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The Impact of Conditioning Periods and Rock Phosphate on Phosphorus Enrichment, Total Nutrient Content and Microbial Count in Compost

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ABSTRACT: A field experiment was conducted at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat) during the years 2021 and 2022. The experiment was laid out in completely randomizes design for preparing phosphorus enriched compost. Treatments including E_1: Only Compost, E_2: Compost + 400% RDP of rice through rock phosphate and E_3: Compost + 600% RDP of rice through rock phosphate, were enriched for 20, 40 and 60 days. Periodical changes and tabular analysis worked out for solubility of phosphorus and total nutrient content in different interval as well as total microbial count from the enriched compost. The treatments for compost enrichment including T_1: 0 days conditioned compost, T_2: 0 days conditioned 400% RDP compost, T_3: 0 days conditioned 600% RDP compost, T_4: 20 days conditioned compost, T_5: 20 days conditioned 400% RDP compost, T_6: 20 days conditioned 600% RDP compost, T_7: 40 days conditioned compost, T_8: 40 days conditioned 400% RDP compost, T_9: 40 days conditioned 600% RDP compost, T_{10}: 60 days conditioned compost, T_{11}: 60 days conditioned 400% RDP compost and T_{12}: 60 days conditioned 600% RDP compost. The experiment was conducted for two consecutive years. Based on the results of two years experimentation, it can be concluded that rock phosphate enriched compost is proven to alternative with chemical phosphatic fertilizers. Enriched compost for 40-60 days with 600 % RDP through rock phosphate, enhanced water-soluble phosphorus, ensured total nutrient levels and fostered a thriving microbial environment.

Keywords: Conditioning periods**,** Enrichment**,** Rock phosphate, Solubility of phosphorus, Total nutrient content and Total microbial count.

INTRODUCTION

The widespread and indiscriminate application of chemical fertilizers and pesticides in agriculture has led to a decline in crop productivity, diminished efficiency in fertilizer utilization, accelerated environmental degradation and the deterioration of soil health. This poses a significant threat to the sustainability of agriculture, ecological equilibrium and human health.

However, there is a growing awareness of the impending dangers associated with such practices. People are increasingly interested in adopting sustainable crop production methods, such as the heightened use of organic manures, to rejuvenate and preserve soil fertility, as well as to restore microbial activity in the soil. Traditional sources of organic nutrients, including farmyard manure, animal wastes and compost, have been conventionally employed for enhancing soil fertility and crop yields. Nonetheless, their limited nutrient content, unwieldy nature, handling challenges and labour-intensive application have hindered widespread adoption by growers.

To address these challenges, there is a shift towards enriching composts by incorporating both mineral (rock phosphate) and biological additives (PSB and *Azotobactor*). This enrichment offers numerous benefits to crops, including increased yields, improved quality, enhanced resistance to diseases and pests and greater availability of essential nutrients. Simultaneously, the enrichment process has the potential to reduce bulkiness, overcoming a significant limitation associated with traditional organic manures.

Phosphorus is required by the plants for optimum growth and yield. But it is considered as limited factor of many crop production system, due to its unavailability of soluble forms in the soils. About 80% of applied P fertilizers are immobilized due to the formation of complex with Al or Fe in acidic soils or Ca in calcareous soils (Nisha *et al*. 2004). The P content in an average soil is about 0.05% (w/w) but only 0.1% of the total P is available to plant because of poor solubility and its fixation in soil (Illmer and Schinner 1995). Unfortunately, Phosphatic fertilizer are not readily available to the plants in soils with a pH > 5.5-

6.0. Because of this, extension services are reluctant to be recommended and farmers are hesitant to utilize phosphatic fertilizer directly. Several P-solubilizing microorganisms have the ability to convert insoluble low grade rock phosphates into soluble forms available for plant growth.

Rock phosphate reserves are not found everywhere. It is geographically concentrated in few countries and this concentration of reserves poses uncertainty for future agriculture production. For instance, Europe has no any deposits of rock phosphate depending on imports and currently China which has 23% of the world rock phosphate reserve has restricted export and USA with 6.9% share of world rock phosphate reserve has stopped export. Alternative sources of phosphorus that can replace rock phosphate and meet the world agriculture and industry phosphorus demand is not yet developed. Even though recovery and recycling of phosphorus have the potential to reduce and replace rock phosphate use it could take decades to develop the technology for large scale and implement it (Cordell *et al*., 2009).

P-fertilizer industry largely depends on sulphur, phosphoric acid, ammonia besides rock phosphate. India imports around 1.7 million tonnes of sulphur, 2-4 million tonnes of phosphoric acid, 1.5 million tonnes of NH_3 and 4.9 million tonnes of rock phosphate for phosphate industry (Sengupta *et al.*, 2004) which constitutes a substantial part of our international trade in fertilizer raw material. Thus, the rapidly increasing price of soluble phosphatic fertilizer has raised interest in cheaper alternatives. Under such conditions, we must explore new methodologies for the utilization of indigenous low grade rock phosphate by converting it into a potential resource of P for direct application to the soil. The direct utilization of indigenous rock phosphate deposits could only alleviate the dependence of the country on foreign suppliers.

Phosphate Solubilizing Bacteria (PSB) plays an important role in solubilisation of soil P through secretion of various organic acids (formic, acetic, butyric, propionic, citric, glucomic, succinic, oxalic, malic, maleic and lactic acids) and make it available to plant (Gaur, 1991). The PSB like Pseudomonas and Bacillus also enhance the availability of phosphorus to plant by converting insoluble phosphorus from the soil into soluble form.

Among biofertilisers, *Azotobacter* is generally used in any non-legume crop. It could give good response to many cereal crops in their growth and development. *Azotobacter* inoculation enhanced seed germination of rice, maize, wheat, jowar etc. The nitrogen requirement of cereal crops could be reduced by *Azotobacter* inoculation.

Conditioning periods, representing the duration of compost enrichment, play a pivotal role in determining the efficacy of nutrient incorporation and microbial activity. Understanding the intricate relationships between conditioning periods, the addition of rock phosphate and their combined impact on compost quality is essential for optimizing agricultural practices.

The experiment was aimed to explore the possibility of preparation of phosphorus enriched compost. These findings are anticipated to contribute valuable insights to the realm of sustainable agriculture, guiding the development of practices that optimize compost quality for enhanced nutrient availability and microbial activity in soil ecosystems.

MATERIALS AND METHODS

25 kg of compost mixed with rock phosphate (E_1: Only Compost, E_2: Compost + 400% RDP of rice through rock phosphate and E_3: Compost + 600% RDP of rice through rock phosphate) and filled in respective pits. Common application of PSB and *Azotobacter* as per recommendation for rice in the pit. The pits were covered by Gunny bags and allowed to decompose for 20, 40 and 60 days. The periodical analysis for phosphorus solubilization and microbial count were done at 0, 20, 40 and 60 days of enrichment. The mixture was turned over at 0, 20, 40 and 60 days interval and also maintained moisture (Table 1 & 2).

Observation Recorded:

1) Solubility of Phosphorus and Total Nutrient Content at 0, 20, 40 and 60 Days of Enrichment

2) Total Microbial count (cfu/g of compost) at 0, 20, 40 and 60 Days after enrichment.

Table 1: Treatments for compost enrichment experiment.

Treatment No.	Treatment Details
T_1	0 days conditioned compost
T_2	0 days conditioned 400% RDP compost
T_3	0 days conditioned 600% RDP compost
T_4	20 days conditioned compost
T_5	20 days conditioned 400% RDP compost
T_6	20 days conditioned 600% RDP compost
T_7	40 days conditioned compost
T_8	40 days conditioned 400% RDP compost
T_9	40 days conditioned 600% RDP compost
T_{10}	60 days conditioned compost
T_{11}	60 days conditioned 400% RDP compost
T_{12}	60 days conditioned 600% RDP compost
Experimental Design:	Completely Randomized Design

Table 2: Nutrients content of initial Compost and Rock phosphate.

Sr. No.	Nutrients	Compost	Rock phosphate
1	N%	1.351	0.311
2	P%	0.780	30.031
3	K%	1.271	1.294
4	Zn%	0.065	0.031
5	Mn%	0.009	0.005
6	Fe%	0.141	0.065
7	Cu%	0.024	0.015

RESULT AND DISCUSSION

A. Solubility of Phosphorus and Total Nutrient Content at 0, 20, 40 and 60 Days of Enrichment

Impact on total nitrogen content of compost. Table 3 and Fig. 1 provide the results on periodic total nitrogen content at 0, 20, 40 and 60 days after compost enrichment. Significantly higher nitrogen content (1.459, 1.466 and 1.462 %) recorded with treatment T_{12} (60 days conditioned 600% RDP compost) in both the year as well as in pooled analysis. Significantly the lower nitrogen content (1.338, 1.345 and 1.341 %) were recorded with treatment T_3 (0 days 600% RDP compost) in both the year and pooled analysis as well.

The quantity of rock phosphate employed in different treatments results in variations in the total nitrogen content of the compost. Moreover, *Azotobacter* plays a crucial role in breaking down complex nitrogen-containing substances, such as proteins and amino acids into simpler forms. This decomposition process releases nitrogen in various forms, including ammonium (NH_4^+), amino acids and other organic nitrogen molecules.

Azotobacter, characterized by the nitrogenase enzyme, acts as a nitrogen-fixing bacterium capable of converting atmospheric nitrogen (N_2) into ammonia (NH_3) through the nitrogen fixation process. It facilitates the ammonification process by incorporating the released ammonium into its cellular metabolism. *Azotobacter* effectively concentrates and retains nitrogen within its cells by absorbing ammonium into its biomass, effectively removing ammonium from the local environment.

Longer composting periods allow more time for further decomposition of organic matter and nitrogen-containing compounds to undergo transformations, potentially leading to increased nitrogen accumulation in the compost. Additionally, rock phosphate enriched compost can aid in nitrogen conservation by mitigating nitrogen losses through ammonia volatilization and leaching. The slow-release properties of rock phosphate help stabilize nitrogen, reducing the risk of nitrogen loss during conditioning period. Akbari *et al.* (2010) discovered that the nitrogen content of compost increase with increasing composting time regardless of treatment.

According to Ladan (2006), the inoculation of nitrogen fixing bacteria *Azotobactor chrococcum* into compost increased nitrogen content. The addition of microbial inoculants increased the nitrogen content when compared to compost material without enrichment (Kavitha and Subramanian (2007). Gogoi *et al*. (2013) described the higher total N (1.85-1.97%) of ninety-day-old rice straw compost under incubation through inoculation of nitrogen fixing and phosphate solubilizing bacteria amid rock phosphate amendments.

b) Impact on phosphorus content of compost

The findings of periodic total phosphorus content at 0, 20, 40 and 60 days following compost enrichment are shown in Table 3. Phosphorus concentration recorded significantly greater (4.199, 4.208 and 4.203 %) with T_{12} (60 days conditioned 600% RDP compost) in both the year as well as in pooled analysis. Treatment T_1 (0 days conditioned compost) had significantly lowest phosphorus content (0.771, 0.783 and 0.777 %) in both the year and pooled analysis.

The findings of periodic water-soluble phosphorus content at 0, 20, 40 and 60 days following compost enrichment are shown in Table 4 and Fig. 2. Phosphorus concentration recorded significantly greater (0.941, 0.921 and 0.931 %) with T_{12} (60 days conditioned 600% RDP compost) in both the year as well as in pooled analysis. Treatment T_1 (0 days conditioned compost) had significantly lowest phosphorus content (0.364, 0.373 and 0.369 %) in both the year and pooled analysis.

Varied applications of rock phosphate across different treatments result in a notable discrepancy in the overall phosphorus content of the compost. Additionally, PSB (Phosphate-Solubilizing Bacteria) generate organic acids such as gluconic, citric or oxalic acid *via* metabolic processes. These organic acids play a pivotal role in reducing the pH of the rhizosphere. As part of this process, PSB release protons (H^+) into the compost, contributing to a further reduction in pH. The heightened acidity created by the organic acids facilitates the dissolution of insoluble phosphate compounds found in rock phosphate. The reduced pH, induced by the organic acids, effectively breaks down the chemical bonds between phosphate ions and other minerals present in rock phosphate. This process results in the release of soluble phosphate ions ($H_2PO_4^-$ and HPO_4^{-2}) into compost. Besides these, phosphorus is most soluble in slightly acidic to neutral pH ranges (pH 5.5 to 7) created by PSB or other processes, the solubility of phosphorus increases. However, extremely acidic or alkaline pH levels can reduce phosphorus solubility.

Extending the conditioning time of rock phosphate enriched compost can enhance phosphorus content by facilitating microbial activity and chemical reactions that gradually convert the insoluble phosphorus in rock phosphate into more soluble forms. Longer conditioning periods also promote better moisture management and aeration, allowing leaching and absorption of phosphorus from rock phosphate into the compost. This extended time frame provides opportunities for nutrient testing and adjustments ultimately increasing the availability of phosphorus.

Proper moisture level and higher temperature produced in compost support microbial metabolism.

Apart from that, finely round rock phosphate has a lager surface area, which increases the contact between phosphate compounds and the surrounding solution, leading to greater solubility.

Table 3: The impact of conditioning periods and rock phosphate on total nitrogen, phosphorus and potassium content of compost.

Treatment	N %			P_2O_5 %			K_2O %		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: 0 days conditioned compost	1.353	1.350	1.352	0.771	0.783	0.777	1.273	1.270	1.272
T_2: 0 days conditioned 400% RDP compost	1.339	1.347	1.343	3.147	3.127	3.137	1.287	1.280	1.283
T_3: 0 days conditioned 600% RDP compost	1.338	1.345	1.341	4.161	4.184	4.173	1.300	1.343	1.322
T_4: 20 days conditioned compost	1.356	1.355	1.356	0.778	0.789	0.784	1.274	1.274	1.274
T_5: 20 days conditioned 400% RDP compost	1.387	1.381	1.384	3.157	3.129	3.143	1.340	1.374	1.357
T_6: 20 days conditioned 600% RDP compost	1.427	1.428	1.427	4.175	4.191	4.183	1.386	1.420	1.403
T_7: 40 days conditioned compost	1.364	1.371	1.367	0.780	0.793	0.787	1.274	1.275	1.275
T_8: 40 days conditioned 400% RDP compost	1.393	1.387	1.390	3.179	3.142	3.160	1.356	1.389	1.373
T_9: 40 days conditioned 600% RDP compost	1.448	1.439	1.444	4.193	4.203	4.198	1.515	1.482	1.498
T_{10}: 60 days conditioned compost	1.367	1.378	1.373	0.789	0.796	0.793	1.275	1.276	1.275
T_{11}: 60 days conditioned 400% RDP compost	1.417	1.397	1.407	3.179	3.148	3.163	1.360	1.393	1.377
T_{12}: 60 days conditioned 600% RDP compost	1.459	1.466	1.462	4.199	4.208	4.203	1.608	1.574	1.591
SEm ±	0.024	0.022	0.017	0.075	0.091	0.058	0.02	0.03	0.02
CD (P = 0.05)	0.071	0.065	0.047	0.219	0.264	0.167	0.07	0.08	0.05
Y	-	-	NS	-	-	NS	-	-	NS
Y x T									
SEm ±	0.023			0.083			0.085		
CD (P = 0.05)	NS			NS			NS		
CV (%)	3.05	2.80	2.93	4.80	5.81	5.33	3.16	3.73	3.46

Table 4: Impact of conditioning period and rock phosphate on water soluble P_2O_5 in compost.

Treatment	Water soluble P_2O_5		
	2021	2022	Pooled
T_1: 0 days conditioned compost	0.364	0.373	0.369
T_2: 0 days conditioned 400% RDP compost	0.380	0.381	0.380
T_3: 0 days conditioned 600% RDP compost	0.393	0.410	0.402
T_4: 20 days conditioned compost	0.441	0.421	0.431
T_5: 20 days conditioned 400% RDP compost	0.554	0.548	0.551
T_6: 20 days conditioned 600% RDP compost	0.903	0.858	0.880
T_7: 40 days conditioned compost	0.437	0.435	0.436
T_8: 40 days conditioned 400% RDP compost	0.763	0.764	0.764
T_9: 40 days conditioned 600% RDP compost	0.921	0.863	0.892
T_{10}: 60 days conditioned compost	0.488	0.465	0.476
T_{11}: 60 days conditioned 400% RDP compost	0.868	0.840	0.854
T_{12}: 60 days conditioned 600% RDP compost	0.941	0.921	0.931
SEm ±	0.018	0.021	0.011
CD (P = 0.05)	0.054	0.060	0.034
Y	-	-	NS
Y x T			
SEm ±	0.019		
CD (P = 0.05)	NS		
CV (%)	5.22	5.91	5.57

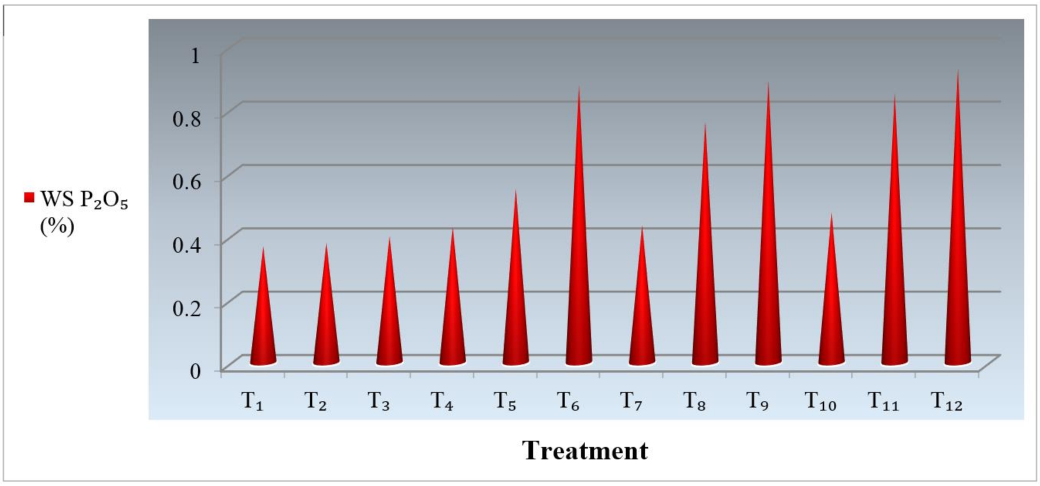

Fig. 2. Impact of conditioning period and rock phosphate on water soluble P_2O_5 (%) in compost.

The presence of organic matter in compost can have a positive impact on phosphorus solubility. Organic matter acts as a source of carbon for PSB and other microorganisms, supporting their growth and activity. The metabolic by products of microorganisms, such as organic acids released during the further decomposition of organic matter contribute to phosphorus solubilisation.

Biswas and Narayanasamy (2006) reported in their incubation study that P release increased up to 13 weeks, this might be due to greater production of organic acids, which slowed down afterwards and solubilized P started to be converted into insoluble form. Kavitha and Subramanian (2007) discovered that on the 20th day, phosphorus content increased significantly after enrichment. This rise in phosphorus content can be linked to the addition of phosphorus-rich composted chicken litter as well as the use of rock phosphate and microbial inoculants. Akbari *et al.* (2010) discovered that the total P content of composts supplemented with rock phosphate ranged from 1.92 to 2.74%, while composts without rock phosphate ranged from 0.66 to 0.74%. Gogoi *et al.* (2013) noted the higher total P (1.03-1.15%) in ninety-day-old rice straw compost under incubation through inoculation of nitrogen fixing and phosphate solubilizing bacteria amid rock phosphate amendments at curing stage. Saleem *et al.* (2013) reported that RP and compost improved the release of RP-P and indigenous insoluble P. It is very likely that compost served as a rich source of C for the indigenous microbes as well as PSB present in soil and decomposition of compost produced organic acids which enhanced the release of available P from RP and indigenous insoluble P. The compost also supported greater population of PSB, which might have also acted more efficiently. Soil spiking with RP enriched compost (RPEC) further enhanced the dissolution of RP and soil indigenous insoluble P and improved the P release in the soil for plant use, which corroborates the findings of Imran *et al.* (2011). According to Iqbal *et al.* (2014), soluble P ranged between 37 and 43 mg/kg at the beginning of composting and between 61 and 120 mg/kg at the end. The soluble P content increased from 37 mg/kg to 120 mg/kg at the end of composting, indicating a higher concentration of soluble P. In treatments that combined the use of rock phosphate and P solubilizing bacteria, soluble P considerably increased between the two rates of rock phosphate (5% and 10%). An increase in the amount of soluble P was anticipated due to the breakdown/mineralization of organic molecules.

Impact on potassium content of compost. The data in Table 3 demonstrate the periodic potassium concentration at 0, 20, 40 and 60 days after compost enrichment. Significantly highest potassium content (1.608, 1.574 and 1.591%) recorded with T_{12} (60 days conditioned 600% RDP compost) in both the year as well as in pooled analysis. Treatment T_1 (0 days conditioned compost) had significantly lowest potassium content in both the year and pooled analysis. In rock phosphate-enriched compost, total potassium levels increase through the amount of rock phosphate used in different treatments. Rock phosphate is often associated with potassium-bearing minerals (1.51% K) and the solubilisation of rock phosphate releases potassium from these minerals. Microbial activity and organic acids produced during the solubilization process facilitate the release of potassium. Microorganisms present in the compost contribute to nutrient cycling. They break down organic matter and release potassium and other nutrients into the compost. They also convert organic forms of potassium into more soluble forms. As organic matter in the compost decomposes, potassium and other nutrients are released. Microbial activity further breaks down complex organic compounds, making potassium more soluble.

Conditioning time in rock phosphate enriched compost enhances overall compost quality it doesn't increase potassium content directly. The potassium content in compost mainly originates from the organic materials used in composting and it remains relatively stable during the process. Potassium is a slow-release nutrient with its availability influenced by factors like soil pH, microbial activity and plant uptake, while conditioning mainly impacts phosphorus availability.

These processes collectively result in an increment in potassium content in RPEC, making it a valuable source of potassium for plants. Akbari *et al.* (2010) discovered the higher total potassium levels ranged from 0.94 to 1.38% after 90 days of composting. Gogoi *et al*. (2013) described higher total K (0.81-0.91%) of ninety-day-old rice straw compost under incubation through inoculation of nitrogen fixing and phosphate solubilizing bacteria amid rock phosphate amendments in the final product.

Impact on total micronutrient content of compost. Table 5 and 6 revealed a non-significant effect of phosphorus enriched compost on total Zn, Mn, Fe and Cu content for both individual years and pooled analyses. Though, maximum zinc content (680.5, 683.8 and 682.1 mg/kg), Mn (104.93, 103.93 and 104.45 mg/kg), Fe (1535, 1520 and 1528 mg/kg) and Cu (261.4, 262.0 and 261.7 mg/kg) noted with application of treatment T_{12} (60 days conditioned 600% RDP compost) in both the individual year as well as in pooled analysis. The lowest values of all these micronutrients were recorded with treatment T_1 (0 days conditioned compost) in both year and pooled analysis as well.

Table 5: The impact of conditioning periods and rock phosphate on total zinc and manganese content of compost.

Treatment	Zn (ppm)			Mn (ppm)		
	2021	2022	Pooled	2021	2022	Pooled
T_1: 0 days conditioned compost	656.0	652.7	654.3	97.17	98.08	97.63
T_2: 0 days conditioned 400% RDP compost	666.3	665.9	666.1	99.83	99.52	99.68
T_3: 0 days conditioned 600% RDP compost	666.3	666.3	666.3	100.61	100.42	100.51
T_4: 20 days conditioned compost	656.3	652.8	654.5	97.47	98.15	97.81
T_5: 20 days conditioned 400% RDP compost	671.8	668.5	670.2	101.32	101.02	101.17
T_6: 20 days conditioned 600% RDP compost	677.8	681.2	679.5	103.98	102.14	103.06
T_7: 40 days conditioned compost	656.6	653.0	654.8	97.79	98.30	98.05
T_8: 40 days conditioned 400% RDP compost	674.7	678.0	676.4	101.70	101.20	101.45
T_9: 40 days conditioned 600% RDP compost	678.2	682.2	680.2	104.23	103.47	103.85
T_{10}: 60 days conditioned compost	656.7	653.1	654.9	98.04	98.59	98.32
T_{11}: 60 days conditioned 400% RDP compost	676.3	679.7	678.0	102.00	101.50	101.75
T_{12}: 60 days conditioned 600% RDP compost	680.5	683.8	682.1	104.98	103.93	104.45
SEm ±	12.98	13.03	9.20	2.73	2.16	1.74
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Y	-	-	NS	-	-	NS
Y x T						
SEm ±	13.01			2.46		
CD (P = 0.05)	NS			NS		
CV (%)	3.37	3.38	3.37	4.70	3.72	4.24

Table 6: The impact of conditioning periods and rock phosphate on total iron and copper content of compost.

Treatment	Fe (ppm)			Cu (ppm)		
	2021	2022	Pooled	2021	2022	Pooled
T_1: 0 days conditioned compost	1441	1444	1442	245.4	244.4	244.9
T_2: 0 days conditioned 400% RDP compost	1491	1453	1472	251.3	247.6	249.4
T_3: 0 days conditioned 600% RDP compost	1493	1465	1479	252.8	250.2	251.5
T_4: 20 days conditioned compost	1442	1444	1443	245.9	244.9	245.4
T_5: 20 days conditioned 400% RDP compost	1495	1486	1491	253.0	250.3	251.7
T_6: 20 days conditioned 600% RDP compost	1511	1493	1502	260.3	252.9	256.6
T_7: 40 days conditioned compost	1443	1445	1444	246.0	245.0	246.0
T_8: 40 days conditioned 400% RDP compost	1499	1488	1494	254.3	251.5	252.9
T_9: 40 days conditioned 600% RDP compost	1532	1514	1523	260.8	259.5	260.1
T_{10}: 60 days conditioned compost	1444	1446	1445	246.3	245.6	247.7
T_{11}: 60 days conditioned 400% RDP compost	1504	1489	1497	255.0	251.9	253.5
T_{12}: 60 days conditioned 600% RDP compost	1535	1520	1528	261.4	262.0	261.7
SEm ±	36.14	33.55	24.66	7.58	5.66	4.73
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Y	-	-	NS	-	-	NS
Y x T						
SEm ±	34.87			6.69		
CD (P = 0.05)	NS			NS		
CV (%)	4.21	3.94	4.08	5.20	3.91	4.61

The micronutrient concentrations of rock phosphate (0.065% Fe, 0.03% Zn, 0.005% Mn and 0.015% Cu) improve their availability in compost *via* certain microbial inoculants or compost activators known to aid micronutrient solubilization and availability. PSB plays important role to release and convert bound micronutrients in rock phosphate into soluble form. Plant residues, bone meal, kelp meal or agricultural by-products are micronutrient-rich materials that add them to the compost mixture to enrich it.

Conditioning time in rock phosphate enriched compost can indirectly influence the availability of micronutrients. Longer conditioning periods promote microbial activity, aiding in the breakdown and mineralization of micronutrients. Decomposing organic matter releases compounds that can chelate micronutrients, making them more accessible to plants. The pH of the compost may also be adjusted over time. Interactions between minerals in rock phosphate and compost components can further enhance micronutrient availability.

Furthermore, adequate turning, aeration, moisture management and maintaining an optimal temperature range stimulated microbial activity and enzymatic reactions that improved micronutrient release and solubility. Acidic conditions of compost frequently favour the solubilization of micronutrients from rock phosphate. Akbari *et al*. (2010) discovered that the total micronutrient content (Fe, Zn, Mn and Cu) rise with increasing composting time. The values ranged from 1203 to 1362 ppm for Fe, 54.2 to 72.9 ppm for Zn, 519 to 558 ppm for Mn and 33.8 to 38.9 ppm for Cu after 90 days.

B. Microbial Count (cfu/g of compost) at 0, 20, 40 and 60 Days After Enrichment

Impact on PSB population of compost. Table 7 and Fig. 2 showed the significant result of PSB population influenced by phosphorus enriched compost during both individual years and pooled analysis. Significantly higher PSB population (3.57×10^4, 3.67×10^4 and 3.62×10^4 cfu/g) were observed by application of treatment T_{12} (60 days conditioned 600% RDP compost) in both the individual year as well as in pooled analysis. The lowest PSB population (1.25×10^4, 1.26×10^4 and 1.26×10^4 cfu/g) was observed in treatment T_1 (0 days conditioned compost) in both year as well as in pooled analysis.

Table 7: The impact of conditioning periods and rock phosphate on PSB, *Azotobacter* and total microbial population of compost.

Treatment	PSB (cfu×10^4)			*Azotobacter* (cfu×10^4)			Total microbial (cfu×10^6)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1: 0 days conditioned compost	1.25	1.26	1.26	1.50	1.51	1.51	2.76	2.78	2.77
T_2: 0 days conditioned 400% RDP compost	1.26	1.27	1.27	1.59	1.55	1.57	2.85	2.83	2.84
T_3: 0 days conditioned 600% RDP compost	1.27	1.28	1.27	1.60	1.57	1.59	2.87	2.86	2.86
T_4: 20 days conditioned compost	1.35	1.33	1.34	1.67	1.59	1.63	3.02	2.92	2.97
T_5: 20 days conditioned 400% RDP compost	2.48	2.33	2.41	2.47	2.77	2.62	4.95	5.10	5.02
T_6: 20 days conditioned 600% RDP compost	3.33	3.20	3.27	3.27	3.24	3.25	6.60	6.43	6.52
T_7: 40 days conditioned compost	1.93	1.78	1.86	1.93	1.97	1.95	3.86	3.75	3.81
T_8: 40 days conditioned 400% RDP compost	3.14	3.09	3.12	2.77	2.73	2.75	5.91	5.82	5.87
T_9: 40 days conditioned 600% RDP compost	3.48	3.40	3.44	3.37	3.47	3.42	6.85	6.87	6.86
T_{10}: 60 days conditioned compost	2.35	2.23	2.29	2.39	2.35	2.37	4.74	4.58	4.66
T_{11}: 60 days conditioned 400% RDP compost	3.13	3.20	3.17	3.00	2.93	2.97	6.13	6.13	6.13
T_{12}: 60 days conditioned 600% RDP compost	3.57	3.67	3.62	3.68	3.65	3.66	7.25	7.32	7.29
SEm ±	0.06	0.06	0.04	0.06	0.06	0.05	0.12	0.12	0.05
CD (P = 0.05)	0.17	0.19	0.13	0.18	0.17	0.16	0.34	0.34	0.15
Y	-	-	NS	-	-	NS	-	-	NS
Y x T									
SEm ±	0.06			0.06			0.12		
CD (P = 0.05)	NS			NS			NS		
CV (%)	4.31	4.78	4.55	4.58	4.15	4.37	4.17	4.23	4.20

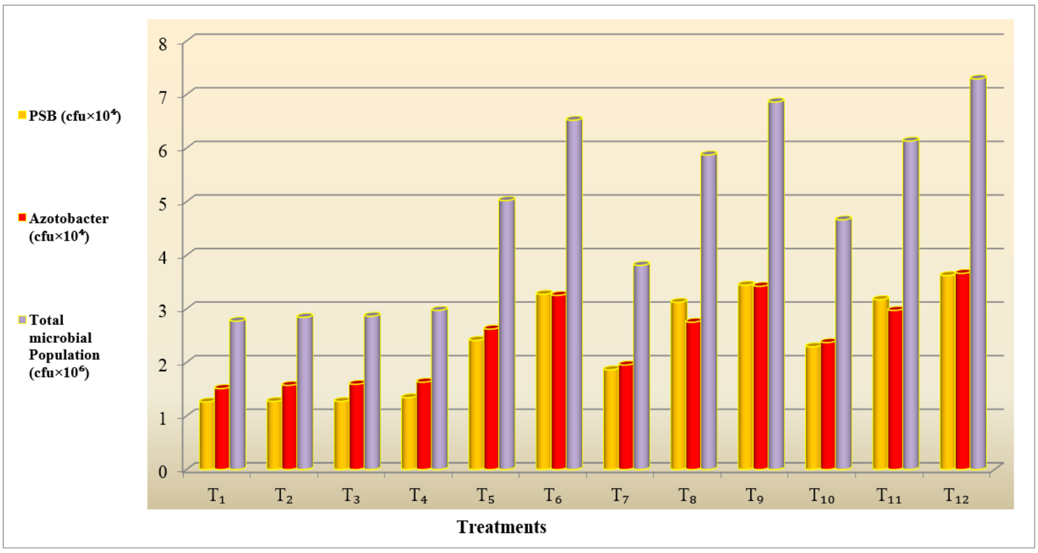

Fig. 3. The impact of conditioning periods and rock phosphate on PSB, *Azotobacter* and total microbial population (cfu/g) of compost.

The pH of rock phosphate is normally high and might be alkaline. PSB are reported to flourish in pH levels ranging from slightly acidic to neutral. When rock phosphate is added to compost, it can buffer the pH and bring it closer to the ideal pH range for PSB growth. This pH modification can boost PSB growth in the compost.

PSB contribute to the compost by solubilizing phosphate compounds in rock phosphate, releasing soluble phosphorus ions. This enhanced availability of nutrients supports the proliferation and multiplication of PSB. Furthermore, the incorporation of rock phosphate-enriched compost, with its added phosphorus content, serves as supplementary nutrient source for PSB. The presence of organic matter plays a crucial role in releasing nutrients and establishing favourable conditions for bacterial activity.

Moreover, conditioning time in rock phosphate enriched compost foster the growth of PSB as it maintaining optimal moisture, aeration and environmental conditions during conditioning further supports PSB activity. Gogoi *et al*. (2013) found that inoculation of nitrogen fixing and PSB led to intense organic matter mineralization of the compost and stabilized the carbon to nitrogen (C:N) ratio. Elevated and reasonably stabilized specific populations of PSB (7.79 x 10^5 cfu/g) at the end of incubation were owing to the added microorganisms. Borah *et al*. (2014) observed the greatest population of PSB at 30 days and the lowest was seen at 15 days after incubation of vermicompost and farmyard manure.

The impact on *Azotobacter* population. Table 7 and Fig. 3 showed the significant result of *Azotobacter* population influenced by phosphorus enriched compost during both individual years and pooled analysis. Significantly the highest *Azotobacter* population (3.68 × 10^4, 3.65 × 10^4 and 3.66 × 10^4 cu/g) were observed by application of treatment T_{12} (60 days conditioned 600% RDP compost) in both the individual year as well as in pooled analysis. The lowest *Azotobacter* population (1.50 × 10^4, 1.51 × 10^4 and 1.51 × 10^4 cfu/g) was observed in treatment T_1 (0 days conditioned compost) in both year as well as in pooled analysis.

The increase in *Azotobacter* population in rock phosphate, PSB and *Azotobacter*-inoculated compost can be attributed to multiple mechanisms. Firstly, PSB solubilize insoluble phosphates in rock phosphate, making phosphorus available for uptake by *Azotobacter*. This enhanced phosphorus availability stimulates the growth and reproduction of *Azotobacter*. Additionally, the combination of rock phosphate, PSB and *Azotobacter* creates synergistic interactions, with PSB solubilizing phosphorus and *Azotobacter* providing metabolites that enhance activity of PSB.

This mutualistic relationship benefits both microorganisms leading to increased population sizes. Furthermore, the further decomposition of organic matter in compost provides a nutrient-rich environment for *Azotobacter* to thrive, utilizing the breakdown products as a food source. The presence of readily available carbon compounds supports *Azotobacter* growth. Finally, *Azotobacter's* nitrogen-fixing ability converts atmospheric nitrogen into usable forms, increasing nitrogen availability in the compost and promoting *Azotobacter* population growth. Overall, these mechanisms with conditioning period work together to enhance its population.

Study conducted by Kavitha and Subramanian (2007) have observed a significant increase in *Azotobacter* population in compost. They reported a three to six-fold increase in *Azotobacter* population within three weeks after compost inoculation. Gogoi *et al*. (2013) found the elevated and reasonably stabilized specific populations of *Azotobacter* (92.09-126.62 × 10^5 cfu/g) at the end of incubation owing to the added microorganisms. Borah *et al*. (2014) observed the greatest population of *Azotobacter* at 30 days and the lowest was seen at 15 days after incubation of vermicompost.

The impact on total microbial population. Table 7 and Fig. 3 displays the significant effect of phosphorus enriched compost on total microbial population for both individual year and pooled analysis. Significantly the highest total microbial population (7.25×10^6, 7.32×10^6 and 7.29×10^6 cfu/g) were observed with application of treatment T_{12} (60 days conditioned 600% RDP compost) in both the individual year as well in pooled analysis as well. The lowest total microbial population (2.76×10^4, 2.78×10^4 and 2.77×10^4 cfu/g) was observed in treatment T_1 (0 days conditioned compost) in both year as well as in pooled analysis.

The increase in the total microbial population in rock phosphate, PSB and *Azotobacter*-inoculated compost is influenced by a combination of biotic and abiotic factors. Biotic factors include microbial interactions, competition for resources and microbial inoculation, which affect the population dynamics and composition of microorganisms in the compost. Abiotic factors, such as nutrient availability, pH and temperature, moisture and oxygen levels and the rate of organic matter decomposition, create a suitable environment for microbial growth and activity. These factors collectively determine the dynamics and growth of the total microbial population in the compost, contributing to nutrient cycling and the overall health of the microbial community.

Conditioning time in rock phosphate enriched compost significantly influences the total microbial population. Extended conditioning allows for the development of a diverse microbial community, with various microorganisms playing different roles in composting, nutrient cycling and decomposition. This diversity arises as different microbial species establish themselves over time, fostering a richer and more varied population. Additionally, conditioning time provides microorganisms with an extended window for growth and reproduction benefiting overall population density.

The breakdown of complex organic compounds into simpler forms during conditioning increases nutrient availability, further supporting microbial growth. While longer conditioning periods can lead to competition among microbial species and shifts in population composition, they ultimately contribute to the development of a thriving and dynamic microbial ecosystem in rock phosphate enriched compost.

Apart from that, using enriched compost instead of soluble inorganic fertilizer increased phosphatase activity (acid and alkaline). Phosphatase activity may be reduced by chemical or inorganic fertilizers. Simultaneously, rock phosphate enriched compost offered organic matter as well as nutrients that aid in the formation of soil bacteria, which are principally responsible for alkaline phosphatase activity in soil (Wu, 2007). As a result, the compost may have delivered a significant amount of carbon and nitrogen for maximal microbial development. The beneficial microbe absorbed all of the nutrients and energies from the enriched compost, resulting in a rise in microbial population. Achal *et al*. (2007) agreed with the findings. Borah *et al*. (2014) observed an increase in the overall population of the inoculated microorganisms in the compost due to incubation process.

CONCLUSIONS

The findings of two year compost enrichment experiments indicate that to achieving increased water-soluble phosphorus and total nutrient levels (nitrogen and phosphorus), compost required to enriched for 40-60 days with 600 % RDP through rock phosphate, PSB and *Azotobacter*. While in case of higher total potassium and maximizing microbial populations (PSB, *Azotobacter* and total microbial population), compost required to conditioning with 600% RDP through rock phosphate for duration of 60 days.

FUTURE SCOPE

The present investigation has shed light on the influence of conditioning periods and rock phosphate on compost quality. To further advance our understanding and contribute to sustainable agricultural practices, the following avenues for future research are proposed:

Exploration of Additional Conditioning Agents: Investigate the effects of alternative conditioning agents, such as various organic materials or biochar, to assess their potential in enhancing nutrient content and microbial activity in compost.

Long-term Effects: Extend the study duration to analyze the long-term impacts of conditioning periods and rock phosphate on compost quality. This will involve monitoring nutrient levels and microbial activity over an extended period to ascertain the sustainability of the observed effects.

Field Trials: Conduct field trials to evaluate the practical implications of the produced compost in real-world agricultural settings. Assess crop yield, soil health and environmental impacts to provide valuable insights for farmers and policymakers.

REFERENCES

Achal, V., Savant, V. V. and Reddy, M. S. (2007). Phosphate solubilization by a wild type strain and UV-induced mutants of Aspergillus tubingensis. *Soil Biology and Biochemistry, 39*(1), 695–699.

Akbari, K. N., Vora, V. D., Sutaria, G. S., Hirpara, D. S. and Padmani, D. R. (2010). Enrichment of compost by bio inoculants and natural mineral amendments. *An Asian Journal of Soil Science, 5*(1), 100-102.

Biswas, D. R. and Narayanasamy, G. (2006). Rock phosphate enriched compost: An approach to improve low-grade Indian rock phosphate enriched compost. *Journal of Bioresource Technology, 97*(2), 2243-2251.

Borah, N., Deka, N. C., Deka, J., Barua, I. C., Nath, D. J. and Medhi, B. K. (2014). Enrichment of compost through microbial inoculation. *International Journal of Current Research*, *6*(8), 8026-8031.

Cordell, D., Drangert, J. and White, S. (2009). The story of phosphorus: global food security and food for thought. *Journal of Global Environmental Change*, *19*(2), 292-305.

Gaur, A. C. (1991). Phosphate solubilizing microorganism and bio-fertilizers. Omega Scientific Publishers, New Delhi. 176.

Gogoi, D., Nath, D. J. and Borah, D. K. (2013). Augmentation of the fertilizer values of compost through beneficial microbes amid rock phosphate amendments during curing stage. *Indian Journal of Agricultural Research*. *47*(4), 304-310.

Illmer, P. A. and Schinner, F. (1995). Solubilization of inorganic calcium phosphates solubilization mechanisms. *Journal of Soil Biology and Biochemistry*, *27*(1), 257-263.

Iqbal, T., Jilani, G., Rasheed, M. and Siddique, M. T. (2014). Effect of P-enriched compost application on soil and plants. *International Journal of Biosciences*, *5*(7), 32-39.

Imran, M. R., Waqas, Z. I., Nazli, H., Shaharoona, B. and Arshad, M. (2011). Effect of recycled and value-added organic waste on solubilization of rock phosphate in soil and its Influence on maize growth. *International Journal of Agriculture and Biology*, *13*(1), 751-755.

Kavitha, R. and Subramanian, P. (2007). Bbioactive compost- a value added compost with microbial inoculents and organic additives. *Journal of Applied Science*, *7*(17), 2514-2518.

Ladan, R. (2006). Enriching sugarcane bagasse compost by sulphur, nitrogen fixing (*Azotobactor chrooccum*) and phosphate solubilizing bacteria (*Enterobactor clocae*) bagasse decomposition and produced compost enrichment. 18th world congress of soil science, July 9-15, Philadelphia, Pennsylvania, USA.

Nisha, K., Padma Devi, S. N., Vasandha, S. and Sunitha kumari, K. (2004). Role of phosphorous solubilizing microorganisms to eradicate p- deficiency in plants. *International Journal of Scientific and Research Publications*, *4*(1), 2250-3153.

Saleem, M. M., Arshad, M. and Yaseen, M. (2013). Effectiveness of various approaches to use rock phosphate as a potential source of plant available P for sustainable wheat production. *International Journal of Agriculture and Biology*, *15*(2), 223-230.

Sengupta, S., Nawaz, T. and Beaudry, J. (2004). Nitrogen and phosphorus recovery from wastewater. *Fertilizer News*, *49*(2), 55-57.

Wu, J., Huang, M., Xiao, H. A., Su, Y. R., Tong, C. L., Huang, D. Y. and Syers, J. K. (2007). Dynamics in microbial immobilization and transformations of phosphorus in highly weathered subtropical soil following organic amendments. *Plant and Soil*, *290*(1), 333-342.

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