Original research paper

Comparative Efficacy of Inorganic and Bio-Fertilizers on Growth and Yield of Rainfed Winter Rice (*Oryza sativa* L.)

Abstract

Modern agriculture exclusively depends on chemicals, hence, the study was carried out with the objective of reducing dependency on chemical fertilizer, to find out best integrated dose of inorganic and bio-fertilizer for successful *rainfed* rice cultivation and analyses the effect of inorganic and bio-fertilizer on the soil fertility. Integrated nutrient management is best for sustainable *rainfed* rice cultivation rather than purely organic or chemical. Reduction in chemical fertilizer to an extent of 20% with bio-fertilizer not only curtails the cost of production; it also increases the yield of *rainfed* rice by enhancing the growth and yield attributing characters. Recommended fertilizer dose with *Azospirillum* and *Phosphobacterium* (T4) recorded the highest rice grain yield (6.59 t ha^{-1}), Maximum gross return (`1,02,930.00), highest net return (`71,230.00) and benefit–cost ratio (2.25), which were at par with T7 (net return of `65,330.00 and benefit–cost ratio of 2.11). 50% RDF + *Phosphobacterium* (T9) exhibited lowest gross return (`74,350.00), net return (`44,190.00) and benefit-cost ratio (0.86).

***Keywords*:** *Azospirillum*, growth, inorganic fertilizers, *Phosphobacterium,* winter rice

1. INTRODUCTION

The present situation of food supply and demand is far from satisfactory especially in developing countries. The quickest and practical way to increase the food supply is to increase the yield per unit area per unit time. To meet the challenge of producing more rice

from suitable lands, it is necessary to use high yielding rice varieties with greater yield stability [9]. Under intensive cropping system balanced fertilization is very important for boosting in production. Most valuable factors of increasing production are - use of high yielding varieties and adequate fertilizer application. But the question arises 'how much fertilizer can be made available to meet the over increasing demand for food production'. There is insufficient scientific knowledge of sustainability and fertilizer or nutrient use efficiency. Combination of bio and inorganic fertilizers may be considered to solve both the hitches partially.

Rice is the primary food in Asian continent and over 85% of rice is produced here. India ranks second with respect to both production and acreage of rice in the world. It contributes over 40% of the annual food grain production of the country. The area under rice cultivation is 43 m ha of which only 19 m ha is irrigated. Yield under *rainfed* situations are poor with a high degree of variability and dependency on the vagaries of monsoon. The major challenge for agricultural scientists, researchers and climatologists is - 'how to increase the production in *rainfed* areas'.

Most of the rice growing farmers follow rice-rice, rice-wheat or maize-rice sequence in a year and with adequate irrigation facilities they obtain at least 10-12 ton ha^{-1} $annum^{-1}$ of food grains by using high quantity of synthetic fertilizers. Presently, the costs of fertilizers have been increased and their availability may also be limited in some places. In such conditions, use of 'bio- fertilizers' and 'how far inorganic fertilizers can partly be substituted with the available bio-fertilizers' with respect to soil health is a crucial issue. Keeping this in mind, the present investigation had been planned to study the effect of combination of bio-fertilizers with inorganic fertilizers on growth and yield of *rainfed* winter rice.

2. MATERIALS AND METHODS

2.1. Study site

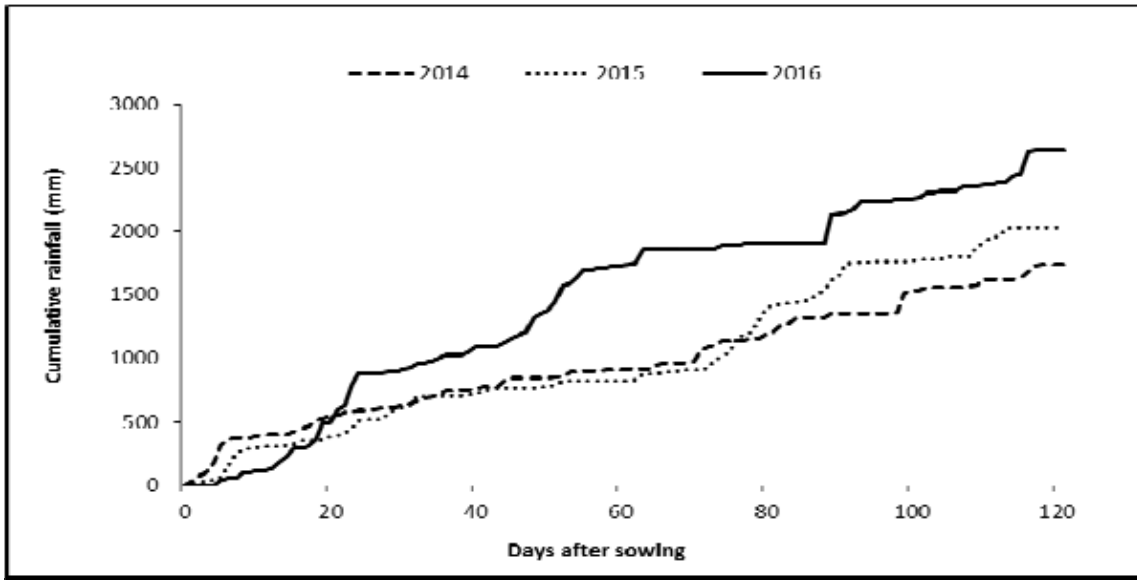

Figure 1. Cumulative rainfall during the 2014, 2015 and 2016 growing seasons

The field experiment was carried out in the *kharif* seasons of 2014, 2015 and 2016 in the "Instructional Farm" under Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India. The research plot was located in 26.40N latitude, 89.27E longitude and 37.0 meter above mean sea level (MSL). An average annual rainfall of 2914 mm was recorded in the experimental site, most of which was precipitated during June to September (figure 1). The experimental soil was well drained sandy loam in texture (sand 49.2%, silt 31.9% and clay 19.0%) with medium fertility status having soil reaction 5.85. Nitrogen status (91.4kg ha^{-1}) of the soil was low, whereas P_2O_5 (19.4kg ha^{-1}) and K_2O (70.6kg ha^{-1}) content were medium.

2.2. Experimental design and crop management

Ten (10) treatments were arranged in Randomized Complete Block Design (RCBD) with three replications, viz. T1= 100 % of recommended dose of fertilizer (RDF) i.e. 60 : 30 : 30 kg ha^{-1} N : P: K; T2= 100 % RDF + *Azospirillum* (Azos); T3= 100 % RDF +

Phosphobacterium (Phos); T4= 100 % RDF +Azos +Phos; T5= 75 % RDF (45 : 22.5 : 22.5 kg ha^{-1} N : P: K;) + Azos; T6= 75 % RDF + Phos; T7= 75 % RDF + Azos + Phos; T8= 50 % RDF (30 : 15 : 15 kg ha^{-1} N : P: K;) + Azos; T9= 50 % RDF + Phos and T10= 50 % RDF + Azos + Phos. The variety Swarna (MTU-7029) was taken for testing. The seeds were sown in the seed bed on June 1, during the years of experimentation. Twenty days old seedlings were transplanted in the experimental plots on June 21, with 2–3 seedlings $hill^{-1}$, with a spacing of 20 cm × 15 cm. well decomposed farmyard manure (FYM) was applied @ 5 t ha^{-1} at the time of land preparation. Bio-fertilizers like *Azospirillum* and *Phosphobacterium* were applied two weeks before transplanting @ 5 kg ha^{-1} and mixed with the soil after application of FYM. One fourth of scheduled nitrogen, full P_2O_5 and K_2O were applied before transplanting as basal according to the treatments. Half of N was applied at tillering stage on 20 days after transplanting (DAT) and rest one-fourth N was applied at panicle initiation stage (45 DAT). The sources of N, P_2O_5 and K_2O were urea, single super phosphate (SSP), and muriate of potash (MOP) respectively. Hand weeding was done three weeks after transplantation and regular plant protection measures recommend for rice were followed to avoid any disease and pest incidence.

2.3. Field observations

At the time of harvesting ten hills were selected from each plot for counting total number of productive tillers and panicle number per hill. Ten panicles were randomly selected from each plot for counting total number of spikelet per panicle. Composite soil sample from each plot were collected after harvesting of rice. The samples were thoroughly dried in shade, pulverized, sieved through 0.2mm mesh and then analyzed for the available N, P and K. Plant samples from each plot were collected for the purpose of the determination of N content by micro-Kjeldahl method, total P by vanadomolybdo phosphoric yellow color method using spectrophotometer method and K by mix acid (Perchloric acid and nitric acid) digestion and

flame photometry as described by Jackson [7]. The samples were at first air dried then oven dried and ground to fine dust by grinder. Nutrients uptake was calculated after harvesting of the crop by multiplying nutrient content and dry matter.

2.4. Economic assessment

A partial economic analysis, accounting of the total variable costs and gross returns was done to determine a change in profit. Net profit used to define the relative profitability and it was calculated by following formula:

Net benefit = Total Income (TI) – Total Cost (TC) ---------- (1)

Total income was valued as the product of grain yield (t ha^{-1}) and grain price (` ha^{-1}). Grain prices were obtained from local market survey at harvest time. TC was the sum of the cost of the inputs and labour for the different field activities. Labour cost was based on the local daily wage per person to complete the action ha^{-1} and multiplied by the total man-days required to perform the activity.

2.5. Statistical analysis

The data were analyzed statistically by randomized completely block design. The significance of different sources of variation was tested by "error mean square" by Fisher and Snedecors' F test at P = 0.05. Comparison of F tables and computation of critical differences (CD) at P = 0.05 were made with the consultation of Fisher and Yates table. Statistical analysis and interpretation of results were made by calculating values of standard error means and critical difference at 5% level of significance. To compare the difference between means, the standard error mean (SEm) and the values of critical difference (CD) were presented in the tables of results.

3. RESULTS AND DISCUSSION

3.1. Effect on growth and yield attributes

3.1.1. Effect on leaf area index

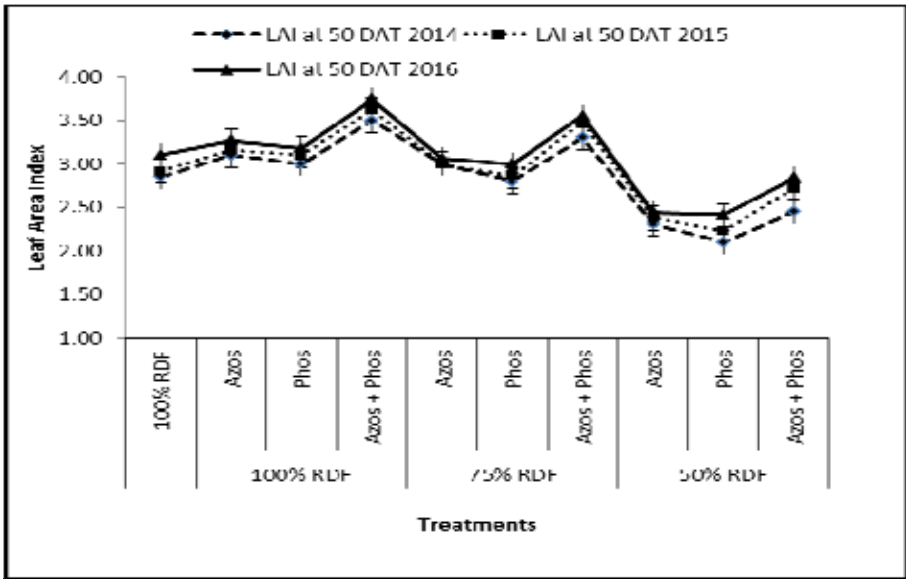

Figure 2. Leaf area index (LAI) as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments.

An increasing trend in LAI was noticed when rice crop was treated with both bio-fertilizers and inorganic fertilizers (figure 2). Applied bio-fertilizer with recommended fertilizer dose significantly influenced the LAI over control. During all three seasons, the highest LAI (3.40, 3.62 and 3.74) ware recorded with 100 % RDF + *Azospirillum* + *Phosphobacterium* at 50 DAT followed by 75% RDF + *Azospirillum* + *Phosphobacterium* (3.38, 3.48 and 3.55 respectively). 50% RDF + *Phosphobacterium* (T9) produced the lowest LAI (2.43, 2.23 and 2.41) at 50 DAT.

Chemical fertilizer offers nutrients which are readily soluble in soil solution and thereby instantly available to plants. Application of phosphate solubilizing bacteria and *Azospirillum* is increases nutrient availability probably due to steady supply of nutrients like phosphorus and nitrogen to rice plants. Effect of *Azospirillum* on growth of rice was also reported by Gupta et al. [4]. *Azospirillum* also improves the stress tolerant capacity of rice crop. Gupta et al. [5] demonstrated a fascinating effect of phosphorus solubilizing bacteria on *rainfed* rice crop. The *Phosphobacterium* improved the temperature and humidity tolerance of the crop,

side by side the phosphorus status in the soil was increased remarkably. Leaf area index is directly influenced by the availability of plant nutrient in soil, particularly nitrogen [2]. Reduction of synthetic fertilizer by 25% did not reduce LAI significantly at all growth stage and it was at par with maximum doses of NPK fertilizer, this amount of chemical fertilizer was supplemented from bio-fertilizer. The available nutrients might have helped in enhancing the leaf area, which thereby resulted in higher photo-assimilates and more dry matter accumulation. These results were supported by the findings of Roy et al. [20] and Uthiraselvam et al. [26].

3.1.2. Effect on tillers and panicles

The data depicted in Figure 3 revealed that, after 50 DAT all the bio-fertilizer applied treatments performed significantly better over control when combined upto 75% of RDF. The maximum number of tiller (466.0) m^{-2} was found with the treatment T4 i.e. 100 % RDF + *Azospirillum* + *Phosphobacterium.* 50% RDF + *Phosphobacterium* (T9) produced the lowest number of tillers (350.0) m^{-2} at 50 DAT during last year of experimentation.

Maximum number of panicles (453.0) per square meter area was noted in rice when treated with 100 % RDF + *Azospirillum* + *Phosphobacterium* (T4) which was followed by T7 i.e. 75% RDF + *Azospirillum* + *Phosphobacterium* (443.0), however, T4 and T7 recorded statistically at par results. 50% RDF + *Phosphobacterium* (T9) treatment recorded 330.0 as an average panicle number in said unit area resembling the lowest one (Figure 4).

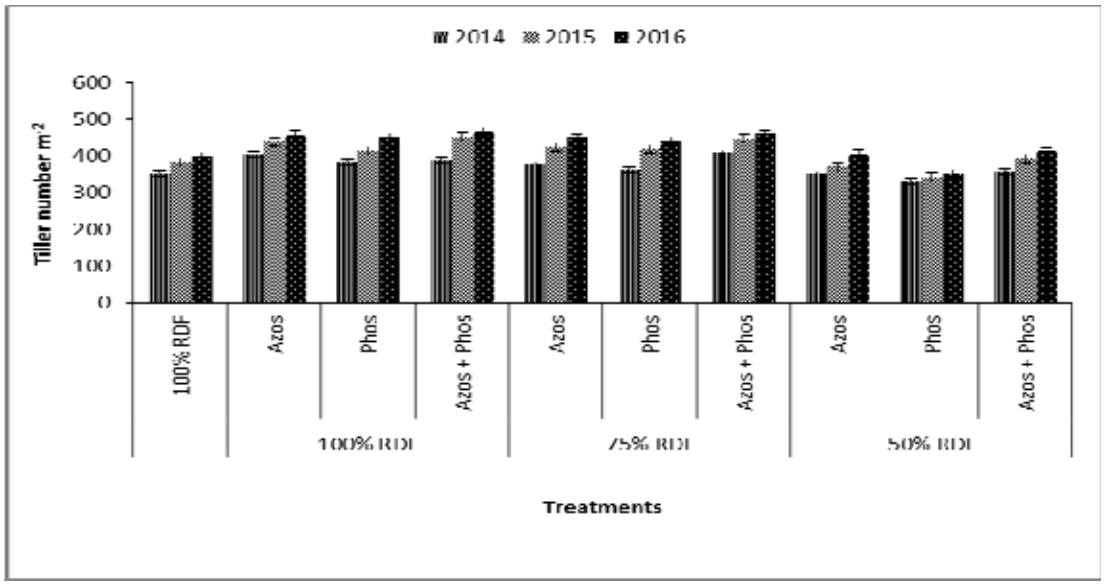

Figure 3. Number of tillers (m^{-2}) as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments

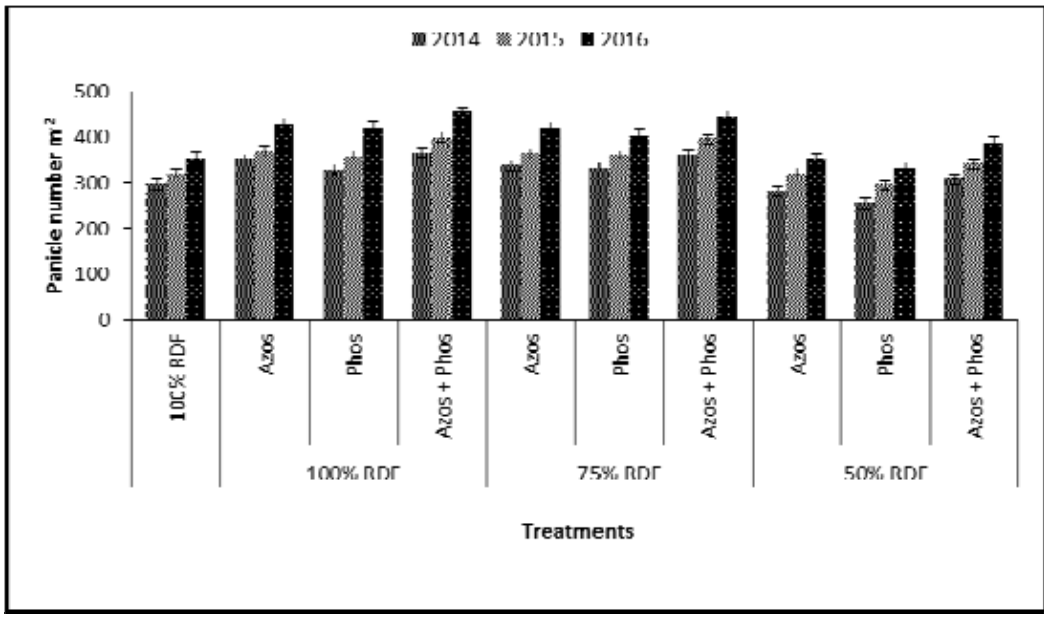

Figure 4. Number of Panicles (m^{-2}) as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments

Tillering is an important trait for grain production in rice. More number of tillers was might be due to the more availability of nitrogen, which plays a vital role in cell division and due to increment in root length and root biomass. Similarly, development in root, shoot and average number of tillers per square meter with the inoculation of *Azospirillum* and phosphate solubilizing bacteria was also opined by Uthiraselvam et al. [26]. Pandey and Kumar [17] reported beneficial effects of *Azotobacter* and *Azospirillum* in addition to their ability to produce anti-bacterial and anti-fungal compounds along with growth regulators.

Along with synthetic fertilizers, bio-fertilizer played significant role in increasing productive tiller numbers. More number of tillers converted to productive tiller which might be due to the high supply of available N and P to the rice plant. De Datta [2] observed that rice plants require large amount nitrogen at early to active tillering stages which endorse rapid growth, increased height and tiller number. Phosphate plays an important role to convert tiller to productive tiller. Sarwar et al. [22] found higher number of productive tiller per square meter with the addition of organic manure. Santai et al. [21] reported that the number of productive tiller per square meter considerably influenced by the rate nitrogen fertilizer.

3.1.3. Effect on grains per panicle and test weight

It was revealed from Figure 5, during all the seasons, highest number of grains per panicle (76.2, 79.1 and 85.0) ware observed in plants treated with 100% RDF + *Azospirillum* + *Phosphobacterium* and it was strongly followed by 75% RDF + *Azospirillum* + *Phosphobacterium* (71.1, 78.4 and 83.4 respectively). Treatment T4 and T7 recorded significantly higher number of grains per panicle over control (T1). 50% RDF + *Phosphobacterium* (T9) showed the least performance with 57.3, 61.8 and 61.3 numbers of grains per panicle respectively.

No significant differences between the treatments were recorded with respect to test weight (1000 grains weight) of rice (Figure 6), however, highest test weight (17.2g) was observed with T3, T6 and T7.

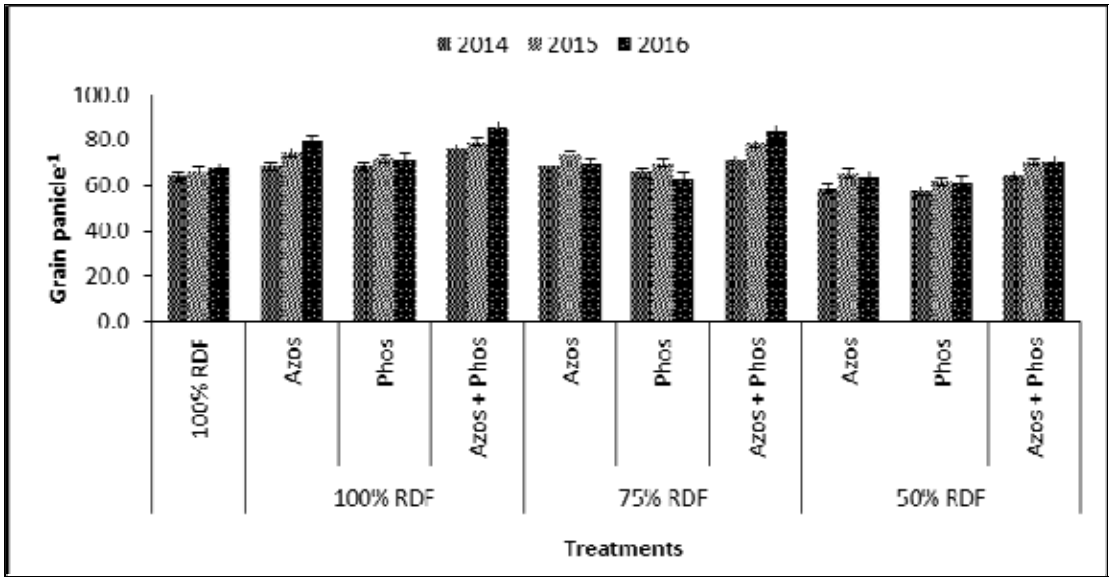

Figure 5. Number of grains (panicle^{-1}) as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments

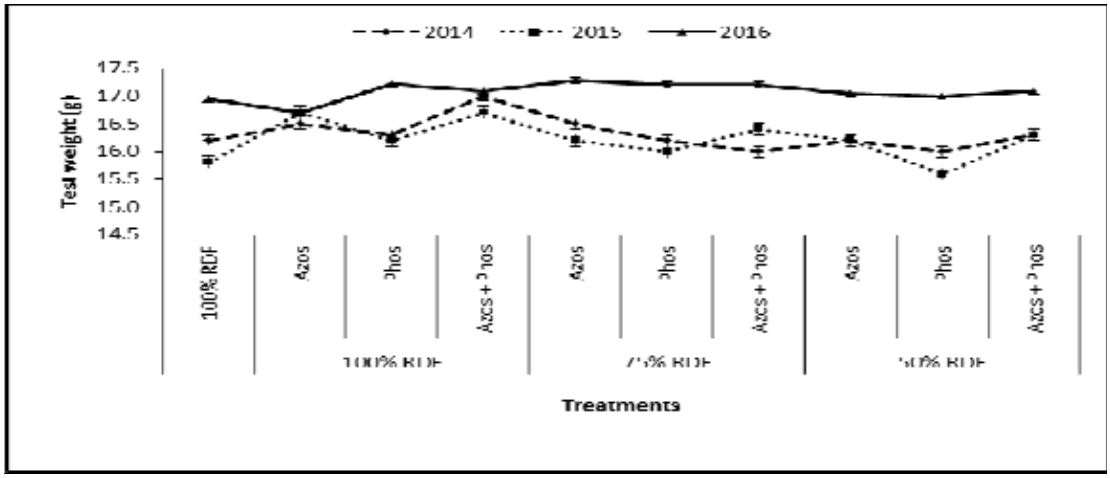

Figure 6. Test weight (g) of rice grains as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments.

Yield components of rice crop showed significant differences due to bio-fertilizer application. Solubilization of P by phosphate solubilizing micro-organisms was attributed to excretion of organic acids like citric, glutamic, succinic, lactic, oxalic, maleic, fumaric, tartaric and α - ketobutyric acid [3]. These organic acids might be acted as chelating compounds and saved essential nutrients from leaching and made available to plants which ultimately reflected in development in yield components of rice. Mishustin and Naumova [13] were of the opinion that the P solubilizers also produced fungistatic and growth promoting substances which influence plant growth. These factors might be considered for increment in ear bearing tiller number as well as other yield attributes. Full recommended dose of NPK along with bio-fertilizers produced maximum grains per panicle but bio-fertilizer can substitute 25% inorganic fertilizer without any loss in the number of spikelet's per panicle. Nitrogen plays important role to increase the number of spikelet's per panicle particularly when it is sufficiently available at panicle initiation stage [2].

Test weight is a genetic property, which was influenced significantly by bio-fertilizers over control. Beneficial effect of organic matter on test weight has also been reported by Sarwar et al. [22] and Hossaen et al. [6].

3.1.4. Effect on grain and straw yield

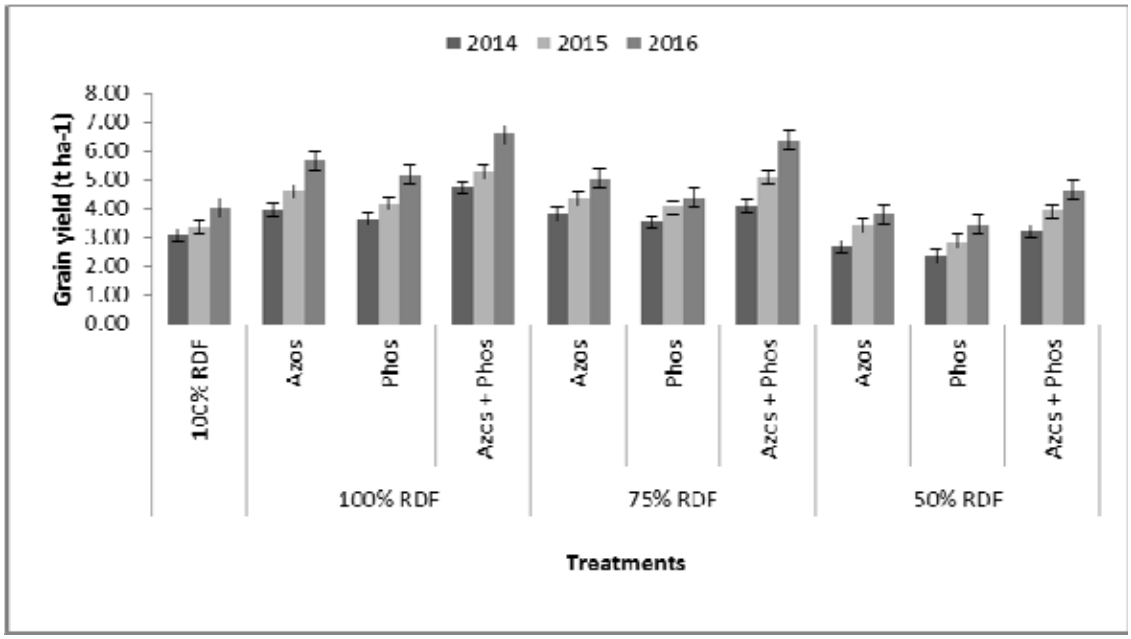

Figure 7. Grain yield (t ha^{-1}) of rice as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments.

Figure 7, revealed increasing trend in yield over control upto 25% replacement of RDF with bio-fertilizer combination. Highest grain yield (4.74, 5.28 and 6.59t ha^{-1}) ware observed in rice treated with 100% RDF + *Azospirillum* + *Phosphobacterium* (T4) which was statistically at par with 75% RDF + *Azospirillum* + *Phosphobacterium* (4.11, 5.09 and 6.35t ha^{-1}). T4 and T7 recorded significantly higher yield over control (T1). Lowest grain yield (2.35, 2.85 and 3.44t ha^{-1}) ware noticed in rice crop when fertilized with 50% RDF + *Phosphobacterium* (T9).

Application of inorganic fertilizers in combination with *Azospirillum* influenced the straw yield of rice (up to 75% of RDF). Highest straw yield (9.54t ha^{-1}) was produced with the combination of 100% RDF + *Azospirillum* + *Phosphobacterium* (T4) during 2016. The combination of 75% RDF + *Azospirillum* + *Phosphobacterium* (T7) trailed just behind T4 without any significant difference and produced 9.16t ha^{-1} straw (Figure 8).

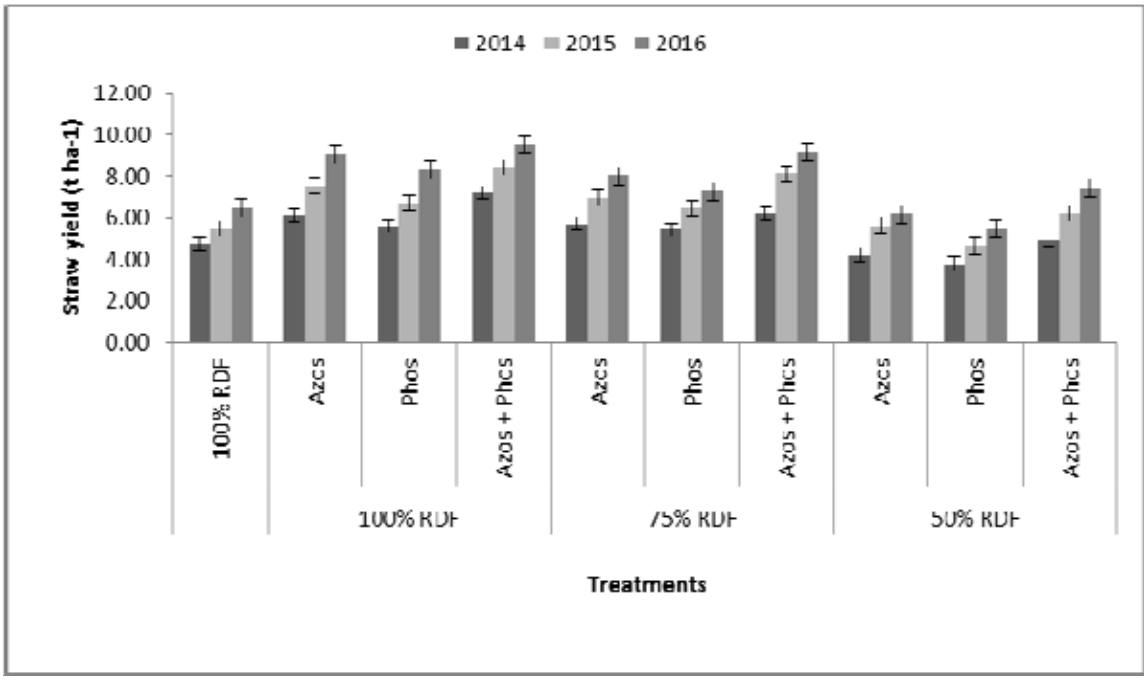

Figure 8. Straw yield (t ha^{-1}) of rice as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments.

The increase in biomass and grain yield might be attributed to the increase in yield attributes (number of productive tillers/hill, grains per panicle and 1000-grain weight), consequently, the increment in yield components were recorded due to the enhanced nutrient availability which improved nitrogen and other macro and micro-elements absorption as well as enhancing the production and translocation of the dry matter from source to sink. Similar results were also reported by Oblisami et al. [16]. Application of bio-fertilizers along with full dose of inorganic fertilizers (100% RDF + *Azospirillum* + *Phosphobacterium*) was necessary to harvest a good crop of paddy. Singh and Sirvastawa [25] were of the opinion that the application of full dose of fertilizers was necessary to harvest a good crop during evaluation of the effect of *Azotobacter* and *Phosphobacterium* on the yield of paddy crop. Reduction of chemical fertilizer up to one fourth of recommended dose was added by the bio-fertilizer. But almost all the yield components were drastically reduced when half of the

recommended doses of inorganic fertilizer were curtailed. Bio-fertilizers were unable to supplement NPK fertilizer, when the dose reduced to half of the recommended dose. Kasirajan, et al. [8] reported that *Azotobacter* inoculation increases the rice yield by saving nitrogenous fertilizer to an extent of 25% of the recommended does. But, the increase in yield due to bio-fertilizer may not be solely due to N-fixation or P solubilization but because of several other factors such as release of growth promoting substances, control plant pathogens, proliferation of beneficial organisms in the rhizosphere [12].

3.2. Effects on nutrient status

Nutrient uptake by rice recorded significant variation during the years of experimentation. Nitrogen uptake was found to be maximum (Nitrogen 141.9kg, 136.2kg, 141.0kg ha^{-1}), with T4 i.e. 100% RDF + *Azospirillum* + *Phosphobacterium,* during 2014, 2015 and 2016 respectively (Figure 9). whereas, the lowest uptake (41.2 kg, 44.6kg, 46.3kg ha^{-1}) was observed with T1 i.e. 100% RDF during all the year of experimentation.

Phosphorous uptake found to be minimum (20.8kg, 20.6kg, 18.4kg ha^{-1}) with T1 and maximum (56.8kg, 55.8kg, 52.0kg ha^{-1}) with T4 (Figure 10).

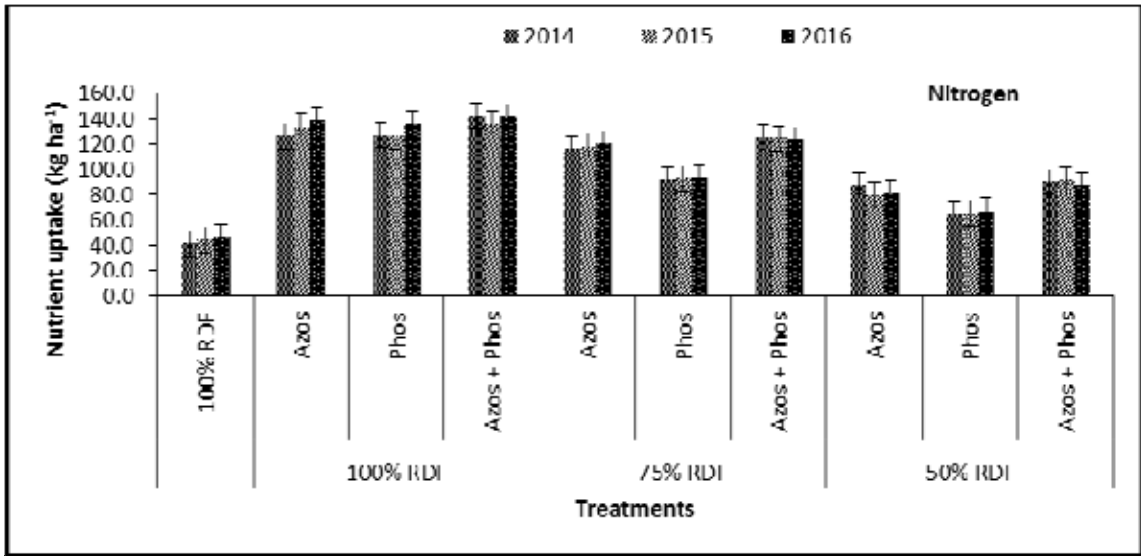

Figure 9. Nitrogen uptake (kg ha^{-1}) by plant as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments.

Use of bio-fertilizer did not make any difference regarding potassium uptake by rice plant. Highest potassium uptake (136.2kg ha^{-1}) recorded with T1 during 2015, whereas lowest uptake (103.4kg ha^{-1}) with T6 during 2014 (Figure 11).

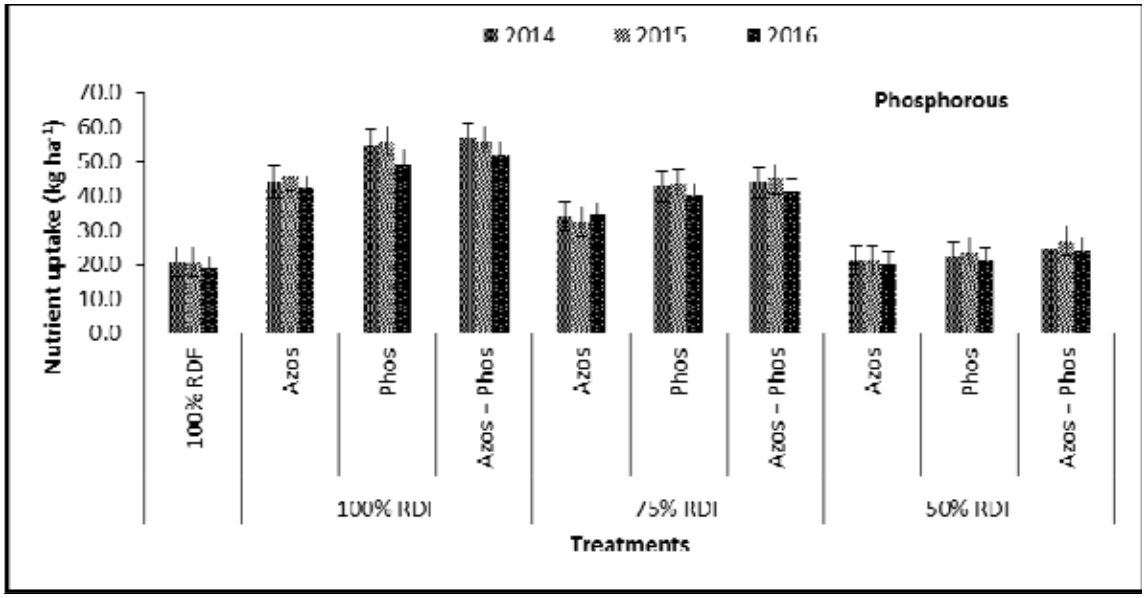

Figure 10. Phosphorous uptake (kg ha^{-1}) by plant as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments.

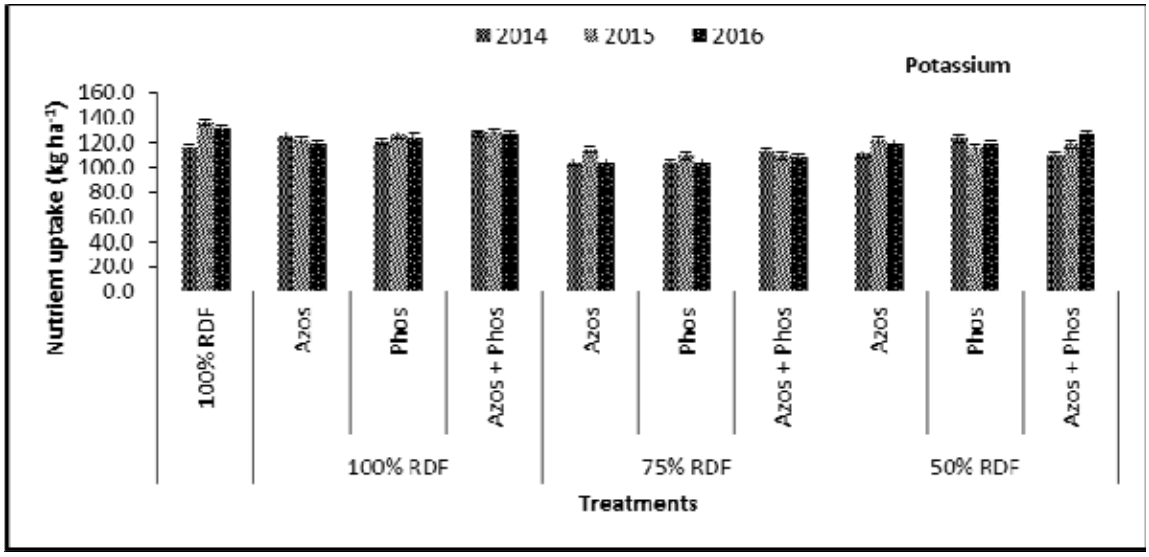

Figure 11. Potassium uptake (kg ha^{-1}) by plant as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016. The error bars specifies standard error difference between means for treatments.

Results indicated that available nutrients (Figure 12) in soil after harvest of rice, varied significantly due to various treatments. Maximum available N (102.4kg ha^{-1}, 97.3kg ha^{-1}, 89.4kg ha^{-1}) of experimental soil after harvest was found during 2014, 2015 and 2016 respectively with T4 i.e. 100% RDF + *Azospirillum* + *Phosphobacterium* and minimum available N (23.7kg ha^{-1}, 42.1kg ha^{-1}, 38.3kg ha^{-1}) also found on 2014, 2015 and 2016 respectively with 100% RDF (T1).

Addition of bio-fertilizers (*Azospirillum* and *Phosphobacterium*) with inorganic fertilizers had the beneficial effect in increasing the phosphorus availability (Figure 13). Highest available P (33.1, 31.2 and 29.8kg ha^{-1}) ware observed with T4, whereas lowest available P (5.1, 9.6 and 6.4kg ha^{-1}) ware obtained with control during all the year of experimentation.

K content in soil did not vary by use of bio-fertilizers. Highest available K (298.4kg ha^{-1}) in soil at harvest was recorded with T4 during 2016 and simultaneously, lowest available K level (203.3kg ha^{-1}) obtained with control treatment during 2015 (Figure 14).

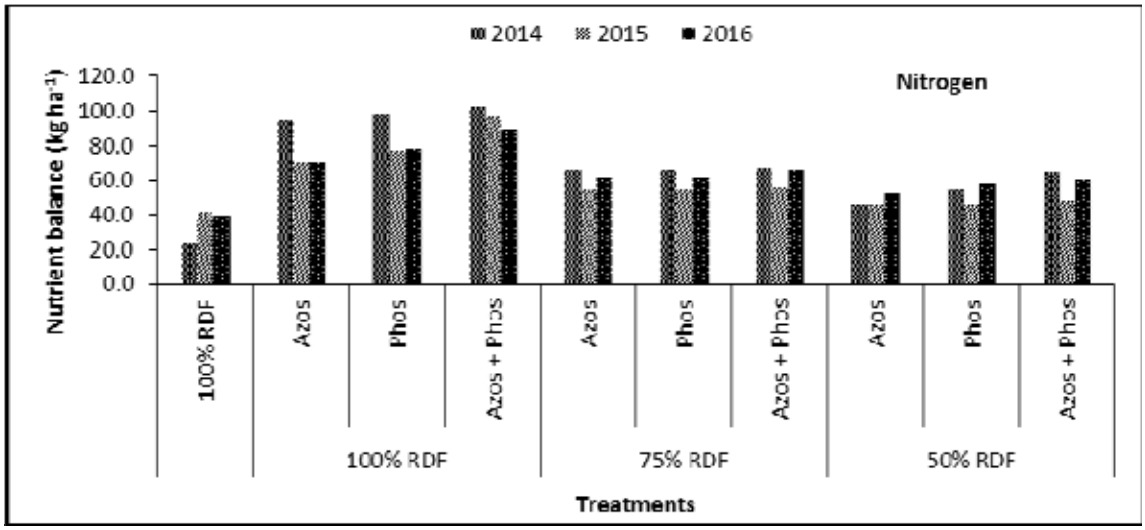

Figure 12. Nitrogen balance (kg ha^{-1}) as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016.

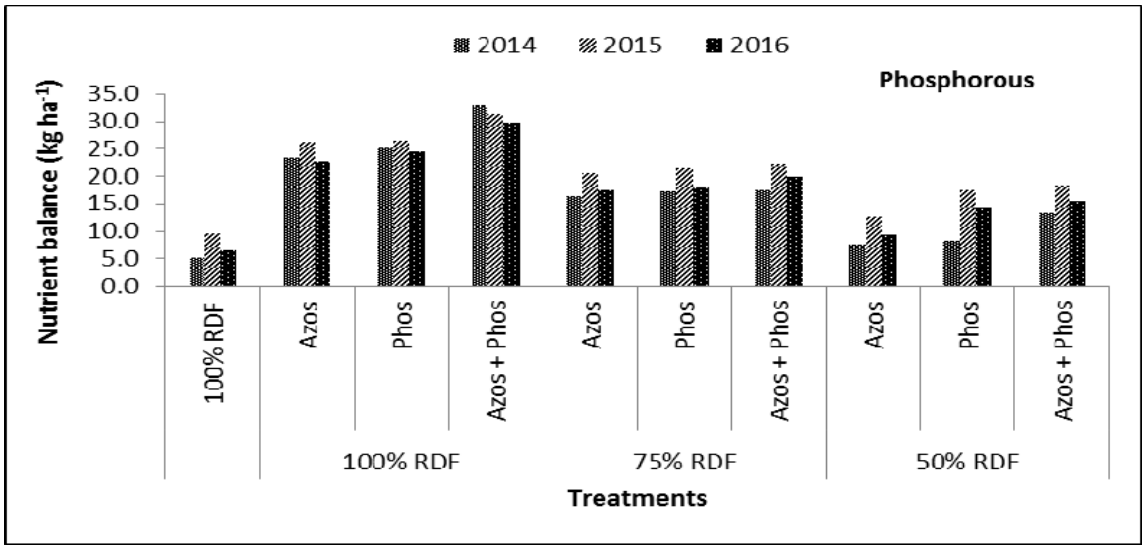

Figure 13. Phosphorous balance (kg ha^{-1}) as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016.

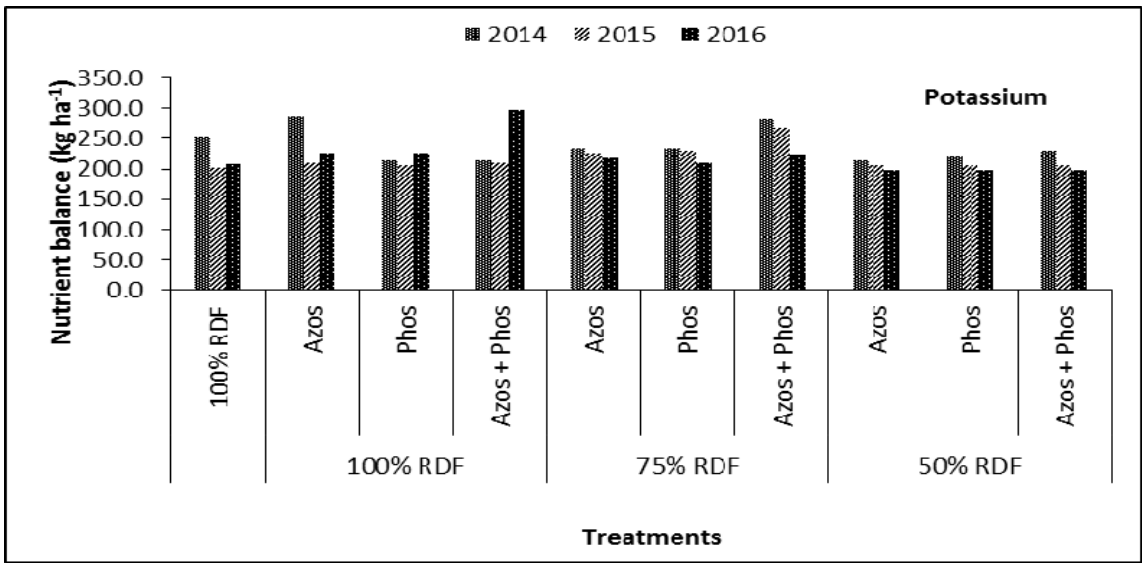

Figure 14. Potassium balance (kg ha^{-1}) as affected by inorganic and bio-fertilizers during 2014, 2015 and 2016.

In present study beneficial role *of Azospirillum* on atmospheric N fixation was found. Rangaswami [19] reported that bio-fertilizer could supplement the nitrogen requirement for

rice up to 20 - 40 kg N per ha. Bio-fertilizer saved the nitrogenous fertilizer to an extent of 25% of the recommended dose [8]. But the beneficial role of this microbes to increase yield might not be solely due to its ability to supply N to crop but also due to its ability to produce growth substances and antifungal antibiotics [1, 10, 14, 15].

Role of PSB to make phosphate available to plant from unavailable form are well established. Phosphate solubilizing bacteria secretes some organic acids in the soil which acts upon fixed insoluble forms of phosphate and solubilize it to plant available form. Panhwar et al. [18] reported that PSB inoculation can effectively enhance P solubility of applied rock phosphate fertilizers, maintain a favorable soil P pool and increase productivity of aerobic rice. They also concluded that in the long term, this approach would ensure a cost effective, sustainable and environmental friendly production system for aerobic rice. In this study, efficiency of PSB to solubilize phosphate was found more with lower dose of chemical fertilizer. Shaharoona et al. [23] reported that the efficacy of PSB in solubilizing P can be decreased with increasing rates of chemical fertilizers applied to soil.

Application of the reduced doses of potash fertilizer did not decrease the available K content significantly in the post-harvest soil samples. At the same time, available K content in soil did not vary by use of bio-fertilizers, because when solution K depleted from soil, it is replenished by other forms of K. As a result, available K content in soil does not vary immediately by the restricted supply of potassium through fertilizer. But when this practice continues over a long period, significant depletion of available K content in soil may be observed.

3.3. Economic analysis

The results in Table 1 showed that different levels of fertilization increased gross return, net return and B: C as compared to control treatment up to the combination of 75% of RDF and bio-fertilizers.

Table 1. Gross return, production cost, net return and benefit-cost ratio as affected by inorganic and bio-fertilizers (Average of 3 seasons)

Treatments	Gross return ($\times 10^3$ ` ha^{-1})	Production cost ($\times 10^3$ ` ha^{-1})	Net return ($\times 10^3$ ` ha^{-1})	BCR*
100% Recommended Fertilizer Dose (RDF)	66.14	30.58	35.56	1.16
100% RDF + *Azospirillum*	90.07	31.20	58.87	1.89
100% RDF + *Phosphobacterium*	82.23	31.08	51.15	1.65
100% RDF + *Azospirillum* + *Phosphobacterium*	102.93	31.70	71.23	2.25
75% RDF + *Azospirillum*	82.80	30.43	52.37	1.72
75% RDF + *Phosphobacterium*	75.69	30.31	45.38	1.50
75% RDF + *Azospirillum* + *Phosphobacterium*	96.26	30.93	65.33	2.11
50% RDF + *Azospirillum*	63.01	29.66	33.35	1.12
50% RDF + *Phosphobacterium*	54.91	29.54	25.37	0.86
50% RDF + *Azospirillum* + *Phosphobacterium*	74.35	30.16	44.19	1.47
SEm (±)	2.26	-	2.03	0.08
C.D (P = 0.05)	6.71	-	6.03	0.24

*BCR= Benefit-cost ratio;

Maximum gross return (`1,02,930.00 $ha^{-1}$) was obtained with T4 i.e. 100% RDF + *Azospirillum* + *Phosphobacterium* followed by T7 i.e. 75% RDF + *Azospirillum* + *Phosphobacterium* (`96,260.00 ha^{-1}) due to extra return obtained from higher yield. Maximum net return (`65,330.00 ha^{-1}) and benefit-cost ratio (2.11) were obtained with T7 i.e.

Azospirillum + *Phosphobacterium* + 75% RDF which might be attributed to reduction in cost of inorganic fertilizers. Net return was recorded to be the lowest (`25,370.00 ha^{-1}) with *Phosphobacterium* + 50% RDF due to less supply of N and other nutrients and consequently lower yield and comparatively lower return.

Production cost showed marked variation due to the use of bio-fertilizers. However, the additional cost due to the use of bio-fertilizer was balanced by extra returns due to higher production. The results corroborated the findings of Lampe [11]. Siavosh et al. [24] pointed out, integration of organic fertilizer and reduced rate of synthetic fertilizer required to boost up the yield of rice and improve soil health.

4. CONCLUSION

Organic fertilizers has a large contribution towards the supply of plant nutrients, but to meet the food demand of rapidly increased world human population, extensive rise in the use of synthetic fertilizers will be required especially in the developing countries. Phosphate solubilizing bacteria (PSB) and *Azospirillum* can able to supplement one fourth (25%) of synthetic fertilizer, although bio-fertilizers together must not be total substitute of chemical fertilizer. Hence, integrated nutrient management is best for sustainable rice cultivation rather than purely organic. Application of bio-fertilizers improves stress tolerance capacity in plants, increase in root and shoot biomass, also rise the number of productive tillers, rice grain weight, nutrient availability and uptake by the plants which ultimately affect the rice grain yield. PSB can be used to make the unavailable soil phosphorous available for plants by which cost of cultivation would be reduced.

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