Effect of Rock Phosphate, Single Super Phosphate and Phosphorus Solubilizing Bacteria on phosphorus concentration and dry matter yield of paddy

ABSTRACT

The majority of tropical and subtropical soils are acidic which are mostly deficient in phosphorus and have strong phosphorus sorption capacity. Exploring different phosphorus inputs is essential not only to increase crop production but also to improve soil phosphorus status to avoid further soil degradation. Acidic nature of the soils of these regions help to solubilize the rock phosphate and increases the amount of phosphorus that is made available to the plants. A pot experiment was conducted in Department of Soil Science and Agricultural Chemistry of College of Agriculture, Central Agricultural University, Imphal (Manipur) during *kharif* season of 2021 to study the effect of rock phosphate, single super phosphate and phosphorus solubilizing bacteria on phosphorus concentration and dry matter yield of paddy. To each experimental pot, recommended dose of 60 kg of N ha^{-1} in the form of urea and 30 kg K_2O ha^{-1} in the form of muriate of potash were applied as basal and thoroughly mixed with the soil. Rock phosphate and single super phosphate were administered to the pots as phosphorus sources according to different sets of treatment based on the recommended amount of 40 kg P_2O_5 ha^{-1} for paddy. Seeds were treated with *Bacillus megatherium*. Result revealed that the changes in soil phosphorus concentration and dry matter yield of paddy were significantly affected by rock phosphate applied either singly or in combination with single super phosphate and phosphorus solubilizing bacteria. All the parameters showed different trend of changes during the whole crop growth stages till harvest. Among the treatments higher values were recorded in soil treated with T_{10} (50% recommended dose of P_2O_5 from single super phosphate + 50% recommended dose of P_2O_5 from rock phosphate + phosphorus solubilizing bacteria). Addition of phosphorus solubilizing bacteria enhances release of less soluble and fixed forms into easily available form as well as reduces phosphorus fixation. Efficiency of rock phosphate as phosphorus source for crop production is improved by the solubility effect of phosphorus solubilizing bacteria.

Keywords: Dry matter, Paddy, Phosphorus Solubilizing Bacteria, Rock Phosphate, Single super phosphate, Total phosphorus.

1. INTRODUCTION

More people are directly fed by rice than any other crop, making it the most significant crop for human food production worldwide. India's national economy significantly depends on the production of rice. With a cultivated area of about 43 mha, India ranks second globally in terms of production, producing 22% of the world's rice. A staple food crop, rice thrives in hot, humid weather because it is a tropical plant. It can be grown under diverse soil and climatic conditions. Developing resourceful fertilizers and fertilization methods are imperative considerations for sustainable rice production (Slaton, 2011).

Phosphorus is one of 17 nutrients essential for plant growth and is found in every living plant cell. It participates in a number of essential plant processes, including the transfer of energy, photosynthesis, the conversion of sugars and starches, the flow of nutrients within the plant, and the transmission of genetic traits from one generation to the next. Numerous different organic and inorganic substances containing phosphorus can be found in soil. Both organic as well as inorganic forms of phosphorus are found as compounds with aluminium (Al), iron (Fe), and calcium (Ca). These compounds affect the availability of phosphorus to plants. Acidic soils commonly have large reserves of 'fixed' P that could be mobilized through appropriate soil management involving organic matter additions and/or use of P solubilizing microbes. Organic resources, mineral P fertilizers, or phosphate rocks are available options for P inputs. Despite the fact that the overall amount of P in the soil may be high, P availability in the soil is frequently a limiting factor for plant growth. Solubility and how quickly phosphorus fixes in soils determine its availability (Manimaran, 2014). There is a significant amount of benefits in the use of rock phosphate (RP) due to the high expense of soluble phosphate fertilizer, such as single or triple super phosphate. Since rock phosphate releases phosphorus slowly, it frequently falls short of crop needs for phosphorus (Bhattacharyya and Singh, 1990). Actinomycetes, bacteria, and fungus are among of the microorganisms that are known to assist in the dissolution of fixed P. Many crops could use RP as a P source in conjunction with phosphate-solubilizing microbes and organic manure (Wahid *et al*., 2015). Inorganic P has been reported to be effectively solubilized in soils by phosphobacterins in general. Rice output in the nation may rise with proper soil management, which includes the use of effective phosphatic biofertilizers and inorganic sources of P. To improve the use efficiency of chemical P fertilizer by rice crops, integrated usage of chemical fertilizers and phosphatic biofertilizer may be a viable solution. The application of effective PSB strain as phosphatic biofertilizer for rice agriculture, however, is poorly documented.

The investigation was carried out with the abovementioned considerations in mind to study the effect of rock phosphate, single super phosphate and phosphorus solubilizing bacteria on total phosphorus concentration and dry matter yield of paddy (variety CAU-R1) grown in soil of Manipur, India.

2. MATERIALS AND METHODS

A pot experiment was conducted during the *Kharif* season of 2021 to investigate the effect of applied rock phosphate, single super phosphate and phosphorus solubilizing bacteria on phosphorus concentration and dry matter yield of paddy (variety CAU-R1). Composite soil samples (0-15 cm depth) were collected from the Research farm, College of Agriculture, Central Agricultural University, Imphal, Manipur, India following the standard process as described by Jackson (1973). The general characteristics of the experimental soil were: sand (28.20%), silt (22.50%), clay (49.30%), soil texture (clayey), pH (5.20), EC (0.31 dSm^{-1}), CEC [14.92 cmol(p+) kg^{-1}], organic carbon (1.65%), available N (263.42 kg ha^{-1}), available P_2O_5 (22.76 kg ha^{-1}) and available K_2O (211.73 kg ha^{-1}) (Table 1).

A total of 198 plastic pots were procured and each pot was filled with 5 kg of air-dried soil. To each experimental pot, recommended dose (RD) of 60 kilograms of N ha^{-1} in the form of urea and 30 kg K_2O ha^{-1} in the form of muriate of potash were applied as basal and thoroughly mixed with the soil. Rock phosphate and SSP were administered to the pots as phosphorus sources according to different sets of treatment based on the recommended amount of 40 kg P_2O_5 ha^{-1} for paddy. Seeds were treated with PSB (*Bacillus megatherium*) collected from the department of Plant Pathology, College of Agriculture, CAU, Imphal, Manipur, India). The inoculated seeds were dried under shade and four seeds per pot were sown immediately. After germination, a single healthy seedling was retained

Table 1: General properties of the soil used in the experiment

Soil property	Results	Remarks
Soil Texture:		Clayey Soil
Sand (%)	28.20	
Silt (%)	22.50	
Clay (%)	49.30	
pH (1:2.5 soil: water ratio)	5.20	Acidic
EC (1:2.5 soil: water ratio, dSm^{-1})	0.31	No deleterious effect on crops
CEC (cmol(p+) kg-1)	14.92	
Organic carbon (%)	1.65	High
Available nitrogen (kg ha^{-1})	263.42	Medium

Available phosphorus (kg ha^{-1})	22.76	Medium
Available potassium (kg ha^{-1})	211.37	Medium

throughout the experiment. The soils of each treatment were kept at submergence during the entire experiment. The experiment was conducted in a completely randomized block design replicated thrice. The treatments were: T_1= Control, T_2= 100% RD of P_2O_5 from SSP, T_3= 100% RD of P_2O_5 from RP, T_4= 75% RD of P_2O_5 from SSP + 25% RD of P_2O_5 from RP, T_5= 50% RD of P_2O_5 from SSP + 50% RD of P_2O_5 from RP, T_6= 25% RD of P_2O_5 from SSP + 75% RD of P_2O_5 from RP, T_7=100% RD of P_2O_5 from SSP + PSB, T_8=100% RD of P_2O_5 from RP + PSB, T_9=75% RD of P_2O_5 from SSP + 25% RD of P_2O_5 from RP + PSB, T_{10}=50% RD of P_2O_5 from SSP + 50% RD of P_2O_5 from RP + PSB, T_{11}=25% RD of P_2O_5 from SSP + 75% RD of P_2O_5 from RP + PSB.

The plant samples were collected on 25^{th}, 50^{th}, 75^{th} and 100^{th} days after sowing (DAS) seeds and at harvest from the rhizosphere region by destructive sampling. Different soil parameters like soil texture (hydrometer method), pH (1:2.5 soil: water suspension using glass electrode systronic pH meter), EC (1:2.5 soil: water suspension using systronic direct reading conductivity meter), organic carbon (Walkley and Black`s rapid titration method, 1934), cation exchange capacity (leaching with 1N NH_4OAc), available N (alkaline potassium permanganate), P (Bray and Kurtz No.1, 1945) and K (flame photometrically by using extractant 1N NH_4OAc) were estimated as described by Jackson (1973).

Plant fresh weight, dry weight and dry matter yield were also recorded on 25^{th}, 50^{th}, 75^{th} and 100^{th} days after sowing seeds (DAS) and at harvest. Plant samples were digested in a di-acid mixture of nitric acid and perchloric acid in a 4:1 ratio, and the digested plant materials were examined using Vanadomolybdo phosphoric yellow colour technique described by Jackson (1973).

The experiment was carried out under completely randomized design (CRD). For the purpose of comparing the effects of the treatments, the experiment's data were statistically analyzed using the analysis of variance technique. At a 5% level of probability, the importance of various impacts was evaluated. (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1. TOTAL PHOSPHORUS IN PLANT

Data on variations in P concentration in paddy cultivated in soil treated with SSP, RP, and PSB are shown in Table 2. Regardless of the various treatments, the results showed that there was a growing tendency up to the 50^{th} day and a declining trend up until the 100^{th} day, with a minor increase at harvest (Delin and Zhu,1996). Total-P accumulation is noticeably higher under all phosphorus application treatments compared to the control. Similar reports on higher P concentration in rice plants receiving P sources was also presented by White *et al*. (1999) and Banerjee and Pramanik (2009) and Vandamme *et al*. (2016). Molla *et al.* (1984); Gaur (1990) and Adhikari *et al.* (2014) recorded that introduction of P solubilizing microorganisms in the rhizosphere of crop and soil increases the availability of P from insoluble sources of phosphates, desorption of fixed phosphates and also increases the efficiency of phosphorus fertilizers. Application of PSB significantly enhanced plant total P concentration comparing with the corresponding treatment without PSB at different stages of crop growth. Supportive reports were also given earlier by Costa *et al.* (2015). At all growth stages, beginning on the 50^{th} day and continuing through harvest, soil fertilized with T_{10} (50%SSP + 50%RP + PSB) exhibits a relatively larger accumulation of total P. At 50^{th} day, among the PSB untreated soils T_4 (75% SSP + 25% RP) show greater concentration which was at par with T_5 (50% SSP + 50% RP).

Table 2: Changes in total phosphorus in paddy plant (mg kg^{-1})

Treatment	Sampling Days				
	25DAS	50DAS	75DAS	100DAS	Harvest
T_1	514.30^{l}	675.60^{l}	537.00^{e}	201.67^{g}	259.33^{g}
T_2	566.47^{e}	709.53^{h}	641.60^{e}	256.50^{e}	283.40^{f}

T_3	555.83^{f}	728.63^{fg}	667.53^{c}	252.63^{e}	315.57^{e}
T_4	540.57^{c}	742.70^{d}	655.23^{d}	244.03^{f}	327.40^{d}
T_5	575.07^{d}	737.33^{de}	666.70^{c}	264.50^{d}	349.63^{c}
T_6	613.77^{c}	741.10^{d}	675.60^{b}	252.97^{e}	332.72^{d}
T_7	532.80^{h}	723.93^{g}	667.37^{c}	253.57^{e}	357.62^{c}
T_8	636.70^{ab}	732.53^{ef}	682.80^{ab}	275.53^{c}	354.33^{c}
T_9	640.13^{a}	764.13^{b}	678.17^{b}	283.47^{b}	415.40^{b}
T_{10}	641.81^{a}	777.77^{a}	685.47^{a}	311.47^{a}	440.07^{a}
T_{11}	630.63^{b}	752.23^{c}	680.60^{ab}	284.83^{b}	430.92^{a}
S.E.d(±)	3.41	3.69	3.62	2.67	4.42
$CD_{0.05}$	7.07	7.65	7.50	5.55	9.16

3.2. DRY MATTER YIELD

The information on the dry matter yield of paddy cultivated in soil treated with SSP and RP in the presence or absence of PSB is shown in Table 3. According to the findings, there was a rising trend in the dry matter of paddy up until harvest regardless of the various treatments. Delin and Zhu (1996) also observed that the increase in rice dry matter correlated with crop growth. All phosphorus-treated soil showed significantly higher dry matter yields of paddy at various stages of crop growth as compared to the untreated control. This is consistent with the findings of Muraoka *et al*. (2002); Poleshi *et al*. (2008) and Banerjee and Pramanik (2009). Compared to the other treatments, the soil that received T_9 (75% SSP + 25% RP + PSB) application had considerably more dry matter on 50th day followed by T_{10} (50%SSP + 50%RP + PSB). Moreover, subsequent data analysis showed that paddy grown in T_{10} (50%SSP + 50%RP + PSB) treated soil had greater dry matter build-up on 100th day and at harvest which is analogous to T_9 (75% SSP + 25% RP + PSB) and T_{11} (25% SSP + 75% RP + PSB), respectively. Results also showed that paddy planted in T_2 (100% SSP) treated soil had significantly higher dry matter yields than paddy cultivated in T_3 (100% RP) treated soil. Increased dry matter production was a result of rock phosphate improving agronomic performance (Ikerre *et al.,* 1994). Furthermore, it was shown that starting on the 50th day until harvest, applying PSB considerably enhanced the dry matter yield of paddy compared to the similar phosphorus-treated soil without PSB. The sustained availability of P may have contributed to the proliferation of root development, which improved nutrient uptake and biomass accumulation. This could account for the enhanced output under rock phosphate and PSB application (Egamberdiyeva *et al.* 2004; Saleem *et al*., 2013; Yu *et al*., 2014 and Costa *et al*., 2015).

Table 3: Changes in dry matter yield (g plant^{-1}) content in paddy plant

Treatments	SAMPLING DAYS				
	25 DAS	**50 DAS**	**75 DAS**	**100 DAS**	**Harvest**
T_1	2.44^{d}	4.37^{d}	8.63^{g}	21.68^{g}	27.68^{j}
T_2	2.58^{d}	5.64^{c}	10.59^{f}	23.51^{e}	31.79^{i}
T_3	3.44^{bc}	5.47^{c}	10.37^{f}	22.53^{f}	32.95^{h}
T_4	3.34^{c}	6.67^{b}	11.28^{e}	23.75^{e}	34.12^{g}
T_5	3.46^{bc}	5.69^{c}	11.27^{e}	24.60^{d}	34.86^{f}
T_6	3.47^{bc}	6.63^{b}	11.50^{de}	24.62^{d}	36.58^{e}
T_7	3.52^{bc}	6.55^{b}	11.92^{cd}	24.75^{d}	40.80^{d}
T_8	3.66^{ab}	7.54^{a}	12.16^{bc}	25.09^{c}	42.32^{b}

T_9	3.52[bc]	7.66[a]	12.30[abc]	25.56[b]	41.54[c]
T_{10}	3.87[a]	7.56[a]	12.72[a]	26.65[a]	43.33[a]
T_{11}	3.54[bc]	7.46[a]	12.46[ab]	25.56[b]	42.70[b]
S.E.d(±)	0.13	0.12	0.25	0.14	0.22
CD(p=0.05)	0.25	0.25	0.51	0.29	0.46

4. CONCLUSION

The application of a single superphosphate, rock phosphate, and phosphorus-solubilizing bacteria greatly altered the phosphorus concentration and dry matter yield of paddy variety CAU-R1. Higher values are observed in soil treated with T_{10} (50% SSP + 50% RP + PSB). The application of single superphosphate and phosphorus-solubilizing bacteria together increases the agronomic effectiveness of rock phosphate. At all phases of the plant's growth, rock phosphate and SSP-fertilized soil significantly outperforms the control in terms of dry matter production and total P concentration.

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