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Effect of phosphorus enriched compost on growth, yield attributes and yield of *kharif* rice

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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 *kharif* season of the years 2021 and 2022 to assess the “Effect of phosphorus enriched compost on growth, yield attributes and yield of *kharif* rice”. The field treatments was laid out in randomized block design including T_1: RDP + Compost, T_2: 20 days conditioned compost, T_3: 20 days conditioned 400% RDP compost, T_4: 20 days conditioned 600% RDP compost, T_5: 40 days conditioned compost, T_6: 40 days conditioned 400% RDP compost, T_7: 40 days conditioned 600% RDP compost, T_8: 60 days conditioned compost, T_9: 60 days conditioned 400% RDP compost and T_{10}: 60 days conditioned 600% RDP compost. The experiment was conducted for two consecutive years in different location. Result of field experiment showed that the growth parameter of *kharif* rice namely plant height and yield parameter test weight found non-significant with different treatments of phosphorus-enriched compost in both year as well as in pooled analysis. The significant effect of treatment T_{10} (60 days conditioned 600% RDP compost) were found in case of no. of tillers/hill and panicle length in both year and pooled analysis as well. Significantly the higher grain and straw yield of *kharif* rice were observed with treatment T_{10} in both year and pooled analysis.

Keywords: Conditioning periods**,** enrichment**,** growth parameters, rock phosphate and yield

Introduction
Intensification in agriculture through indiscriminate and irrational use of chemical fertilizers and pesticides has resulted in reduction of crop productivity, lowered fertilizer use efficiency, accelerated environmental degradation and deterioration of soil health. Thus posing as serious threat to the sustainability of agriculture, ecological balance and human health. However, people are gradually realizing the emerging danger and showing interest towards sustainable crop production practices such as increased use of organic manures to revitalize and restore soil fertility and reviving the microbial activity of the soil. Traditionally farmyard manure, animal wastes and compost are used as source of organic nutrients for improving soil fertility and crop productivity. However, low nutrient content, bulkiness, handling difficulties and labour intensive application prevent the growers for larger use of these traditional organic manures. Enrichment of composts by incorporation of mineral (Rock phosphate) and biological (PSB and *Azotobacter*) additives have lots of benefits on crops in terms of higher yield, better quality, increased disease and pest resistance and availability of essential nutrients. At the same time, if the nutrient content increases through enrichment, the bulkiness also can be reduced.
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) [21]. 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) [15]. Unfortunately, Phosphatic fertilizers 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) [9].

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 NH3 and 4.9 million tonnes of rock phosphate for phosphate industry (Sengupta *et al*., 2004) [23] 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) [12]. 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 biofertilizers, *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.

Rice (*Oryza sativa* L.) is a staple food for about 50 per cent of the world's population that resides in Asia, where 90 per cent of the world's rice is grown and consumed. In Asia, India has the largest area under rice (41.66 million ha) accounting for 29.4 per cent of the global rice area. Among the total area, about 46 per cent is irrigated, 28 per cent is rain fed lowland, 12 per cent is rain fed upland and 14 per cent is flood prone. The area, production and productivity of total *kharif* rice in Navsari district since 2019 to 2022 is 501 ha, 1354 MT and 2702 kg/ha respectively and it contributes 6.82% of area of Gujarat. Rice is one of the largest traded commodities in the world with a total quantity touching 16.4 million tonnes. The southeast countries account for about 40 per cent of the rice trade in the world (Mangla, 2004) [19]. Rice is staple food crop of 63 to 65 per cent people of India. The crop at present is grown in 43 million hectares of land with production of 96.7 million tones. Its production has to be raised to 160 million tons by 2030 with a minimum annual growth rate of 2.35 per cent (Mishra *et al*., 2013) [20].

The experiment on "Effect of phosphorus enriched compost on growth, yield attributes and yield of *kharif* rice" is aimed to explore the possibility of utilization of phosphorus enriched compost on rice (*kharif*) growth and yield.

Materials and Methods

A field experiment was conducted at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat) during the *kharif* season of the years 2021 and 2022 to assess the "Effect of phosphorus enriched compost on growth, yield attributes and yield of *kharif* rice". The experiment was conducted for two consecutive years in different location. The soil of the experimental field was clay in texture, low in organic carbon (0.45 and 0.48%) and available nitrogen (204.10 and 206.47 kg/ha), medium in available phosphorus (44.30 and 46.88 kg/ha), high in available potassium (291.10 and 310.49 kg/ha), low in available iron (3.25 and 3.53 mg/kg), medium in available zinc (0.54 and 0.59 mg/kg), medium in available manganese (5.21 and 5.46 mg/kg) and high in available copper (1.24 and 1.16 mg/kg). The soil was found slightly alkaline (pH 8.1 and 8.0) with normal electrical conductivity (0.40 and 0.46 dS/m) in the year 2021 and 2022 respectively. Treatments for field experiment is depicted in table 1.

The required quantity of enriched compost and fertilizer was worked out as per the unit area and treatments basis. The enriched compost was thoroughly and uniformly spread and mixed in respective plots. 50 per cent dose of nitrogen (50 kg N/ha) in the form of urea were applied manually uniformly before sowing of rice crop and full dose of phosphorus was applied through single super phosphate in control plot only. Remaining 50 per cent nitrogen (50 kg N/ha) in the form of urea was applied at 40 days after sowing when irrigation was applied. All the other management practices were adopted in these crops as per the recommendations.

Each experimental unit of rice had 20 rows out of which 3 outermost rows from one and 4 from another side were left as border rows or ring line. Remaining 14 rows were treated as the net plot area. Five plants were randomly selected in the net plot area and labelled. All the successive observations during the crop growth were recorded from these plants. The same plants were harvested separately for generating the data on yield attributes. The mean values of all observations were utilized for statistical analysis.

Table 1: Treatments for field experiment

Treatment No.	Treatment Details
T_1	RDP + Compost
T_2	20 days conditioned compost
T_3	20 days conditioned 400% RDP compost
T_4	20 days conditioned 600% RDP compost
T_5	40 days conditioned compost
T_6	40 days conditioned 400% RDP compost
T_7	40 days conditioned 600% RDP compost
T_8	60 days conditioned compost
T_9	60 days conditioned 400% RDP compost
T_{10}	60 days conditioned 600% RDP compost
Experimental Design	Randomized Block Design

Note: Common application of RDN (100 kg/ha) as per recommendation for *kharif* rice was performed.

Result and Discussion

Effect of Phosphorus Enriched Compost on Growth, Yield attributes and Yield

Plant height (cm): Plant height of *kharif* rice was recorded at harvest as influenced by different treatments are presented in Table 2. The plant height of *kharif* rice was not significantly influenced by phosphorus enriched compost at harvest during both individual years and pooled analysis. The maximum plant height (133.0, 130.3 and 131.7 cm) of rice crop was observed under the treatment T_{10} (60 days conditioned 600% RDP compost) during both year and in pooled analysis. The lower plant height (114.3, 115.7 and 115.0 cm) was observed under the treatment T_2 (20 days conditioned compost) at harvest during both the individual year and pooled analysis.

A little increase in plant height of rice by applying rock phosphate, PSB and *Azotobacter*-inoculated compost can be attributed to several mechanisms. These include enhanced phosphorus availability through the solubilization of rock phosphate by PSB, nitrogen fixation by *Azotobacter* providing a source of fixed nitrogen, the production of plant growth-promoting hormones by PSB and *Azotobacter*, enrichment of the soil with organic matter from compost decomposition and synergistic effects among rock phosphate, PSB and *Azotobacter*.

Table 2: Plant height and number of tillers of *kharif* rice as affected by different treatments

Treatment	Plant height (cm)			No of tillers/hill		
	2021	2022	Pooled	2021	2022	Pooled
T_1: RDP + compost	127.3	126.7	127.0	10.15	9.97	10.06
T_2: 20 days conditioned compost	114.3	115.7	115.0	8.87	8.71	8.79
T_3: 20 days conditioned 400% RDP compost	121.7	119.7	120.7	9.12	9.16	9.14
T_4: 20 days conditioned 600% RDP compost	126.7	125.3	126.0	9.88	9.73	9.80
T_5: 40 days conditioned compost	117.7	116.0	116.8	8.94	8.75	8.85
T_6: 40 days conditioned 400% RDP compost	122.0	122.7	122.3	9.36	9.38	9.37
T_7: 40 days conditioned 600% RDP compost	130.7	127.3	129.0	10.37	10.13	10.25
T_8: 60 days conditioned compost	120.0	118.3	119.2	9.04	8.96	9.00
T_9: 60 days conditioned 400% RDP compost	123.0	124.0	123.5	9.39	9.51	9.45
T_{10}: 60 days conditioned 600% RDP compost	133.0	130.3	131.7	10.69	10.71	10.70
S.Em ±	6.76	6.61	4.73	0.40	0.39	0.28
CD (P = 0.05)	NS	NS	NS	1.19	1.16	0.80
Y	-	-	NS	-	-	NS
Y x T						
S.Em ±	6.68			0.39		
CD (P = 0.05)	NS			NS		
CV (%)	9.48	9.33	9.46	7.25	7.15	7.20

Phosphorus is essential for energy transfer and efficient photosynthesis, promoting cell division and elongation and forming the structure of cell membranes. Phosphorus also activates enzymes, supports root development and fosters healthy seedling growth. Ensuring an adequate and balanced supply of phosphorus through proper fertilization and soil management is vital for supporting the overall health and height development of *kharif* rice plants. These mechanisms collectively promote root development, nutrient uptake, cell elongation and overall plant growth, resulting in taller rice plants.

Statistical research of Saleem *et al.* (2013) [22] revealed that the plant height of wheat was somewhat enhanced when 25% of phosphatic fertilizer was replaced with RP-EC, but was decreased by 50% when compared to NPK control. However, plant height improved further when these RPEC substitutes were paired with seed inoculation using PSB or PSB + ACC deaminase PGPR, although they were statistically equal to NPK control and RPEC solo. Plant height increased the most when 50% RP-EC+ PSB + ACC-deaminase was used. Billah and Bano (2014) [6] found that wheat seeds treated with rock phosphate-enriched compost after being inoculated with plant growth-promoting *rhizobacteria* significantly increased plant height compared to the untreated uninoculated control.

Tillers per hill (no.)

The data on number of tillers per hill as influenced by different phosphorus enriched compost are presented in Table 2. Application of T_{10} (60 days conditioned 600% RDP compost) recorded significantly higher number of tillers per hill (10.69, 10.71 and 10.70) in both year and in pooled analysis. The lowest number of tillers (8.87, 8.71 and 8.79) per hill found under the T_2 (20 days conditioned compost) during both the years and pooled analysis.

Phosphorus promotes the growth of axillary buds, which are essential for tiller formation. Additionally, phosphorus enhances the activity of plant hormones like auxins, cytokinins and strigolactones contributing to bud initiation and outgrowth. As a key component of ATP, phosphorus provides energy for metabolic processes, including tiller development. It also regulates carbohydrate metabolism, directing sufficient carbohydrates towards promoting tiller growth. Moreover, phosphorus supports root development and nutrient uptake, facilitating the absorption of essential nutrients for tiller formation. Its involvement in biomolecule synthesis including nucleic acids and phospholipids plays a role in cell division and growth further contributing to tiller production. The synergistic interactions among rock phosphate, PSB and *Azotobacter* create a balanced nutrient supply, optimal root development and hormonal effects, creating an environment conductive to increased tiller formation in rice plants. According to Khan *et al.*, (2019) [18] the treatment receiving PEC at 6 Mg/ha had the maximum number of tillers/plant, while the control treatment had the lowest. Treatments that received SSP at 100 kg P_2O_5/ha, PEC at 4 Mg/ha and PLC at 8 Mg/ha produced considerably more tillers per plant.

Table 3: Panicle length and test weight of *kharif* rice as affected by different treatments

Treatment	Panicle length (cm)			Test weight (g)		
	2021	2022	Pooled	2021	2022	Pooled
T_1: RDP + compost	22.37	22.03	22.20	28.80	28.98	28.89
T_2: 20 days conditioned compost	15.07	15.40	15.24	26.30	25.83	26.07
T_3: 20 days conditioned 400% RDP compost	17.23	16.90	17.07	27.48	27.10	27.29
T_4: 20 days conditioned 600% RDP compost	21.33	21.00	21.17	28.18	28.25	28.22
T_5: 40 days conditioned compost	15.77	16.10	15.93	26.69	26.38	26.54
T_6: 40 days conditioned 400% RDP compost	19.10	18.37	18.73	27.75	27.58	27.67
T_7: 40 days conditioned 600% RDP compost	23.77	23.43	23.60	29.23	29.27	29.25
T_8: 60 days conditioned compost	16.53	16.87	16.70	26.89	26.57	26.73
T_9: 60 days conditioned 400% RDP compost	20.13	19.13	19.63	28.07	27.93	28.00
T_{10}: 60 days conditioned 600% RDP compost	25.10	24.80	24.95	29.67	29.82	29.75
S.Em ±	1.05	1.04	0.74	1.44	1.30	0.97
CD (P = 0.05)	3.14	3.10	2.13	NS	NS	NS
Y	-	-	NS	-	-	NS
Y x T						
S.Em ±	1.05			1.37		
CD (P = 0.05)	NS			NS		
CV (%)	9.33	9.32	9.32	8.92	8.13	8.53

Panicle length (cm)

A perusal of the data in Table 3 revealed that different treatments of phosphorus-enriched compost had a significant effect on panicle length of *kharif* rice during individual years as well as in pooled data. At harvest, panicle length of *kharif* rice (25.10, 24.80 and 24.95 cm) was found significantly higher with the application of T_{10} (60 days conditioned 600% RDP compost) during both the years and also in pooled analysis. The lower panicle length observed in treatment T_2 (20 days conditioned compost) during both the years as well as in pooled analysis.

The application of RPEC leads to an increase in the length of rice panicles through various mechanisms. These mechanisms include the improved availability of nutrients, particularly phosphorus, due to the solubilization activity of PSB. Phosphorus promotes cell division and elongation in the panicle meristem, ensuring the extension of the panicle. Phosphorus also serves as a component of ATP, providing the energy required for panicle growth and supporting efficient photosynthesis. Additionally, it is essential for biomolecule synthesis, including nucleic acids and phospholipids, contributing to genetic information encoding and cell membrane formation crucial for panicle development. Moreover, phosphorus acts as a cofactor for enzymes involved in metabolic pathways and influences the synthesis and activity of plant hormones like gibberellins, which promote panicle elongation. Das *et al*. (2010) [1] noted that eupatorium and rice straw MNFC (Enriched with microbial culture, rock phosphate and neem cake) composts recorded a considerably greater panicles/hill over control when compared to other composts from different sources.

Test weight (g)

The data on test weight as influenced by different phosphorus enriched compost is presented in Table 3. Test weight of *kharif* rice was not significantly influenced by phosphorus enriched compost during both individual year and pooled analysis. However, maximum test weight (29.67, 29.82 and 29.75 g) were recorded with the treatment T_{10} (60 days conditioned 600% RDP compost) in both year and in pooled analysis whereas treatment T_2 (20 days conditioned compost) recorded minimum test weight in both year and in pooled analysis.

Adequate phosphorus availability by applying RPEC enhances grain filling by facilitating efficient carbohydrate and nutrient transport to developing grains, leading to denser and heavier grains ultimately contributing to fairly increased test weight. As a key component of ATP, phosphorus supports photosynthesis and energy transfer, ensuring an ample supply of carbohydrates required for grain development. It also influences carbohydrate partitioning, directing carbohydrates from source tissues to developing grains during grain-filling, promoting larger and heavier grains. Additionally, phosphorus contributes to protein synthesis, which enhances grain quality and test weight. Furthermore, it is involved in cell wall development, ensuring the structural integrity of grains and supporting their weight and density. Through these physiological mechanisms, phosphorus positively impacts test weight in *Kharif* rice. Das *et al.* (2010) [1] noted a substantial improvement in test weight of rice with application of MNFC (enriched with microbial culture, rock phosphate and neem cake) over control when compared to other composts from different sources. According to Bhadu *et al.* (2017) [5], rock phosphate enriched with FYM + PSB had the highest number of grains per spike and 100 grain weight of wheat were found with RP + FYM + PSB being statistically equal to other enrichment treatments except RP alone and RP + FYM.

Grain yield (kg/ha)

The data show the grain yield of *kharif* rice are presented in Table 4 fig 1 was significantly influenced by different treatments during both the year and also in pooled analysis. Among the different treatments, treatment T_{10} (60 days conditioned 600% RDP compost) recorded significantly higher grain yield (5216, 5387 and 5302 kg/ha) in both individual year and in pooled studies. The response of different treatments in grain yield of *kharif* rice was in order of $T_{10} > T_7 > T_1 > T_4 > T_6 > T_9 > T_3 > T_8 > T_5 > T_2$. The percent increase in grain yield of *kharif* rice with these treatments was 25.27, 23.07, 21.77, 13.37, 7.83, 7.67, 6.63, 3.89, 2.73 and 1.83 percentages respectively over the treatment T_0 on the basis of pooled data.

Adequate phosphorus availability enhances root development and nutrient uptake, improving water and nutrient absorption from the soil which leads to better plant health and higher grain yield. Additionally, as a key component of ATP, phosphorus supports efficient photosynthesis, increasing carbohydrate production necessary for grain development. During the grain-filling stage, phosphorus ensures efficient transport and deposition of carbohydrates and nutrients into developing grains, resulting in larger and heavier grains and ultimately contributing to increased grain yield.

Table 4: Grain and straw yield of *kharif* rice as affected by different treatments

Treatment	Grain yield (kg/ha)			Straw yield (kg/ha)		
	2021	2022	Pooled	2021	2022	Pooled
T_1: RDP + compost	5154	5163	5159	6574	6719	6646
T_2: 20 days conditioned compost	4215	4160	4188	5422	5573	5498
T_3: 20 days conditioned 400% RDP compost	4446	4558	4502	5632	5652	5642
T_4: 20 days conditioned 600% RDP compost	4802	4821	4812	6188	6161	6175
T_5: 40 days conditioned compost	4323	4352	4338	5514	5617	5565
T_6: 40 days conditioned 400% RDP compost	4471	4617	4544	5654	5681	5668
T_7: 40 days conditioned 600% RDP compost	5197	5207	5202	6743	6751	6747
T_8: 60 days conditioned compost	4387	4376	4382	5585	5639	5612
T_9: 60 days conditioned 400% RDP compost	4496	4660	4578	5714	5763	5739
T_{10}: 60 days conditioned 600% RDP compost	5216	5387	5302	6754	6764	6759
S.Em ±	224	237	163	293	281	203
CD (P = 0.05)	665	704	468	869	836	582
Y	-	-	NS	-	-	NS
Y x T						
S.Em ±	230			287		
CD (P = 0.05)	NS			NS		
CV (%)	8.30	8.67	8.53	8.48	8.08	8.29

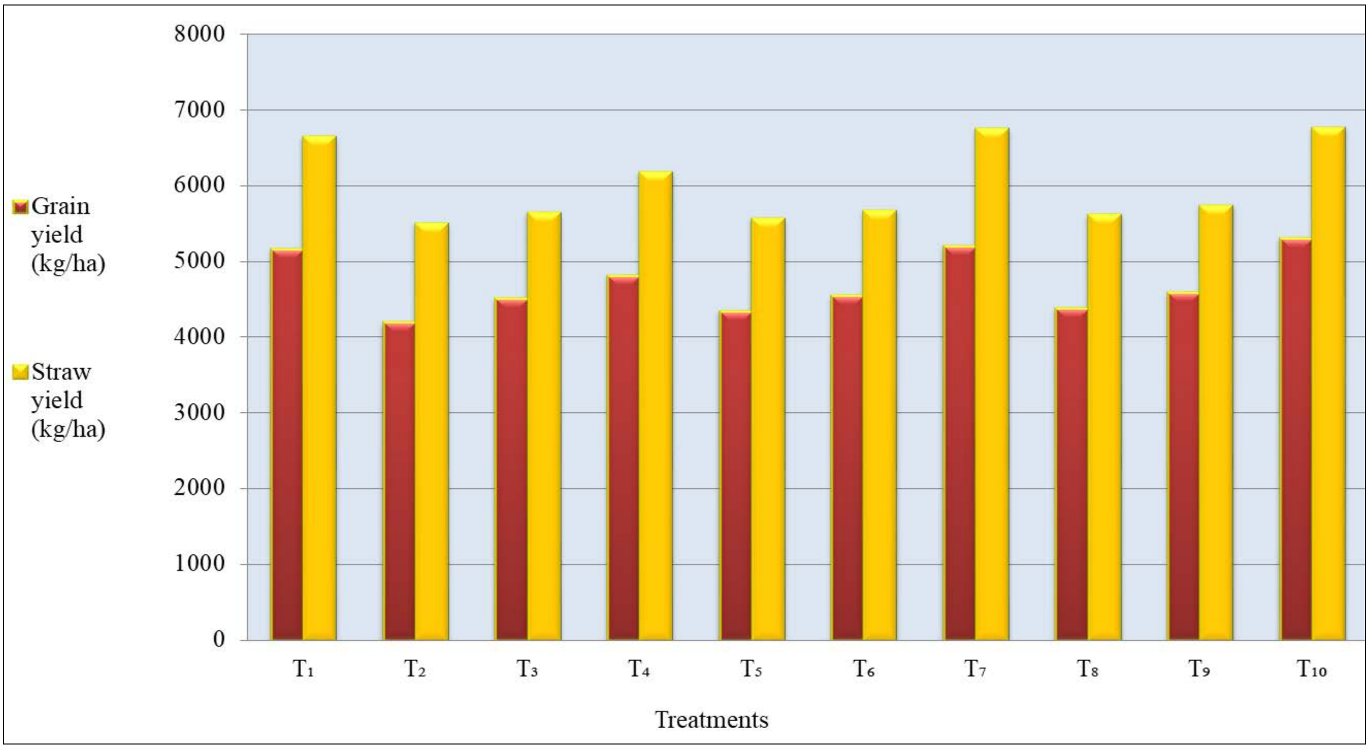

Fig 1: Grain and straw yield (kg/ha) of *kharif* rice as affected by different treatments

Moreover, phosphorus is essential for biomolecule synthesis, including nucleic acids and phospholipids, which are crucial for grain development. Furthermore, phosphorus acts as a cofactor for enzymes involved in various metabolic pathways, impacting nutrient assimilation, photosynthesis and other processes that contribute to higher grain yield. By positively influencing these processes, phosphorus availability in the soil plays a pivotal role in optimizing grain yield in *kharif* rice.

It has been shown that RPEC keep higher levels of P in soil solution longer than fertilizer alone. The increased production with enriched compost treatments could be attributed to increased microbial activity and a greater supply of secondary and micronutrients, which were not delivered by 100% chemical fertilizer (Cheuk *et al*., 2003 and Singh *et al*., 2004) [8, 25]. Rhizobacteria that promote plant growth can release phosphorus from low-grade rock phosphate through composting and the use of compost that has been enhanced with rock phosphate can improve crop yields without the need of chemical fertilizers (Billah and Bano, 2014) [6]. Asewar *et al*. (2003) [3] observed that using 20 kg P_2O_5 as rock phosphate in combination with PSB (*Bacillus magaterium*) was preferable to using 40 kg P_2O_5 as rock phosphate alone for the grain production of pea. Basavaraj and Manjunthaiah (2003) [4] found that the combined application of P-enriched organic manure at 100% RDF-P had significant effect on grain yield of maize, which accounted 27.50% increase in yield over control. Kaushik *et al*. (2004) [16] reported that 30 kg P_2O_5 as SSP can safely be replaced to increased paddy and wheat yield significantly with 30 kg P_2O_5 as Udaipur Rock Phosphate (URP) in the presence of Blue Green Algae (BGA), Vesicular Arbuscular Mycorrhizae (VAM) and Phosphorus Solubilizing Bacteria (PSB) as inoculants.

Ditta *et al*. (2015) [11] conducted a series of pot and field tests to compare the efficacy of RP-enriched organic fertilizer *vs*. mineral phosphatic fertilizer on lentil yield. When compared to the prescribed chemical phosphatic fertilizer, the results indicated that RP-enriched organic fertilizer with the optimal impregnation ratio of RP and compost, time of application and rate of application had a significant effect on yield of lentil. According to Khan *et al*., (2019) [18], The treatment with PEC (Phosphorus Enriched Compost) applied at 6 Mg/ha produced the highest grain yield of 5, 515 kg/ha of paddy, while the control produced the lowest yield. Billah *et al.* (2020) [7] observed that wheat plants inoculated with *Pseudomonas* sp. demonstrated a maximum grain yield increase of 18%, which was 4% higher than those inoculated with *Proteus* sp. In comparison to the un-inoculated control, the application of $RPEC_1$ (Poultry litter + rock phosphate + *pseudomonas* sp.) resulted in a substantial 67% increase in grain yield of wheat.

Straw yield (kg/ha)

The data pertaining to the straw yield of *kharif* rice are presented in Table 4 and fig 1 was found significantly influenced by different phosphorus enriched compost treatments. Among the different treatments, treatment T_{10} (60 days conditioned 600% RDP compost) recorded significantly higher (6754, 6764 and 6759 kg/ha) straw yield during both the year and in pooled analysis. The minimum value of straw yield (5422, 5573 and 5498 kg/ha) found in treatment T_2 (20 days conditioned compost).

The increase in straw yield of rice by applying rock phosphate, PSB and *Azotobacter*-inoculated compost can be attributed to several physiological mechanisms. Firstly, the presence of PSB in the compost helps solubilize the insoluble phosphorus in rock phosphate, making it more accessible for uptake by rice plants. This increased phosphorus availability promotes vegetative growth and contributes to higher straw yield. Secondly, *Azotobacter*, a nitrogen-fixing bacterium, provides a source of fixed nitrogen to rice plants through the application of *Azotobacter*-inoculated compost. The availability of nitrogen, an essential nutrient, supports vigorous vegetative growth and leads to an increased straw yield.

Additionally, PSB and *Azotobacter* can produce plant growth-promoting hormones that stimulate vegetative growth in rice plants. These hormones, including auxins, cytokinins and gibberellins played a crucial role in regulating physiological processes such as cell division and elongation. Furthermore, the combination of rock phosphate, PSB and *Azotobacter*-inoculated compost enhances photosynthesis in rice plants. Phosphorus availability supports chlorophyll development and photosynthetic machinery, while nitrogen fixation provides additional nitrogen for protein synthesis and enhancing photosynthetic activity. Improved photosynthesis leads to increased assimilation of carbohydrates and contributes to higher straw yield. Lastly, the application of these components promotes root development and nutrient uptake in rice plants. Well-developed root systems efficiently absorb water, phosphorus and nitrogen from the soil, supporting vigorous vegetative growth and ultimately increasing straw yield. Overall, the combination of rock phosphate, PSB and *Azotobacter*-inoculated compost influences multiple physiological mechanisms, including enhanced nutrient availability, hormonal stimulation, improved photosynthesis and better root development, all of which contribute to the increased straw yield of rice.

Hossain *et al*. (2004) [13] reported an increase in grain and straw yield of wheat crop with the application of PSB along with different levels of phosphorus due to phosphate solubilizing microorganisms in combination with different P fertilizers were reported earlier by different workers (Khan and Zaidi 2007, Iftikhar *et al*. 2015 and Sharif *et al.* 2015) [17, 14, 24]. According to Ali *et al*. (2014) [2], the treatments where RP fed FYM + 1/2 SSP were applied, produced the greatest dry matter yield of berseem of 4000 and 3767 kg/ha in two cuts, with 85% and 109% increases above control, respectively. The control group had the lowest yield of berseem dry matter (2167 and 1800 kg/ha). These findings concur with those of Abdelaziz *et al*. (2007) [1] and Yolcu *et al*. (2010) [26], who discovered that the application of RP composted with organic materials considerably boosted dry matter production. According to Khan *et al*., (2019) [18] noted the maximum dry-matter yield of rice was 7.5 Mg/ha with PEC at 6 Mg/ha, followed by 7.3 Mg/ha and 7.2 Mg/ha with PEC at 4 Mg/ha and SSP, respectively. They also discovered that the application of PEC at 6 Mg/ha to the preceding crop resulted in the highest dry-matter yield of 8610 kg/ha, followed by PEC at 4 Mg/ha and PLC at 8 Mg/ha, with total dry-matter yields of 7850 and 7570 kg/ha, respectively.

Conclusion

Result of field experiment showed that the growth parameter of *kharif* rice namely plant height and yield parameter test weight, found non-significant with different treatments of phosphorus-enriched compost in both year as well as in pooled analysis. The significant effect of treatment T_{10} (60 days conditioned 600% RDP compost) were found in case of no. of tillers/hill and panicle length in both year and pooled analysis as well. Significantly the higher grain and straw yield of *kharif* rice were observed with treatment T_{10} in both year and pooled analysis. The replacement of chemical phosphatic fertilizer with Phosphorus-Enriched Compost (RPEC) in *kharif* rice cultivation is motivated by sustainability, slow nutrient release, improved soil health and reduced environmental impact. RPEC enhances soil structure, supports microbial activity and provides a steady supply of phosphorus. The practice promotes cyclic resource utilization and minimizes soil degradation.

Future scope of the study

The study on the effect of phosphorus-enriched compost on the growth, yield attributes and yield of *kharif* rice opens up several avenues for future research and practical applications. Some potential future scopes include:

Optimization of Compost Composition

Further research can focus on optimizing the composition of phosphorus-enriched compost, considering different sources of organic materials and their ratios. This can help identify the most effective compost formulations for enhancing rice growth and yield.

Long-Term Effects and Sustainability

Investigate the long-term effects of phosphorus-enriched compost application on soil health, fertility and sustainability. Assessing the impact over multiple crop cycles can provide insights into the sustainability of the approach and its potential contribution to improving overall soil quality.

Microbial Community Dynamics

Explore the changes in microbial communities in the soil due to the application of phosphorus-enriched compost. Understanding the microbial dynamics can shed light on the mechanisms through which compost influences plant growth and nutrient uptake.

Economic Analysis
Conduct economic analyses to evaluate the cost-effectiveness of using phosphorus-enriched compost compared to traditional fertilization methods. This can help farmers and policymakers make informed decisions about adopting this approach on a larger scale.

Field Trials in Different Agro-ecosystems
Expand the research to different agro-ecosystems and geographical locations to assess the adaptability and effectiveness of phosphorus-enriched compost under varying environmental conditions. Different soil types and climates may influence the compost's impact on rice growth.

Integration with Other Sustainable Practices
Investigate the potential synergies between phosphorus-enriched compost application and other sustainable agricultural practices such as conservation agriculture, crop rotation and water management. Integrated approaches may offer comprehensive solutions for sustainable rice production.

Response in Different Rice Varieties
Explore the variation in response to phosphorus-enriched compost among different rice varieties. Some varieties may exhibit a more pronounced positive response and understanding this variability can guide recommendations for specific varieties in different regions.

Impact on Nutrient Use Efficiency
Evaluate the nutrient use efficiency of phosphorus-enriched compost compared to conventional fertilizers. Assessing how efficiently plants utilize nutrients from the compost can contribute to more precise and sustainable nutrient management practices.

Climate Change Resilience
Investigate whether phosphorus-enriched compost application contributes to climate change resilience in rice cultivation. This includes assessing the impact on water use efficiency, carbon sequestration and adaptability to changing climatic conditions.

Knowledge Transfer and Farmer Adoption
Develop extension programs and knowledge transfer initiatives to disseminate the findings to farmers. Understanding the practical aspects of implementing phosphorus-enriched compost application on a larger scale is crucial for widespread adoption and impact.

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