, protein, compost, maize, soil properties

INTRODUCTION

The quest for sustainable options at managing the ever increasing amount of degraded land has assumed a huge dimension at recent times. This rapid decrease in soil fertility is a common feature of arable land in arid mountainous regions like most of the Azad Jammu and Kashmir, Pakistan. Fertilizer application has been a major strategy for soil nutrient replenishment. The exclusive use of inorganic fertilizers is not popular among farmers because of its adverse environmental effect such as soil acidification, pollution of water bodies and its scarcity and high cost.

Phosphorus is an essential nutrient required for plant growth and development and is intimately involved in a wide range of physiological and biochemical processes. However, large areas of soil used for agriculture across the world are deficient in plant-available forms of phosphate which can limit agricultural production (Runge-Metzger, 1995). P-based fertilizers are therefore used routinely in agricultural systems to over-come deficiency of soil P. Some 17.5 million tones of P is processed annually from world reserves of rock phosphates, of which approximately 85% is used in the production of fertilizers (Cordell *et al*., 2009). However, reserves of rock-P are finite with an estimated depletion of quality sources expected to occur within the next 50–80 years (Isherwood, 2000).

The need to use renewable forms of energy and reduce costs of fertilizing crops has revived the use of organic fertilizers worldwide. Compost plays a vital role in sustaining forming by providing plant N-supply (Korsaeth *et al*., 2002). The addition of mature compost at reasonable rates enhance the plant growth, soil physical properties and also increases available soil nutrient level (Ahmad *et al*., 2008; Zafar *et al*., 2011).

Hence, it is obvious that sustainable crop production could be achieved in depleted soils if both organic (plant and animal sources combined) and inorganic nutrient sources are properly integrated. Keeping in view the ecosystem value, resource poor farmers and soil fertility condition of Azad Jammu and Kashmir, the present study was therefore, performed with an objective to investigate the impacts of different P fertilizer sources on the growth, yield, nutrient uptake of maize and their effect on soil properties.

MATERIALS AND METHODS

The study site, experiment description and treatments: 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 mean monthly weather attributes like rainfall, mean maximum and minimum temperature of the experimental area are presented in Figure 1.

Before actual experiment, soil samples from the experimental field were collected for physical and chemical characteristics (Table 1). The experiment was laid down under completely randomized design (CRD) and the treatments include: T_1 = without fertilization (P_0); T_2 = DAP @ 90 kg P_2O_5 ha^{-1}; T_3 = SSP @ 90 kg P_2O_5 ha^{-1}; T_4 = NP @ 90 kg P_2O_5 ha^{-1}; T_5 = TSP @ 90 kg P_2O_5 ha^{-1}; T_6 = COM equivalent to 90 kg P_2O_5 ha^{-1}; T_7 = DAP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio); T_8 = SSP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio); T_9 = NP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio) and T_{10} = TSP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio). The physicochemical composition of COM is presented in (Table 1). A basal dose of N @120 kg ha^{-1} by urea and K @ 60 kg ha^{-1} as sulphate of potash (SOP), by broadcast method was applied. Maize (*Zea mays* L) variety "Sarhad White" was used in the experiment. Maize was sown in lines on May 16, 2008. 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.

Measurements: The agronomic characteristics of the crop like plant height, leaf area and leaf chlorophyll content were recorded. Five plants were tagged at random from central rows of each plot for data recording at silking stage. After measuring, plant samples (leaves) were first sun-dried and then oven-dried at 70 ^{0}C for about 48 h for chemical analysis. Crop was harvested to determine the grain and straw yield. Plant material was collected from the whole plot to determine biological yield.

Soil and plant analysis: Soil samples were collected from the surface layer (0–15 cm) after the harvest of maize, mixed well and air dried for 2–3 days. Samples were lightly ground and subsequently sieved through a 2-mm mesh to remove stones and roots. Total N was determined by sulphuric acid digestion using Se, $CuSO_4$ and K_2SO_4 as catalyst. Nitrogen in the digest was determined by Kjeldahl distillation and titration method (Bremner and Mulvaney, 1982), available P by the Olsen extraction method (Olsen and Sommers, 1982) and available K was extracted with 1 N ammonium acetate (Simard, 1993). Soil pH was determined by preparing a saturated soil suspension of 1:2.5 (soil and water) by method of McLean, (1982).

Plant material (shoot 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(Bremner and Mulvaney, 1982; Murphy and Riley, 1962). Protein concentration in the grain was determined using the formula: protein concentration = %N × 6.25 and then it was converted into g kg^{-1}.

Statistical Analysis: 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 (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Morphological characteristics: Analysis of Variance (ANOVA) indicated significant difference ($P \leq 0.05$) among different P fertilizers and their combinations with COM for plant height, leaf area and chlorophyll content. Plant height was significantly greater for all the treatments with P fertilizers and combination of each with COM than those for the control (Table 2). The relative increase in plant height was 10–27% over the control without P addition. All the treatments showed significant increase in leaf surface area (LSA) compared with the control (Table 2). In general, at equivalent rates of application, DAP+COM resulted in higher LSA followed by plants treated with DAP, then by TSP+COM and the least were plants treated with NP alone. The increase in LSA with the P fertilization was 12–59% compared with the control. Application of DAP and TSP either alone or in combination with COM significantly increased the chlorophyll content of maize plants. Chlorophyll content was significantly increased due to addition of P inputs, ranging from 5.26 mg cm^{-2} in the control to 9.05 mg cm^{-2} DAP+COM, followed by 8.62 mg cm^{-2} with TSP+COM. Average across treatments, the increase in chlorophyll content due to application of P fertilizers and COM was 10–89% compared with the control. Combine application of all inorganic P fertilizers with PM exhibited higher chlorophyll content than their sole application at equivalent rate.

Growth of maize showed similar response to different inorganic P fertilizers application under climatic conditions of Peshawar (Ammanullah *et al*., 2009). 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 (2006) reported that application of poultry manure and P fertilizers influences plant growth and yield by providing more nutrients. Zafar *et al*. (2011) reported that integrated application organic and inorganic phosphorus sources had significant positive role in the growth characteristics of 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 and their integration with COM for 1000-grain weight, grain yield, dry matter yield, total biomass yield and harvest index. Highest 1000 grain weight 263 g was recorded where combine application of DAP+COM was carried out, whereas average across treatments, the increase in 1000 grain weight due to application of P fertilizers and COM was 18–68% over the control. Grain yield recorded for different P treatments was significantly greater than the un-amended control (Table 2). Grain yield in DAP+COM was significantly higher 4674 kg ha^{-1} than the rest of treatments. The treatments that consistently led to the greatest maize productivity was the integrated application of inorganic P fertilizers with COM. Average increase in grain yield following the different P inputs either alone or in combination was 10-61% over the control. Application of inorganic P fertilizers and COM alone or in combination significantly increased dry matter yield (DMY). Dry matter yield in the control was 4425 kg ha^{-1} that significantly increased to a range of 7387, 7175, 7092 and 6984 kg ha^{-1} in TSP+COM, DAP+COM, SSP alone and SSP+COM respectively. On an average, increase in DMY due to P fertilization, COM and their combination ranged between 40–67%. The total biomass yield also showed similar trend to dry matter and ranged between 30–67% when compared to the control. Application of different P inputs did not significantly increased harvest index.

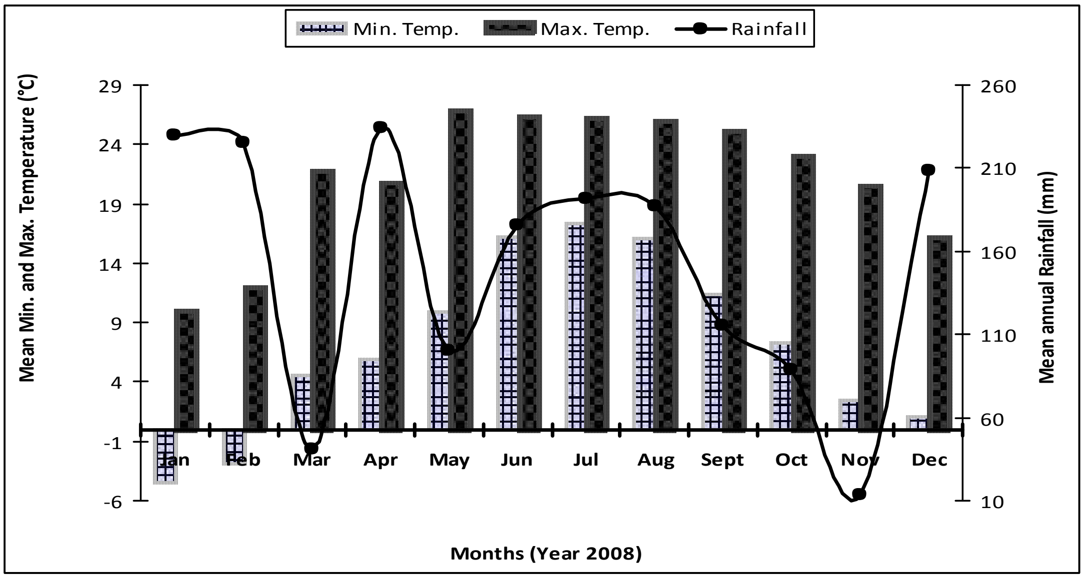

Fig. 1. Mean annual rainfall, minimum and maximum temperature at Rawalakot during the study year 2008.

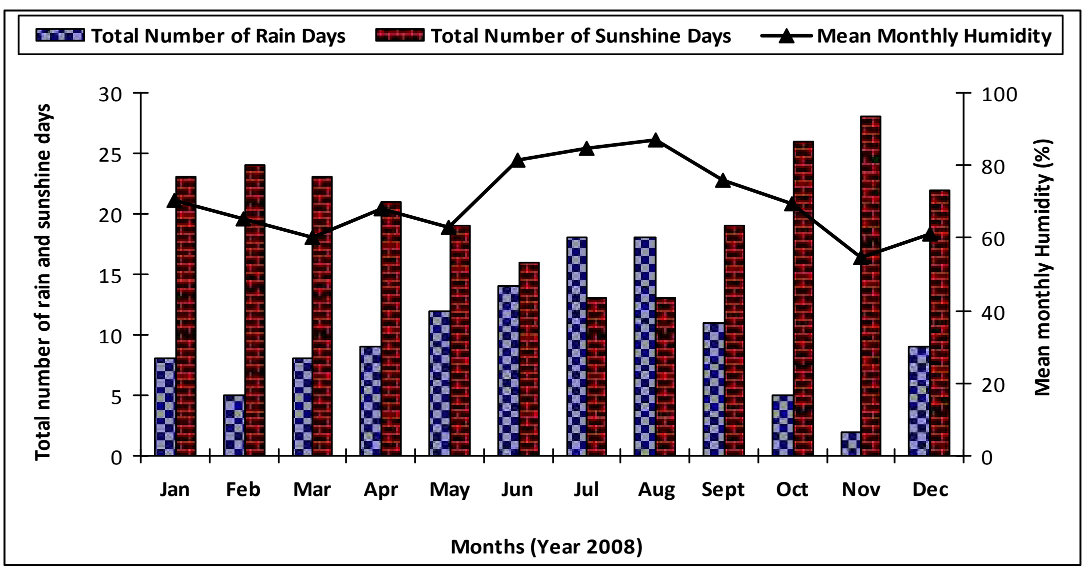

Fig. 2. Total number of rain days, total number of sunshine days and mean monthly humidity at Rawalakot during the study year 2008.

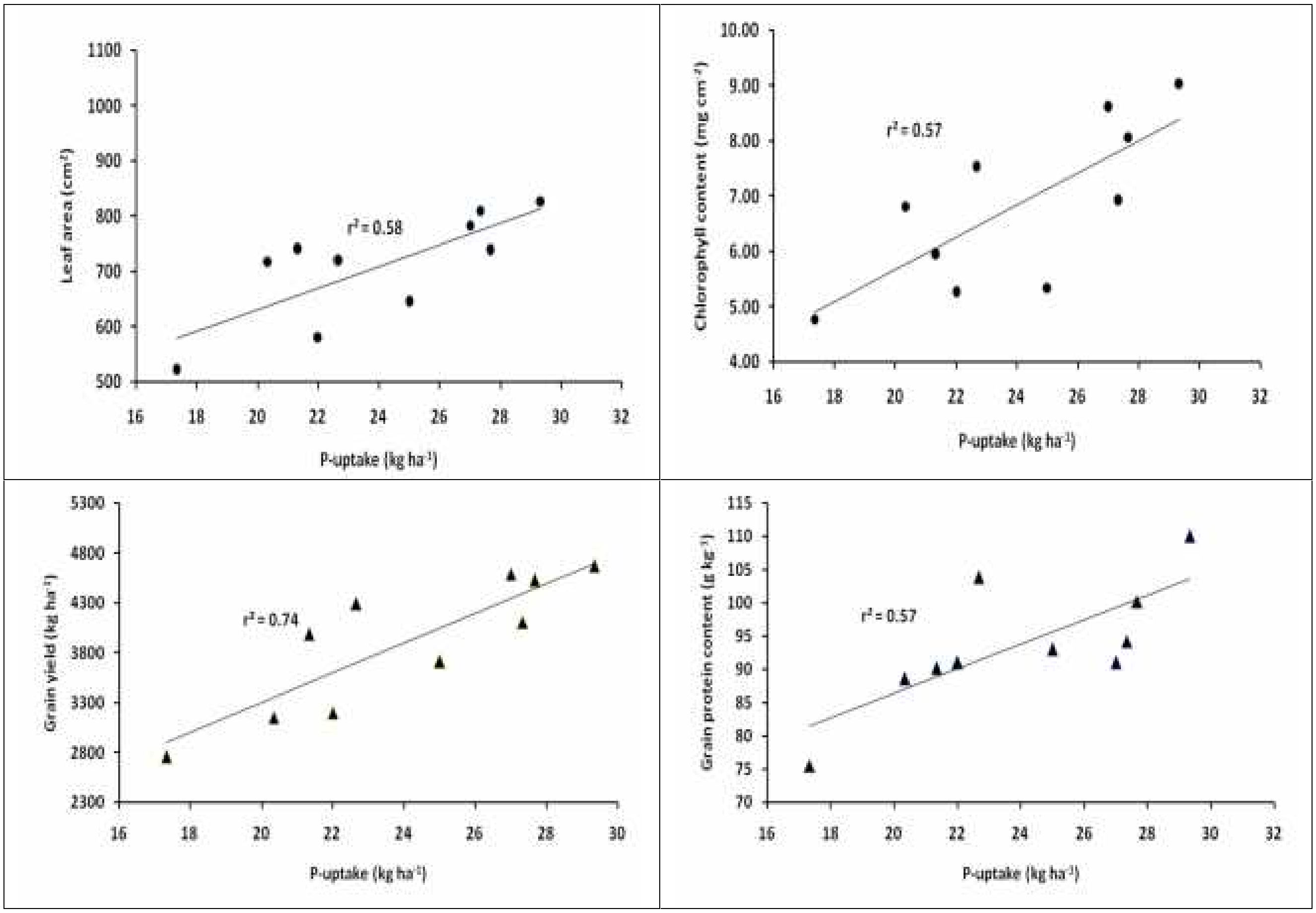

Fig. 3. Correlation between total (shoot +seed) maize P-uptake vs. maize leaf area, total maize P-uptake vs. maize leaf chlorophyll content, total maize P-uptake vs. maize grain yield and total maize P-uptake vs. maize grain protein content.

The results found in the present study were comparable to those reported by Ammanullah *et al*. (2009); Opala *et al*. (2009) and Meena, (2010) for maize. Application of COM alone resulted in lower maize grain yields when compared to equivalent amount of inorganic P fertilizers. This indicated that P applied through COM alone may not be adequately available to the crop when it is needed because of lower rates of compost decomposition and subsequent P release (mineralization) to the maize crop. Therefore, COM alone was not able to produce maize yield equivalent to mineral P. Mugwe *et al*. (2009) and Zafar *et al*. (2011) also reported the similar results while Connor, (2008) stated that organic agriculture alone cannot feed the world.

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 2. Analysis of Variance (ANOVA) indicated significant difference ($P \leq 0.05$) among different P fertilizers and their combination with COM for protein content in grain and P uptake of maize. The average increase in protein content following the P inputs, DAP+COM, NP+ COM, SSP+COM and TSP+COM was 46, 38, 33 and 21%, respectively over the control showing highest concentration in combine treatments of mineral P fertilizers with COM (Table 3). Similar to protein content, P uptake in plants treated with COM alone or combination with P fertilizers was significantly higher than the P content in control and sole P fertilizer treatments. Maximum P uptake 29 kg ha^{-1} was recorded with DAP+COM, followed by SSP+ COM with 28 kg ha^{-1} over rest of treatments. Average across treatments, the increase in P uptake due to P addition was 17–69% over the control. Similar results regarding increased N and P uptake with combine application of inorganic P sources with manure application were reported by Korkmaz *et al*. (2009) in wheat, Fernandez *et al*. (2009) and Zafar *et al*. (2011) in maize.

Soil properties: The pH of the soil did not showed much variation in different treatments. However, significant increase in pH was observed in the combined treatments receiving COM (Table 3). Likewise, soil total N, available P and K were significantly increased in the combined treatments of mineral P fertilizers and COM than those under their sole application and control. The increase in total N was 13−75% higher than the control treatment; available P 7−57% and available K up to 20%, respectively. The concentration of these major nutrients in soil increased with integration of COM. Similar effects on soil properties by integrated use of nutrients were observed by Ramesh *et al*. (2009) and Panwar *et al*. (2010).

P uptake and correlations: Many measurements in this study were significantly correlated with each other (Figure 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. r^2 = 0.58, 0.57, 0.74 and 0.59 respectively.

Table 1. Physico-chemical properties of soil and compost used in study

Characteristic	Value	
	Soil	Compost
Organic C (g Kg^{-1})	4.6	378
Total N (g kg^{-1})	0. 26	25.2
Available P (g kg^{-1})	0.007	12.9
K (g kg^{-1})	0.136	35.4
pH	6.63	6.98
Moisture (%)	36	44
Dry matter (%)	--	56
Sand (g kg^{-1})	265	--
Silt (g kg^{-1})	476	--
Clay (g kg^{-1})	259	--

Table 2. Effect of different P sources and compost on the growth and yield 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})	1000 grain weight (g)	Grain yield (kg ha^{-1})	Dry matter yield (kg ha^{-1})	Total biomass yield (kg ha^{-1})	Harvest Index (%)
T_1	173 ^{h}	521 ^{h}	4.78 ^{e}	157 ^{h}	2759 ^{h}	4425 ^{h}	7184 ^{g}	39 ^{a}
T_2	219 ^{b}	810 ^{b}	6.92 ^{cd}	231 ^{d}	4108 ^{d}	6811 ^{cd}	10919 ^{c}	38 ^{b}
T_3	197 ^{f}	645 ^{f}	5.35 ^{e}	196 ^{f}	3713 ^{f}	7092 ^{b}	10805 ^{c}	34 ^{c}
T_4	192 ^{g}	581 ^{g}	5.26 ^{e}	185 ^{g}	3206 ^{g}	6513 ^{ef}	9719 ^{e}	33 ^{d}
T_5	212 ^{c}	740 ^{d}	5.95 ^{de}	226 ^{d}	3990 ^{e}	6421 ^{fg}	10411 ^{d}	38 ^{ab}
T_6	198 ^{f}	718 ^{e}	6.82 ^{cd}	216 ^{e}	3155 ^{g}	6173 ^{g}	9328 ^{f}	33 ^{d}
T_7	226 ^{a}	827 ^{a}	9.05 ^{a}	263 ^{a}	4674 ^{a}	7175 ^{ab}	11849 ^{a}	39 ^{a}
T_8	209 ^{cd}	739 ^{d}	8.07 ^{abc}	249 ^{b}	4533 ^{b}	6984 ^{bc}	11517 ^{b}	39 ^{a}
T_9	204 ^{e}	719 ^{e}	7.53 ^{bc}	241 ^{c}	4296 ^{c}	6704 ^{de}	11000 ^{c}	39 ^{a}
T_{10}	206 ^{de}	783 ^{c}	8.62 ^{ab}	250 ^{b}	4593 ^{ab}	7387 ^{a}	11980 ^{a}	38 ^{ab}
LSD ($P \leq 0.05$)	3.54	13.12	1.33	4.86	89.51	264.13	258.33	1.33

T_1 = without fertilization (P_0); T_2 = DAP @ 90 kg P_2O_5 ha^{-1}; T_3 = SSP @ 90 kg P_2O_5 ha^{-1}; T_4 = NP @ 90 kg P_2O_5 ha^{-1}; T_5 = TSP @ 90 kg P_2O_5 ha^{-1}; T_6 = COM equivalent to 90 kg P_2O_5 ha^{-1}; T_7 = DAP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio); T_8 = SSP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio); T_9 = NP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio) and T_{10} = TSP + COM @ 90 kg P_2O_5 ha^{-1} (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 3. Effect of different P sources and compost on the grain protein content, plant P-uptake, soil pH, total N, available P and available K after maize harvest at Rawalakot, Azad Jammu and Kashmir

Treatments	Grain protein content (g kg^{-1})	P-uptake (kg ha^{-1})	pH	Total N (g kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
T_1	76 ^{d}	17 ^{e}	6.81 ^{e}	0.30 ^{i}	6.4 ^{j}	133 ^{e}
T_2	94 ^{bc}	27 ^{ab}	6.76 ^{i}	0.40 ^{ef}	7.4 ^{f}	140 ^{cd}
T_3	93 ^{bc}	25 ^{bc}	6.79 ^{g}	0.34 ^{h}	7.0 ^{h}	124 ^{f}
T_4	91 ^{c}	22 ^{cd}	6.76 ^{h}	0.36 ^{gh}	7.2 ^{g}	126 ^{f}
T_5	90 ^{c}	21 ^{d}	6.8 ^{f}	0.38 ^{fg}	6.9 ^{i}	125 ^{f}
T_6	89 ^{c}	20 ^{de}	6.87 ^{a}	0.46 ^{bc}	7.7 ^{e}	160 ^{a}
T_7	110 ^{a}	29 ^{a}	6.83 ^{d}	0.53 ^{a}	10.1 ^{a}	154 ^{b}
T_8	100 ^{abc}	28 ^{ab}	6.84 ^{c}	0.43 ^{cd}	9.3 ^{b}	137 ^{d}
T_9	104 ^{ab}	23 ^{cd}	6.86 ^{a}	0.49 ^{b}	8.7 ^{c}	143 ^{c}
T_{10}	91 ^{c}	27 ^{ab}	6.85 ^{b}	0.42 ^{de}	8.7 ^{d}	139 ^{d}
LSD ($P \leq 0.05$)	12.40	3.51	0.007	0.030	0.0064	3.13

T_1 = without fertilization (P_0); T_2 = DAP @ 90 kg P_2O_5 ha^{-1}; T_3 = SSP @ 90 kg P_2O_5 ha^{-1}; T_4 = NP @ 90 kg P_2O_5 ha^{-1}; T_5 = TSP @ 90 kg P_2O_5 ha^{-1}; T_6 = COM equivalent to 90 kg P_2O_5 ha^{-1}; T_7 = DAP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio); T_8 = SSP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio); T_9 = NP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio) and T_{10} = TSP + COM @ 90 kg P_2O_5 ha^{-1} (50:50 ratio).
Means in the same column followed by the same letter do not differ significantly according to the LSD test ($P \leq 0.05$).

Conclusions: The results obtained in the present study indicated that integrated use of inorganic P sources + COM not only increased crop yield but also increased nutrient uptake, protein content and P uptake in maize. The results of the present study can be used for better P management practices to improve maize yield, phosphorus use efficiency and nutrient uptake and their subsequent effect on soil properties. Compost with half dose of mineral P fertilizer is recommended for maize in the mountain region of Azad Jammu and Kashmir for soil fertility and sustainable crop production.

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