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Effect of Cultivars and Biofertilizers on Growth, Yield and Nutrient Content of Aerobic Rice (*Oryza sativa* L.)

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Abstract A field study was taken up to evaluate the influence of eco-friendly biofertilizers in aerobic rice during *kharif,* 2015. The experiment was laid out in split plot design with four replications. The main plot treatments were V_1-PA-6444 (Hybrid), V_2-DRR Dhan-44 (HYV) and sub plot treatments consisted of N_1-125% RDF, N_2-125% RDF + Biofertilizers, N_3-100% RDF, N_4-100% RDF + Biofertilizers, N_5-75% RDF, N_6-75% RDF + Biofertilizers. *Azospirillum,* Phosphorus Solubilizing Bacteria and Potassium Solubilizer were applied as biofertilizers @ 5 kg ha^{-1}. It was observed that significantly higher plant height was recorded in DRR Dhan-44 (51.29 cm) compared to PA-6444 (45.41 cm). But more number of tillers (495 No. m^{-2}), leaf area index (1.67), crop dry matter production (356.67 g m^{-2}), root dry matter production (88.28 g m^{-2}), number of panicles (535 m^{-2}), panicle length (23.81 cm) and nutrient content (%) in grain and straw was found to be high in PA-6444 compared to DRR Dhan-44. Rice fertilized with 125% RDF + Biofertilizers (N_2) produced higher plant height (52.63 cm), leaf area index (1.85), number of tillers (483 No. m^{-2}), crop dry matter production (383.15 g m^{-2}) and root dry matter production (91.45 g m^{-2}). Maximum yield was obtained with the highest N level amended with biofertilizer in PA-6444. Among the different nutrient combinations, application of 125% RDF + Biofertilizers (N_2) recorded higher N, P and K content in grain and straw than other nutrient combinations. There was a significant interaction between varieties and nitrogen levels combined with biofertilizers with respect to grain yield. For both the-cultivars, application of 100% RDF + biofertilizer was found to be more beneficial over 100% RDF and other lower rates.

Keywords Aerobic rice, Biofertilizers, Yield, Nutrient content.

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Introduction

Aerobic rice is a new method of rice cultivation where it is grown on non-puddled, non-flooded and non-saturated soil conditions just like maize, wheat and upland rice but with higher inputs such as supplementary irrigation and fertilizers [1]. Although aerobic rice has a great potential for saving water but all this is at the cost of severe reduction in yield due to lack of suitable varieties. Use of suitable high yielding drought resistant varieties with good inputs play an important role under limited water situation under aerobic production system. The application of chemical fertilizers alone does not bring significant increase in crop yield on sustainable basis over the years as these fertilizers supply only limited nutrients. With the increase in scientific knowledge regarding the negative effects of using various inorganic fertilizers, the application of alternative sources viz., biofertilizers in various cropping systems has gained more popularity. It improves soil organic matter content, enzymes, microbial population and also increases the yields of crops on sustainable basis. The beneficial effect of inoculation of aerobic rice with *Azospirillum,* Phosphorus Solubilizing Bacteria (PSB) and rooting mycorrhiza have been documented [2]. Potassium solubilizing bacteria such as *Bacillus* spp. solubilize rock K minerals (e.g., micas, illite and orthoclase) through the synthesis of organic acids or directly solubilize K by chelating silicon ions [3, 4]. Keeping in view the benefits of biofertilizer on nutrient management, the present investigation was undertaken to find out the effect of biofertilizers with graded levels of inorganic fertilizers on growth and yield of aerobic rice cultivars.

Materials and Methods

A field experiment was conducted during *kharif* 2015 at the research farm of ICAR-Indian Institute of Rice Research (IIRR), Hyderabad, Telangana state. The farm is geographically situated at an altitude of 542.7m above mean sea level on $17^0 19''$ N latitude and $78^0 29''$ E longitudes. The soil of the experimental field was sandy loam in texture and alkaline in reaction (pH 8.08, EC : 0.74 dS m^{-1}). Two cultivars (PA-6444 and DRR Dhan-44) and six nutrient levels viz. N_1-125% RDF (Recommended dose of fertilizer), N_2-125% RDF + Biofertilizers, N_3-100% RDF, N_4-100% RDF + Biofertilizers, N_5-75% RDF, N_6-75% RDF + Biofertilizers were compared in a split plot design with three replicates. Recommended dose of fertilizers (120 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}) was applied in all the treatments through urea, diammonium phosphate and muriate of potash. Entire dose of phosphorus and potassium and half of nitrogen were applied as basal. The remaining dose of nitrogen was top dressed equally at active tillering and panicle initiation stages as per treatments, *Azospirillum*, Phosphorus Solubilizing Bacteria and potassium Solubilizer were applied as biofertilizers @ 5 kg ha^{-1}. The plot size was 4.5 m ×2.5 m (11.25 m^2). Rice seed was directly sown by dibbling in lines in the dry field at a depth of 3-5 cm. In treated plots, biofertilizer treated seed was dibbled two to three seed $hill^{-1}$ with a spacing of 20 × 10 cm. After sowing, immediately light irrigation was applied through border strip method. Subsequent irrigation was given as and when needed, for proper growth and development of the crop. The growth parameters were recorded at 60 DAS of crop, yield attributes and yield were collected at the time of harvest and nutrient content in grain and straw was analyzed after the harvest of the crop. The collected data was statistically analyzed and presented in tables. The plant height was recorded from five hills using a meter scale from the base of the plant to the tip of the longest leaf or the panicle and expressed as centimeters. The number of tillers were counted and recorded from the five hills within the net plot area from each plot expressed as number m^{-2}. Leaf area was calculated by measuring leaf area of five hills using leaf area meter with transparent belt conveyor utilizing an electronic digital display.

LAI was calculated using the following formula

$$LAI = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Unit land area (cm}^2\text{)}}$$

Dry matter production (g m^{-2}) of five hills at different crop stages were uprooted from every experimental plot from the area demarcated for destructive sampling. These five hills were sun dried and later even dried till constant weight occurred. The dry weights of the five hills was recorded later and was converted to kg ha^{-1}. The number of panicles in square meter area of each plot were counted at maturity, averaged and expressed as number of panicles m^{-2}. Ten panicles were randomly selected and length of each panicle was measured from base of the primary rachis to the top most spikelet. The mean length of panicle was averaged. Ten panicles selected for measuring the length were weighed and then mean was worked out and expressed in g. After harvesting, the crop was sundried, eleaned, weighed and expressed in q ha^{-1} at 12 to 14% moisture content in grain. Straw obtained from each net plot area after threshing was sun dried for four days and then weighed and ex-

Table 1. Growth parameters of aerobic rice as influenced by graded nutrient levels.

Treatments Main factors : Cultivars (V)	At 60 days after sowing (DAS) Plant height (cm)	Leaf area	Number of tillers m^{-2}	Crop dry matter ($g\ m^{-2}$)	Root dry matter ($g\ m^{-2}$)
V_1-PA-6444	45.41	1.67	495	356.67	88.28
V_2-DRR Dhan-44	51.29	0.87	395	195.35	61.39
SEm ±	0.12	0.03	2.19	8.92	0.08
CD (p = 0.05)	0.3	0.09	6.57	26.76	0.24
Sub factors : Nutrient levels (N)					
N_1- 125% RDF	52.03	1.82	482	382.43	90.95
N_2-125% RDF +Biofertilizers*	52.63	1.85	483	383.15	91.45
N_3- 100% RDF	47.74	0.94	433	201.11	68.51
N_4-100% RDF + Biofertilizers*	52.01	1.78	480	382.47	90.93
N_5-75% RDF	41.75	0.55	394	143.19	49.24
N_6-75% RDF + Biofertilizers*	43.95	0.66	400	163.72	57.96
SEm ±	0.22	0.04	8.67	12.31	0.18
CD (p= 0.05)	0.66	0.12	26.01	36.93	0.34
Interaction : (V × N)					
SEm ±	0.29	0.08	11.4	21.84	0.25
CD (p = 0.05)	0.87	0.24	34.2	65.52	0.75

pressed in q ha^{-1}. Nitrogen content (%) in grain and straw were estimated by micro-Kjeldhal method at harvest. Phosphorus content (%) in grain and straw were estimated by using spectrophotometer. The potassium content (%) in grain and straw was determined by using flame photometer. The benefit : cost ratio of each treatment was calculated by dividing net returns by cost of cultivation of respective treatments.

$$\text{Benefit : Cost ratio} = \frac{\text{Net returns (Rs ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

Results and Discussion

Growth attributes

Plant height was significantly higher in DRR Dhan-44 (51.29) compared to PA-6444 (45.41cm (Table 1). DRR Dhan-44 recorded 12.94% increase in plant height compared to PA-6444. More plant height in DRR Dhan-44 might be due to its genetic makeup, enabling better utilization capacity of available nutrients, moisture and space [5]. Maximum leaf area index (1.67), more number of tillers m^{-2} (495 m^{-2}), crop dry matter production (356.67g m^{-2}) and root dry matter production (988.28 g m^{-2}) were observed in PA-6444 over DRR Dhan-44. Higher leaf area index in PA-6444 might be due to better root growth and adequate availability of nutrients. Similar findings were reported earlier [6]. The number of tillers m^{-2} recorded in PA-6444 was significantly more by 25.31% over DRR Dhan-44. This can be attributed to hybrid vigor and rapid conversion of synthesized carbohydrates to increase the number and size of growing cells, resulting in increased number of tillers. Such findings are in agreement with the findings of Dinesh et al. [7]. More crop dry matter production in PA-6444 was mainly due to more number of tillers m^{-2} and higher leaf area index which increased the photosynthetic rate. PA-6444 recorded higher root dry matter production due to its hybrid vigor and synergistic relationship of the inoculated biofertilizers, improving the root length and root weight by producing growth regulators like IAA and GA which favor better root development. Similar results were reported earlier [8].

Table 2. Effect of cultivars and graded nutrient levels on yield attributes, yield and economics of aerobic rice.

Treatments Main factors : Cultivars (V)	No. of panicles (m^{-2})	Panicle length (cm)	Panicle weight (g)	100 grain weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)	B : C ratio
V_1-PA-6444	535	23.81	4.56	2.53	34.06	45.37	51.48	2.23
V_2-DRR Dhan-44	493	22.81	4.17	2.35	27.53	35.63	46.97	1.55
SE m ±	6.37	0.64	1.32	0.001	0.32	0.42	0.006	-
CD (p = 0.05)	19.11	1.92	3.96	0.003	0.96	1.26	0.01	-
Sub factors : Nutrient levels (N)								
N_1-125% RDF	529	25.36	4.83	2.51	34.63	43.84	52.9	1.52
N_2-125% RDF + Biofertilizers	532	25.59	5.07	2.52	35.59	46.27	52.91	1.57
N_3-100% RDF	510	21.56	3.95	2.4	29.31	38.75	46.74	1.24
N_4-100% RDF + Biofertilizers	528	25.29	4.74	2.51	33.39	43.41	52.89	1.51
N_5-75% RDF	489	21.74	3.66	2.34	26.98	34.36	43.83	1.11
N_6-75% RDF + Biofertilizers	494	23.52	3.96	2.38	27.65	36.36	46.06	1.18
SEm ±	20.57	0.13	0.12	0.004	0.93	1.21	0.007	-
CD (p = 0.05)	61.71	0.39	0.36	0.01	2.79	3.63	0.02	-
Interaction (V × N)								
SEm ±	15.6	0.35	0.28	0.003	0.79	1.03	0.013	-
CD (p = 0.05)	NS	1.05	0.84	0.009	2.37	NS	0.03	-

Application of 125% RDF + Biofertilizers (N_2) recorded significantly higher plant height (52.63 cm), leaf area (1.85) and more number of tillers m^{-2} (483 m^{-2}), crop dry matter production (383.15 g m^{-2}) and root dry matter production (91.45g m^{-2}). It was found to be on par with N_1-125% RDF and N_4-100% RDF + Biofertilizers and lowest was observed in N_5-75% RDF (41.75 cm, 0.55 and 394 m^{-2}, respectively). Plants were taller with the increasing amount of nutrients with the biggest incremental increase between 75% RDF and 125% RDF + Biofertilizer. Higher N application rates resulted in higher growth attributes but the difference between 125% RDF + Biofertilizer and 100% RDF + Biofertilizer was not significant. Higher leaf area index and tillers might be due to added beneficial effect from inorganic nutrients integrated with biofertilizers leading to continuous nutrient release through mineralization which enhanced the plant growth and canopy development [9]. Higher dry matter production might be due to the application of biofertilizers which helped in balanced availability of nutrients at all the crop growth stages. These results are in close conformity with the earlier findings [8-10]. The interaction between the cultivars and treatments was found to be significant.

Yield attributes and yield

The number of panicles (535m^{-2}), panicle length (23.81 cm), panicle weight (4.56 g), 100 grain weight (2.53g) was significantly higher in PA-6444 over DRR Dhan-44 (493 m^{-2} and 22.81 cm, 4.17 g, 2.35 g respectively) (Table 2). The in crease inhundred grain weight was significantly more by 7.65% in PA-6444 over DRR Dhan-44.

More number of panicles m^{-2} (532), panicle length (25.59), panicle weight (5.07 g) and hundred grain weight (2.52 g) was recorded in N_2-125% RDF + Biofertilizers (and cm, respectively) and was comparable with N_1-125% RDF and N_4-100% RDF + Biofertilizers. More yield attributes might be due to increased nutrient supply at distinct physiological phase, which would have supported better assimilation of photosynthates and translocation to the sink, resulting in the production of more number of panicles m^{-2} at higher nutrient level. The lowest number of panicles (489 m^{-2}) and panicle length (21.74 cm) was noticed in N_5-75% RDF. The interaction effect between the cultivars and treatments was found significant in case of panicle length, panicle weight and hundred

Table 3. Effect of cultivars and graded nutrient levels on nutrient content of aerobic rice.

Treatments	*kharif* 2015					
	N content (%)		P content (%)		K content (%)	
Main factors : Cultivars (V)	Grain	Straw	Grain	Straw	Grain	Straw
V_1-PA-6444	2.16	0.61	0.44	0.15	0.58	1.95
V_2-DRR Dhan-44	1.79	0.45	0.27	0.13	0.54	1.69
SEm ±	0.05	0.009	0.003	0.002	0.003	0.04
CD (p =0.05)	0.26	0.04	0.013	0.009	0.01	0.19
Sub factors : Nutrient levels (N)						
N_1-125% RDF	2.25	0.58	0.39	0.15	0.6	2.07
N_2-125% RDF + Biofertilizers	2.27	0.6	0.39	0.17	0.64	2.13
N_3-100% RDF	1.79	0.53	0.34	0.14	0.53	1.67
N_4-100% RDF + Biofertilizers	2.06	0.52	0.38	0.15	0.57	1.9
N_5-75% RDF	1.73	0.46	0.3	0.12	0.5	1.54
N_6-75% RDF + Biofertilizers	1.76	0.51	0.31	0.13	0.52	1.61
SEm ±	0.04	0.009	0.008	0.005	0.005	0.03
CD (p = 0.05)	0.12	0.04	0.02	0.01	0.017	0.1
Interaction (V × N)						
SEm ±	0.08	0.015	0.007	0.007	0.008	0.06
CD (p = 0.05)	NS	0.05	NS	NS	0.02	0.23

grain weight. This was mainly due to increase in dry matter production and enhanced uptake of nutrients.

Yield

PA-6444 produced significantly higher grain yield (34.06 q ha^{-1}) and straw yield (45.37 q ha^{-1}) over DRR Dhan-44 (27.53 q ha^{-1} and 35.63 q ha^{-1}, respectively). Increase in the grain yield of PA-6444 is due to its superiority in number of productive tillers m^{-2}, dry matter production and number of panicles m^{-2}. PA-6444 produced over 23.71% and 27.33% more grain and straw yield compared to DRR Dhan-44. Harvest index was significantly high in PA-6444 (51.48%) over DRR Dhan-44 (46.97%). The results are in agreement with the earlier findings [9, 11].

With respect to nutrient levels, 125% RDF + Biofertilizers (N_2) recorded significantly higher grain yield (35.59 q ha^{-1}), straw yield (46.27 q ha^{-1}) and harvest index (52.91%) and was comparable with 125% RDF and 100% RDF + Biofertilizers. The lowest grain and straw yield was recorded in N_5-75% RDF (26.98 q ha^{-1} and 34.36 q ha^{-1}). Combined inoculation of *Azospirillum* + Phosphorus Solubilizing Bacteria with 100% RDF gave markedly higher yield over 75% RDF alone [12]. The interaction between cultivars and treatments was found significant in case of grain yield and harvest index.

Nutrient content in grain and straw (%)

The maximum N (2.16%), P (0.44%) and K (0.58%) content in grain was recorded in PA-6444 and minimum in DRR Dhan-44 (1.79%, 0.27% and 0.54%, respectively) (Table 3). The maximum nitrogen (0.61%), phosphorus (0.15%) and potassium (1.95%) content in straw was recorded in PA-6444 over DRR Dhan-44 (0.45%, 0.13% and 1.69%, respectively).

Among the different nutrient levels, N_2-125% RDF + Biofertilizers recorded higher nitrogen (2.27%), phosphoeus (0.39%) and potassium (0.64%) content in grain and higher nitrogen (0.6%), phosphorus (0.17%) and potassium content (2.13%) in straw. It was found on par with N_1-125% RDFand N_4-100% + Biofertilizers. The lower N, P and K content in grain was recorded in N_5-75% RDF (1.73%, 0.3% and 0.5% respectively). Maximum phosphorus content in N_2-125% RDF + Biofertilizers treated plot was due to solubilization of P in the soil by PSB which is made available to the crop. Similar results are also reported earlier [13]. Interaction between cultivars and nutrient levels on Nitrogen and Phosphorus content in grain and straw was not significant.

Economics

PA-6444 recorded higher B : C ratio (2.23) over DRR Dhan-44 (1.55). Higher B : C ratio was recorded in N_2-125% RDF + Biofertilizers (1.57) followed by N_1- 125% RDF (1.52) and N_4-100% RDF + Biofertilizers (1.51). The lowest was recorded in N_5- 75% RDF(1.18). Combined use of 50% RDF, *Gliricidia* @ 2.5 t ha^{-1} and biofertilizers recorded higher B : C ratio (1.6) over control [14].

Conclusion

Higher growth characters except for plant height was observed in PA-6444 with N_2-125% RDF + Biofertilizers. Whereas, plant height was recorded higher in DRR Dhan-44 with N_2-125% RDF + Biofertilizers. Higher yield attributes and yield was observed in PA-6444 with N_2-125% RDF + Biofertilizer as compared with all other treatments. NPK content (%) in grain and straw were found to be higher in PA-6444 with N_2-125% RDF + Biofertilizer as compared with rest of treatments.

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