Applied Soil Ecology 113 (2017) 80–85

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Enhancement of applicability of rock phosphate in alkaline soils by organic compost

Hemendra Yadav*, Rukhsar Fatima, Ankita Sharma, Sujata Mathur

Department of Botany, University of Rajasthan, Jaipur, Rajasthan, India

ARTICLE INFO

Article history:
Received 16 August 2016
Received in revised form 20 December 2016
Accepted 4 February 2017
Available online 11 February 2017

Keywords:
Rock phosphate
Compost
Phosphate mines
Thermotolerant
Phosphate solubilizing bacteria

ABSTRACT

Rock phosphate is a natural phosphorus source but unfortunately we lack robust technologies to make it applicable in alkaline soils. In this study we tried to charge organic compost with rock phosphate in different concentrations along with thermotolerant phosphate solubilzing bacteria isolated from phosphate mines having Fe-P, Al-P solubilizing ability along with Tri Calcium Phosphate and Rock Phosphate. Concentration of RP and compost showing maximum soluble P was used in pot experiments to study its effect on growth of plants. We found that 75:25 ratio of compost and rock phosphate showed maximum soluble P and found higher plant growth as compared to plants fertilized with normal compost and rock phosphate.

1. Introduction

Phosphorus (P) is a major key nutrient for plants and affects several characteristics of plant growth. Though P, both in organic and inorganic forms is abundant, but due to its ability to form complexes with other soil constituents, it is not easily available for uptake by the plants (Takahashi and Anwar, 2007; Khan et al., 2009). Around 60–70% of the P applied to soils in the water soluble forms is unavailable to the plants as applied phosphorous is converted to immobile form by Fe, Al, Mn ions in acidic soils and by Ca, Mg ions in alkaline soils into complexes that plants cannot take up (Gyaneshwar et al., 2002). Therefore, frequent application of important amounts of chemical fertilizers containing soluble forms of P is needed to achieve maximum plant productivity (Gyaneshwar et al., 2002).

Production of chemical fertilizers is based on chemical processing of insoluble mineral phosphate (high-grade ore) by treating them with sulfuric acid at high temperature. Thus, the process is environmentally undesirable and a costly affair (Vassilev et al., 2006). Excessive and indiscriminate application of chemical fertilizers show adverse impact on the soils in that soil micro flora and fauna (which impart natural properties to the soils) are destroyed thereby resulting into decreased agricultural production after years of application. Rock Phosphate (RP) is a natural phosphorus source which can be an alternative to chemical fertilizers; unfortunately it is soluble in acidic soils only and is not applicable in alkaline soils. Microbial solubilization of rock phosphate is gaining importance as microbes release organic acids to solubilize rock phosphate which are having ability to solubilize rock phosphate. Phosphate solubilizing bacteria having ability to solubilize rock phosphate can be used for solubilization of rock phosphate (Yadav et al., 2014). Phosphate solubilization by bacteria is more efficient than fungi and bacterial processes are much easier for industrial application. Rock phosphate can be used along with phosphate solubilizing bacteria for its direct application in alkaline soils. Efficiency of both can be increased when both are used simultaneously in a nutrient medium such as compost. It has been observed that farm yard manure (FYM) enriched with high grade (+34% P_2O_5) rock phosphate in fine size (d80 at 23 μm) shows better agronomic efficiency than di-ammonium phosphate when applied on equal P_2O_5 basis (Sekhar et al., 2002).

Compost preparation is very popular in Asian countries as a means of recycling agricultural by-products, poultry, livestock, industrial, and municipal wastes. The application of compost to soil can improve the soil quality, supply nutrients to plants and soil microbes, and reduce environmental pollution (Yang, 2003). Further organic matter (that matrixed rock phosphate particles) complexes soil cations, thereby preventing fixation of P. Composting is a microbiological process that transforms various organic wastes into biofertilizers and soil conditioners. Inoculation of the appropriate microbes during compost preparation can shorten the maturity period and improve the quality of compost (Yang and Chen, 2003; Zayed and Abdel-Motaal, 2005a, 2005b; Biswas and Narayanasamy, 2006). Thus compost is an ideal medium to

* Corresponding author.
E-mail address: Yadavhemendra1@gmail.com (H. Yadav).

http://dx.doi.org/10.1016/j.apsoil.2017.02.004
0929-1393/

increase the efficacy of rock phosphate and appears to be the best medium for direct application of rock phosphate in alkaline soils, compost charged by rock phosphate along with thermotolerant phosphate solubilizing bacteria can be used as an efficient P fertilizer.

One major hindrance in applicability of the rock phosphate is high Fe-P and Al-P and R_2O_3 (R- > Fe, Al and Cr) content present in various rock phosphate. High Fe-P and Al-P content containing rock phosphate is hard to solubilize even by acidic treatment. For biological treatment of such rock phosphate we need to isolate phosphate solubilizing bacterial strains having the ability to solubilize Fe-P and Al-P. Phosphate solubilizing ability of PSBs (Phosphate Solubilizing Bacteria) has been traditionally associated with the production of low-molecular-weight organic acids (Rodriguez and Fraga, 1999; Goldstein, 2000; Chen et al., 2006). These acids diffuse freely outside the cells and facilitate solubilization of P from mineral phosphates in high amounts by supplying both protons and metal complexing organic acid anions (Gadd, 1999). Phosphate solubilizing bacteria having ability to solubilize Fe-P and Al-P can solubilize rock phosphate, having high Fe and R_2O_3 content, efficiently and can be helpful in solubilizing rock phosphate. Such bacterial strains can be isolated from phosphate mines rich in Fe-P and Al-P content. PSBs having ability to solubilize Fe-P and Al-P release organic acids specific for solubilization of insoluble phosphatic salts. PSBs can retain in compost for long period of time and thus extract P from RP. However, most of the phosphate-solubilizing bacteria studied and applied to date have been mesophiles that could only be used under mesophilic conditions. These types of bacteria are not appropriate for usage in compost preparation as the high temperature (over 50 °C) that occurs during the first stage of composting (Yang and Chen, 2003) is not favorable to their growth. We isolated thermotolerant phosphate solubilizing bacteria having the ability to solubilize Fe-P and Al-P alongwith rock phosphate from phosphate mines of Jhamarkotra.

Therefore, in order to develop a cost effective, eco-friendly and sustainable system where the supply of phosphorus to plants can be ensured, this study was undertaken to explore the possibility of increasing the availability of P from low-grade rock phosphate incorporated during decomposition of organic matter in organic compost. Enhancement of applicability of rock phosphate in alkaline soils as a fertilizer in direct application by adding rock phosphate and thermotolerant phosphate solubilizing bacteria having the ability to solubilize RP along with Fe-P and Al-P was the main objective of our study. Organic compost enriched by rock phosphate in different concentrations along with and without phosphate solubilizing bacteria was used to study potential biochemical transformations of P to evaluate the products through an incubation study and a greenhouse experiment.

2. Materials and methods

2.1. Site and sample collection

Soil samples were collected in October 2011 from Jhamarkotra rock phosphate mines, near Udaipur city (Rajasthan, India), located at latitude 24° 27′ 30” to 24° 29′ 30” and longitude 73° 49′ to 73° 52”. The phosphate ore of these mines have high iron content and associated with broken phosphatic columnar and laminated stromatalite fragments (Dwivedi and Gupta, 2006). The main minerals present at the sampling site are the dolomite, fluorapatite, apatite, quartz, calcite and micas. Samples were collected from upper 30 cm of the soil surface. They were collected in sterile plastic bags and vials and transported immediately to the laboratory, stored at 4 °C and finally processed within 96 h. The chemical compositions of the samples were 5.9–22.5% P_2O_5, 0.012–0.023% Nitrogen, 0.14–0.27% Organic Carbon, 0.75–1.1 $\mu g\,g^{-1}$ Zn, 4.82–8.52 $\mu g\,g^{-1}$ Fe, 0.22–0.32 $\mu g\,g^{-1}$ Cu, 0.26–0.88 $dS\,m^{-1}$ electrical conductivity and soil pH in the range of 7.8–8.5.

2.2. Isolation and screening of thermotolerant phosphate solubilizing bacteria

Isolation, screening and selection of thermotolerant phosphate solubilzing bacteria was done by method as described in our previous publication (Yadav et al., 2015) in which isolated cultures were grown on PKV (Pikovskaya, 1948) agar plates amended with Fe-P, Al-P, RP-J (Rock Phosphate -Jhamarkotra) and TCP. Cultures grown on each and every type of amended PKV plates efficiently at 50 °C were selected and were used to extract P from RP when mixed in compost alongwith RP, their phylogenetic affiliations has been reported in our previous study (Yadav et al., 2015). Cultures used belong to *Brevibacillus* and *Bacillus* genera and were able to solubilize Fe-P, Al-P and RP in higher quantities as compared to previous studies. Following cultures were used *Brevibacillus* sp. BISR-HY07, *Brevibacillus* sp. BISR-HY65, *Brevibacillus* sp. BISR-HY55, *Brevibacillus* sp. BISR-HY62, *Brevibacillus* sp. BISR-HY64, *Brevibacillus* sp. BISR-HY66, *Brevibacillus* sp. BISR-HY43 and *Bacillus* sp. BISR-HY63. Quantification of soluble P was done by molybdenum method (Bray and Kurtz, 1945) by taking KH_2PO_4 as standard. The soluble P was expressed in terms of $mg\,L^{-1}$ P released in the culture medium.

2.3. Enrichment of organic compost by rock phosphate and phosphate solubilizing bacteria

Raw material for compost formation consist of 10 kg agriculture waste (straw) with 2.5 kg fresh dung and 1.25 kg organic kitchen waste followed by moistening up to 3% level and finally stirred well

Table 1
Chemical constituents of the Low-Grade Rock Phosphate samples used in this study from two different mine sources.

S.No.	Chemical constituents* (%)	Jhamarkotra Rock Phosphate (RP-J)	Purulia Rock Phosphate (RP-P)
1.	Phosphorus (as P)	7.54	9.42
2.	Silica (as SiO_2)	Max. 9	8.3
3.	Magnesium oxide (MgO)	10 ± 2	5.8
4.	Calcium oxide (CaO)	Not determined	39.4
5.	R_2O_3**	<3	Not determined
6.	Fe	0.68	0.87
7.	C	Not determined	0.9
8.	F	Not determined	4.1

* As provided by the supplier.
** Metal oxides of Fe, Al and Cr.