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Impact of Bacterial Inoculums, Organic Residues and Mineral Fertilization Levels on Growth Traits of Dry Direct Seeded Rice Grown under Aerobic Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at Agricultural Research Station, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka during *kharif* seasons for two consecutive years (2019 and 2020) to study the influence of zinc and iron biofortification on physiological parameters of dry direct seeded rice under aerobic condition. The experiment was laid out in split plot design and comprised of two factors for the study *viz.,* main plots and sub plot treatments. Perusal of pooled data of two years showed that, among the rice genotypes, G_3: GNV-10-89 recorded significantly higher dry matter production accounted for 23.75, 69.92 and 82.73 g hill^{-1} at 60, 90 DAS and at harvest, respectively, leaf area 512.09, 543.92 and 376.57 cm^2 hill^{-1}, leaf area duration 45.60, 79.05 and 68.92 days and crop growth rate 34.78, 76.95 and 21.34 g cm^{-2} day^{-1} for the same sequences as compared to other genotype. With respect to micronutrient application, M_6: Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at 30 and 45 DAS recorded significantly higher dry matter production (27.26, 80.88 and 93.22 g hill^{-1} at 60, 90 DAS and at harvest, respectively), leaf area (514.21, 542.65 and 382.68 cm^2 hill^{-1} at 60, 90 DAS and at harvest, respectively), leaf area duration (46.27, 79.20 and 69.22 days during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively) and crop growth rate (39.10, 89.37 and 20.56 g cm^{-2} day^{-1} at 30-60 DAS, at 61-90 DAS and at 91 DAS-at harvest, respectively) as compared to other micronutrient application. The observed trends during 2019 and 2020 were nearly closed to each other.

Keywords: Leaf area duration; crop growth rate; genotypes; micronutrient; biofortification.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most important cereal crop and is a staple food for more than half of the world's population. Asia accounts for 60 per cent of the global population and stands first in world's rice production and as well as consumption (92 and 90%, respectively) [1]. Rice plays a vital role related with the diet and human health and is rich in various nutrient components like carbohydrates, proteins, certain fatty acids and micronutrients. In India, rice is grown in an area of 46.2 m ha and production of 117.32 m t with an average productivity of 2585 kg ha^{-1} [2]. India is the second largest country in terms of rice production and continues to hold the key to sustain food production by contributing 20 to 25 per cent of agriculture and assures food security for more than half of the total population [3]. In Karnataka, rice is cultivated in command areas of Cauvery, Tungabhadra and Upper Krishna. The total area under rice cultivation in Karnataka is 9.93 lakh ha, with an annual production of 29.07 lakh tonnes and productivity of 3082 kg ha^{-1} [4]. In Kalyana-Karnataka region, rice is cultivated in an area of 5.63 lakh ha with a production of 14.4 lakh tonnes and productivity of 2778 kg ha^{-1}. Among the districts of Kalyana-Karnataka region, rice is cultivated in an area of 1.13 lakh ha with a production of 3.15 lakh tonnes and productivity of 2931 kg ha^{-1} in Raichur district [5].

Direct seeded rice (DSR) is one of the resource conservation technologies which requires less labour and tends to mature faster than transplanted crops. Here, rice crop is not subjected to transplanting stress. Direct seeding can be done in two ways depending on the land preparation method used such as dry seeding and wet seeding. Dry seeding is done for rainfed crop in which sowing is done in dry soil surface. In case of wet seeding, sowing is done either through broadcasting or drilling seeds into the mud with drum seeders in wet fields. In this method sole crop competition from weeds, deficiency of micronutrients (iron and zinc) and nematodes are the major limitation for successful DSR production [6,7]. However, DSR could be an alternative to transplanted puddled rice (TPR) as it consumes less irrigation water without any significant yield reduction, requires less labour, as puddling and transplanting is completely avoided and can be highly mechanised. Dry direct seeded rice cultivation is a method wherein rice seeds are directly broadcasted or sown in lines using drills and irrigation is given as and when required without impounding water in the field as in traditional rice. In many countries where labor is limited or labor cost is very high, sowing of rice is effectively done by direct seeding method. To overcome the risks related to the extensive use of chemical fertilizers, the bacterial inoculation technique could be used. Use of biofertilizers improves the beneficial microbial community particularly biological nitrogen fixing bacteria that fixes atmospheric nitrogen and reduces chemical N fertilizer quantities by one fourth. In the same time, phosphate solubilizing bacteria can solubilize insoluble form of phosphate into soluble one which makes them available to plant. helps in maintains the soil health and providing plant growth promoting substances like organic acid, IAA, gibberellins, cytokinins, vitamins, minerals and enzymes. They are cost effective, eco-friendly and renewable sources of plant nutrients to supplement chemical fertilizers. Nitrogen fixing and P-solubilizing inoculants are important biofertilizers used in rice fields.

2. MATERIALS AND METHODS

A field experiment was conducted at Agricultural Research Station, Gangavathi, which is situated between 15º 35' 07" latitude 76º 15' 47" longitude with an altitude of 419 meters above mean sea level and is located in Northern Dry Zone (Zone-3) of Karnataka. The experiment was laid out in split plot design with four RDF levels i.e., M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1}, M_2: 75% recommended NPK without FYM, M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1} and M_4: 100% recommended NPK without FYM as main plot treatments and six biofertilizer applications i.e., S_1: Seed inoculated with *Azospirillum Brasilense* + PSB @ 500 g each ha^{-1}, S_2: Soil application of *Azospirillum Brasilense* + *Pseudomonas aeruginosa* @ 3.5 kg each ha^{-1}, S_3: Seed inoculated with *Azospirillum Brasilense* + PSB @ 500 g each ha^{-1} + soil application of *Azospirillum Brasilense* + *Pseudomonas aeruginosa* @ 3.5 kg each ha^{-1}, S_4: Soil application of *Azospirillum Brasilense* + *Pseudomonas aeruginosa* @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1}, S_5: Soil application of microbial consortium @ 3.5 kg ha^{-1} and S_6: Control as sub plot treatment. All treatments were replicated three times during the experimental course. The plot size was 4.5 m length × 3.6 m width (16.2 m^2). The experimental soil was medium black with clay loam texture with soil organic carbon 0.65%, pH 8.35, EC 0.58 dS m^{-1}, DTPA extractable zinc (0.68 ppm) and iron (4.77 ppm). During the cropping period, total rainfall was 570.1 mm in 2019 and 603.4 mm in 2020. September and October months of 2019 received higher rainfall (251.4 and 160.9 mm, respectively) whereas, July and September months of 2020 received higher rainfall in second year (140.1 and 141.4 mm, respectively). Mean monthly maximum temperature ranged between 28.7°C to 39.2°C in 2019 and 29.5°C to 36.7°C in 2020. The mean monthly minimum temperature was noticed during December and January months of both years (17.6°C and 13.7°C during 2019 and 15.7°C and 18.0°C during 2020, respectively). The highest relative humidity of 58.32% and 41.25% was noticed during September of both the cropped years.

3. RESULTS AND DISCUSSION

3.1 Dry Matter Production

In general, dry matter production and its distribution into leaves, stem and panicles increased with advances in age till maturity. Among the RDF levels, M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1} recorded significantly higher dry matter production (23.25, 77.44 and 92.94 g hill^{-1} at 60, 90 DAS and at harvest, respectively on pooled basis) as compared to M_2: 75% recommended NPK without FYM (18.29, 63.10 and 72.70 g hill^{-1} at 60, 90 DAS and at harvest, respectively on pooled basis). However, it was found to be on par with M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1} (21.63, 72.88 and 86.81 g hill^{-1} at 60, 90 DAS and at harvest, respectively on pooled basis). Among the biofertilizer application, S_3: Seed treatment with *Azospirillum* + PSB @ 500 g each ha^{-1} + soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} recorded significantly higher dry matter production on pooled basis throughout (25.19, 79.13 and 97.27 g hill^{-1} at 60, 90 DAS and at harvest, respectively), whereas the lowest dry matter production was recorded under control treatment (19.05, 59.34 and 65.55 g hill^{-1} at 60, 90 DAS and at harvest, respectively on pooled basis). But it was found to be on par with S_4: Soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1} (24.15, 75.13 and 91.04 g hill^{-1} at 60, 90 DAS and at harvest, respectively on pooled basis) over rest of the treatments. Similar trend of observations were noticed during 2019 and 2020.

3.2 Leaf Area

Among the RDF levels, M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1} recorded significantly higher leaf area (444.35, 551.76 and 397.53 cm^2 hill^{-1}, respectively, on pooled basis) when compared with M_2: 75% recommended NPK without FYM (388.46, 370.35 and 367.57 cm^2 hill^{-1}, respectively, on pooled basis) but was found to be on par with M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1} (431.16, 488.73 and 387.73 cm^2 hill^{-1}, respectively, on pooled basis) at all the growth stages at 60 and 90 DAS and at harvest. Similarly seed treatment with *Azospirillum* + PSB @ 500 g each ha^{-1} + soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} recorded significantly higher leaf area (453.67, 618.94 and 398.46 cm^2 $hill^{-1}$ at 60, 90 DAS and at harvest, respectively on pooled basis) as compared to other biofertilizer application, whereas the lowest leaf area (374.89, 408.58 and 364.68 cm^2 $hill^{-1}$ at 60, 90 DAS and at harvest, respectively on pooled basis) were observed in control. But it was found to be on par with S_4: Soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1} (434.75, 573.26 and 391.01 cm^2 $hill^{-1}$ at 60, 90 DAS and at harvest, respectively on pooled basis). Higher dry matter production was mainly because of the adequate availability of nutrients due to RDF level coupled with FYM @ 7.5 t ha^{-1} and seed treatment with *Azospirillum* + PSB @ 500 g each ha^{-1} + soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} which maintained throughout crop growing season nutrient supplying capacity of soil. Increased availability of nutrients in the soil through mineralization of organic manures and improved soil properties could have resulted in higher dry matter production over control. In the same line Govindappa [8] reported that the high leaf area per plant was responsible for photosynthetic activity which in turn resulted in higher dry matter production. The higher dry matter accumulation resulted due to combination of organic or inorganic sources, contributed for accelerating the enzymatic activity and auxin metabolism in plants and improved the cell division and enlargement due to increased photosynthetic rate subsequently increasing the total dry matter production. Similar results were obtained by Guggari and Kalaghatagi [9].

3.3 Leaf Area Duration

The trend in leaf area duration was same as that of leaf area index at different growth stages and differed due to different RDF levels and biofertilizer application. Significantly higher leaf area duration among the RDF levels was observed with M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1} recorded (39.90, 74.55 and 71.02 days during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively on pooled basis) than M_2: 75% recommended NPK without FYM but it was on par with M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1} (39.00, 69.22 and 65.62 days during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively on pooled basis). Among the biofertilizer application, S_3: Seed treatment with *Azospirillum* + PSB @ 500 g each ha^{-1} + soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} recorded significantly higher leaf area duration (41.10, 80.32 and 76.12 days during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively on pooled data basis). Whereas the lowest leaf area duration on pooled basis was recorded by S_6: Control (32.85, 58.65 and 57.82 days during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively) which was found to be on par with S_4: Soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1} (39.30, 75.45 and 72.15 days during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively). Similar observations were recorded during 2019 and 2020.

3.4 Crop Growth Rate

Among the RDF levels, M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1} registered higher crop growth rate (34.48, 90.31 and 25.83 g cm^{-2} day^{-1} during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively on pooled basis) over M_2: 75% recommended NPK without FYM (26.60, 74.67 and 16.00 g cm^{-2} day^{-1} during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively on pooled basis) but was found to be on par with M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1} (31.91, 85.42 and 23.20 g cm^{-2} day^{-1} during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively on pooled basis).

With respect to biofertilizer application, the treatment S_3: Seed treatment with *Azospirillum* + PSB @ 500 g each ha^{-1} + soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} recorded significantly higher crop growth rate (35.95, 89.90 and 30.24 g cm^{-2} day^{-1} during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively on pooled basis). Whereas the lowest crop growth rate on pooled basis was recorded by control (S_6) (29.10, 67.15 and 10.34 g cm^{-2} day^{-1} during 30-60 DAS, 61-90 DAS and 91 DAS-at harvest, respectively) but was found to be on par with S_4: Soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1} (35.06, 84.97 and 26.51 g cm^{-2} day^{-1} at 30-60 DAS, 61-90 DAS and at 91 DAS-at harvest, respectively on pooled basis). Similar trend of observations were noticed during 2019 and 2020. Application of *Azospirillum* and PSB performed well which may act as a stimulus in the plant system which inturn increased the production of growth regulators in the cell system and action of growth hormones such as organic acid, IAA, gibberellins, cytokinins, vitamins, minerals and enzymes resulted in better growth and yield of rice [10].

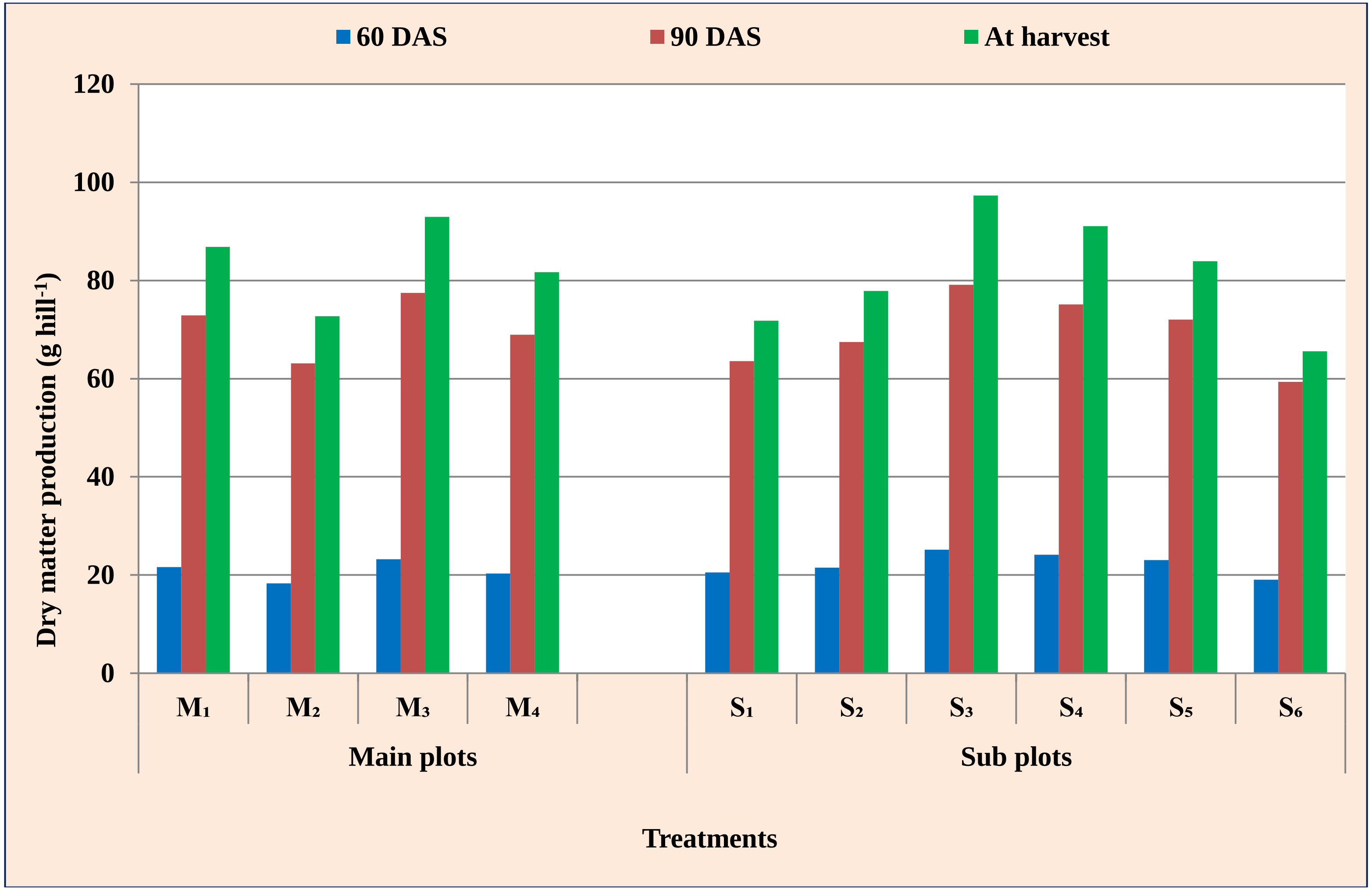

Fig. 1. Dry matter production (g hill^{-1}) at different growth stages as influenced by RDF levels and biofertilizer application in direct seeded rice

Table 1. Dry matter production at different growth stages as influenced by RDF levels and biofertilizer application in DSR

Treatments	Dry matter production (g hill^{-1})								
	60 DAS			90 DAS			At harvest		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Main plot: RDF levels (M)									
M_1	20.63	22.63	21.63	70.54	75.23	72.88	84.27	89.35	86.81
M_2	17.56	19.03	18.29	61.37	64.83	63.10	71.51	73.89	72.70
M_3	22.07	24.43	23.25	74.00	80.88	77.44	90.26	95.62	92.94
M_4	19.31	21.30	20.30	67.18	70.68	68.93	79.24	84.11	81.67
S.Em±	**0.68**	**0.50**	**0.69**	**1.21**	**1.42**	**1.31**	**1.53**	**1.60**	**2.05**
C. D. (P=0.05)	**1.91**	**1.86**	**1.71**	**3.58**	**5.69**	**4.85**	**5.12**	**5.30**	**6.28**
Sub plot: Biofertilizer application (S)									
S_1	19.96	21.14	20.55	62.12	64.99	63.55	69.63	74.02	71.82
S_2	20.91	22.07	21.49	65.54	69.40	67.47	75.86	79.84	77.85
S_3	24.36	26.02	25.19	77.49	80.77	79.13	95.77	98.78	97.27
S_4	23.38	24.92	24.15	73.27	77.00	75.13	89.16	92.93	91.04
S_5	22.36	23.73	23.04	70.07	74.04	72.05	81.63	86.18	83.90
S_6	18.28	19.82	19.05	57.50	61.19	59.34	63.37	67.73	65.55
S.Em±	**0.50**	**0.40**	**0.40**	**1.43**	**1.26**	**1.52**	**2.23**	**2.03**	**2.12**
C. D. (P=0.05)	**1.51**	**1.20**	**1.19**	**4.29**	**3.78**	**4.54**	**6.69**	**6.15**	**6.36**
Interaction (M × S)									
S.Em±	**0.47**	**0.48**	**0.48**	**1.22**	**1.18**	**1.15**	**1.06**	**1.01**	**1.09**
C. D. (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: DAS-Days after sowing NS-Non significant

G_1: RP Bio-226
G_2: GGV-05-01
G_3: GNV 10-89

M_1: Seed treatment with $ZnSO_4$ @ 1 % and $FeSO_4$ @ 1 %
M_2: Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
M_3: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at 30 and 45 DAS
M_4: Seed treatment + soil application (M_1 + M_2)
M_5: Seed treatment + foliar application (M_1 + M_3)
M_6: Soil application + foliar application (M_2 + M_3)
M_7: Control

Table 2. Leaf area at different growth stages as influenced by RDF levels and biofertilizer application in direct seeded rice

Treatments	Leaf area (cm^2 $hill^{-1}$)								
	60 DAS			90 DAS			At harvest		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Main plot: RDF levels (M)									
M_1	423.92	438.41	431.16	485.35	492.12	488.73	386.52	388.94	387.73
M_2	382.91	394.02	388.46	368.34	372.36	370.35	366.73	368.42	367.57
M_3	429.83	458.88	444.35	549.08	554.44	551.76	395.24	399.83	397.53
M_4	403.54	429.41	416.47	424.61	429.28	426.94	374.91	377.58	376.24
S.Em±	**6.21**	**5.14**	**3.94**	**19.02**	**18.42**	**17.43**	**4.59**	**5.23**	**3.71**
C. D. (P=0.05)	**21.30**	**17.60**	**15.60**	**65.71**	**63.72**	**64.84**	**15.87**	**18.03**	**13.83**
Sub plot: Biofertilizer application (S)									
S_1	378.44	385.08	381.76	385.94	452.35	419.14	367.37	369.39	368.38
S_2	390.02	407.17	398.59	424.28	503.67	463.97	378.47	380.49	379.48
S_3	439.31	468.04	453.67	572.35	665.54	618.94	397.45	399.47	398.46
S_4	423.95	445.55	434.75	528.71	617.81	573.26	389.51	392.52	391.01
S_5	408.94	425.34	417.14	484.82	571.32	528.07	382.84	387.86	385.35
S_6	367.16	382.62	374.89	368.53	448.63	408.58	363.75	365.61	364.68
S.Em±	**6.02**	**7.61**	**6.57**	**17.70**	**17.57**	**16.27**	**4.50**	**3.78**	**3.75**
C. D. (P=0.05)	**18.10**	**22.80**	**19.74**	**53.10**	**52.70**	**48.80**	**13.49**	**11.31**	**11.27**
Interaction (M × S)									
S.Em±	**9.15**	**9.54**	**6.91**	**36.9**	**36.6**	**33.9**	**14.60**	**16.36**	**10.90**
C. D. (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: DAS- Days after sowing NS-Non significant

M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1}
M_2: 75% recommended NPK without FYM
M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1}
M_4: 100% recommended NPK without FYM

S_1: Seed treatment with Azospirillum + PSB @ 500 g each ha^{-1}
S_2: Soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1}
S_3: Seed treatment with Azospirillum + PSB @ 500 g each ha^{-1} + soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1}
S_4: Soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1}
S_5: Soil application of microbial consortium @ 3.5 kg ha^{-1}
S_6: Control

Table 3. Leaf area duration at different growth stages as influenced by RDF levels and biofertilizer application in direct seeded rice

Treatments	Leaf area duration (Days)								
	30-60 DAS			61-90 DAS			91 DAS-At harvest		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Main plot: RDF levels (M)									
M_1	37.95	40.05	39.00	68.10	70.35	69.22	65.25	66.00	65.62
M_2	33.90	34.95	34.42	56.25	57.45	56.85	55.05	55.50	55.27
M_3	38.70	41.10	39.90	73.20	75.90	74.55	70.65	71.40	71.02
M_4	35.40	36.75	36.07	61.35	62.70	62.02	59.85	60.30	60.07
S.Em±	**0.22**	**0.32**	**0.29**	**1.54**	**2.32**	**2.41**	**1.68**	**1.74**	**1.56**
C. D. (P=0.05)	**0.98**	**1.12**	**1.09**	**5.82**	**7.69**	**7.54**	**5.54**	**5.81**	**5.62**
Sub plot: Biofertilizer application (S)									
S_1	33.45	34.20	33.82	57.30	62.70	60.00	56.40	61.50	58.95
S_2	34.80	36.30	35.55	61.05	68.10	64.57	60.15	66.15	63.15
S_3	39.90	42.30	41.10	75.75	84.90	80.32	72.60	79.65	76.12
S_4	38.40	40.20	39.30	71.40	79.50	75.45	68.70	75.60	72.15
S_5	36.60	38.10	37.35	66.90	74.55	70.72	64.95	71.70	68.32
S_6	32.10	33.60	32.85	55.05	62.25	58.65	54.75	60.90	57.82
S.Em±	**0.58**	**0.75**	**0.65**	**1.48**	**1.86**	**1.66**	**1.28**	**1.57**	**1.42**
C. D. (P=0.05)	**1.74**	**2.25**	**1.97**	**4.45**	**5.58**	**4.98**	**3.84**	**4.73**	**4.28**
Interaction (M × S)									
S.Em±	**0.11**	**0.40**	**0.35**	**1.69**	**1.85**	**1.82**	**2.16**	**1.78**	**1.81**
C. D. (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: DAS- Days after sowing NS-Non significant

M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1}
M_2: 75% recommended NPK without FYM
M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1}
M_4: 100% recommended NPK without FYM

S_1: Seed treatment with Azospirillum + PSB @ 500 g each ha^{-1}
S_2: Soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1}
S_3: Seed treatment with Azospirillum + PSB @ 500 g each ha^{-1} + soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1}
S_4: Soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1}
S_5: Soil application of microbial consortium @ 3.5 kg ha^{-1}
S_6: Control

Table 4. Crop growth rate at different growth stages as influenced by RDF levels and biofertilizer application in direct seeded rice

Treatments	Crop growth rate (g cm^{-2} day^{-1})								
	30-60 DAS			61-90 DAS			91 DAS-At harvest		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Main plot: RDF levels (M)									
M_1	31.06	32.76	31.91	83.18	87.66	85.42	22.88	23.53	23.20
M_2	26.20	27.00	26.60	73.01	76.33	74.67	16.90	15.10	16.00
M_3	33.33	35.63	34.48	86.55	94.08	90.31	27.10	24.56	25.83
M_4	28.88	30.56	29.72	79.78	82.30	81.04	20.10	22.38	21.24
S.Em±	**1.09**	**0.85**	**1.02**	**1.04**	**3.10**	**1.54**	**1.26**	**0.71**	**0.89**
C. D. (P=0.05)	**3.21**	**2.97**	**3.12**	**3.42**	**6.48**	**5.61**	**4.36**	**2.31**	**2.89**
Sub plot: Biofertilizer application (S)									
S_1	31.10	31.43	31.26	70.26	73.08	71.67	12.51	15.05	13.78
S_2	32.38	32.68	32.53	74.38	78.88	76.63	17.20	17.40	17.30
S_3	35.38	36.51	35.95	88.55	91.25	89.90	30.46	30.01	30.24
S_4	34.60	35.53	35.06	83.15	86.80	84.97	26.48	26.55	26.51
S_5	33.58	34.23	33.90	79.51	83.85	81.68	19.26	20.23	19.75
S_6	28.63	29.56	29.10	65.36	68.95	67.15	9.78	10.90	10.34
S.Em±	**0.29**	**0.40**	**0.33**	**1.41**	**1.96**	**1.70**	**1.57**	**1.18**	**1.27**
C. D. (P=0.05)	**0.88**	**1.20**	**0.98**	**4.25**	**5.89**	**5.12**	**4.71**	**3.54**	**3.84**
Interaction (M × S)									
S.Em±	**0.11**	**0.40**	**0.35**	**1.69**	**1.85**	**1.82**	**2.16**	**1.78**	**1.81**
C. D. (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: DAS- Days after sowing NS-Non significant

M_1: 75% recommended NPK with FYM @ 7.5 t ha^{-1}
M_2: 75% recommended NPK without FYM
M_3: 100% recommended NPK with FYM @ 7.5 t ha^{-1}
M_4: 100 % recommended NPK without FYM

S_1: Seed treatment with Azospirillum + PSB @ 500 g each ha^{-1}
S_2: Soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1}
S_3: Seed treatment with Azospirillum + PSB @ 500 g each ha^{-1} + soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1}
S_4: Soil application of Azospirillum + PSB @ 3.5 kg each ha^{-1} + residue mulch @ 2 t ha^{-1}
S_5: Soil application of microbial consortium @ 3.5 kg ha^{-1}
S_6: Control

4. CONCLUSION

The experimental findings indicated that there were marked variations in the productivity of dry direct seeded rice owing to RDF levels and biofertilizer. Based on the present investigation, it can be concluded that the RDF levels, 100% recommended NPK with FYM @ 7.5 t ha^{-1} was found better as compared to 75% recommended NPK without FYM with respect to dry matter production, leaf area and growth indices of rice. With respect to biofertilizer application *i.e.* seed treatment with *Azospirillum* + PSB @ 500 g each ha^{-1} + soil application of *Azospirillum* + PSB @ 3.5 kg each ha^{-1} was a better option in dry direct seeded rice which was found to be most productive, economically viable and sustainable. Hence, biofortification of rice is essential to meet nutritional security of underdeveloped and developing counties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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