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**Original Research Article**

# Performance of Aerobic Rice under Different Sources and Levels of Phosphorus

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**A B S T R A C T**

A field experiment was carried out during autumn season of 2016 at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat to study the performance of aerobic rice under different sources and levels of phosphorous. The treatment of the experiment 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 plant population, dry matter accumulation, yield attributes and grain (2.61t $ha^{-1}$) and straw (4.70 t $ha^{-1}$) yield followed by single super phosphate. Among the doses, highest plant population, dry matter accumulation, yield attributes and 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 plant population, dry matter accumulation, yield attributes or grain yield (2.61t $ha^{-1)}$ and straw yield (4.82 t $ha^{-1}$).

**Keywords**

Aerobic rice, Rock phosphate, Azospirillum, Phosphorus solubilizing bacteria

## 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). Phosphorus is one of the major nutrients. Generally, phosphorus requires in early growth stage and it promotes root development (especially fibrous roots), tillering and early flowering. Dry and aerobic soil can reduce the indigenous supply of phosphorus (P), hence the application of fertilizer P can be more critical for aerobic rice.

Chemical P fertilizer is the main source of plant available P in agricultural soils, but almost 75 to 90% of added P fertilizer is precipitated by iron, aluminum and calcium complexes present in the soils (Turan *et al.*, 2006). Phosphorus deficiency has been recognized as one of the main limiting factor in upland rice (Sahrawat *et al.,* 1995). This P deficiency can be rectified by supplying phosphate to the soil, but a large portion of soluble inorganic phosphorus applied to soil as chemical fertilizer is immobilized and become unavailable to plant (Goldstein, 1986).

Rock phosphate is the cheapest P containing fertilizer, but insoluble in soil and hence there is growing interest in manipulating Rock Phosphate by biological method so that solubility and the agronomic effectiveness are enhanced (Whitelaw, 2000). Rock phosphate is one such indigenous source that can supply P at a unit cost much lower than superphosphate and DAP. Earlier studies have shown that incorporation of finely ground rock phosphate directly into the soil (pH 7.0 or above) in conjunction with phosphorus solubilizing bacteria (PSB) has the potential to improve plant available P (Sharma *et al.,* 2010).

Naturally occurring immobilization of P by microbes can help ration plant available P to crops over the course of a growing season. Bio-fertilizer containing micro-organism especially phosphorus solubilizing bacteria (PSB) has the ability to solubilize P in soil and reduce the dependence on chemical fertilizer (Arpana and Bagyaraj, 2007).

## Materials and Methods

A field experiment on the performance of aerobic rice under different sources and levels of phosphorus was undertaken during autumn season (March to July) of 2016 at Instructional-cum-Research (ICR) farm, Assam Agricultural University, Jorhat, Assam. The geographical position of Jorhat is 24°47'N Latitude, 94°12'E Longitude and at an altitude of 86.6m above the mean sea level. The soil was sandy loam 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, Bulk density 1.35g $cc^{-1}$ of soil, organic carbon 0.62%.

The experiment was laid out in factorial randomized block design with three replications and nineteen treatments were accommodated randomly in each replication.

The treatments consisted of three sources of phosphorus *viz*., single supper phosphate ($S_1$), diammonium phosphate ($S_2$) and rock phosphate ($S_3$); three different phosphorus levels *viz*., 10kg $P_2O_5$ $ha^{-1}$($D_1$), 20kg $P_2O_5$ $ha^{-1}$($D_2$) and 30kg $P_2O_5$ $ha^{-1}$($D_3$) and two biofertilizer i.e. with biofertilizer and without biofertilizer. One absolute control was also maintained. The treatment combinations were with source of phosphorus, level of phosphorus and bio-fertilizers.

The rice seeds variety Inglongkiri were sown on 11$^{th}$ March, 2016. The crop was harvested on 8$^{th}$ 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. 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

The beneficial effect of phosphorous management on growth of rice has been brought about in the experiment. Different phosphorous sources, doses and bio-fertilizer showed significant effect.

## Growth and yield attributing parameters

Result showed that the growth parameter *viz*., number of total tillers and dry matter accumulation, number of effective tillers per meter, number of grain per panicle, number of filled grain per panicle and percentage of false grain was found significantly higher in $S_3$ (RP) treatment (Table 1).

This may be due to the fact that rock phosphate is less water soluble fertilizer which is slowly released and available for longer time. Sharma *et al.,* (2009) reported that rock phosphate increased the growth and yield parameters of rice.

Application of phosphorus at 30kg $P_2O_5$ $ha^{-1}$ recorded significantly highest number of tiller per meter, plant height, dry matter, effective tillers, number of grains per panicle, number of filled grain per panicle were significantly higher with 30 kg P $ha^{-1}$(Table 1).

This may be due to increased dose of phosphorus which increased solubility and availability of phosphorus in soil. These results showed conformity with the findings of (Yadav *et al.,* 2015) who reported that plant growth parameters, *viz.,* plant height, dry matter and leaf area index were lowest in with control and increased significantly with increasing rates of phosphorus up to 30kg P $ha^{-1}$.

The plant growth parameters like plant height, plant population in terms of tiller number, plant dry matter accumulation, number of effective tillers per meter, number of grain per panicle, number of filled grain per panicle and percentage of false grain observed highest in bio-fertilizer treatment i.e. Azospirillum + phosphorus solubilizing bacteria (PSB) over without bio-fertilizer (Table 1). This may be attributed to the fact that PSB could help in increasing the availability of insoluble P for the growth of aerobic rice. The performance of PSB particularly their interactions with plants can enhance plant growth by solubilizing P from different fractions of soil (Ahmed *et al.,* 2008).

## 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 2). 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).

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 $ha^{-1}$, respectively, which was 46.3% higher than control (Table 2).

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).

Significantly higher grain (2.61t $ha^{-1}$) and straw (4.82 t $ha^{-1}$) yield noted with Azospirillum + PSB treatment (Table 2) proved it to be superior to without bio-fertilizer treatment.

**Table.1** Effect of sources and dose of phosphorus on growth and yield attributes at maturity of aerobic rice

| Treatment | No. of tillers $m^{-2}$ | Plant height (cm) | dry matter accumulation (g $m^{-2}$) | No. of effective tillers $m^{-2}$ | Length of panicle (cm) | No. of grains $panicle^{-1}$ | No. of Filled grains $panicle^{-1}$ | No. of false grains $panicle^{-1}$ | % of false grains $panicle^{-1}$ | 1000 seed wt. (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Source of phosphorus** | | | | | | | | | | |
| $S_1$ : SSP | 242.0 | 123.4 | 778.6 | 139.2 | 22.8 | 109.0 | 80.5 | 28.6 | 25.8 | 19.2 |
| $S_2$ : DAP | 219.7 | 120.9 | 687.2 | 132.4 | 22.2 | 105.2 | 73.7 | 31.4 | 29.9 | 19.0 |
| $S_3$ : RP | 247.6 | 125.7 | 834.2 | 142.3 | 23.8 | 114.3 | 88.4 | 25.9 | 22.8 | 19.5 |
| SEm $\pm$ | 6.0 | 1.4 | 32.5 | 2.5 | 0.5 | 2.5 | 2.6 | 1.5 | 1.4 | 0.3 |
| CD (P = 0.05) | 17.2 | NS | 93.3 | 7.3 | NS | 7.3 | 7.6 | NS | 4.0 | NS |
| **Dose of phosphorus** | | | | | | | | | | |
| $D_1$ : 10 kg $P_2O_5$ $ha^{-1}$ | 205.6 | 121.0 | 626.7 | 132.50 | 22.2 | 104.3 | 74.7 | 29.6 | 28.4 | 19.0 |
| $D_2$ : 20 kg $P_2O_5$ $ha^{-1}$ | 226.3 | 123.0 | 734.3 | 138.4 | 23.0 | 108.3 | 79.8 | 28.4 | 26.3 | 19.2 |
| $D_3$ : 30 kg $P_2O_5$ $ha^{-1}$ | 277.4 | 126.0 | 939.1 | 143.0 | 23.5 | 115.9 | 88.2 | 27.8 | 23.8 | 19.5 |
| SEm $\pm$ | 6.0 | 1.4 | 32.50 | 2.5 | 0.5 | 2.5 | 2.6 | 1.5 | 1.4 | 0.3 |
| CD (P = 0.05) | 17.2 | 4.0 | 93.3 | 7.3 | NS | 7.3 | 7.6 | NS | NS | NS |
| **Biofertilizer (B)** | | | | | | | | | | |
| $B_1$ : Without biofertilizer | 222.9 | 121.6 | 705.7 | 133.4 | 22.5 | 105.4 | 76.0 | 29.3 | 28.0 | 19.0 |
| $B_2$ : Azospirillum + PSB | 250.0 | 125.1 | 827.7 | 142.6 | 23.3 | 113.7 | 85.7 | 28.0 | 24.3 | 19.4 |
| SEm $\pm$ | 4.9 | 1.1 | 26.54 | 2.0 | 0.4 | 2.0 | 2.2 | 1.3 | 1.1 | 0.2 |
| CD (P = 0.05) | 14.0 | 3.3 | 76.2 | 6.0 | NS | 6.0 | 6.2 | NS | 3.2 | NS |
| **Treatment vs. Control** | | | | | | | | | | |
| Treatment | 236.4 | 123.3 | 766.7 | 138.0 | 22.9 | 109.5 | 80.9 | 28.6 | 26.2 | 19.2 |
| Control | 181.2 | 107.4 | 579.5 | 118.3 | 18.0 | 90.0 | 50.0 | 40.0 | 44.5 | 17.0 |
| SEm $\pm$ | 10.6 | 2.5 | 57.84 | 4.5 | 0.8 | 4.5 | 4.7 | 2.7 | 2.4 | 0.6 |
| CD (P = 0.05) | 30.6 | 7.10 | 166.0 | 13.0 | 2.4 | 13.0 | 13.5 | 7.8 | 7.0 | 1.6 |
| **Interaction** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

**Table.2** 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 $\pm$ | 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 $\pm$ | 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 $\pm$ | 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 $\pm$ | 0.10 | 0.25 | 0.16 |
| CD (P = 0.05) | 0.31 | 0.73 | NS |
| **Interaction** | NS | NS | NS |

**Table.3** Effect of sources, doses and biofertilizer on economics of aerobic rice.

| Treatment | Cost of cultivation ₹ha$^{-1}$ | Gross cultivation ₹ha$^{-1}$ | Net return ₹ha$^{-}$ | B:C |
|---|---|---|---|---|
| **A. Source of phosphorus** | | | | |
| $S_1$ : SSP | 21311.00 | 59232.00 | 37921.00 | 1.78 |
| $S_2$ : DAP | 21501.00 | 54573.00 | 33071.00 | 1.54 |
| $S_3$ : RP | 21371.00 | 62809.00 | 41438.00 | 1.94 |
| **B. Dose of phosphorus** | | | | |
| $D_1$ : 10 kg $P_2O_5$ ha$^{-1}$ | 21221.00 | 52399.00 | 31178.00 | 1.47 |
| $D_2$ : 20 kg $P_2O_5$ ha$^{-1}$ | 21394.00 | 58373.00 | 36978.00 | 1.73 |
| $D_3$ : 30 kg $P_2O_5$ ha$^{-1}$ | 21568.00 | 65842.00 | 44274.00 | 2.05 |
| **C. Biofertilizer (B)** | | | | |
| $B_1$ : Without biofertilizer | 21335.00 | 54390.00 | 33055.00 | 1.55 |
| $B_2$ : Azospirillum + PSB | 21455.00 | 63354.00 | 41899.00 | 1.95 |
| Control | 20142.00 | 44161.00 | 24019.00 | 1.19 |

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).

## Economics

A perusal of data on economics indicated that among the various sources, the highest gross return of ₹ 62,809.00 $ha^{-1}$, net return of ₹ 41438.00 $ha^{-1}$ with B: C ratio of 1.94 was obtained under the treatment where application of phosphorus was done with rock phosphate (Table 3). Application of rock phosphate significantly increased economical and straw yield of aerobic rice through its positive effect on plant growth parameters and yield attributes which might have contributed to highest economic returns. Similar effect of mussorie rock phosphate on net returns of rice was reported by Sharma *et al.*, 2009.

So far the dose of phosphorus is concerned, the highest gross return of ₹ 65842.00 $ha^{-1}$, net return of ₹ 44274.00 $ha^{-1}$ and B: C ratio of 2.05 could be recorded with application of phosphorus at the rate of 30 kg $P_2O_5$ $ha^{-1}$ (Table 3).

The phosphorus applied at higher dose in soil, recorded the highest grain and straw yield (marketable products) which might be due to higher uptake of nutrients and dry matter production reflected in higher values in respect of different yield attributing characters. The highest benefit: cost ratio was obtained with 30kg $P_2O_5$ $ha^{-1}$ through rock phosphate + PSB treatment was reported by (Yadav *et al.*, 2015).

Higher gross return (₹ 63353.00 $ha^{-1}$), net return (₹ 41898.00 $ha^{-1}$) and B: C ratio (1.95) could be obtained in case of Azospirillum + PSB treatment ($B_2$) than without bio-fertilizer ($B_1$) (Table 3). Comparable grain and straw yield production in case of bio-fertilizer treatment might have contributed to higher net return and benefit-cost ratio (B: C). This might be due to the fact that biofertilizer i.e. PSB used in combination with appropriate doses of fertilizers maintained better plant growth. Similar result was reported by (Meena *et al.*, 2014).

On the basis of one year field and laboratory studies, among the three sources of phosphorus, the crop performed better in terms of growth, yield and benefit-cost ratio 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 and benefit-cost ratio. Similarly in biofertilizer treatments, Azospirillum + PSB treated plots exhibited better growth, higher values of yield attributes, yields and benefit-cost ratio as compared to without biofertilizer treatment.

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