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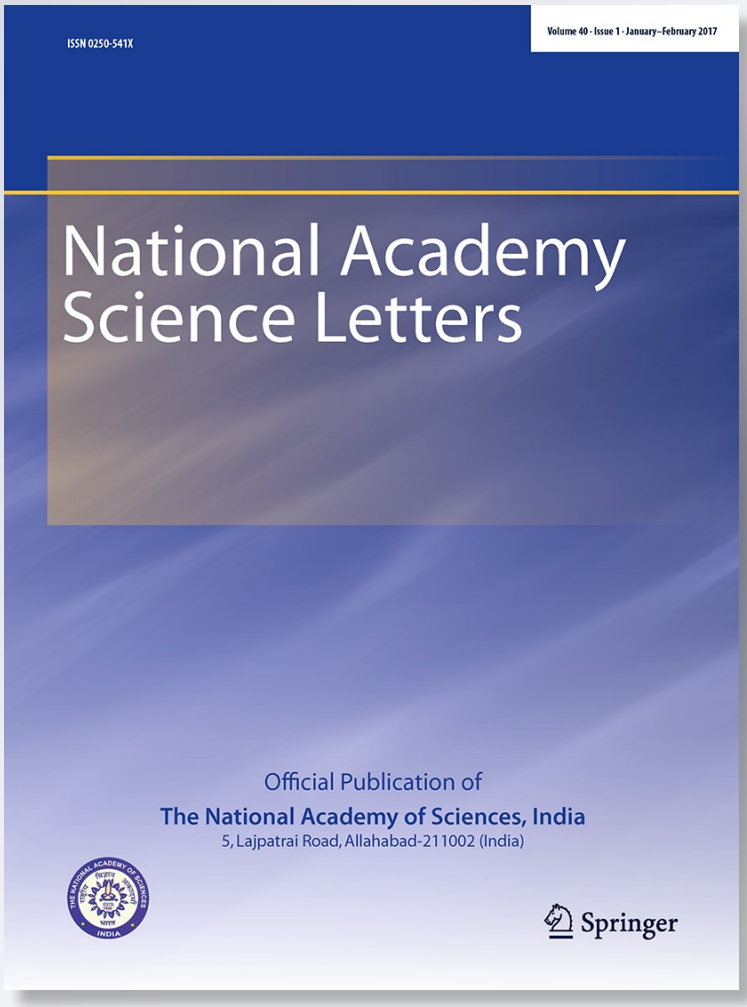

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SHORT COMMUNICATION

Phosphorus Solubilization Through Organic Acids Production in Pressmud Composted with Rockphosphate

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Abstract Rockphosphate enriched pressmud compost (RPEPMC) was prepared by mixing fresh pressmud with rockphosphate (RP) inoculated with a composite microbial culture consisting of *Pseudomonas* spp., *Aspergillus* spp., *Streptomycetes* spp., *Penicillium* spp. and *Trichoderma* spp. at 0.1 % (w/w) level. The production of organic acids and solubilization of phosphorus during pressmud composting was studied at 30, 60, 90 and 120 days of composting. The presence of oxaloacetic, citric, succinic, tartaric, malic and maleic acids in the compost was detected and quantified. In general the organic acids produced at 30 days were highest which rapidly decreased at 120 days of composting. The positive influence of various organic acids on solubilization of P from RP was evident from concomitant increase in citrate-soluble and water-soluble-P content in the compost. After 120 days of composting the end product had a stable C:N ratio and higher soluble P. Thus RPEPMC could be an alternative source of P fertilizer in crop production.

Keywords Pressmud · Rockphosphate · Compost · Organic acids · Soluble P · C:N ratio

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In present-day agriculture, the recycling of agricultural and industrial wastes is of prime importance not only because it adds much needed organic matter that improves physical and microbiological properties of soil but also supplements sufficient amount of nutrients to the soil. The nutrient potential of all biological and industrial wastes has been estimated at about 19.11 Mt in India [1]. India is the second largest sugar-producing country in the world, and sugar industries discharge about 5, 45 and 7.5 Mt annually of pressmud (PM), bagasse and molasses, respectively, as wastes [2]. Rock phosphate (RP) is basically tri-calcium phosphate with non available P [3] to plant and is the main raw material for preparing chemical phosphatic fertilizers by treating mostly with sulphuric acid (H_2SO_4). However, the feasibility of commercial production for P fertilizers by partial acidulation and compaction are low due to the cost involved in those methods. Composting of organic materials with RP may serve as a viable option to meet the crops' P requirements.

It is generally assumed that organic acids produced during composting are mainly responsible for solubilizing the insoluble phosphates [4, 5]. Solubilization of organic P by organic acids is mainly achieved by complex formation between organic acid anions and metal ions such as Fe, Al and Ca [6]. Addition of acid producing microbes can further enhance the P availability. The mechanism behind the solubilization of P from RP by microorganisms is also mostly related to the production of organic acids and chelating substances [7]. The objectives of the study were (i) to characterize and quantify various organic acids namely, oxaloacetic, citric, succinic, tartaric, malic and maleic acids produced, and (ii) to study the changes in C:N ratio, total, citrate-soluble and water-soluble P_2O_5 contents in rockphosphate enriched pressmud compost (RPEPMC) at various stages of decomposition.

The fresh PM was collected from Daurala Sugar Works, Uttar Pradesh, India. The low-grade RP was obtained from Rajasthan State Mines and Minerals Ltd., Udiapur, Rajasthan. The PM had following properties: total P_2O_5 2.11 %; citrate-soluble P_2O_5 0.10 %; water-soluble P_2O_5 0.08 %; organic C 32.6 % and nitrogen 1.20 %. The RP had following properties: total P_2O_5 20 % and citrate-soluble P_2O_5 0.06 %. RPEPMC was prepared in the Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi by composting PM and RP mixture in the ratio of 20:1. Composite microbial culture consisting of *Pseudomonas* spp., *Aspergillus* spp., *Streptomycetes* spp., *Penicillium* spp. and *Trichoderma* spp. was added and thoroughly mixed to ensure complete contact with the decomposing materials. Moisture content at 70 % was maintained throughout the composting period. Three replicates of samples were collected periodically at 30, 60, 90 and 120 days.

Organic acids were extracted with 0.85 M NaF from 50 g moist compost (equivalent to dry compost) and were determined using high-performance liquid chromatography (HPLC) with buffer solution of 0.05 M KH_2PO_4 [8]. Total organic C in compost was determined by wet oxidation method [9]. Total N was determined by the method outlined by Bremner [10]. Total P content in the compost was analyzed by yellow colour method [11]. Water-soluble phosphorus and citrate-soluble phosphorus were determined as per the procedure outlined by Fertilizer Control Order [12]. The data was analyzed statistically and critical difference was used to compare the treatment means at 5 % probability level [13].

The concentration of organic acids which were detected at 30, 60, 90 and 120 days in compost is listed in Table 1. Oxaloacetic, citric, succinic, tartaric, malic and maleic acids were detected during composting. A sharp and significant decline in production of various organic acids was noticed with the progression of composting time from 30 to 120 days, except the succinic acid which showed a significant increase in its concentration from 30 to 60 days. These low-molecular-weight organic acids were produced due to decomposition of pressmud and had a transitory existence. The amount of organic acids present in compost at any given point of time is a balance between synthesis and destruction processes carried out by micro-organisms [14]. Under optimum conditions, the added microbial culture consisting of *Pseudomonas* spp., *Aspergillus* spp., *Streptomycetes* spp., *Penicillium* spp. and *Trichoderma* spp., utilize the organic matter as their sole source of carbon resulting into decomposition of organic matter and production of organic acids. Fox and Comerford [15] also made similar observations that decomposition of organic matter produced a range of low-molecular-weight organic acids. The concentration of organic acids from the extracts of RPEPMC decreased significantly with increase in the period of composting due to precipitation of these acids with cations released from RP dissolution [5].

The periodic changes in total C, total N and C:N is presented in Fig. 1. A significant reduction in total organic C content from 32.6 to 14.3 % was noticed from start of the experiment to 120 days of composting. At the end of composting period, about 43 % of the total organic carbon was lost as compared to its initial value. Such loss of organic C is attributed to high microbial activity and faster decomposition of labile pool of C in PM. Atkinson et al. [16] reported that during composting of poultry litter with saw dust, about 29 % C was lost as carbon dioxide. The higher reduction in organic C might be due to more labile nature of PM. A gradual increasing trend of total N with progression in composting period from 30 to 120 days showed that no significant difference existed between the values of total N (Fig. 1). The C:N ratio followed the trend similar to C content, which decreased significantly from 27.2 to 10.2 as a consequence of progression in composting period from 30 to 120 days (Fig. 1). Similar observations were made by Bhanawase et al. [17] who reported that the addition of RP resulted in lower C:N ratio in wheat straw compost.

RPEPMC prepared through PM significantly enhanced the content of total P_2O_5 in final product (Fig. 2). Total citrate-soluble and water-soluble P_2O_5 content in RPEPMC increased gradually from 30–120 days. Total P_2O_5 and citrate-soluble P_2O_5 contents in RPEPMC significantly

Table 1 Quantity of organic acids identified during composting of fresh pressmud with rockphosphate

Composting period (days)	Organic acids (μg/g)						LSD ($P = 0.05$)
	Oxaloacetic	Citric	Succinic	Tartaric	Malic	Maleic	
30	343	322	274	255	248	195	11
60	167	127	298	104	204	54	12
90	67	50	123	34	65	21	12
120	14	nd	11	18	18	nd	5.0
LSD ($P = 0.05$)	16	6.0	11	9.0	13	10	

LSD least significant difference; *nd* not detected

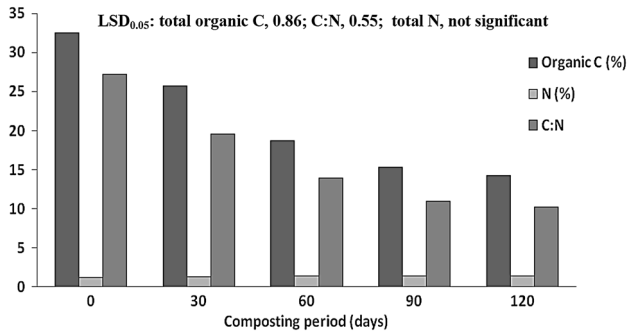

Fig. 1 Changes in total organic C, total N and C:N during composting of fresh pressmud with rockphospahte

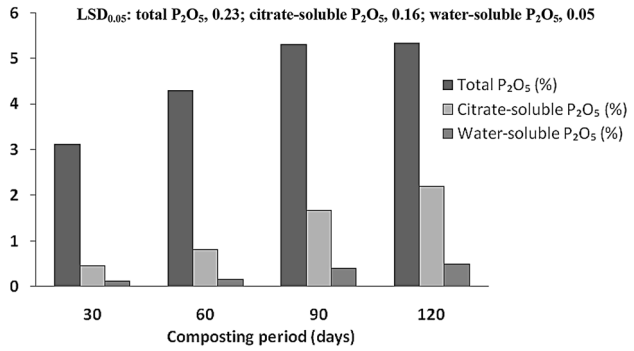

Fig. 2 Total citrate-soluble and water-soluble P_2O_5 content rockphospahte enriched pressmud compost at different intervals

varied between the days of composting, while water-soluble P_2O_5 content in RPEPMC at 30 days was not significant as compared to 60 days. This may be due to solubilization of P compounds by organic acids through complex formation between organic anions and metal ions. Similar, observations were recorded by Singh and Amberger [5]. Further, the decomposition of organic manures leads to evolution of large quantity of carbon dioxide, and forms weak carbonic acid resulting into dissolution of RP. Thus, P availability as well as efficiency of RP increases [18].

The relationships between different P_2O_5 fractions versus days of composting have been presented through various regression equations (Fig. 3a–c). The prediction of changes in total P_2O_5 content in RPEPMC is best fitted in a logarithmic curve with a very high R^2 value of 0.99. The relationship of citrate-soluble P versus days of composting is best explained by exponential equation ($R^2 = 0.97$), while the water-soluble P_2O_5 content with days best fitted in polynomial equation ($R^2 = 0.94$).

In conclusion, the production of organic acids namely oxaloacetic, succinic, citric, tartaric, malic and maleic during preparation of RPEPMC might be responsible for solubilization of P from rockphosphate. The rockphosphate enriched pressmud compost prepared over 120 days period with stable C:N ratio and higher P_2O_5 content (total, citrate-soluble and water-soluble) could be an

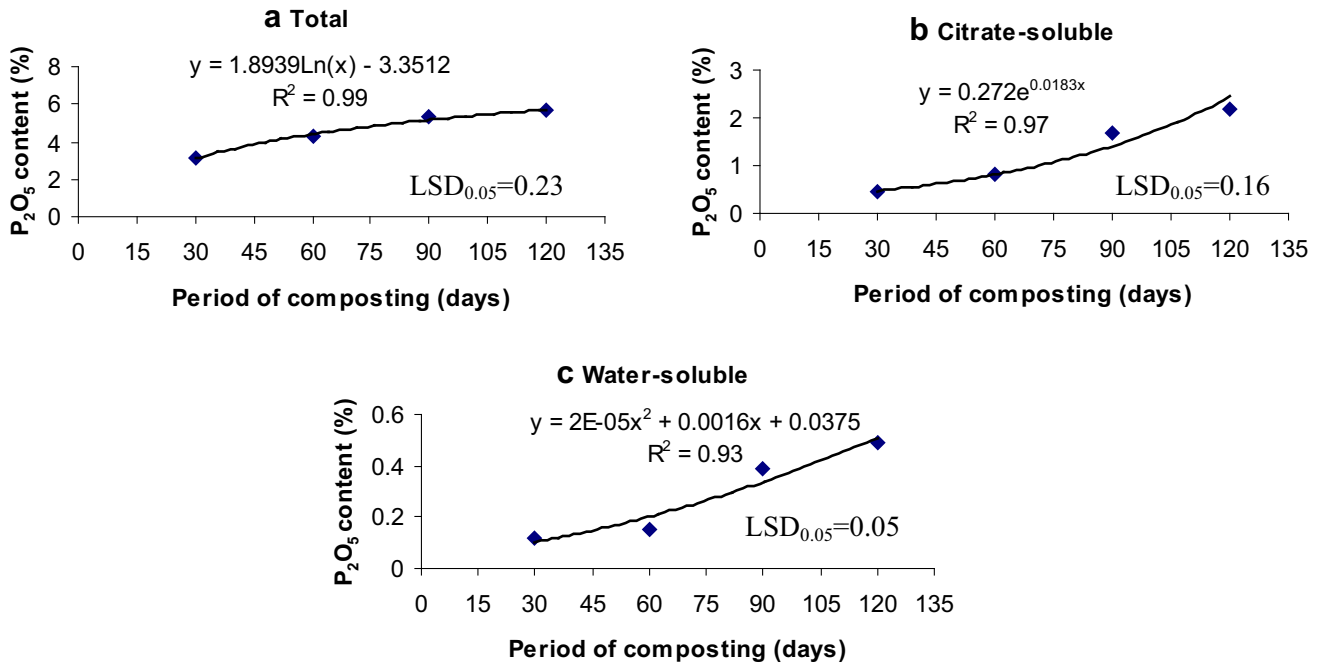

Fig. 3 Rate of changes in P_2O_5 **a** total, **b** citrate soluble and **c** water soluble during composting

economically attractive source of P as compared to costly chemical fertilizer like DAP in crop production.

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