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Evaluate the potential of P use efficiency to evaluate the potential of phosphorous use efficiency

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Abstract
A field study was conducted during *autumn* season, 2016at the Instructional-Cum-Research Farm of Assam Agricultural University to evaluate the potential of P use efficiency in aerobic rice. The treatment consisted of three phosphorus sources *viz*., $S_{1:}$ Single super phosphate (SSP), S_2: Diammonium phosphate (DP) and S_3: Rock phosphate (RP), three doses of phosphorus viz., $D_{1:}$10 kg P_2O_5 ha^{-1}, D_2:20kg P_2O_5 ha^{-1} and D_3:30 kg P_2O_5 ha^{-1} and two biofertilizer treatments i.e. $B_{1:}$ without biofertilizer and B_2: Azospirillum + phosphorus solubilizing bacteria (PSB). One absolute control was included for comparison. The experiment was laid out in factorial randomized block design (RBD). Recommended doses of N (40 kg ha^{-1}) and K (20 kg ha^{-1}) were applied in all the treatments. Out of the three phosphorus sources, rock phosphate recorded the highest grain (2.61t ha^{-1}) and straw (4.70 t ha^{-1}) yield followed by single super phosphate. Among the doses, highest grain (2.7t ha^{-1}) or straw (4.93 t ha^{-1}) yield were recorded in 30kg P_2O_5 ha^{-1}. In case of bio-fertilizer, Azospirillum + phosphorus solubilizing bacteria (PSB) recorded highest grain yield (2.61t ha^{-1}) and straw yield (4.82 t ha^{-1}). Significantly higher N, P and K uptake were recorded with phosphorus application through rock phosphate which was statically at par with single super phosphate. Rock phosphate recorded higher values of agronomic (39.76kg kg^{-1}) and physiological use efficiency (207.02kg kg^{-1}) of phosphorus which was followed by the source single super phosphate. Application of 30kg P_2O_5 ha^{-1} recorded higher values N, P and K uptake by grain, straw and total and significantly higher available P_2O_5 (31.2 kg ha^{-1}) in soil after harvest. Out of the three doses of phosphorus, application of 10kg P_2O_5 ha^{-1} registered highest agronomic use efficiency (36.16kg kg^{-1}) and the highest physiological use efficiency of phosphorus (234.18kg kg^{-1}) was recorded with 30kg P_2O_5 ha^{-1}. Azospirillum + PSB exhibited significantly higher N, P, K uptake, agronomic use efficiency (39.43kg kg^{-1}) and physiological use efficiency of phosphorus (223.48kg kg^{-1}) than without biofertilizer treatment.

Keywords: Aerobic rice, rock phosphate, Azospirillum, phosphorus solubilizing bacteria, agronomic use efficiency, physiological use efficiency

Introduction
Rice is one of the chief grains of India. India is one of the leading producers of rice and rice being a tropical plant; it flourishes comfortably in hot and humid climate. Rice is grown in all the states of India under diverse agro-climatic conditions from below the sea level (Samal *et al.*, 2012) [13]. Rice consumes much more water than other cereals and nearly 3000-5000 liters of water is required to produce one kg of rice (Bouman, 2009) [5]. The projected demand for rice in India will be 113 mt by 2020-21 and to achieve this target, the projected productivity of rice (un-milled) has to be 4 tones ha (Kumar *et al.*, 2009) [9].

Aerobic rice is a production system in which potentially high yielding, fertilizer responsive rice varieties are grown in fertile aerobic soils that are non-puddled and have no standing water. Supplementary irrigation, however, can be given in the same way as to any other upland cereal crop (Wang *et al.*, 2002) [17]. Thus in aerobic rice system, soils are kept aerobic almost throughout the rice growing season. Imbalanced use of fertilizers and unscientific water management has resulted in rapid degradation of rice ecologies putting tremendous pressure on the rice growers to make rice farming economically viable and ecologically sustainable. The concept of aerobic rice thus, holds promise for farmers in water-short irrigated rice environments where water availability at the farm level is too low or where water is too expensive to grow flooded lowland rice. Aerobic rice cultivation has been identified as a potential new technology, which can reduce water use in rice production and also recognize as an economically attractive crop.

Phosphorus is one of the major nutrients. Phosphorus deficiency has been recognized as one of the main limiting factor in upland rice (Sahrawat *et al.*, 1995) [12].

Rock phosphate (RP) is the cheapest P containing fertilizer, but insoluble in soil and hence there is growing interest in manipulating RP by biological method so that solubility and the agronomic effectiveness are enhanced (Whitelaw, 2000) [18]. Efficiency of phosphate fertilizers was more when applied along with organic manures and phosphobacteria (Baskar *et al.*, 2000) [3]. Rock phosphate (RP) is one such indigenous source that can supply P at a unit cost much lower than Further, there are reports which indicate the response of rice to P fertilization. Significant increase in the P content in rice grain was observed due to increased application of P. Bio-fertilizer containing micro-organisms especially phosphorus solubilizing bacteria (PSB) has the ability to solubilize P in soil and reduce the dependence on chemical fertilizer (Arpana and Bagyaraj, 2007) [2]. Keeping these facts in view present experiment was conducted to evaluate the potential of P- use-efficiency in aerobic rice.

Materials and Methods

The experiment was conducted at the Instructional-Cum-Research Farm of Assam Agricultural University during 2016 on a sandy loam soil having 285.36kg N ha^{-1}, 22.85 kg ha^{-1} of available phosphorous and 138.04 kg ha^{-1} available potassium. The pH of the soil was 5.2. The experiment was laid out in factorial randomized block design and replicated thrice. The experiment was laid out in factorial randomized block design with three replications and nineteen treatments were accommodated randomly in each replication. The treatment consisted of three phosphorus sources *viz*., $S_{1:}$ Single super phosphate (SSP), S_2: Diammonium phosphate (DP) and S_3: Rock phosphate (RP), three doses of phosphorus viz., $D_{1:}$10 kg P_2O_5 ha^{-1}, D_2:20kg P_2O_5 ha^{-1} and D_3:30 kg P_2O_5 ha^{-1} and two biofertilizer treatments i.e. $B_{1:}$ without biofertilizer and B_2: Azospirillum + phosphorus solubilizing bacteria (PSB). One absolute control was included for comparison. The treatment combinations were with source of phosphorus, level of phosphorus and bio-fertilizers. The rice seeds variety Inglongkiri were sown on 11th March, 2016. The crop was harvested on 8th July, 2016. Seed rate of 75 kg ha^{-1} was used. Powder form of phosphorus solubilizing bacteria (PSB) and Azospirillum was inoculated with seed at 400 gm^{-1} in 10 kg seed before sowing. N (40 kg ha^{-1}) and K (20 kg ha^{-1}) were applied in all treatments and P was applied as per the treatments. Observations were recorded as per standard procedure. Data on agro-economic aspects of the crop were recorded and were analysed statistically adopting the procedure of analysis of variance given by cochran and cox (1962) and differences among treatment means were tested using t-test at 5% level of significance.

Results and Discussion

Yield parameters

Application of phosphorus through rock phosphate recorded significantly the highest grain and straw yield of 2.61t ha^{-1} and 4.70 t ha^{-1} respectively (Table 1). The highest grain yield recorded by rock phosphate was 39.7% higher than control. The increase in yield might be due to the improvement in leaf photosynthetic rate, biomass production and sink formation, which promoted the grain and straw yields of aerobic rice. The grain yield and straw yield of rice increased significantly due to application of phosphorus either through mussorie rock phosphate or DAP (Sharma *et al.*, 2009) [14].

Application of phosphorus at 30kg P_2O_5 ha^{-1} recorded highest grain and straw yield of 2.7t ha^{-1} and 4.93 t ha^{-1}, (Table 1) respectively, which was 46.3% higher than control. The reason for this effect may be that rock phosphate at lower rate might have not released sufficient quantity of available P to meet the P requirement of crop. Application of phosphorus fertilizer at 35.2 to 52.5kg ha^{-1} significantly increased grain and straw yield of rice, respectively over the control, (Sharma *et al.*, 2009) [14].

Significantly higher grain (2.61t ha^{-1}) and straw (4.82 t ha^{-1}) yield (Table 1) noted with Azospirillum + PSB treatment proved it to be superior to without bio-fertilizer treatment. Thus harvest index was not significantly affected by biofertilizer treatment. PSB might have dissolved poorly soluble P and convert these insoluble P into soluble forms by the process of acidification, chelation, exchange reactions and production of organic acids however Azospirillum sp. helped to release phytohormones similar to gibberellic acid and indole acetic acid (IAA), which could stimulate plant growth, absorption of nutrients, and photosynthesis due to similar result found by (Khorshidi *et al.,* 2011, Midrarullah *et al.*, 2014) [8, 10].

Nutrient content and uptake

Different sources brought significant difference in total uptake of N, P and K. The phosphorus source S_3 (rock phosphate) recorded significantly the highest uptake of N, P and K (kg ha^{-1}) (Table 2,3,4). The adequate supply of phosphorus played a vital role which might be on account of better removal and translocation of nutrients resulting in higher uptake of NPK by grain and straw. The control treatment showed the lowest NPK content in grain and straw. The results are in close conformity with the findings of Tripathi *et al.* (2007) [16].

Among the doses, application of phosphorus at 30 kg P_2O_5ha^{-1} (D_3) claimed significantly greater removal of N, P, K by grain, straw and total uptake (Table 2,3,4). All growth and P uptake parameters increased significantly with increasing levels of soil P (Fageria *et al*., 1988) [6].

The effect of bio-fertilizer on N, P, K uptake in grain, straw and total uptake was significant. N, P and K uptake in grain, straw and total uptake observed in with Azospirillum + PSB treatment (B_2) were higher than that without bio-fertilizer treatment (B_1) (Table 2,3,4). This may be the effect of phosphate solubilising bio-fertilizer on phosphate. The PSB strains significantly increased soluble P and plant P uptake compared to non-inoculated treatments in aerobic rice (Panwar *et al.,* 2011) [11]. Azospirillum was a free living nitrogen fixing bacteria were found to have not only the ability to fix nitrogen but also the ability to release phytohormones and increased nitrogen-supplying inoculation of wheat with Azospirillum sp. increased N-uptake and N-yield (Bhattarai and Hess, 1993) [4].

Phosphorus use efficiency

The application of rock phosphate (S_3) recorded highest agronomic use efficiency (AUE) of phosphorus which was at par with single super phosphate (S_1) and significantly higher than diammonium phosphate (S_2), whereas physiological use efficiency (PUE) was significantly higher than both single super phosphate and diammonium phosphate (Table 5). This may be due to the fact that rock phosphate increased the availability of phosphorus, its uptake and efficient utilization. Similar results were also reported by (Sharma *et al.*, 2009) [14].

The effect of dose of phosphorus was non-significant in respect of AUE (kg kg^{-1}), but statistically significant in respect of PUE (kg kg^{-1}). The highest value of PUE (234.18kg kg^{-1}) was recorded at 30kg P_2O_5 ha^{-1} (D_3). The lowest value of PUE (131.89kg kg^{-1}) was observed in 10kg P_2O_5 ha^{-1} (D_1) (Table 5). The physiological efficiency (kg grain/kg P uptake) showed a slight increase with increase in P levels from 15 to 30kg P ha^{-1}. (Sharma *et al.*, 2009) [14].

The effect of bio-fertilizer AUE (kg kg^{-1}) was found statistically significant. Azospirillum + PSB treatment (B_2) exhibited significantly higher AUE (kg kg^{-1}) than without bio-fertilizer treatment (B_1) (Table 5). This may be attributed to the plant growth promoting bacteria ((PGPR) that increased amount of nitrogen and phosphorus resulting in improvement of leaf photosynthetic rate, biomass production and sink formation which increased the grain yield of the rice. (Afzal *et al.*, 2005) [1] also reported that P use efficiency was increased due to the inoculation of PSB.

Soil parameters after harvest

Application of phosphorus through different sources did not bring significant effect on available N, K_2O and organic carbon in soil after harvest, whereas the available P_2O_5 was significantly affected. The highest value of available P_2O_5 (31.63kg ha^{-1}) was recorded in the case of rock phosphate (S_3), which was statistically at par with single super phosphate (S_1) (28.64kg ha^{-1}) and significantly higher than diammonium phosphate (S_2). Single super phosphate (S_1) was found statistically at par with diammonium phosphate (S_2) (Table 6). The used P_2O_5 remains in various organic and inorganic fractions in the soil and small amount of phosphorus bound in acidic soil. However, there was, in general, slight improvement in available status of N and K_2O also after harvest over their initial values indicating the overall improvement in soil fertility after harvest of rice crop. The organic carbon was found to increase slightly due to application of organic manures and their residual presence. Mussorie rock phosphate maintained a higher amount of available P in the soil after the harvest of each crop as compared to the equivalent level of single superphosphate, (Karmakar *et al.*, 1995) [7].

Dose of phosphorus did not show significant effect available N, K_2O and organic carbon in the soil after harvest. But available P_2O_5 was significantly affected by the doses, the highest (31.20kg ha^{-1}) being at 30kg P_2O_5 ha^{-1}, which was statistically at par with 20kg P_2O_5 ha^{-1} (D2) and significantly higher than 10kg P_2O_5 ha^{-1}(D_1) (Table 6). Application of MRP @ 120 and 160kg P_2O_5 ha^{-1} significantly increased the available P after the harvest of both crops and after the harvest of second *(kharif* rice) crop, it was significant at 160kg P_2O_5 ha^{-1} over all levels, (Karmakar *et al.*, 1995) [7].

In case of bio-fertilizer treatment also, there was no significant effect on available N, K_2O and organic carbon in soil after harvest. However, Azospirillum + PSB treatment (B_2) recorded significantly higher available P_2O_5 (30.49kg ha^{-1}) than without bio-fertilizer treatment (B_1) (Table 6). This may be due to the fact that PSB increased availability of phosphorus in soil and it changed insoluble phosphorus to soluble form. The application of the PSB *Bacillus megatherium* increased the PSB population in the rhizosphere and P availability in the soil (Sundara *et al.*, 2002) [15].

Apparent phosphorus balance sheet

The data recorded in apparent phosphorus balance sheet indicated that the treatment combination of $S_3D_3B_2$ which included application of phosphorus through rock phosphate at 30kg P_2O_5 ha^{-1} with Azospirillum + PSB showed the highest value of apparent phosphorus balance (Table 7). Rock phosphate was slow releasing fertilizer and with this the PSB might have improved phosphorus availability in soil and reduce fixation loss of phosphorus in soil. This happened because the apparent recovery of DAP decreased with increase in the rate of P application, but that of MRP increased when the rate of P application increased from 17.5 to 35kg P ha^{-1}, (Sharma *et al.*, 2009) [14].

Table 1: Effect of sources and dose of phosphorus on grain and straw yield

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
A. Source of phosphorus			
S_1 : SSP	2.48	4.39	3.64
S_2 : DAP	2.25	4.16	3.52
S_3 : RP	2.61	4.70	3.60
SEm ±	0.06	0.14	0.09
CD (P = 0.05)	0.17	0.41	NS
B. Dose of phosphorus			
D_1 : 10 kg P_2O_5 ha^{-1}	2.23	3.77	3.73
D_2 : 20 kg P_2O_5 ha^{-1}	2.37	4.54	3.43
D_3 : 30 kg P_2O_5 ha^{-1}	2.74	4.93	3.59
SEm ±	0.06	0.14	0.09
CD (P = 0.05)	0.17	0.41	NS
C. Biofertilizer (B)			
B_1 : Without biofertilizer	2.28	4.01	3.64
B_2 : Azospirillum + PSB	2.61	4.82	3.53
SEm ±	0.05	0.12	0.07
CD (P = 0.05)	0.14	0.34	NS
Treatment vs. Control			
Treatment	2.45	4.42	3.58
Control	1.87	3.21	3.71
SEm ±	0.10	0.25	0.16
CD (P = 0.05)	0.31	0.73	NS
Interaction	NS	NS	NS

Table 2: Effect of phosphorus source, dose and biofertilizer on N uptake of grain and straw of aerobic rice.

Treatment	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Total uptake (kg ha^{-1})
A. Source of phosphorus			
S_1 : SSP	39.3	34.5	73.8
S_2 : DAP	34.2	31.5	65.9
S_3 : RP	43.2	39.3	82.5
SEm ±	1.6	1.6	2.7
CD (P = 0.05)	4.7	4.6	7.7
B. Dose of phosphorus			
D_1 : 10 kg P_2O_5 ha^{-1}	34.4	28.3	62.7
D_2 : 20 kg P_2O_5 ha^{-1}	37.7	35.9	73.6
D_3 : 30 kg P_2O_5 ha^{-1}	44.7	41.2	85.5
SEm ±	1.6	1.6	2.7
CD (P = 0.05)	4.7	4.6	7.7
C. Biofertilizer (B)			
B_1 : Without biofertilizer	35.5	30.9	66.4
B_2 : Azospirillum + PSB	42.4	39.3	81.7
SEm ±	1.3	1.3	2.2
CD (P = 0.05)	3.8	3.74	6.3
Treatment vs. Control			
Treatment	38.9	35.1	74.0
Control	24.0	14.9	38.9
SEm ±	2.9	2.8	4.8
CD (P = 0.05)	8.3	8.2	13.7
Interaction	NS	NS	NS

NS: Non significant

Table 3: Effect of phosphorus source, dose and biofertilizer on P uptake of grain and straw of aerobic rice

Treatment	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Total uptake (kg ha^{-1})
A. Source of phosphorus			
S_1 : SSP	5.9	7.8	13.7
S_2 : DAP	5.0	6.9	11.9
S_3 : RP	6.5	8.5	15.0
SEm ±	0.3	0.3	0.6
CD (P = 0.05)	0.8	1.0	1.7
B. Dose of phosphorus			
D_1 : 10 kg P_2O_5 ha^{-1}	5.0	6.4	11.4
D_2 : 20 kg P_2O_5 ha^{-1}	5.6	8.0	13.6
D_3 : 30 kg P_2O_5 ha^{-1}	6.7	8.9	15.6
SEm ±	0.3	0.3	0.6
CD (P = 0.05)	0.8	1.0	1.7
C. Biofertilizer (B)			
B_1 : Without biofertilizer	5.3	6.9	12.2
B_2 : Azospirillum + PSB	6.3	8.5	14.8
SEm ±	0.2	0.3	0.5
CD (P = 0.05)	0.6	0.8	1.4
Treatment vs. Control			
Treatment	5.8	7.7	13.5
Control	2.0	3.2	5.2
SEm ±	0.5	0.6	1.0
CD (P = 0.05)	1.4	1.7	3.0
Interaction	NS	NS	NS

NS: Non significant

Table 4: Effect of phosphorus source, dose and biofertilizer on K uptake of grain and straw of aerobic rice.

Treatment	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Total uptake (kg ha^{-1})
A. Source of phosphorus			
S_1 : SSP	21.0	59.5	80.5
S_2 : DAP	18.0	55.4	73.3
S_3 : RP	22.5	68.8	91.3
SEm ±	0.9	2.5	3.0
CD (P = 0.05)	2.7	7.3	8.7
B. Dose of phosphorus			
D_1 : 10 kg P_2O_5 ha^{-1}	17.3	48.0	65.4
D_2 : 20 kg P_2O_5 ha^{-1}	19.7	62.2	81.9
D_3 : 30 kg P_2O_5 ha^{-1}	24.5	73.3	97.8
SEm ±	0.9	2.5	3.0

CD (P = 0.05)	2.7	7.3	8.7
C. Biofertilizer (B)			
B_1 : Without biofertilizer	18.9	53.3	72.1
B_2 : Azospirillum + PSB	22.1	69.2	91.3
SEm ±	0.8	2.0	2.5
CD (P = 0.05)	2.2	5.9	7.0
Treatment vs. Control			
Treatment	20.5	61.2	81.7
Control	11.3	33.3	44.6
SEm ±	1.7	4.5	5.4
CD (P = 0.05)	4.8	12.9	15.5
Interaction	NS	NS	NS

NS: Non significant

Table 5: Effect of phosphorus source, dose and biofertilizer on phosphorus use efficiency (kg kg^{-1}) of aerobic rice**.**

Treatment	Agronomical use efficiency (kg kg^{-1})	Physiological use efficiency (kg kg^{-1})
A. Source of phosphorus		
S_1 : SSP	31.75	187.22
S_2 : DAP	18.67	172.41
S_3 : RP	39.76	207.02
SEm ±	4.91	18.28
CD (P = 0.05)	9.97	NS
B. Dose of phosphorus		
D_1 : 10 kg P_2O_5 ha^{-1}	36.16	131.89
D_2 : 20 kg P_2O_5 ha^{-1}	25.07	200.58
D_3 : 30 kg P_2O_5 ha^{-1}	28.94	234.18
SEm ±	4.91	18.28
CD (P = 0.05)	NS	37.12
C. Biofertilizer (B)		
B_1 : Without biofertilizer	20.69	154.28
B_2 : Azospirillum + PSB	39.43	223.48
SEm ±	3.00	14.93
CD (P = 0.05)	8.14	25.00
Interaction	NS	NS

NS: Non significant

Table 6: Effect of phosphorus source, dose and biofertilizer on available N, P_2O_5, K_2O (kg ha^{-1}) and organic carbon (%) at0-30 cm soil depth after crop harvest.

Treatment	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	O.C. (%)
A. Source of phosphorus				
S_1 : SSP	291.8	28.6	144.0	0.64
S_2 : DAP	291.9	25.9	138.3	0.61
S_3 : RP	294.0	31.6	148.9	0.68
SEm ±	4.46	1.20	6.91	0.03
CD (P = 0.05)	NS	3.5	NS	NS
B. Dose of phosphorus				
D_1 : 10 kg P_2O_5 ha^{-1}	290.7	26.6	134.4	0.61
D_2 : 20 kg P_2O_5 ha^{-1}	292.8	28.4	142.3	0.63
D_3 : 30 kg P_2O_5 ha^{-1}	294.2	31.2	154.6	0.68
SEm ±	4.46	1.20	6.91	0.03
CD (P = 0.05)	NS	3.5	NS	NS
C. Biofertilizer (B)				
B_1 : Without biofertilizer	290.3	27.0	139.7	0.62
B_2 : Azospirillum + PSB	294.9	30.5	147.8	0.66
SEm ±	3.64	0.98	5.64	0.02
CD (P = 0.05)	NS	2.8	NS	NS
Initial soil samples	285.36	22.83	138.04	0.62
Treatment vs. Control				
Treatment	292.6	28.7	143.8	0.64
Control	247.2	15.8	92.7	0.52
SEm ±	7.94	2.14	12.30	0.04
CD (P = 0.05)	22.8	6.1	35.31	0.12
Interaction	NS	NS	NS	NS

NS: Non significant

Table 7: Apparent phosphorus -balance sheet as influenced by phosphorus sources, doses and biofertilizer in aerobic rice cultivation

Treatment	Initial soil value P_2O_5 (kg ha^{-1})	After harvest P_2O_5 (kg ha^{-1})	Apparent P-balance (kg ha^{-1})
$S_1 D_1 B_1$	22.85	25.93	3.08
$S_1 D_1 B_2$	22.85	26.79	3.94
$S_1 D_2 B_1$	22.85	29.35	6.50
$S_1 D_2 B_2$	22.85	22.51	-0.34
$S_1 D_3 B_1$	22.85	24.22	1.37
$S_1 D_3 B_2$	22.85	25.93	3.08
$S_2 D_1 B_1$	22.85	27.64	4.79
$S_2 D_1 B_2$	22.85	28.50	5.65
$S_2 D_2 B_1$	22.85	31.92	9.07
$S_2 D_2 B_2$	22.85	27.64	4.79
$S_2 D_3 B_1$	22.85	29.35	6.50
$S_2 D_3 B_2$	22.85	32.77	9.92
$S_3 D_1 B_1$	22.85	25.08	2.23
$S_3 D_1 B_2$	22.85	27.64	4.79
$S_3 D_2 B_1$	22.85	30.21	7.36
$S_3 D_2 B_2$	22.85	31.06	8.21
$S_3 D_3 B_1$	22.85	33.63	10.78
$S_3 D_3 B_2$	22.85	37.05	14.20
Control	22.85	15.76	-7.09

Conclusion

On the basis of one year field and laboratory studies, among the three sources of phosphorus, the crop performed better in terms of yield and phosphorus use efficiency under rock phosphate followed by single super phosphate. Out of the three phosphorus doses, application of 30kg P_2O_5 ha^{-1} resulted in higher grain and straw yield, N, P and K uptake, phosphorus use efficiency. Similarly, in biofertilizer treatments, Azospirillum + PSB treated plots exhibited yields as compared to without biofertilizer treatment. Thus, application of rock phosphate at the rate of 30kg P_2O_5 ha^{-1} inoculated with Azospirillum + PSB appeared to be the best treatment combination which may be one of the strategies for phosphorus management in aerobic rice.

References

1. Afzal A, Ashraf M, Asad SA, Farooq M. Effect of phosphate solubilizing microorganisms on phosphorus uptake, yield and yield traits of wheat (*Triticum aestivum* L.) in rain fed area. International Journal of Agricultural Biology. 2005;7(2):207-9.
2. Arpana J, Bagyaraj DJ. The response of kalmegh to an arbuscular mycorrhizal fu ngus and a plant growth promoting rhino microorganism at two levels of phosphorus fertilizer. Am.- Eura. J Agri. and Envi. Sci. 2007;2:33-38.
3. Baskar M, Solaimalai A, Sivakumar C, Suresh R. Phosphorus Management In Rice: A Review Agri. Rev. 2000;21(3):168-177.
4. Bhattarai T, Hess D. Yield responses of Nepalese spring wheat (*Triticum aestivum* L.) cultivars to inoculation with *Azospirillum* spp. of Nepalese origin. Plant Soil. 1993;151:67-76.
5. Bouman BAM. How much water does rice use. Rice Today. 2009;8:28-29.
6. Fageria NK, Wright RJ, Baligar VC. Rice cultivar evaluation for phosphorus use efficiency Plant and Soil. 1988;111:105-109.
7. Karmakar RM, Barthakur HP. Phosphorus Availability from Mussoorie Rock Phosphate in an Aeric Haplaquept in a Rice-Rice Sequence Agropedology. 1995, 5.
8. Khorshidi YR, Mohammad RA, Mahmoud R. Response of yield and yield components of Rice (*Oryza sativa* L.) to *Pseudomonas florescence* and *Azospirillum lipoferum* under different nitrogen levels. American-Eurasian J Agric Environ Sci. 2011;10(3):387-95.
9. Kumar P, Joshi PK, Birthal PS. Demand projections for food grains in India. Agri. Econ. Res. Rev. 2009;22:237-43.
10. Midrarullah, Ahmed B, Mirza. response of rice to inoculation with plant growth promoting rhizobacteria in control lab environment and field experiment. Pak. J bot. 2014;46(3):1121-1124.
11. Panwar QA, Radziah O, Rahman AZ, Sariah M, Razi IM, Naher UA. Contribution of phosphate-solubilizing bacteria in phosphorus bioavailability and growth enhancement of aerobic rice. Span. J of Agri. Res. 2011;9(3):810-820.
12. Sahrawat KL, Jones MP, Diatta S. Response of upland rice to phosphorus in an ultisol in the humid forest zone of West Africa. Ferti. Res. 1995;41:11-17.
13. Samal P, Singh ON, Ghosh A. Assessment of production potential of water saving technologies on rice (*Oryza sativa)* in india. Ind. J of agric.l sci. 2012;82(12):1027-31.
14. Sharma SN, Prasad R, Shivay YS, Dwivedi MK, Kumar S, Kumar D. Effect of rates and sources of phosphorus on productivity and economics of rice (*Oryza sativa*) as influenced by crop-residue incorporation. Ind. J of Agro. 2009;54(1):42-46
15. Sundara B, Natarajan V, Hari K. Influence of phosphorus solubilizing bacteria on the changes in soil available phosphorus and sugarcane and sugar yields. Field Crops Res. 2002;77(1):43-49.
16. Tripathi HP, Mauriya AK, Kumar A. Effect of integrated nutrient management on rice wheat cropping system in eastern plain zone of Uttar Pradesh. Journal of the Ind. Soci. of the Soil Sci. 2007;49(2):332-336.
17. Wang H, Bouman BAM, Zhao D, Wang C, Moya PF. 20 02. Aerobic rice in northern china: Opportunities and challenges in B A M, water- wise rice production. IRRI, Los Banos, Philippines.2002, 143-154.
18. Whitelaw MA. Growth promotion of plants inoculated with phosphate solubilizing fungi. Ad. Agro. 2000;69:99-151.