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Effect of Recycled and Value-added Organic Waste on Solubilization of Rock Phosphate in Soil and its Influence on Maize Growth

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ABSTRACT

Rock phosphate (RP), a naturally occurring mineral source of insoluble phosphate used predominantly in acidic soils, while in calcareous/basic soils it is insoluble. The solubilization of insoluble forms of P (using RP as P-source) by organic acids is the major advantage of composting through, which organic wastes are converted biologically into partially humified material. A series of experiments were conducted to investigate the impact of two sources of organic waste (cow dung & fruit waste) blended with RP @ 10% P_2O_5 and unblended compost on release of plant available P in soil. The organic wastes (blended & unblended) were subjected to composting. The soil was spiked with different rates of compost (blended & unblended with RP). The results revealed that RP-blended cow dung (RP-CD) released maximum plant available P than RP-enriched fruit waste (RP-FW). Further experiments indicated that RP enriched compost (RP-EC) was more effective in releasing plant available P than that when RP and compost were independently applied to soil. Pot trial on maize confirmed the significance of RP-EC for enhancing plant available P as it not only enhanced growth and yield of maize but also decreased the cost of production. In crux, RP-EC could be an effective strategy for obtaining maximum maize yield with low cost input, in addition to improved soil fertility. © 2011 Friends Science Publishers

Key Words: Rock phosphate; Compost; Organic waste; Enrichment; P-solubilization

INTRODUCTION

Phosphorus (P) is the major plant nutrient and considered one of the primary factors limiting crop yields (Raghothama, 1999; Raghothama & Karthikeyan, 2005; Zaidi *et al.*, 2009). Therefore, application of phosphatic fertilizers is essentially required to maximize crop yields. The overall P use efficiency of applied phosphatic fertilizer such as SSP, DAP, TSP etc. is lower than optimal and only 15 to 20% of applied phosphorus is recovered by the first crop, because of the formation of insoluble P compounds in soil (Vance, 2001). An important factor contributing to this low recovery is high Ca content in calcareous soils, which are very much prevalent in Pakistan (Aziz *et al.*, 2006). So addition of sufficient P through P fertilizers is direly needed. Current domestic production of P fertilizers from rock phosphate (RP) is very little, because of low and poor quality indigenous RP resources. Thus, large quantity of P fertilizers is imported every year at the expense of foreign exchange. The world's non-renewable good quality resources of RP are depleting at an alarming pace. In Pakistan, continuously increasing prices of phosphatic fertilizers and their scarcity at the right time of application mostly accounts for low P fertilizers use by the farmers resulting in relatively low crop yields in Pakistan. This situation warrants the formulation of a cheaper and locally developed P product for the field use.

Phosphatic fertilizers are designed to replenish the soils with P for plant uptake (Vassilev & Vassileva, 2003). Almost all the P fertilizers are manufactured from the RP, generally these fertilizers are mainly imported in Pakistan due to the poor quality indigenous resources of RP which is difficult to be used in manufacturing of phosphatic fertilizer. Under such circumstances there is a dire need of low cost product, which could be used as source of plant available P. RP has good P content (28-30%) but cannot be directly used as a fertilizer because of its poor release of P for the use of plant (Reddy *et al*., 2002).

Composting is biological process in which biodegradable organic wastes are converted into hygienic, humus rich product (compost) that can be beneficially applied to soil (Hoitink & Fahy, 1986; Millner *et al*., 1998). It is well documented that during composting process of organic waste a variety of organic acids are released. The interaction of organic acids released during composting results in P solubilization from RP for plant uptake.

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However, the extent of RP-P solubilization by composting material depends on many factors such as nature of organic waste, compost: RP ratio and time of incubation. The use of organic fertilizers made up of various composted materials, is now established as a key strategy not only for improving soil organic matter contents and nutrients supply to plants but also for reducing the input cost of mineral fertilizers and promoting healthier environments (Ahmad *et al.*, 2006).

In alkaline soils of Pakistan, direct use of RP is not feasible because of its poor solubility. However, if RP is allowed to react with organic acids produced during composting, a major part of RP-P could be solubilized for plant uptake (Singh & Reddy, 2011). This may imply that the low grade RP reserves of Pakistan could be used efficiently by preparing a RP-EC. This approach is not only economical but also environmental friendly. This study was planned to investigate the contribution of RP-EC in plant available P in soil and on growth of maize crop.

MATERIALS AND METHODS

P-released from organic waste material: To determine this, different kinds of organic waste materials were collected for the formulation of enriched compost. Cow dung (CD) was collected from livestock farm, University of Agriculture, Faisalabad, while fruits waste (FW) was collected from fruit and vegetable market of Faisalabad city, Pakistan. After collection of waste materials, their P contents were determined by using method described in subsequent sections.

For the preparation of RP-enriched compost from CD and FW, a locally fabricated composting unit (composter) was used. Air-dried organic waste was put into the composter (processing unit) to convert organic waste materials into compost. Water was added to maintain suitable moisture for optimum composting process (~30%). In case of CD, the water content was adjusted before composting. Both kinds of composted materials (CD & FW) spiked with 33.4% RP or without spiking were analyzed for P-content. Composting was done for six days under controlled conditions. After six days of incubation, composted material was passed through a grinder to make granules of RP-EC. The compost was packed in gunny bags prior to use.

P-Released in soil spiked with RP-enriched compost: The soil used for the study was sandy clay loam having organic matter 0.05%, saturation percentage 29.13%, ECe 2.2 dS m^{-1}, pH 7.6 and available phosphorus 7.3 mg kg^{-1}. The soil was spiked with RP-EC 500, 1000, 1500 and 2000 kg ha^{-1} in pots and were placed in natural conditions in the wire house, Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan. After 20 days of spiking samples were collected for the determination of available P. The release of plant available P in soil spiked with RP @ and RP-EC @ 500 kg ha^{-1} was determined after 8 weeks of spiking. Soil without spiking was used as a check for comparison.

Pot trial: Pot experiment was conducted to assess the efficacy of RP-EC for the improvement of growth and yield of maize (*Zea mays* L.). A composite soil sample was collected from the field, air-dried, ground, sieved (2 mm 10 mesh $^{-1}$) and was analyzed for physico-chemical characteristics. Seeds of maize (Sahiwal-2002) were sown in pots containing 12 kg soil per pot by using recommended doses of nitrogen and potassium fertilizers [N & K @ 175 (70) & 60 (25) kg/ha (acre), respectively] were applied as basal dose in all treatments. Half N was applied at the time of sowing and remaining half as second dose, while P was applied @ 115(46) kg/ha (acre) and to maize, respectively at sowing time from various phosphorus sources i.e., RP, DAP and RP-EC. Following treatment plan was followed:

F0 = Control (NK fertilizer, P from rock phosphate)
F1 = NK fertilizer, P from DAP
F2 = NK fertilizer, P from RP-EC @ 500 kg ha^{-1}.

All the treatments were replicated thrice and data regarding growth and yield parameters were collected two month after sowing.

Determination of available phosphorous in soil: Available phosphorous was determined by taking 10 g soil and 20 mL of AB-DTPA [1 M in the ammonium bicarbonate (NH_4HCO_3) and 0.005 M DTPA] solution adjusted at pH 7.6. One mL aliquot of the soil extract was diluted to 10 mL with deionized water. Then 2.5 mL color developing reagent was added carefully, stirred and kept in stand for 30 min. Color intensity was measured on spectrophotometer (Nicolet evolution 300, Thermo Electron Corporation, Japan) at 880 nm (Soltanpour & Schwab, 1977).

Plant analysis: The dried and ground shoot material (0.1 g) was digested with sulphuric acid and hydrogen peroxide according to the method of McGill and Figueiredo (1993). For this purpose, the dried ground plant material (0.1 g) was placed in digestion tubes, 2 mL of conc. H_2SO_4 was added and incubated over night at room temperature. Then 1 mL of H_2O_2 (35% A. R. grade extra pure) was poured down through the sides of the digestion tubes and was rotated. Tubes were ported in a digestion block and heated up to 350°C until fumes were produced and continued to heat for another 30 min. Digestion tubes were removed from the block and cooled. Then 1 mL of H_2O_2 was slowly added and tubes were placed back into the digestion block until fumes were produced for 20 min. Again digestion tubes were removed. Above step was repeated until the cooled material became colorless. The volume of extracts was made up to 50 mL with distilled water. Then it was filtered and used for determination of mineral elements.

Phosphorus determination: As described by Ryan *et al.* (2001), the extracted material (5 mL) was mixed with 10 mL of Barton reagents and total volume was made as 50 mL. The samples were kept for half an hour and phosphorus contents were measured at 410 nm by spectrophotometer (Nicolet evolution 300, Thermo Electron Corporation, Japan) using standard curve.

Statistical analysis: completely randomized design was used and to separate the treatment means (P=0.05), the least significant difference (LSD) test was employed (Steel & Torrie, 1980) using MSTATC computer software.

RESULTS

Both of the organic waste materials (CD & FW) and soil were checked for total P contents and soil was analyzed for available P. It was noted that CD had maximum P content (~120 mg Kg^{-1}) followed by FW, which had ~70 ppm P. The indigenous content of avaiable P in soil was less than 8 ppm. The spiking of soil was done with either CD/FW alone or with RP enriched CD/FW compost in soil. Release of available P from spiking of RP-EC was much more promising than that contributed by CD/FW application alone at same rate, even after 3 weeks (Fig. 1 & 2). Different application rates for spiking of soil by both non-riched compost of CD and FW and respective RP-enriched compost (RP-EC) were used (500, 1000, 1500 & 2000 kg ha^{-1}) in small pots to monitor the release of plant available P. RP-EC of CD and FW @ 2000 kg ha^{-1} gave 38 and 25%, respectively more available P as compared to their respective non-enriched compost and 331 and 255%, respectively over non-spiked soil control after 3 weeks of application. Similarly, RP-EC of CD and FW @ 1500 kg ha^{-1} resulted in 17 and 18% more available P over respective non-enriched compost application. The release of available P from RP-EC of CD and FW @ 1000 kg ha^{-1} was 20 and 30% greater than their respective non-enriched compost application, while 230 and 229% more P was released over non-spiked control. However, both RP-EC of CD and RP-EC of FW @ 500 kg ha^{-1} proved more efficient, because of its less application rate and high return of available P as they provided 50 and 12% of more available P as compared to respective non-enriched compost and 204 and 127% over non spiked control, respectively after 3 weeks of application.

The effectiveness of value addition/enrichment of compost when spiked in soil was further checked for the release of P under controlled conditions. Value addition of RP in CD compost was done and applied @ 500 kg ha^{-1}. Data showed that spiking of soil with RP-EC provided 59, 139 and 224% more available P over simultaneous spiking of soil with RP and compost, spiking with RP alone and unspiked soil, respectively after 1 week of application (Fig. 3a). Similarly, the effect was further strengthened after 8 weeks (Fig. 3b), where RP-EC released more available P by 27, 231 and 345% over spiking simultaneously with RP and compost, spiking with RP alone and unspiked soil, respectively. This suggested that value addition with RP of

Fig. 1: Release of plant available P in soil spiked with different rates of RP-enriched CD compost and CD without RP

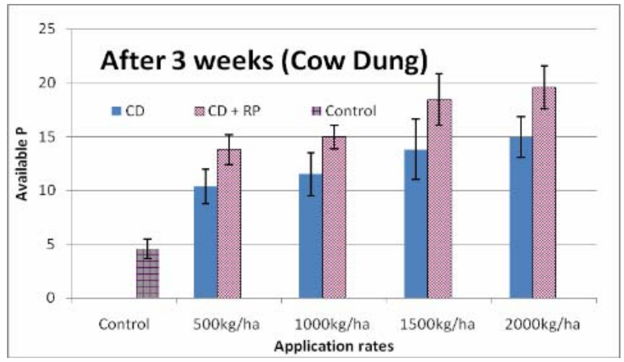

Fig. 2: Release of plant available P in soil spiked with different rates of RP-enriched fruit compost and fruit waste without RP

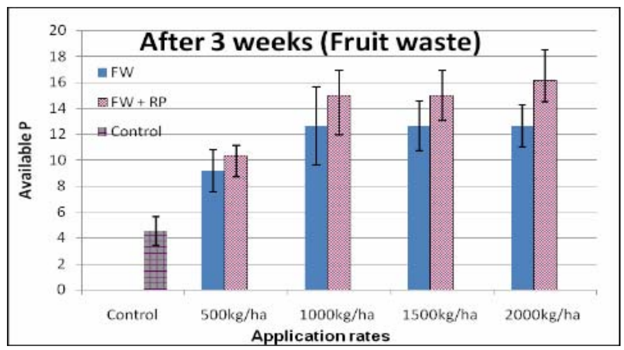

Fig. 3a, b: Release of plant available P in soil spiked with RP, RP + compost and RP-EC after one (a) and eight (b) weeks of spiking

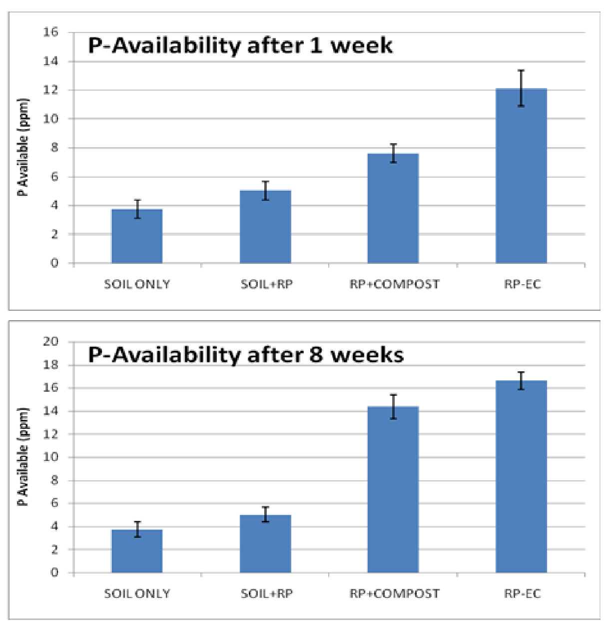

Table I: Effect of DAP, RP and RP-EC on shoot growth parameters of maize

Treatments	Plant height (cm)	Fresh biomass (g pot^{-1})	Dry biomass (g pot^{-1})	Root fresh mass (g pot^{-1})	Root dry mass (g pot^{-1})	Root length (m)	[P] (%) in maize stover	P uptake (mg pot^{-1}) of maize stover
N(DAP)K	89.8±2.3a	63.3±1.7a	19.9±0.7a	53.5±1.1a	16.3±0.4a	37.1±0.5a	0.22±0.01a	48.7±0.4a
N(RP)K	45.5±4.6c	35±3.2c	13.6±1.0b	21.7±2.7b	6.6±0.8b	9.9±1.9c	0.06±0.01c	7.3±2.5c
N(RP-EC)K	75.7±3.88b	49.9±2.5b	17.8±0.9a	50.5±2.6a	15.4±0.8a	27.5±1.41b	0.16±0.008b	26.1±1.3b

composted CD waste material could provide more available P when spiked in soil over the time of incubation.

Based on above findings a pot study was done on maize to check the effeciency of this value added organic fertilizer on plants in comparison with RP alone and diammonium phosphate (DAP). The data summerized in Table I showes that application of RP-EC @500 kg ha^{-1} resulted in better growth of maize than RP alone and in some cases the effect was almost at par with DAP. RP-EC application increased plant height of maize upto 66% over RP application alone. Similarly, fresh biomass was increased by 43 and 80%, while dry biomass enhancement was 31 and 46% in response to RP-EC and DAP, respectively over simple RP application. Root growth exhibited almost same trend as observed for shoot growth as RP-EC increased 133, 134 and 177% more root fresh mass, root dry mass and root length while DAP increased these parameters by 146, 147 and 274%, respectively over simple RP application.

The uptake of P and P concentration in maize stover were much more in case of DAP application. However, RP-EC also yielded an increase of 166 and 257% in P-concentration and P-uptake, respectively over respective RP alone treatments.

DISCUSSION

Main problem in using the RP is to solublize and enhance availability of P contents (Khan *et al.*, 2009). RP-P is released under acid conditions and for that production of acids (organic & inorganic) can be very useful for solubilization of RP. Composting of organic waste acts as a rich source of organic acids (Nishanth & Biswas, 2008) and thus could be useful for releasing plant available P from RP. In this study different combinations of RP and composted organic waste were investigated as a source of plant available P. it is noteworthy that soil spiked with RP-EC had more plant available content of P compared to directly applied RP and compost. It is very likely that during composting of CD and FW, organic acids were produced, which solubilized P of RP. This may imply that RP-EC can act as excellent source of P. RP-CD product proved better than RP-FW product in terms of release of P. this might be due to the more acidic nature of CD than FW. Previous studies have demonstrated that composting of different wastes generated products of different quality (Ahmad *et al*., 2006).

Results also showed that RP-EC not only provide better amount of available P in soil but also enhanced the growth and yield of maize. This might be due to soluble P released from RP by the organic acids produced during composting but also its impact on soil health. Several scientists reported the importance of compost in increasing the availability of P from RP (Zayed & Motaal, 2005; add more references). Similarly, Biswas and Narayanasamy (2006) have also documented the positive impact of RP-enriched organic fertilizer (OF) as effective organic fertilizer for enhancement of growth and yield of plants. The positive impact of composting is also reported by Nishanth and Biswas (2008) on wheat crop.

In conclusion, RP could be used as a potential suppliment to phosphatic fertilizer for replenish our soils with plant available P if RP is spiked into composting organic wastes at the initial phase of the process. Moreover, this technology is economical and environmental friendly.

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