INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 13, No. 4, p. 8-17, 2018

RESEARCH PAPER OPEN ACCESS

Improving quality of compost by using rock phosphate, sulphur and sulphur oxidizing bacteria

Ghazanfar Naeem[1], Tanveer Iqbal[1*], Ghulam Jilani[1], Arshad Nawaz Chaudhry[1], Muhammad Rashid Hameed[2], Muhammad Rasheed[3], Irfan Ali[4]

[1]Department of Soil Science, PMAS Arid Agriculture University Rawalpindi, Pakistan [2]Soil and Water Conservation Research Institute, Fateh Jang, Pakistan

[3]Department of Agronomy, PMAS Arid Agriculture University Rawalpindi, Pakistan

[4]Department of Horticulture, PMAS Arid Agriculture University Rawalpindi, Pakistan

Key words: Compost, Manure, Phosphorous fractions, Rock phosphate, SOB.

http://dx.doi.org/10.12692/ijb/13.4.8-17 Article published on October 14, 2018

Abstract

Phosphorous (P) is essential macronutrient for plant growth. Pakistani soils are deficient in available P. To overcome this P deficiency enriched compost was prepared by combining different organic and inorganic amendments. Organic amendments included farm yard manure (FYM), green waste (GW) and sulfur oxidizing bacteria (SOB), while inorganic amendments included rock phosphate (RP) and sulfur (S). The aim of this study was to enhance the solubility of RP by composting it aerobically in different combinations with farm yard manure (FYM), green Waste (GW), sulfur (S) and sulfur oxidizing bacteria (SOB). The treatments included control, FYM (80%) + GW (20%), FYM (80%) + GW (20%) + R (4%) and FYM (80%) + GW (20%) + RP (4%) + S (0.5%). There were two sets of above treatments with and without SOB. Compost samples were collected after 30, 60 and 90 days of composting. Parameters to be studied were temperature, EC, pH, total P, Olsen P citric acid soluble P (CSP), water soluble P (WSP), total potassium (K) and total nitrogen (N). Analysis of compost samples revealed higher total P content (4.51%) in RP amended treatment while higher soluble P content (99 mg kg^{-1}) was recorded in RP + S + SOB. Higher total K content (1.20%) was noted in FYM + GW+SOB and higher total N content (2.53%) was noted in FYM + GW + RP + S + SOB. Addition of S and SOB along with RP proved to be very effective regarding dissolution of RP. The results revealed that P content of final compost can be increased by using suitable amendments.

* **Corresponding Author:** Tanveer Iqbal ✉ tanveeriqbal@uaar.edu.pk

Introduction

Phosphorus (P) is an essential macronutrient which is highly unavailable and inaccessible in soil (Vance *et al.*, 2003). A vast area throughout the world is suffering from P deficiency, as a result of high P fixation (Blake *et al.*, 2000). Phosphate (PO_4^-) form chelates to metal cations, clay particles and organic soil material rendering it unavailable for plant uptake. Soil P is also influenced by pH, ionic strength, adsorption and dissolution from clay particles (Vance *et al.*, 2003).To increase the P concentration in soil, different types of manures can be used. These manures include organic wastes such as crop residue, leaves, trimmings and farm yard manure (FYM) (Wang *et al.*, 2011; Li *et al.*, 2014). Composting of organic waste is often carried out to increase nutrients availability in soil by its application (Larney *et al.*, 2006). Composting of wastes from different sources may have different impact on P fractions, which may affect the plant P accessibility (Zvomuya *et al.*, 2006; Ngo *et al.*, 2013). Researchers have used rock phosphate (RP), microorganisms (Chi *et al.*, 2007), elemental S (Stanislawska-Glubiak *et al.*, 2014) and green manuring (Rick *et al.*, 2011) to enhance P solubilisation (Kaur and Reddy, 2014). Rock phosphate is used as raw material for many phosphatic fertilizers. Unfortunately, in basic soils availability of RP is very less (Khasawneck and Doll, 1978). But in basic soils availability of RP can be improved, by using RP together with organic amendments (Biswas and Narayanasamy, 2006). Phosphorous solubilisation by microorganisms is one of the important mechanisms to enhance release of P from insoluble phosphate in the soil (Singh and Amberger, 1998). Availability of P to plants can be improved through microbial processes such as “mineralization” of P through which microorganisms change the organic form of P into inorganic or plant available form and reduce the P precipitation with other ions through solubilisation process (Chen *et al.*, 2006). Phosphorous solubilizing bacteria (PSB) and sulfur oxidizing bacteria have been used to solubilize RP. Different acids are formed during oxidation processes, which react with the insoluble calcium which form strong bond with P compounds and ultimately change them into bio-available, soluble and simple P compound (Khan *et al.*, 2009). Addition of sulphur, in soil reduces pH and increase NH_4-N by inhibiting the volatilization of ammonia gas so nitrogen loss is reduced. Reduction of pH during this process is reported to increase solubilization of RP thus improving P availability (Wenjie *et al.*, 2011). The purpose of this study was to improve the P content of compost by adding RP, SOB and S during the composting process. So that it could be used later on to overcome phosphorous deficiency in alkaline soils.

Materials and methods

Preparation of P-Enriched Compost

Experiment was carried out in the research area of PMAS Arid Agriculture University Rawalpindi, Pakistan. Compost materials included farmyard manure (FYM), green waste (GW), rock phosphate (RP), sulfur (S) and sulfur oxidizing bacteria (SOB). Farm yard manure was collected from animal sheds near university area. Green waste was collected from the lawns of university. Rock phosphate was obtained from National Agriculture Research Center (NARC), Islamabad. Sulfur oxidizing bacteria (SOB) were taken from the Department of Soil Science which were already isolated and used in previous study.

Farmyard manure was air dried before putting in the perforated cemented column of 1m × 1m size. Balance was used to weigh the correct amount of composting materials for use. Before filling the material in the column, FYM and GW were thoroughly mixed. Rock Phosphate and S were also added according to the treatments. The treatments involved: control, FYM (80%) + GW (20%), FYM (80%) + GW (20%) + RP (4%) and FYM (80%) + GW (20%) + RP (4%) + S (0.5%). Another set of treatments were prepared with SOB. SOB used in the compost was 50 times diluted. Composite Compost samples were collected at 30, 60 and 90th day of composting and analyzed for EC, pH, P fractions, K and N on dry weight basis. Moisture content was monitored regularly throughout the composting process. Aeration was provided by turning of compost mixture on weekly basis.

Compost Analysis

Sample Preparation

Five subsamples were taken from different locations of the ring (top to bottom). Then all these subsamples were mixed thoroughly and representative sample was obtained. Compost samples were first dried in an oven at 65°C for 24 hours. After drying, the samples were grinded in plant grinder and stored in plastic bottles.

Analytical Methods

Temperature was monitored by inserting the digital thermometer in compost column at three places after 2 days interval throughout the composting process. Compost samples were analyzed for electrical conductivity (EC) and pH with 1:10 (w/v) compost, water ratio. Olsen phosphorous (OP) and total phosphorus (TP) were determined through extraction method by using 0.5 M $NaHCO_3$ and $HClO_4$-H_2SO_4 respectively following blue color method (Murphy and Riley, 1962). Citric acid soluble phosphorous (CSP) and water soluble phosphorous (WSP) were measured by extraction with 30 ml 2% citric acid solution and distilled water respectively. Phosphorous concentration was measured colorimetrically at 882 nm wavelength (Murphy and Riley, 1962). Total potassium was determined from already digested filtrate. Potassium content was measured directly by flame photometer (JENWAY PEP 7). Total N was analyzed by Kjeldahl method (Van Schouwenberg and Walinge, 1973).

Statistical Analysis

Statistical analysis of data was performed by using Statistix 8.1 and by using (ANOVA) following completely randomized design (CRD). Mean difference was acknowledged at < 0.05 significance level (Steel *et al.*, 1997).

Results and discussion

Temperature

Temperature is very important parameter regarding monitoring of composting process and it determines the degree at which different bio-chemical processes take place (Bustamante *et al.*, 2013). Soon after the materials were arranged in heaps their temperature started increasing.

After 4^{th} day of composting temperature was in thermophilic range (> 45°C) which was a sign that microorganisms were working well due to favorable composting condition (Figure 1).

Table 1. Changes in EC during composting.

	Composting time (days)			
Treatment	EC (dS/m)			
	0	30	60	90
FM	3.1 ab	2.9 b	2.8 d	1.6 e
FM+GW	2.7 b	3.3 b	3.2 cd	2.6 cd
FM+GW+RP	3 ab	3.5 b	3.9 bc	2.1 de
FM+GW+RP+S	3.7 a	4.9 a	4.8 a	4.9 a
FM+SB	3 ab	2.9 b	3.3 cd	2.2 d
FM+GW+SB	2.7 b	3.4 b	3.3 cd	3.4 b
FM+GW+RP+SB	3.1 ab	3.2 b	3.6 cd	3.6 b
FM+GW+RP+S+SB	3.8 a	4.5 a	4.5 ab	4.9 a

FM: Farmyard manure; GW: Green waste; RP: Rock phosphate; S: Sulphur; SB: Sulphur oxidizing bacteria.

Maintaining thermophilic temperature for more than three consecutive days is essential for killing pathogens (Rashad *et al.*, 2010). Highest temperature (58°C) was noted in the treatments amended with SOB. Fast decomposition of low molecular weight compound generates heat which ultimately increases compost temperature (Lopez-Gonzalez *et al.*, 2013). Gradual decrease in temperature was noted as composting proceeded. It might be due to reduced carbonaceous material. Decrease in temperature is a sign of decrease in microbial activity. Decrease in temperature was noted after 68th days. Turning of composting material increased compost temperature for short time and it again came down. However after 80th days of composting no increase in temperature was noted even after turning which was a sign that compost had matured.

pH variations during composting

Initial pH ranged from 6.8 to 8.48 (Table 2) in various treatments. After one month the pH of all the treatments increased except RP and S amended treatments. Treatments without RP and Shad non-significant change in pH from beginning to compost maturity. Initial increase in pH could be due to organic acids degradation and release of different NH_4^+ compound during composting (Lopez-Gonzalez *et al.*, 2013). Rock Phosphate amended treatment showed lower pH which could be due to production of various acids during RP dissolution process (Li *et al.*, 2012), adsorption of NH_4^+ and other cations by RP has also been cited as a reason for decrease in pH (Wong *et al.*, 2009). In present study sulfur amended treatments showed lower pH which could be due to S oxidation into H_2SO_4 (Gu *et al.*, 2011). Sulfur application appeared to have significant effect on compost pH. After 30 days of composting gradual declined in pH was noted in all the treatments. At compost maturity, the final pH values of all the treatments ranged from 6.9 to 8.3. Compost pH in this range has been reported to be normal (Wei *et al.*, 2016).

Table 2. Changes in pH during composting.

Treatment	Composting time (days)			
pH				
	0	30	60	90
FM	8.4 a	8.7 a	8.1 ab	8 ab
FM+GW	8.4 a	8.6 a	8 ab	8.1 ab
FM+GW+RP	7.8 ab	7.6 b	7.4 bc	7 bc
FM+GW+RP+S	6.8 c	6.4 c	6.6 c	6.5 c
FM+SB	8.4 a	8.9 a	8.1 ab	8.2 a
FM+GW+SB	8.4 a	8.4 a	8.6 a	8.1 ab
FM+GW+RP+SB	8.2 a	8.23 a	8.6 a	8.1 ab
FM+GW+RP+S+SB	7.1 b	7.1 b	7.3 b	6.7 c

FM: Farmyard manure; GW: Green waste; RP: Rock phosphate; S: Sulphur; SB: Sulphur oxidizing bacteria.

Electrical conductivity

Electrical conductivity (EC) is an indicator of soluble salts and specifies the quality of compost mixture for application in soil (Karak *et al.*, 2013). Electrical conductivity in different treatments at the start ranged from 2.72 dS/m to 3.8 dS/m (Table 1). Least changes in EC were observed in control and FYM + SOB throughout the composting process. At compost maturity the highest EC (4.94 dS/m) was noted in RP + S + SOB and the lowest EC (1.67 dS/m) was noted in control. Electrical conductivity in RP, S and SOB amended treatments increased which could be due to greater release of SO_4^{-2} as a result of S oxidation process which consequently contributes in the EC of compost (Roig *et al.*, 2004).

Total phosphorous

Total phosphorous (TP) content improved in all the treatments with composting process. However comparatively higher P content was noted in the treatments with RP application (Table 3). At the start of composting P content ranged from 0.51% to 1.85% while at the end of composting it ranged from 2.06% to 4.51%. Rock phosphate used in this study had 24% TP and its addition appeared to have improved the P content. Similar findings were also reported by Wei *et* *al.* (2016). Nishanth and Biswas (2008) reported improved P content of rice straw compost when it was treated with RP. Loss of carbonaceous material as CO_2 during the composting process could be another reason for improved P content (Lu *et al.* 2014). This phenomenon is supported by the reduction of compost volume.

In our study heaps of composting material was reduced to half volume at compost maturity.

Table 3. Changes in total P (TP) and Olsen P (OP) during composting.

Treatment	Composting time (days)							
	TP (%)				OP (gkg^{-1})			
	0	30	60	90	0	30	60	90
FM	0.5b	1.6 a	1.9 b	2.1 b	0.8 a	1.02 d	1.2 b	1.3 d
FM+GW	0.5 b	1.7 a	2.01b	2.1 b	0.87 a	1.14 d	1.3 b	1.6 d
FM+GW+RP	2.0 a	2.51a	3.2 a	4.51a	0.89 a	1.51bc	1.9 b	2.1 c
FM+GW+RP+S	1.9 a	2.5 a	3.1 a	4.1a	0.93 a	1.93 a	2.4 a	2.8 a
FM+SB	0.5 b	1.7 a	2.1 b	2.1 b	0.89 a	1.15 d	1.2 b	1.6 d
FM+GW+SB	0.6 b	1.9 a	2.1 b	2.2 b	0.9 a	1.2 cd	1.5 b	1.6 d
FM +GW+RP+SB	1.9 a	2.4 a	3.1a	4.2 a	1.02 a	1.8 ab	2.2 a	2 bc
FM+GW+RP+S+SB	1.85 a	2.3 a	3.03 a	4.07 a	0.95 a	1.97 a	2.6 a	2.8 a

FM: Farmyard manure; GW: Green waste; RP: Rock phosphate; S: Sulphur; SB: Sulphur oxidizing bacteria.

Water soluble phosphorous

Water soluble phosphorous (WSP) is one of the most important bio-available forms of P generally taken up by plants. Initially, the difference in terms of WSP was small among the treatments and it increased as the composting proceeded. At the start of composting, it ranged from 39 mg kg^{-1} in control to 43 mg kg^{-1} in RP + S + SOB. At 30th day of composting, the highest WSP content (58 mg kg^{-1}) was noted in unamended treatment (FYM 80% + GW 20%).

Table 4. Changes in citric acid soluble P (CSP) and water soluble P (WSP) during composting.

Treatment	Composting time (days)							
	CAP (gkg^{-1})				OP ($mgkg^{-1}$)			
	0	30	60	90	0	30	60	90
FM	0.41a	0.55b	0.67a	0.73b	39a	55a	63b	73b
FM+GW	0.43a	0.54b	0.69a	0.76ab	42a	58a	70ab	78b
FM+GW+RP	0.44a	0.65ab	0.74a	0.82ab	40a	47a	59b	69b
FM+GW+RP+S	0.45a	0.71ab	0.83a	0.90ab	42a	62a	68ab	73b
FM+SB	0.42a	0.54b	0.68a	0.74b	41a	54a	69ab	75b
FM+GW+SB	0.44a	0.58ab	0.71a	0.78ab	43a	57a	76ab	83ab
FM +GW+RP+SB	0.46a	0.67ab	0.79a	0.85ab	41a	54a	67ab	72b
FM+GW+RP+S+SB	0.46a	0.73a	0.84a	0.92a	43a	57a	81a	99a

FM: Farmyard manure; GW: Green waste; RP:Rock phosphate; S: Sulphur; SB: Sulphur oxidizing bacteria.

The lowest WSP content (47 mg kg^{-1}) was noted in RP amended treatment (FYM 80% + GW 20% + RP 4%). Higher WSP in FYM 80% + GW 20% could be due to the release of soluble P during the decomposition of organic material (Galvez-Sola *et al.*, 2010). The reduction of WSP content in RP amended treatments could be due to different reactions which take place during composting. During these reactions, soluble P reacts with the components of RP like $CaCO_3$, due to which soluble P content can decrease in RP amended treatments (Lu *et al.* 2014). At compost maturity highest WSP content (99 mg kg^{-1}) was observed in RP + S + SOB. Higher P content could be attributed to the application of S and inoculation of *Thiobacillus* which might have enhanced dissolution of RP and release of soluble contents by reducing the pH and producing different acids (Aria *et al.*, 2010).

Table 5. Changes in total K and N during composting.

Treatment	Composting time (days)							
	K (%)				N (%)			
	0	30	60	90	0	30	60	90
FM	0.5 a	0.7 a	0.9 a	0.9 a	1.4 a	1.3 b	1.7 d	1.8 d
FM+GW	0.5 a	0.7 a	0.9 a	1.1 ab	1.4 a	1.3 b	1.78 cd	1.93 cd
FM+GW+RP	0.4 a	0.5 a	0.7 b	0.8 ab	1.5 a	1.28 c	1.9 bcd	2.2 abc
FM+GW+RP+S	0.4 a	0.6 a	0.7 b	0.8 b	1.5 a	1.3 cd	2.1 abc	2.3ab
FM+SB	0.5a	0.7a	0.9a	1.0 a	1.4 a	1.3bc	1.7 cd	1.8 d
FM+GW+SB	0.5 a	0.8 a	0.9 a	1.2 a	1.5 a	1.2 d	1.9 bcd	2.2 bcd
FM+GW+RP+SB	0.5 a	0.6 a	0.7 b	0.8 ab	1.5 a	1.4 ab	2.1 ab	2.3 ab
FM+GW+RP+S+SB	0.4 a	0.6 a	0.8 b	0.8 a	1.5 a	1.4 a	2.3 a	2.5 a

FM: Farmyard manure; GW: Green waste; RP: Rock phosphate; S: Sulphur; SB: Sulphur oxidizing bacteria.

It is already known that solubility of RP in alkaline condition is negligible while only under acidic environment its dissolution takes place (Biswas *et al.*, 2009). Olsen phosphorous (Olsen-P) is very important indicator of available P in compost prepared from different organic waste materials. Olsen-P showed increasing trend throughout the composting process. Higher Olsen-P content was noted in RP amended treatment.

Initially, difference among the treatments was no significant. After 60 days of composting significant differences was noted in RP amended treatments. Olsen-P value ranged from 0.95 g kg^{-1} to 2.56 g kg^{-1} at 60th day of composting.

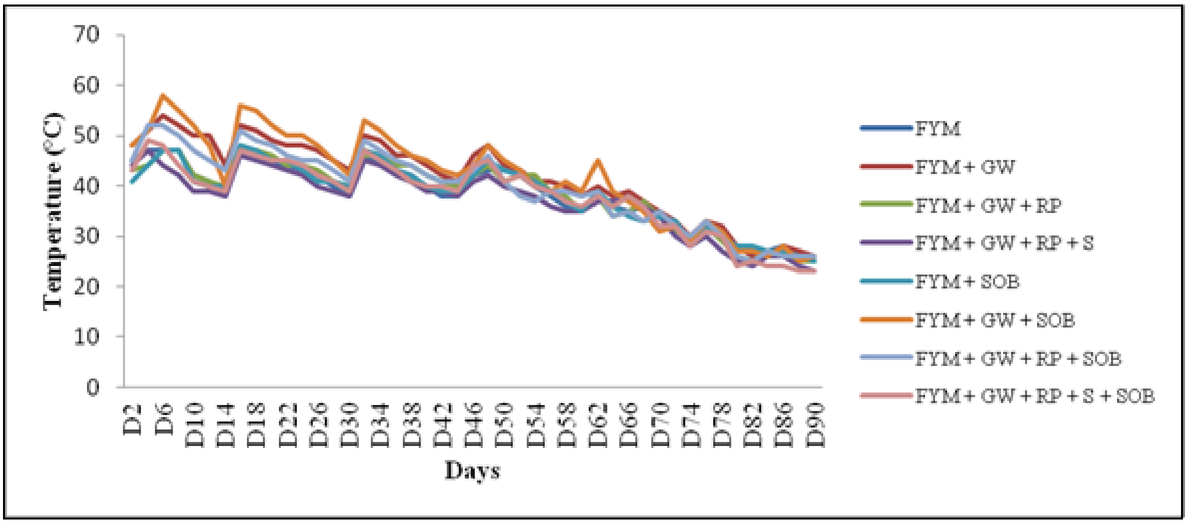

Fig. 1. Temperature variations during composting.

This higher value of Olsen-P could be due to solubilisation of RP by SOB and resultant low pH of the medium (Evans *et al.*, 2006). Citric acid soluble and water soluble P also contributes to Olsen-P content (Biswas and Narayanasamy, 2006). Furthermore during decomposition process, microorganisms secrete some enzymes like phytases and phosphatases, which help to mobilize fixed P in RP (Nishanth and Biswas, 2008). At compost maturity higher Olsen-P content was noted in RP + S + SOB which could be due to the addition of S and SOB in RP amended treatment increasing the available P content in compost mixture by acidulation (Evans *et al.*, 2006).

Citric acid soluble P

Citric acid soluble P (CSP) is important P fraction showing easily available form of P. Citric acid soluble P was also affected positively during composting. At start CSP content ranged from 0.41 g kg^{-1} in FYM 100% to 0.46 g kg^{-1} in FYM 80%+GW20%+RP4%+S0.5%+SOB (Table 4). At 30th day of composting, the highest value of CSP content was noted in RP+S+SOB, where it was 0.73 g kg^{-1}. Same treatment showed the highest CSP even at compost maturity stage. It was followed by FYM80%+GW20%+RP4%+S0.5% where CSP was 0.71 g kg^{-1}. The lowest CSP content (0.54 g kg^{-1}) was noted in FYM 100% + SOB. Higher value of CSP could be due to increased quantity of RP and its subsequent solubilization by microbial activity. Similar effect was also reported by Biswas and Narayanasamy (2006). In their study they found that rice straw compost amended with RP had higher CSP content (1.53%) than un-amended compost (0.89%). They attributed higher CSP to obvious contribution of P from RP during composting process (Moharana and Biswas, 2016). In present study among RP amended treatments, highest value of CSP was noted in RP + S + SOB. Addition of S and SOB appears to have positive effect on CSP content. Their activities reduce the pH and thus increased the solubilization of RP. Ghani *et al.* (2002) reported 9 times increase in RP solubilization by the addition of S and SOB. Considerable variations were noted in potassium content of compost.

Extractable K

At the beginning, K content varied from 0.43% in FYM80%+GW20%+RP4% to 0.56% in FYM80%+ GW20%+SOB (Table 5). Potassium content improved with the passage of time. At the end of ninety days the highest total K content (1.20%) was noted in un-amended treatment and lowest K content (0.75%) was noted in RP amended treatments. In the treatments amended with RP comparatively lower K content was recorded. It could be due to the dilution effect caused by the addition of RP. Rock phosphate used in this study was highly deficient in K (Iqbal *et al.*, 2014). So its addition rather diluted K content. Similar behavior was also reported by Nishanth and Biswas (2008). They reported higher K content in simple rice straw compost while in combinations involving application of waste mica and RP reduced K content were recorded.

Nitrogen

At 0 day of composting, N content of compost treatments varied non significantly. It ranged from 1.44% to 1.53%. Compost samples analysis at 30th day of composting showed low level of N while the sampling at 60th and 90th day of composting showed higher N content. In fact the N content gradually improved after 30th day of composting, and it continued till 90th day of composting. Loss of carbonaceous material in the form of CO_2 as indicated by reduction in compost volume could be one reason. Loss of carbon leads to enhanced N content (Biswas *et al.*, 2009; Wei *et al.*, 2015). The highest N content (2.53 %) was noted in FYM+GW+S+SOB. Gua *et al.*, (2017) have attributed this increase in N content to the addition of S and SOB. These microbes oxidize S to SO_4^+ which reacts with ammonium ions to form more stable products. This finding is further verified by this study.

Conclusion

It was concluded from this study that phosphorus content of compost could be improved by the combined application of rock phosphate, elemental sulphur and sulphur oxidizing bacteria under aerobic conditions.

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