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Full Length Research Paper

Response of fed dung composted with rock phosphate on yield and phosphorus and nitrogen uptake of maize crop

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Two experiments were conducted to determine the extent of phosphate (P) solubility from rock phosphate (RP) fed dung through composting with RP and to determine its effects on yield and P uptake of maize crop. Different composts of RP fed dung and simple dung were prepared with and without RP. Field experiment was conducted on silty clay loam soil at the research farm of Khyber Pakhtunkhwa Agricultural University, Peshawar to study the effect of RP fed dung composted with RP on the yield, yield components and P uptake of maize *(Zea mays. L. Azam).* The fertilizers, N, P and K, were applied at the rate of 120- 90- 60 kg ha^{-1}, respectively in a randomized complete block design (RCBD) with three replications. Compost and urea were used as a fertilizer source for N, compost and single super phosphate (SSP) as a fertilizer source for P and sulphate of Potash (SOP) was used as a fertilizer source for K. Application of the compost prepared from RP fed dung with RP, improved the yield and yield components of maize crop. The maximum and significantly ($P \leq 0.05$) increased grain yield of 3264 kg ha^{-1}, total dry matter yield of 9634 kg ha^{-1}, stover yield of 7293 kg ha^{-1}, and thousand grain weight (231 g) of maize crops were recorded in the treatment where full dose of the prepared compost was applied with half dose of SSP, followed by the treatment of full recommended SSP. The data of soil analysis showed increase in soil organic matter content and a decreasing trend in soil pH values. Application of compost with SSP significantly ($P \leq 0.05$) increased soil N and P concentration and their uptake by the maize plants. Maximum net return of Rs. 24060 ha^{-1} with a value cost ratio (VCR) of 3.0:1 was obtained by the application of full dose of compost with half SSP, followed by the treatment of full dose of compost applied alone with a net return of Rs. 14555 ha^{-1} and VCR of 2.8 : 1. Results suggest that application of the compost prepared from RP fed dung with RP is economical, environment friendly and has the potential to improve maize yield, plants N and P uptake.

Key words: Maize, dung, rock phosphate, composts, yield, plants P uptake.

INTRODUCTION

Phosphorous is considered as the second macronutrient after nitrogen, which is essential for plant growth. Plants absorb P as primary orthophosphate ($H_2PO_4^{-1}$) or secondary orthophosphate (HPO_4^{-2}). Relative quantities of these ions taken up by plants depend on soil pH. In acidic soil, $H_2PO_4^{-1}$ dominates, while alkaline soils have abundance of HPO_4^{-2}. The inorganic P is derived from the weathering of rocks containing mineral apatite, while organic P is derived from plants and animals' residues. The inorganic form of P is present in a variety of combination with Fe, Al, Ca and Mg plus other elements. The relative importance of each type in a soil will be largely dependent on soil pH and amount of clay (Chavarria, 1981). Quantification of N use efficiency requires better understanding of soil N mineralization during plants' growth period. Ismaily et al. (2008) reported that soil N content and its plant availability increased with the application of organic manures.

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However, the potential of N mineralization of organic residues and their impact on crop growth varied (Deenik and Yost, 2008).

Organic materials have beneficial effects on soil fertility and physical properties of soil. The physical properties of soil play an important role in influencing the behaviors of plant growth, thereby contributing to efficient crop production. Farm yard manure (FYM) on an average contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O. Application of organic materials to the soil reduces the dependence on chemical fertilizers (Guar, 1990). The addition of organic materials to the soil helps microorganisms to produce polysaccharides and organic acids which improve the soil structure and help in P solubilization (Guar, 1994). The availability of P can be increased if mixed with FYM and other organic materials. Organic materials application to soil increase water holding capacity, water infiltration rate, improve soil aeration, conserve soil moisture, porosity and decrease soil bulk density, thereby contributing to efficient crop production (Castellanos and Munoz, 1985).

Composting is a biological process in which microorganisms convert organic materials into a soil like material called compost. During composting, microbes utilize the carbon of organic matter as a source of energy and for synthesis of new microbial cells. Optimum conditions for decomposition of organic materials in composting pile are oxygen (>5 %), moisture content (40 - 65 %), C/N ratio (< 30:1) and temperature (90 to 140°F). However, the smaller the particle size, the faster it will be turned into compost. Smaller particle sizes have a large surface area that can be attacked by microbes readily. Composting of manures and other organic materials with rock phosphate (RP) has been shown to enhance the solubility of P from RP (Mishra and Bangar, 1986; Singh and Amberger, 1991) and is practiced widely as a low-input technology to improve the fertilizer value of manures (Mahimairaja et al., 1995).

Maize (*Zea mays.* L.), along with wheat and rice, is one of the world's leading grain crops. It is a source of food, feed and fodder and it constitutes 6.4% of the grain production. The grain of maize is a valuable source of protein (10.4%), fats (4.5%), starches, vitamins and minerals (71.8%). In spite of the high yielding potential of maize, its yield per unit area is very low in Pakistan as compared to advanced countries of the world. The area, production and average yield in Pakistan is 1052.1 thousand ha, 3593.0 thousand tons and 3415 kg ha^{-1}, respectively, while in KPK province, the area, production and average yield is 509.5 ha, 957.9 tons and 1880 kg ha^{-1}, respectively (MINAFL, 2008, 2009).

Research investigations have been mainly focused on the quality of composts (Liang et al., 1996) and on the forms and availability of compost nitrogen N (Kuo, 1995 and Sanchez et al. 1997), and little has been done to unravel the forms and availability of P. Keeping in view the important role of organic materials in solubilizing P from RP by creating a suitable environment in the medium through releasing of organic acids, this experiment was planned to determine the extent of P solubility from RP fed FYM by composting with RP and then determining its effects on the growth, yield and P uptake of maize crop.

MATERIALS AND METHODS

Experiments were conducted to determine the extent of P solubility from RP fed dung through composting with RP and then to determine its effects on the yield and P and N uptake of maize crop.

Experiment 1: Composting RP fed dung with rock phosphate

Rock phosphate of Hazara area was mixed with animal feed at the rate of 2% and fed to some selected animals. The dung collected from these animals was composted with further RP using the ratio of 2 : 1 (Dung : RP) according to the procedure as described by the Food and Agriculture Organization (FAO) (1977). Mixture of effective microorganism (EM) and molasses solution was sprayed uniformly on these materials before dumping into pits. Thorough mixing of the organic materials was done uniformly for the inputs' contents. Reshuffling/mixing was carried out with an interval of 15 days. The heaps were covered with polythene sheet for maintaining heat, while the moisture contents of the heap were frequently observed. Data on organic C, total N, extractable P and pH were recorded. Composts become ready for use when the temperature in the pits drop to the temperature of the surrounding air, it smells earthy not sour, putrid or like ammonia, it no longer heats up after turned or watered, it looks like dark soil and does not have identifiable food items, leaves or grass. However, the volume of the well prepared compost becomes reduced. Composts so prepared were applied to maize crop to determine its effects on the yield and plants' P uptake.

Experiment 2: Response of RP fed dung composted with RP on maize crop

A field experiment on "Response of RP fed dung composted with RP on the yield and P and N uptake of maize crop *(Zea mays* L, Azam) was conducted at Agriculture Research Farm of KPK Agriculture University, Peshawar in Kharif season during 2010. Chemical fertilizers were applied at the rate of 120, 90 and 60 kg ha^{-1} for N, P and K, respectively in the form of urea and compost for N, SSP and compost for P and SOP for K on the basis of their analysis. The experiment was done as a randomized complete block design (RCBD) with three replications. There were seven treatments with a plot size of 3 x 5 m^2. The row to row distance was 75 cm and plant to plant distance was 50 cm with a seed rate of 120 kg ha^{-1}.

Soil and plant analysis

Composite soil samples at the depth of 0 to 20 cm were collected from each treatment after crop harvests and analyzed by using established standard procedures. Soil pH was determined by McClean (1982), soil texture by Koehler (1984), soil organic matter (SOM) by Nelson and Sommers (1982) and Ammonium bicarbonate – diethylene triamine penta acetic acid (AB-DTPA) and extractable P and K were determined by Soltanpour and Schwab (1977). Total N concentrations in soil and plant samples were determined by Kjeldhal method (Bremner and Mulvaney, 1996). Representative plant samples were collected from each treatment and analyzed for phosphorous concentration by wet digestion method (Walsh and Beaton, 1977). However, the parameters recorded in this experiment were maize grain yield, total dry matter yield, stover yield, thousand grains weight, soil and plants N and P concentrations and their uptake by maize plants.

Statistical analysis

The data collected were analyzed statistically according to the procedure given by Steel and Torrie (1980) using MStatC package, while least significant difference (LSD) test was used for any significant difference among the treatments.

RESULTS AND DISCUSSION

Composting experiment

The RP fed and unfed animals' dung was composted with and without RP and their properties were determined with time (Table 1).

It is evident from Table 1 that with composting, extractable P increased by 56% in RP fed dung without RP and 110% with RP, while 107% increase was observed in cases where simple dung was composted with RP. Composting RP fed dung and simple dung with RP increased P concentration to 96 and 91%, respectively when compared with composting these materials without RP. Total N increased by 6% in RP fed dung without RP and by 23 and 22% in RP fed dung and simple dung with RP, respectively, while it increased by 283 and 249% in RP fed dung composted without RP. Organic carbon decreased by 93, 113 and 85% in RP fed dung without and with RP and in simple dung with RP, respectively with composting. Slight reduction in pH values was noted by composting RP fed dung and simple dung.

Crop experiment

A field experiment was conducted to study the response of compost prepared from RP fed dung with RP on the yield and yield components of maize (*Zea mays.* L. Azam) at the research farm of Khyber Pakhtunkhwa Agricultural University, Peshawar, during kharif season, 2010. The soil under study was silty clay loam in texture, calcareous in nature (18% $CaCO_3$) and alkaline in reaction (pH 8.1), although it was low in organic matter content (0.81%) and available phosphorus (3%).

Yield and yield components of maize crop

Data regarding maize grain yield, total dry matter yield, stover yield and thousand grains weight are presented in Table 2.

Grain yield

Maximum and significantly ($P < 0.05$) increased maize grains yield of 3264 kg ha^{-1} was recorded in the treatment where full dose of compost was applied with half dose of SSP followed by the treatment of half compost, half SSP and full dose of SSP (Table 2). Ibrahim et al. (2008) concluded that the application of organic fertilizers increased the grain yield of maize significantly.

Total dry matter yield

Statistical analysis of the data indicated that compost significantly ($P \leq 0.05$) affected the total dry matter yield of maize (Table 2). The maximum dry matter yield (9634 kg ha^{-1}) was obtained in a treatment where full dose of compost and half dose of recommended SSP were applied, while the minimum (8517 kg ha^{-1}) dry matter yield was obtained in the treatment where no fertilizer was applied. Khan et al. (1993) concluded that the total dry matter yield increased significantly by the application of organic fertilizers mixed with rock phosphate.

Stover yield

Maximum Stover yield of 7293 kg ha^{-1} was obtained intreatments where full dose of compost and half dose of SSP were applied (Table 2). This increase in Stover yield was followed by the treatment of full SSP. However, the lowest Stover yield of 6711 kg ha^{-1} was observed in the treatment where no fertilizer was applied.

Thousand grains weight

The study's data showed that the maximum thousand grains weight of 231 g was obtained in the treatment where a full dose of compost with half dose of SSP was applied (Table 2), while the control treatment showed 166 g thousand grains weight as the minimum. Song et al. (1998) found that a combination of organic and NPK fertilizers had a significant effect on 1000 grains weight of maize. However, the increasing order was seen as full compost + half SSP > full SSP > half compost + half SSP > full compost > N and K > half SSP > control.

Post harvest soil pH values, organic matter, total N and extractable P contents

Data regarding post harvest soil pH values, organic matter, total N and extractable P contents are presented in Table 3. It was observed that application of the prepared compost caused slight reduction in soil pH values. Treatments, where full dose of compost was applied alone and with half dose of SSP indicate pH values of 7.58 and 7.56, respectively. The decrease in soil pH values was due to the release of H^+ ions during mineralization process of organic and inorganic fertilizers.

Table 1. Extractable phosphorus, total nitrogen, organic carbon concentrations and pH values of different organic materials as affected by composting with RP.

Treatment	Extractable phosphorus		Total nitrogen		Organic carbon		pH value	
	Concentrations (%)							
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
RP fed dung	0.73	1.143 (56)	1.105	1.175 (6.3)	45.3	41.9	8.30	8.27
Fed dung + RP	1.121	2.356 (110)	1.178	1.452 (23)	45.5	40.12	8.30	8.25
Simple dung + RP	1.119	2.321 (107)	1.145	1.403 (22)	45.8	39.1	8.30	8.25
Simple FYM	-	0.639	-	1.065	-	43.65	-	8.29

Values in parenthesis show percent increase by composting organic materials without and with RP.

Table 2. Effect of the prepared compost on grain yield, total dry matter yield, stover yield and thousand grains weight of maize.

Treatment	Grains yield (kg ha^{-1})	Total dry matter yield (kg ha^{-1})	Stover yield (kg ha^{-1})	1000 grains weight (g)
Control	1806^{a*}	8517.1^{c*}	6711^{b*}	166^{e*}
N and K Fertilizers	2228^{c}	9054.0^{b}	6087^{c}	189^{d}
Half dose of SSP	2525^{c}	9520.8^{ab}	6725^{b}	183^{d}
Half Compost + Half SSP	2763^{b}	9342.1^{ab}	6639^{b}	208^{c}
Full dose of Compost	2871^{b}	9351.5^{ab}	6763^{b}	202^{c}
Full Compost + Half SSP	3264^{a}	9633.6^{a}	7293^{a}	231^{a}
Full SSP dose	2815^{b}	9488.1^{ab}	7012^{ab}	219^{b}

Mean with different letter(s) in the columns are significantly different at $P \leq 0.05$.

Table 3. Effect of the prepared compost on post harvest soil pH, organic matter, and N and P contents.

Treatment	Soil pH (1:5)	SOM (%)	Total N (mg kg^{-1})	AB-DTPA extractable P (mg kg^{-1})
Control	7.90	0.95	1200^{e*}	1.62^{bc*}
N and K fertilizers	7.70	1.08	2100^{d}	1.35^{c}
Half SSP	7.74	1.55	2000^{d}	3.56^{a}
Half compost + Half SSP	7.72	1.65	3100^{c}	2.38^{b}
Full compost	7.58	1.79	4200^{b}	2.27^{b}
Full compost + half SSP	7.56	1.89	4900^{a}	4.02^{a}
Full SSP	7.58	1.72	4900^{a}	3.44^{a}

Mean with different letter(s) in the columns are significantly different at $P \leq 0.05$.

As such, the use of different organic fertilizers caused a reduction of soil pH values, which released H^+ from fertilizers during the nitrification process (Akram, 1978).

The application of full dose of compost with half dose of SSP showed the maximum (1.89%) soil organic matter content, followed by the treatment of full compost when applied alone (1.79%), while the lowest organic matter content of 0.95% was found in the control treatment (Table 3). Rabindra and Gowda (1986) reported that the use of a careful combination of organic and inorganic fertilizers increased the organic matter content, whereas Subramanian and Kamarasswamy (1989) and Wang et al. (2000) concluded that NPK plus organic manure treatments increased the organic matter content of soil.

Total soil N content was maximum (4900 mg kg^{-1}) in the treatment where combination of a full dose of compost and a half dose of SSP were applied, followed by the treatment of a full dose of recommended SSP, while the minimum nitrogen content of 1200 mg kg^{-1} was noted in control treatment (Table 3). Esilab et al. (2000) concluded that application of organic manures and NPK increased maize yield and improved the soil nitrogen

Table 4. Effect of compost on plants N and P uptake.

Treatment	Plant uptake N (kg ha^{-1})	Plant uptake P (kg ha^{-1})
Control	67.0^{f*}	6.57^{c*}
N and K Fertilizers	132.7^{e}	7.84^{bc}
Half dose of recommended SSP	159.2^{c}	15.27^{ab}
Half compost + Half SSP	175.6^{b}	17.25^{ab}
Full compost	144.6^{d}	17.63^{ab}
Full compost + half SSP	190.7^{a}	17.99^{a}
Full recommended dose of SSP	185.9^{ab}	17.87^{ab}

* Mean with different letter(s) in the columns is significantly different at $P \leq 0.05$.

Table 5. Economic analysis of the applied fertilizers.

Treatments	Yield (kg ha^{-1})	Yield increase (kg ha^{-1})	Increased yield value (Rs.ha^{-1})	Cost of fertilizers (Rs.ha^{-1})	Net return (Rs.ha^{-1})	VCR**
N and K	2228					
Half SSP	2525	297	10395	4250	6145	2.4 :1
Half SSP + half compost	2763	535	18725	8225	10500	2.3 :1
Full compost	2871	643	22505	7950	14555	2.8 :1
Full compost + Half SSP	3264	1036	36260	12200	24060	3.0 :1
Full SSP	2815	587	20545	8500	12045	2.4 :1

Price of maize = Rs, 35 kg^{-1}; Dung = Rs. 400 ton^{-1}; RP = Rs. 4.50 kg^{-1} and SSP = Rs. 850 bag^{-1}; *net return = value of increased yield - cost of fertilizer; **VCR = value of increased yield / cost of fertilizer

concentration. In their study, maximum AB-DTPA extractable P concentration in soil was (4.02 mg kg^{-1}) observed in treatment where full dose of compost and half dose of SSP were applied with non-significant difference in SSP treatment. Nonetheless, the minimum phosphorus content (1.62 mg kg^{-1}) was found in the control treatment (Table 3). Laskar et al. (1990) showed that the use of RP alone and in combination with organic manures significantly increased the total organic P content in soils.

Plants N and P uptake

Statistical data in Table 4 indicate that the maximum N uptake of 190.7 kg ha^{-1} was recorded in the treatment where full compost with half dose of recommended SSP were applied followed by the treatment of recommended SSP, while minimum nitrogen uptake of 67 kg ha^{-1} was noted in the control where no fertilizer was applied.

Maximum P uptake of 17.99 kg ha^{-1} was observed in treatments where a combination of full dose of compost and half dose of SSP were applied followed by the treatment of full dose of recommended SSP. Minimum nitrogen uptake of 6.57 kg ha^{-1} was recorded in the control where no fertilizer was applied. Erdal et al. (2000) reported that N and P accumulation in plants were increased by applying organic materials such as dung with chemical fertilizers.

Economic analysis of fertilizers

Economic analysis of the applied fertilizer is shown in Table 5. Maximum net return of Rs. 24060 ha^{-1} with value cost ratio (VCR) of 3.0:1 was recorded by the application of full compost with half SSP, followed by the treatment of full dose of recommended SSP with net return of Rs. 14555 ha^{-1} and VCR of 2.8:1.

The soils of Pakistan are nutrient deficient, especially in nitrogen and phosphorus. With the possible exception of N, no other element has been as critical in plant growth as P. Lack of this element is doubly serious since it may prevent other nutrients from being acquired by the plants. Phosphorus is known to be involved in a plethora of functions in plant growth and metabolism.

Exploitation of soil natural resources and their utilization, as an economical and environmentally friendly source of fertilizer for increased crop production on sustainable basis, plays key roles in the development of a country like Pakistan.

Pakistan has RP deposits in Hazara division of Khyber Pakhtunkhwa province. The reserves are wide spread in the Kakul, Galdaman, Tarnawai and Lagerban villages of District Abbottabad. The so far reported exploration

exploration indicates that total reserves are about 35.7 million tonnes, out of which 14.7 million tonnes are of proven quality and they contain 26 to 31% P_2O_5. The remaining reserves of 21 million tonnes are of inferred quality. The total proven quality reserves are 14.7 million tonnes, while the inferred are 21 million tonnes. The proven reserves at Tarnawai have a potential sustained annual production of 60,000 tonnes for a period of 30 years. Van Kauwenbergh et al. (1991) stated that the high cost of importing soluble P fertilizer is, therefore, forcing many developing countries to increasingly turn to the use of local RP resources to improve their agricultural production.

Many researchers have proved that many micro-organisms in soil produce organic acids like carbonic acids, acetic acids, citric acids, etc. These acids create favorable environment for the enhancement of P solubility from the applied RP. Kucey et al. (1989) has shown that the microbial solubilization of soil phosphate in liquid medium studies have often been due to excretion of organic acids. The availability of P from RP can be increased by several means. The RP is basically complex of tri-calcium phosphates $[Ca_3 (PO_4)_2]_3.CaCo_3$ insoluble in water. Its soluble form is monocalcium phosphate $[Ca (H_2PO_4)_2]$, which is generally called super phosphate (that is, SSP, DSP and TSP). The solubility can be enhanced by treatment with mineral acids, organic acids, a mixture of organic materials, biological treatment, etc.

Biological solubilization of RP is more environmental friendly and economical than acidulation. There is a need therefore to develop the microbial process that will make phosphorus available for plant use with minimum pollution to the environment. Composting of manures and other organic materials with RP has been shown to enhance the solubility of P from RP (Mishra and Bangar, 1986; Singh and Amberger, 1991) and is practiced widely as a low-input technology to improve the fertilizers value of manures (Mahimairaja et al., 1995). Govi et al. (1996) reported that the compost made from selected organic waste was used alone and in mixture (25% of volume) with a substrate from straw beeded horse manure. The compost was found to be suitable for cultivation of crops growth. Rajan et al. (1996) argued that RP has the potential to improve soil fertility and increase agriculture production as P fertilizer do, but the extent of suitability varies with soil, crop, climatic condition and mineral composition of RP. Gajdos (1992, 1997) prepared different composts using a wide range of wastes like sewage sludge, poultry manure, pig slurry, olive mill wastewater, city refuse and the lignocellulosic wastes cotton waste, maize straw and sweet sorghum bagass. Their chemical and biological properties were studied at four stages of the composting process; in the initial mixture, at the thermophilic phase, at the end of the active phase and after two months of maturation and the maturation indexes, based mainly on humification of the organic materials.

Conclusion

Phosphorus concentration increased by 56 and 110% in RP fed dung composted without and with RP, respectively and 107% in simple dung composted with RP. Maize yield and yield components with plant N and P uptake recorded by the application of full dose of compost with half dose of SSP were higher or almost similar to those observed in the treatment of full recommended dose of SSP. The value cost ratio of 3.0 with maximum net return of Rs. 24060 ha^{-1} was obtained by the application of full compost with half SSP, followed by the treatment of full dose of compost with net return of Rs. 14555 ha^{-1} and VCR of 2.8. The composting RP fed dung and simple dung with RP has the potential to enhance P solubility, which may be supplemented with SSP to minimize dependence on the expensive chemical fertilizers. Further research is suggested to prepare composts of different organic materials with RP and determine their direct and residual effect on various crops in different agro ecological zones of Pakistan.

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