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Effect of P-enriched compost application on soil and plants

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Abstract

A study was undertaken to prepare P-enriched compost (PEC) using two rates of rock phosphate (RP), viz. 5 and 10 % of MSW (w/w), and two strains of phosphorus solubilizing bacteria (PSB) viz. *Klebsiella pneumonia* and *Burkholderia cenocepacia*. Composting material samples were collected biweekly from each treatment, and analyzed for micronutrients (Cu, Zn, Fe, Mn) and total and soluble P. Compost involving 10 % RP with both strains of PSB had the highest content of total and soluble P (2 % and 120 mg kg⁻¹ respectively), therefore it was selected for use in further experiments. Different combinations of PEC and P-fertilizer were tested for growing maize under greenhouse conditions. Treatments were: control, half and full dose of P fertilizer, enriched compost for supplying 50, 100, 150 and 200 % of recommended P rate, and mixture of PEC for 75 % P with 25 % P from fertilizer. Soil samples were drawn after crop harvest, while plant samples were obtained at crop maturity. Mixture treatment involving PEC and P-fertilizer (75:25) performed better than other treatments. This combination gave higher dry matter yield (31.5 g pot⁻¹) optimum micronutrients (Fe 53.5, Mn 12.7, Cu 5.5, Zn 8.4 mg kg⁻¹) in soil. It was concluded that enriched compost (75%) along with reduced application (25 %) of P fertilizer could be very helpful in meeting P deficiency in soil.

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Introduction

Pakistani soils are generally deficient in all the major plant nutrients. Therefore farmers have to use chemical fertilizers to meet the deficiency of macronutrients (N, P, K) in soil. Phosphorus is the highly deficient nutrient after nitrogen. Total P contents in soil may be quite high (400-3000 ppm) but plant available form is highly deficient (Rashid, 1994). Around 90 % of Pakistani soils are deficient in phosphorus (NFDC, 2006). Phosphatic fertilizers are used to meet the deficiency but the efficiency of these fertilizers is only 10 to 25% (Isherword, 1998). In acidic soils phosphorus forms insoluble compounds with Fe and Al while in alkaline soils it forms insoluble precipitates with calcium ions (Gyaneshwar *et al.*, 2002). Both reduce phosphorus bioavailability in soil. Pakistan has 26 million ton of rock phosphate (RP) reserves which could serve as cheap source of soil P. However RP cannot be applied directly in alkaline calcareous soils as its solubility is negligible. Many possibilities have been suggested for increasing its solubility like treating with elemental sulphur (Basak *et al.*, 1987), acidulation (Stephan and Condron, 1986) and composting with rice straw (Biswas and Narayanasamy, 2006). In Pakistan, municipal solid waste management is a big problem in urban areas. Management of 55,000 tons/day of city waste (JICA, 2005) is a big task. Unscientific management of MSW creates serious problems for municipalities. Composting of MSW along with local RP and phosphorus solubilizing bacteria (PSB) could be a good option to deal with ever increasing volumes of city waste by converting it into useful enriched compost. Composting of MSW is a well known practice however improving its quality by using RP and PSB has not been studied well. Therefore, present study was carried out to improve phosphorus content of municipal solid waste compost by treating it with RP and PSB. Effect of this enriched compost was also studied in greenhouse experiment on soil and plant.

Materials and methods

Preparation of RP-enriched compost

About one thousand kilogram of municipal solid waste to be used in the experiment was collected from

the nearby dumping points of municipal corporation. Physical composition was determined by first segregating the waste and then weighing each component to find its percentage. For chemical composition three subsamples were collected from the heap and combined to form a representative sample. It was analysed for total N, P, K, micronutrients (Cu, Zn, Fe, Mn), heavy metals (Cd, Cr, Pb) and C/N. Physical components of MSW included plastic, paper, cloth 17.3, 10.7, 5.6 %, metals, glass, animal residues 2.9, 1.5, 3.2 % while stones and wood were 3.4 and 0.4 % respectively. Miscellaneous decomposable material was found to be 55 %. Chemical composition of municipal solid waste involved total N, P, K 0.98, 0.43, 0.56 %; Cu, Zn, Fe, Mn 64, 115, 2445, 268 mg kg⁻¹; Pb, Cr, Cd 110, 51, 0.91 mg kg⁻¹. Electrical conductivity was 2.35 dS m⁻¹ while pH was 7.3. Total C was 34 % while C:N was 34.7. Farm yard manure was added @ 5% along with 5 kg urea. This mixture was a base material for making enriched compost. Two locally identified and isolated phosphorus solubilizing bacteria viz., *Klebsiella pneumonia* and *Burkholderia cenocepacia* were for mixing with base material. Local variety of rock phosphate named "Aurangzeb" containing 24% total P was used. Chemical properties of this RP included Cu, Zn, Fe, Mn, 6.8, 4, 28 and 8.4 mg kg⁻¹, Ca, Mg, K, 190, 6 and 43 mg kg⁻¹ while extractable and soluble P, were 190 mg kg⁻¹ and 2.6 mg kg⁻¹ respectively. Rock phosphate was mixed @ 5 and 10% with or without PSB. Treatments involved Composting mixture (control), RP @ 5 and 10 %, RP @ 5 and 10 % + *Klebsiella pneumoniae* (PSB1), RP @ 5 and 10 % + *Burkholderia cenocepacia* (PSB2), RP @ 5 and 10 % + PSB1+PSB2.

Greenhouse study

A greenhouse pot experiment was carried out in spring, 2013 at PMAS-Arid Agriculture University, Rawalpindi, on maize. Soil for the experiment was collected from the research area of university. The soil was passed through all standard procedures including drying, grinding, sieving through 2 mm sieve to make it uniform. It was filled into the pots @ 10 kg each. The treatments included: Control (N and K fertilizers

only @ 150-75 kg ha⁻¹), half and full rate of P (50 and 100 kg P ha⁻¹), PEC for 50, 100, 150 and 200 % of recommended P rate. Maize was grown for 90 days period. Five seedlings were maintained in each pot. Soil sampling was done in the beginning and at the end of crop harvest. Plant samples were obtained before crop harvest. Soil and plant samples were subjected to the analysis of N, P, K, Cu, Zn, Fe, Mn. Crop growth parameters including fresh and dry biomass and plant height were also recorded.

Analytical Procedures

Total P in compost samples was determined by digesting compost samples with di-acid mixture of nitric and perchloric acid, and using ammonium vanado molybdate as colour developing solution (Jackson, 1973). Water soluble P was determined by following the procedures described in Fertiliser (Control) Order (1985). Extractable soil P and micronutrients were determined through AB-DTPA method by using spectrophotometer and atomic absorption spectrophotometer respectively (Soltanpour and Workman, 1979).

Statistical Analysis

Data were analyzed statistically by using analysis of variance (ANOVA). Comparison of mean values was undertaken by LSD test as described by Steel *et al.* (1997).

Results and discussion

Total P during composting

Total P was affected positively in various treatments. At the start of composting total P content varied from 0.55 % in control to 1.13 % in 10%RP+PSB1+PSB2 (Fig.1). With the passage of time total P content increased. At the end of 120 days of composting the highest total P (2%) was recorded in 10%RP+PSB1+PSB2. Change in the volume of compost heap was also prominent and within few days its volume had reduced to half. In RP-amended compost change in total P was slow however gradual increase in total P continued till the end of composting. Total P was high where higher quantity of RP was added. So the compost mixture treated with

10% RP had higher total P compared to compost mixture treated with 5% RP. Slow increase in total P content was beneficial as such compost could provide P to the crop gradually for a longer period of time. Slow and gradual increase in total P content while co-composting pig manure with saw dust was reported by Huang *et al.* (2004). Nishanth and Biswas (2008) reported as high as 3.9% total P in the final compost prepared from rice straw, rock phosphate and P solubilizing fungus.

Soluble P during composting

At the start of composting soluble P ranged between 37 and 43 mg kg⁻¹ while after the completion of composting, soluble P ranged from 61 to 120 mg kg⁻¹ (Fig. 2). Higher soluble P content (120 mg kg⁻¹) at the end of composting was noted in 10%RP+PSB1+PSB2 where it increased from 37 mg kg⁻¹ to 120 mg kg⁻¹. Sharp change was noted in control while gradual change in soluble P content took place in the treatments where more rock phosphate had been added. Among two rates of rock phosphate (5 % and 10 %), soluble P improved significantly in the treatments where a mixture of rock phosphate and P solubilizing bacteria had been applied. Due to the decomposition/mineralization of organic compounds, improvement in the soluble P content was expected. However initial improvement in the level of soluble P in control was unexpected and could be due to the fact that decomposition of simple municipal waste material was fast. In RP-amended treatments rate of release of soluble P was slow and gradual. Reactions of released inorganic soluble P with other cations could be a reason for reduced availability of soluble P (Singh *et al.*, 1982). Assimilation of inorganic P by microbial population could be another phenomenon which at that time causes reduced availability of P however they are in fact storage of P and slowly release inorganic P in soil for extended period of time (Kouno *et al.*, 2001). However the advantage of RP amended compost could be consistent provision of soluble P for a longer period of time. Phosphorus solubilizing bacteria and fungi are well known to produce organic acids of various types like citric acid, tartaric acid, oxalic acid, gluconic and lactic acid etc

(Babana and Antoun, 2006). These acids produce H⁺ ions which solublize inorganic phosphates and bring them in to soluble forms. Anions of these organic acids chelate with Fe, Al and Ca ions which liberates more soluble P (Vassilev *et al.*, 2006).

Micronutrient dynamics during composting

Concentration of micronutrients improved with composting. At the end of 120 days of composting concentration of micronutrients (Cu, Zn, Fe, Mn) was higher in control compared to RP-amended treatments (Fig. 3-6). So the treatments receiving 5 and 10 % RP had less concentration of these micronutrients. It could be due to the reason that RP had very low concentrations of these micronutrients. It was also noted that micronutrient concentration was better where PSB had been applied. Composting is a useful phenomenon in which microbes convert organic material in to humic substances and bring nutrients in to plant usable form (Marhuenda Egea *et al.*, 2007). Increase in the micronutrient content was due to the decomposition of organic materials. As more and more carbon material was decomposed nutrient content also improved correspondingly. In plain compost, micronutrient status improved significantly with the passage of time which could be

due to reduction in the biomass of composting material, raising the concentration of all mineral nutrients in the remaining compost (Fang and wong, 1999). Furthermore as control treatment had no amendment in the form of rock phosphate (poor in micronutrient status), higher micronutrient content compared to other treatments was noticed where 5 and 10 % rock phosphate had been added. Phosphorus solublizing activity of microbes may also have affected the micronutrient availability from RP. Mechanism of inorganic P solublization involves production of organic and inorganic acids (Stevenson, 2005). As a result, pH of the medium decreases. Gluconic and keto gluconic acids are among many other acids produced by these microbes (Deubel *et al.*, 2000; Khan *et al.*, 2009). This decrease in pH is helpful in increasing/releasing micronutrients in the medium. Availability of Zn is reported to increase hundred time with every decrease in pH by one unit (Rengel, 2001). In our study those treatments showed comparatively better results where a mixture of two P solublizers was applied. Zaki and Radwan (2006) while using different combinations of P solublizing bacteria and fungi reported improved soil P and micronutrients and later better uptake of these nutrients by faba bean (*Vicia faba L.*) plants.

Table 1. Extractable micronutrients (Cu, Zn, Fe, Mn) in soil as affected by the application of various rates of P-enriched compost and P-fertilizer.

Treatment	Copper	Zinc	Iron	Manganese
----- mg kg ⁻¹ -----				
Control	3.1 f	3.6 d	40.0 d	7.5 e
P50	3.9 e	3.8 d	45.1 d	8.7 e
P100	4.7 d	3.4 d	43.5 d	9.3 e
PEC50	5.6 c	8.9 c	52.4 c	11.5 d
PEC100	6.6 b	13.4 b	60.0 b	15.0 c
PEC150	8.2 a	15.5 a	66.5 a	21.5 b
PEC200	8.4 a	16.3 a	69.5 a	23.5 a
PEC75 + P25	5.6 c	8.3 c	53.5 c	12.7 d

Means with same letters are statistically non significant at $p < 0.05$

P25, P50 and P100 represent P fertilizer for 25, 50 and 100 kg P₂O₅ ha⁻¹, respectively

PEC 50, PEC 100, PEC 150 and PEC 200 indicate P-enriched compost for 50, 100, 150 and 200 kg P₂O₅ ha⁻¹ respectively.

Micronutrient content of soil

Analysis of soil samples in control (Cu, 3.1; Zn, 3.6; Fe, 40; Mn, 7.5 mg kg⁻¹) revealed that soil was not

deficient in micronutrients when compared with their critical limits for soil (Soltanpour, 1985). Significant improvement in soil micronutrient status occurred

due to enriched compost application (Table 1). In PEC50 the micronutrients were Cu: 5.6, Zn:8.9, Fe:45.1 and Mn:8.7 mg kg⁻¹ while the micronutrient content in the treatments receiving the highest rate of enriched compost (PEC200) were Cu:8.4, Zn:16.3, Fe:69.5 and Mn:23.5 mg kg⁻¹. In general there was improvement in the micronutrient status of soil by the increased application of PEC. However the researchers have reported conflicting results in this regard. In this study, Cu concentration increased in soil, however, Giusquiani *et al.* (1988) did not observe any appreciable change in the extractable portion of Cu, while Jordao *et al.* (2006) reported significant increase in available Cu content compared to control by the application of MSWC. Mbarki *et al.* (2008) reported significant increase in available Zn and Cu in soil with increased application of MSWC. Effects of

organic amendments on available soil Fe are quite variable depending on the crop and conditions of the soil. Warman *et al.* (2001) did not observe significant change in soil Fe and its uptake in clover and blue berry leaves even by the application of 100-140 Mg ha⁻¹ of MSWC. However, contradictory results were reported by Maftoun *et al.* (2004) by using MSWC. Availability of Mn in soil is affected by pH factor as well as its interaction with Fe (Zheljzkov and Warman, 2004). Increase in soil pH due to the application of MSWC could be the reason for reduced availability of Mn (Warman *et al.*, 2004). However, in some other studies, improved Mn content of soil and its uptake by spinach and lettuce has been reported in calcareous soils also (Maftoun *et al.*, 2004; Gallardo-Lara *et al.*, 2006).

Table 2. Total Cu, Zn, Fe and Mn content of plants as affected by various rates of P-enriched compost and P fertilizer.

Treatment	Copper	Zinc	Iron	Manganese
	mg kg ⁻¹			
Control	19.33 f	12.33 f	93.0 d	19.3 d
P50	21.0 f	19.0 ef	98.0 cd	21.3 d
P100	23.66 f	22.23 e	103.0 cd	25.0 d
PEC50	41.66 d	46.0 d	134.0 bc	48.3 c
PEC100	66.66 b	78.33 c	185.3 a	72.7 b
PEC150	69.0 b	93.3 b	209.0 a	85.43 ab
PEC200	78.33 a	104.0 a	223.0 a	97.7 a
PEC75 + P25	49.33 c	51.0 d	143.0 b	54.9 c

Means with same letters are statistically non significant at $p < 0.05$

P25, P50 and P100 represent P fertilizer for 25, 50 and 100 kg P₂O₅ ha⁻¹, respectively

PEC 50, PEC 100, PEC 150 and PEC 200 indicate P-enriched compost for 50, 100, 150 and 200 kg P₂O₅ ha⁻¹ respectively.

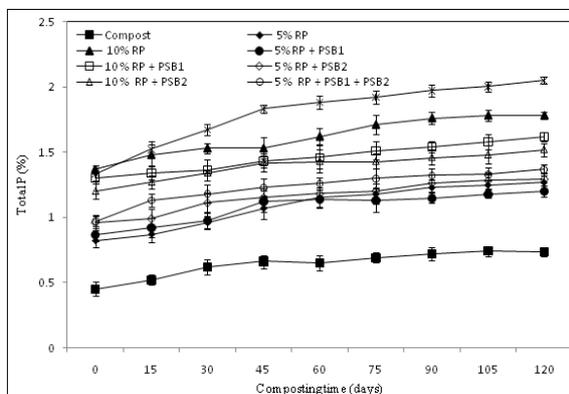


Fig. 1. Total P dynamics during composting as affected by the addition of various levels of rockphosphate and P solubilizing bacterial cultures.

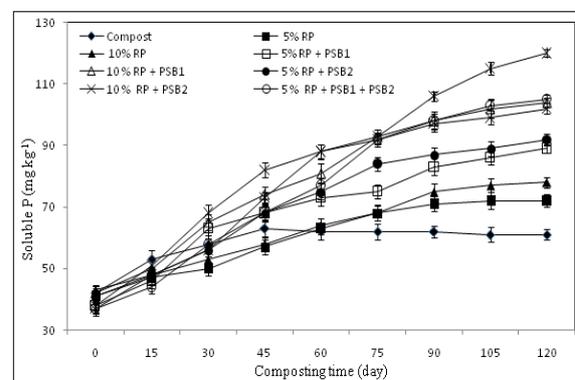


Fig. 2. Soluble P dynamics during composting as affected by the addition of various levels of rockphosphate and P solubilizing bacterial cultures.

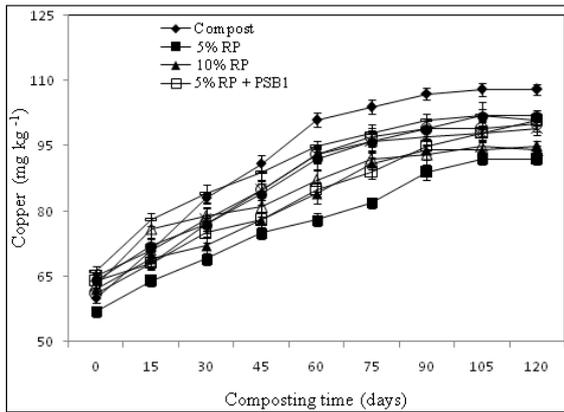


Fig. 3. Copper dynamics during composting of municipal solid waste with RP and PSB.

Micronutrient content of maize plants

Uptake of all the micronutrients (Cu, Zn, Fe, Mn) was improved by the application of increasing doses of enriched compost (Table 2). In non-compost treatments, Cu content in maize leaves varied from 19.3 to 23.6 mg kg⁻¹. In PEC-amended treatments the lowest content (41.6 mg kg⁻¹) was in PEC50 while the highest (78.3 mg kg⁻¹) was in PEC200. The lowest contents of Zn, Fe and Mn (12.3, 93.0, 19.3 mg kg⁻¹) were noted in control while the highest plant contents of these micronutrients (104.0, 223.0, 97.7 mg kg⁻¹) were noted in PEC200. Slight differences for the contents of micronutrients in the first three treatments (non-compost) could be due to differential growth of plants. Different growth of plant roots resulting from different levels of chemical fertilizer will definitely affect plant nutrient uptake. Deficiency of micronutrients can negatively affect plant growth and reduce crop yield (Mann *et al.*, 2002). Among eight micronutrients which are important for plant growth Zn and Mn reduced crop yield particularly in alkaline calcareous soils. Deficiency of Cu can also limit plant growth both in organic and calcareous soils (Pinto *et al.*, 2004). Another important feature of micronutrient deficiency is that no prominent deficiency symptoms appear immediately which makes scientific management of micronutrients in cropping system an essential component (Lombnaes and Singh, 2003). In the present study, the micronutrient contents in leaves were increased with increasing level of PEC, which showed that enriched compost was a good source of micronutrients. The

order of accumulation of micronutrients in plant leaves was found to be Fe>Zn>Mn>Cu. Increase in micronutrients uptake by plant by the application of municipal waste compost is also supported by Mbarki *et al.* (2008) who observed 3 fold increase in Cu uptake and 4-5 fold increase in Zn uptake in alfalfa by the application of MSWC.

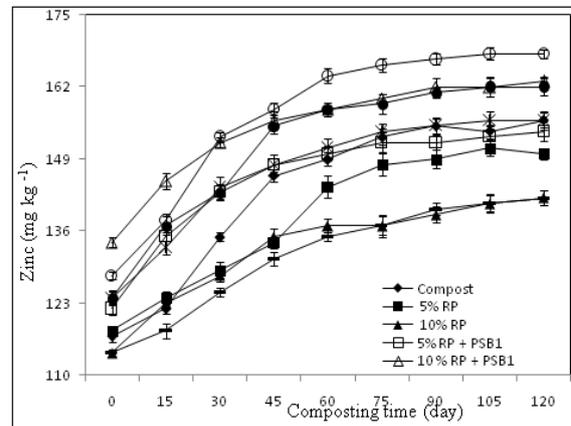


Fig. 4. Zinc dynamics during composting of municipal solid waste with RP and PSB.

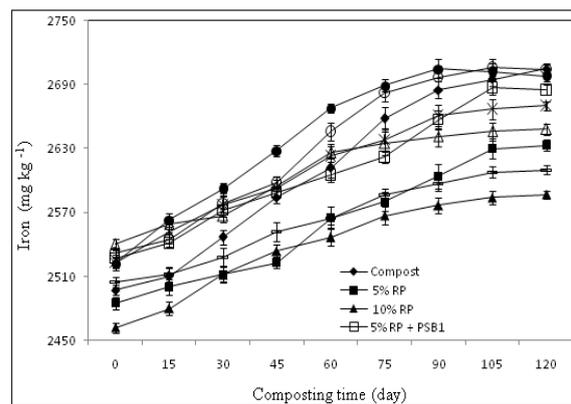


Fig. 5. Iron dynamics during composting of municipal solid waste with RP and PSB.

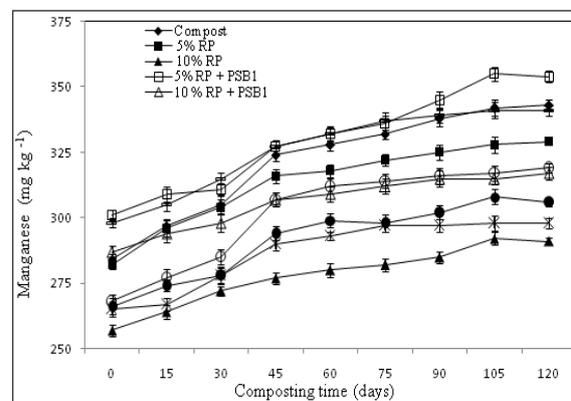


Fig. 6. Manganese dynamics during composting of municipal solid waste with RP and PSB.

Conclusion

It was concluded that the compost enriched with 10% rock phosphate and both strains of PSB had highest total and soluble P. Compost without RP amendment had relatively higher micronutrient content. Similarly micronutrient content (Cu, Zn, Fe, Mn) in soil and plant increased with increasing rates of enriched compost. A mixture of enriched compost and phosphatic fertilizer in 75:25 was highly useful economical.

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