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Performance evaluation of rice genotypes as influenced by water regimes and biofertilizer using the PVC tube method

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Abstract
The investigation was conducted during the summer season of 2021 from February–June at Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala. The lowland rice genotypes viz., Prathyasa and KAU Manu Rathna and aerobic rice variety, Sharada were grown in PVC tubes of 8” diameter and were subjected to different water regimes (flooded, saturated and aerobic condition), with and in the absence of biofertilizer, *Azospirillum lipoferum* KAU isolate. The growth attributes of these genotypes at panicle initiation, flowering and harvest stages and yield attributes at harvesting stage were recorded. The results showed that the plant height, leaf area index (LAI) and dry matter production (at harvest) of the genotype, Sharada were considerably higher than the other two genotypes at all the growth stages. Among the different water regimes, these parameters were significantly reduced under aerobic condition as compared to flooded and saturated condition. Similarly, the yield attributes and yield differed under different genotypes and water regimes. The number of filled grains panicle^{-1}, 1000 grain weight, grain yield and harvest index were remarkably higher under Sharada and its sterility percentage were also lesser as compared to Prathyasa and KAU Manu Rathna. With respect to water regimes, significant reductions in these yield parameters were observed under aerobic condition over flooded and saturated condition. The presence of biofertilizer, *Azospirillum lipoferum* had no significance with respect to growth and yield attributes of rice.

Keywords: Aerobic, *Azospirillum*, Prathyasa, PVC, saturated, Sharada

1. Introduction

Rice is a water guzzler, which requires about 3000–5000 L of water to produce 1 kg of grains (Bouman, 2009, Caine *et al*., 2019) [1, 2]. It is an important cereal crop across the globe and feeds about 3 billion people around the world (Vengatesh and Govindarasu, 2017) [3]. In Kerala, rice is being cultivated during all three seasons *viz*., autumn, winter and summer, except in Wayanad district. The conventional rice production system is very labour intensive, since it requires special operations like nursery establishment, puddling and transplanting. It is suitable in areas where there is high rainfall. It is well evident that conventional rice production system contributes to the bulk of rice production but consumes an enormous quantity of water and labour (Gandhi *et al*., 2012) [4].

Water is the most limited natural resource in agriculture (Joshi *et al*., 2016, Alcamo *et al*., 2017) [5, 6]. Under water limited situation, the conventional rice production system will no longer be sustainable (Phule *et al*., 2019) [7]. It is estimated that by the year 2025, 20% of Asia’s irrigated rice crops will suffer from water scarcity (Sandhu *et al.,* 2012) [8]. Thus, there is a need to develop an alternative rice production system that will focus on “more rice with less water” strategy (Bouman *et al.*, 2002, Maneepitak *et al*., 2019, He *et al*., 2020, Singh *et al*., 2021) [9, 10, 11, 12]. Aerobic rice system is one such technology wherein rice is directly dry seeded in a no-puddled, non-saturated soil with adequate fertilizer application and supplemental irrigation during insufficient rainfall (Bouman *et al*., 2006, Joshi *et al*., 2018) [13, 14]. Moreover, aerobic rice saves significant amount of water (Kadiyala *et al*., 2012) [15], requires less labour (Kato and Katsura, 2014) [16] and also mitigates the effect of global warming by reducing greenhouse gas emissions (Xiong *et al*., 2015, Weller *et al*., 2016, Wang *et al.*, 2017) [17, 18, 19]. Some lowland rice cultivars adapt well under irrigated aerobic condition (Lafitte *et al.*, 2002, Reddy *et al*., 2011) [20, 21] while some show drastic yield reduction (Peng *et al*., 2006) [22]. Kumar *et al*. (2013) [23] identified few lowland rice genotypes that can be cultivated under aerobic conditions because of their ability to produce higher grain yield, harvest index and have lower sterility percentage.

Thus, suitable genotypes should be identified that can produce more yield under water stress condition.

Azospirillum is a plant growth promoting rhizobacteria (PGPR) which produces growth promoters like auxins and gibberellins (de Souza *et al*., 2015) [24] in addition to nitrate reductase that helps in nitrogen fixation (Santos *et al*., 2017) [25] even under stress condition. *Azospirillum* enhances the uptake of nitrogen and other nutrients which promotes plant growth and development and confers tolerance to stress condition (Hamdia and El-Komy, 1998, Cohen *et al*., 2008, Tejaswini *et al.*, 2017) [26, 27, 28]. *Azospirillum* is known to influence the growth and yield of various plant species of agronomic importance (Pii *et al*., 2015) [29]. The notable increase in grain yield and straw yield was reported in dry seeded rice by Siddaram *et al.* (2017) [30] inoculated with *Azospirillum.* On the contrary, Vejan *et al*. (2016) [31] revealed that plant growth regulators have very less influence on the morphology of plants. By taking all these points into consideration, this study was undertaken to evaluate the growth and yield of two lowland rice genotypes and one aerobic rice genotype under different water regimes with and without biofertilizer, *Azospirillum lipoferum*.

2. Materials and Methods

The field experiment was carried out during the summer season of 2021 (February–June at Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala, located at 8°28′25″ N latitude and 76°57′32″ E longitude, at an altitude of 5 m above mean sea level. PVC pipes of 8″ diameter with a density of 4 kg cm^{-3} were used for this experiment. A pit of 1 m depth was dug in the field and the 100 cm long PVC pipes were vertically arranged in this pit. The PVC pipes were then filled with the soil from surrounding area and three seeds were dibbled in each pipe. 3 rice genotypes *viz*., Prathyasa (MO 21), KAU Manu Rathna (HS 16) and aerobic rice genotype, Sharada (MAS 946-1) were used in this experiment. These genotypes were subjected to 3 different water regimes, W_1-flooded condition (water column of 5 cm was maintained throughout the crop growth), W_2-saturated condition (irrigating to 1 cm depth one day after the disappearance of standing water column) and W_3-aerobic condition (irrigation to obtain 2.5 cm depth of irrigation and subsequent irrigation once in five days), with and in the absence of biofertilizer, *Azospirillum lipoferum* (KAU isolate). The growth attributes *viz*., plant height, tillers hill^{-1} and leaf area index were recorded at panicle initiation, flowering and harvesting stages while dry matter production was recorded only at the harvest stage. The plants were then carefully harvested and yield attributes such as productive tillers hill^{-1}, filled grains panicle^{-1}, sterility percentage, thousand grain weight, grain yield, straw yield and harvest index were noted and the recorded data were then subjected to statistical analysis as described by Gomez and Gomez (1984) [32].

3. Results and Discussion

3.1. Growth attributes

Rice genotypes exhibited significant difference in their morphological traits (Table 1). Aerobic rice variety, Sharada recorded significantly taller plants (75.45 cm, 79.82 cm and 90.52 cm) and higher leaf area index (4.87, 5.28 and 4.50) at all the growth stages *viz*., panicle initiation, flowering and harvesting stages, respectively. Plant height is one of the indirect traits governing the yield of a crop (Li *et al.*, 2019) [33]. This trait is a result of genetic makeup of the genotype which governs the total number of internodes and internodal length (Zheng *et al*., 2022) [34]. Leaf area index determines the canopy size, which is the most important morphological trait affected during water stress condition. Higher leaf area index aids in better conversion of light energy into dry matter (Tesfaye *et al.*, 2006) [35]. The leaf area index reduces during terminal crop growth stage due to senescence of the older leaves. Significantly higher dry matter production at harvesting stage (17.31 g plant^{-1}) was recorded under Sharada as compared to the other two genotypes, Prathyasa and KAU Manu Rathna. The increase in dry matter production of Sharada can be attributed to its taller plant and higher leaf area index. The number of tillers hill^{-1} had no significance although Sharada maintained more number of tillers hill^{-1} than Prathyasa and KAU Manu Rathna. The superiority of Sharada in terms of its growth attributes were also reported by Sritharan and Vijayalakshmi (2010) [36] and Gandhi *et al*. (2012) [4].

Among the water regimes, flooded condition resulted in significantly taller plants and higher leaf area index at panicle initiation, flowering and harvesting stages, respectively (Table 1). The plant height and leaf area index of rice under aerobic condition reduced by 9.24–11.91% and 9.79–11.06%, respectively, than under flooded condition. The reduction in plant height under aerobic condition might be due to inhibition of cell growth and cell division because of reduced turgor under water stressed condition that results in inhibition of stem growth (Lu *et al*., 2002, Nguyen *et al.*, 2009) [37, 38]. Similarly, under aerobic condition the expansion of leaves decreases due to reduced turgor pressure (Coussement *et al.*, 2020) [39] resulting in lower leaf area index. Since rice is very sensitive to water stress condition, it starts rolling the leaves to maintain the water status under such conditions (Lafitte and Courtois, 2002) [40]. The dry matter production at harvest was considerably the highest under flooded condition as compared to saturated and aerobic condition. Aerobic condition resulted in 11.16% reduction in dry matter production as compared to that under flooded condition. The reduction in dry matter production is due to decreased plant height and leaf area index under aerobic condition that ultimately inhibits the photosynthetic rate. The decrease in plant height, leaf area index and dry matter production under aerobic condition was also reported by Borrell *et al*. (1997) [41], Nguyen *et al.* (2009) [38] and Joshi *et al*. (2018) [14]. The plant height under saturated condition was at par with the flooded condition at panicle initiation and flowering stages while the leaf area index was at par at flowering and harvesting stages. Likewise, the dry matter production at harvest under saturated condition was comparable with that under flooded condition. This shows that the growth attributes of rice had no significant variations as the water regime shifted from flooded to saturated condition. Higher growth attributes of summer rice under continuous saturation were also reported by Show *et al*. (2014) [42].

The effect of biofertilizer, interaction effect between genotypes and water regimes, genotypes and biofertilizer, water regimes and biofertilizer as well as interaction among genotypes, water regimes and biofertilizer did not vary significantly (Tables 1, 2 and 3).

Table 1: Effect of genotypes, water regimes and *A. lipoferum* on growth parameters of rice

Treatments	Plant height (cm)			Tillers hill^{-1}			Leaf area index			Dry matter (g plant^{-1})
	PI	FL	HS	PI	FL	HS	PI	FL	HS	
Genotypes (G)										
g_1 (Prathyasa)	62.57^{b}	66.53^{b}	76.10^{b}	4.78	3.44	4.83	3.79^{b}	4.33^{b}	3.38^{b}	15.57^{b}
g_2 (KAU Manu Rathna)	61.46^{b}	66.21^{b}	74.44^{b}	4.61	3.47	4.83	3.34^{c}	3.77^{c}	2.80^{c}	14.62^{b}
g_3 (Sharada)	75.45^{a}	79.82^{a}	90.52^{a}	4.94	3.67	5.22	4.87^{a}	5.28^{a}	4.50^{a}	17.31^{a}
SEm$\pm$	1.295	1.210	1.030	0.137	0.132	0.193	0.098	0.088	0.105	0.465
CD (*p*=0.05)	3.714	3.472	2.954	NS	NS	NS	0.281	0.254	0.302	1.334
Water regimes (W)										
w_1 (Flooded)	69.48^{a}	74.59^{a}	84.23^{a}	4.50	3.28	4.67	4.28^{a}	4.70^{a}	3.78^{a}	16.76^{a}
w_2 (Saturated)	66.94^{a}	71.31^{a}	80.66^{b}	4.89	3.69	5.17	3.90^{b}	4.49^{a}	3.48^{ab}	15.85^{ab}
w_3 (Aerobic)	63.06^{b}	66.65^{b}	76.16^{c}	4.94	3.61	5.06	3.82^{b}	4.18^{b}	3.41^{b}	14.89^{b}
SEm$\pm$	1.295	1.210	1.030	0.137	0.132	0.193	0.098	0.088	0.105	0.465
CD (*p*=0.05)	3.714	3.472	2.954	NS	NS	NS	0.281	0.254	0.302	1.334
Biofertilizer *Azospirillum lipoferum* (A)										
a_0 (Without A)	66.30	71.02	80.26	4.74	3.52	4.96	4.02	4.44	3.59	15.69
a_1 (With A)	66.69	70.69	80.44	4.81	3.53	4.96	3.99	4.48	3.52	15.98
SEm$\pm$	1.020	0.954	0.811	0.108	0.104	0.152	0.077	0.070	0.083	0.366
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
PI: panicle initiation stage, FL: flowering stage, HS: harvesting stage										

Table 2: Interaction effect of genotypes, water regimes and *A. lipoferum* on growth parameters of rice

Treatments	Plant height (cm)			Tillers hill^{-1}			Leaf area index			Dry matter (g plant^{-1})
	PI	FL	HS	PI	FL	HS	PI	FL	HS	
Interaction (G×W)										
g_1w_1	67.60	71.35	80.90	4.50	3.00	4.33	3.99	4.59	3.50	16.65
g_1w_2	62.37	66.85	75.88	4.67	3.67	5.00	3.76	4.37	3.38	15.61
g_1w_3	57.74	61.37	71.53	5.17	3.67	5.17	3.64	4.04	3.26	14.44
g_2w_1	63.92	69.73	78.30	4.00	3.17	4.33	3.54	3.93	2.98	15.59
g_2w_2	62.65	66.74	75.29	5.00	3.57	5.33	3.41	3.80	2.83	14.77
g_2w_3	57.83	62.16	69.72	4.83	3.67	4.83	3.07	3.58	2.58	13.50
g_3w_1	76.93	82.69	93.51	5.00	3.67	5.33	5.32	5.59	4.87	18.03
g_3w_2	75.80	80.34	90.80	5.00	3.83	5.17	4.54	5.31	4.24	17.18
g_3w_3	73.61	76.43	87.24	4.83	3.50	5.17	4.76	4.93	4.39	16.73
SEm$\pm$	2.243	2.096	1.784	0.237	0.229	0.335	0.169	0.153	0.183	0.806
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (G×A)										
g_1a_0	62.37	66.58	76.09	4.67	3.33	4.78	3.75	4.23	3.46	15.32
g_1a_1	62.77	66.47	76.11	4.89	3.56	4.89	3.84	4.43	3.30	15.81
g_2a_0	61.29	65.90	74.50	4.44	3.33	4.78	3.35	3.73	2.85	14.49
g_2a_1	61.64	66.51	74.38	4.78	3.60	4.89	3.33	3.80	2.74	14.75
g_3a_0	75.24	80.56	90.19	5.11	3.89	5.33	4.97	5.35	4.46	17.26
g_3a_1	75.65	79.08	90.85	4.78	3.44	5.11	4.78	5.21	4.54	17.37
SEm$\pm$	1.831	1.712	1.457	0.193	0.187	0.274	0.138	0.125	0.149	0.658
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (W×A)										
w_1a_0	69.32	74.43	84.10	4.67	3.44	4.78	4.33	4.72	3.86	16.57
w_1a_1	69.64	74.75	84.37	4.33	3.11	4.56	4.23	4.68	3.70	16.94
w_2a_0	67.04	71.99	80.56	4.67	3.67	4.89	3.87	4.45	3.50	15.80
w_2a_1	66.83	70.63	80.75	5.11	3.71	5.44	3.93	4.54	3.47	15.91
w_3a_0	62.53	66.63	76.11	4.89	3.44	5.22	3.86	4.14	3.42	14.70
w_3a_1	63.59	66.68	76.21	5.00	3.78	4.89	3.79	4.22	3.40	15.08
SEm$\pm$	1.831	1.712	1.457	0.193	0.187	0.274	0.138	0.125	0.149	0.658
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
PI: panicle initiation stage, FL: flowering stage, HS: harvesting stage										

Table 3: Interaction effect of genotypes, water regimes and *A. lipoferum* on growth parameters of rice

Treatments	Plant height (cm)			Tillers hill^{-1}			Leaf area index			Dry matter (g plant^{-1})
	PI	FL	HS	PI	FL	HS	PI	FL	HS	
Interaction (G×W×A)										
$g_1w_1a_0$	67.32	70.90	80.53	4.67	3.00	4.33	3.97	4.53	3.51	16.28
$g_1w_1a_1$	67.88	71.80	81.26	4.33	3.00	4.33	4.01	4.64	3.49	17.02
$g_1w_2a_0$	62.71	67.41	76.38	4.33	3.67	4.67	3.73	4.27	3.40	15.56
$g_1w_2a_1$	62.02	66.29	75.37	5.00	3.67	5.33	3.79	4.47	3.36	15.66
$g_1w_3a_0$	57.07	61.43	71.36	5.00	3.33	5.33	3.53	3.89	3.47	14.14
$g_1w_3a_1$	58.41	61.31	71.70	5.33	4.00	5.00	3.74	4.19	3.05	14.74
$g_2w_1a_0$	63.55	68.69	78.26	4.33	3.33	4.67	3.53	3.89	3.01	15.39
$g_2w_1a_1$	64.28	70.76	78.34	3.67	3.00	4.00	3.56	3.97	2.94	15.78
$g_2w_2a_0$	62.96	67.31	74.94	4.67	3.33	5.00	3.42	3.74	2.95	14.71
$g_2w_2a_1$	62.33	66.16	75.65	5.33	3.80	5.67	3.40	3.85	2.71	14.84
$g_2w_3a_0$	57.34	61.71	70.29	4.33	3.33	4.67	3.10	3.56	2.61	13.37
$g_2w_3a_1$	58.31	62.60	69.15	5.33	4.00	5.00	3.04	3.59	2.55	13.62
$g_3w_1a_0$	77.09	83.71	93.49	5.00	4.00	5.33	5.50	5.74	5.06	18.04
$g_3w_1a_1$	76.77	81.68	93.52	5.00	3.33	5.33	5.14	5.43	4.68	18.02
$g_3w_2a_0$	75.45	81.24	90.37	5.00	4.00	5.00	4.47	5.33	4.15	17.13
$g_3w_2a_1$	76.14	79.44	91.23	5.00	3.67	5.33	4.62	5.30	4.34	17.23
$g_3w_3a_0$	73.18	76.74	86.69	5.33	3.67	5.67	4.93	4.97	4.18	16.60
$g_3w_3a_1$	74.05	76.12	87.79	4.33	3.33	4.67	4.59	4.88	4.59	16.87
SEm±	3.172	2.965	2.523	0.334	0.324	0.474	0.239	0.220	0.258	1.139
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
PI: panicle initiation stage, FL: flowering stage, HS: harvesting stage										

3.2. Yield attributes and yield

The number of filled grains panicle^{-1}, sterility percentage, 1000 grain weight, grain yield and harvest index of rice genotypes differed significantly (Table 4). The aerobic rice variety, Sharada was found to be superior in all the yield attributes over Prathyasa and KAU Manu Rathna. Sharada recorded significantly more number of filled grains panicle^{-1} (132.89) as compared to Prathyasa (108.47) and KAU Manu Rathna (89.59). The sterility percentage was least in Sharada (9.29%) while Prathyasa (20.47%) and KAU Manu Rathna (20.39%) recorded significantly higher sterility percentage. Sharada produced remarkably higher 1000 grain weight (26.68 g), grain yield (311 g m^{-2}) and harvest index (0.49). However, the number of productive tillers hill^{-1} and straw yield showed no significant variations among the genotypes. Higher yield of Sharada might be due to its genetic makeup and higher growth and yield attributes such as plant height, leaf area index, total dry matter production, number of filled grains panicle^{-1}, 1000 grain weight and lower sterility percentage than the other two genotypes. Similar results were also reported by Gandhi *et al*. (2012) [4], Sandhu *et al*. (2012) [8] and Jinsy *et al*. (2015) [43].

The different water regimes resulted in significant difference in terms of yield attributes and yield of rice (Table 4). The number of filled grains panicle^{-1} was significantly higher under flooded condition (117.24) and it was comparable with that under saturated condition (112.74) while aerobic condition resulted in the least number of filled grains panicle^{-1} (100.98). The sterility percentage was considerably lesser under flooded (15.14%) and saturated condition (16.04%) while aerobic condition increased the sterility percentage (18.97%). Water stress condition disrupts floret initiation and reduces the grain filling period resulting in lesser number of filled grains panicle^{-1} and more sterile spikelets thereby reducing the yield of the crop (Kamoshita *et al*., 2004, Farooq *et al*., 2009a, Kumar *et al*., 2021) [44, 45, 46]. Significantly higher grain yield was observed under flooded condition (324 g m^{-2}) followed by saturated condition (283 g m^{-2}) which was at par with aerobic condition (269 g m^{-2}). The grain yield under saturated and aerobic condition got reduced by 12.65 and 16.98%, respectively over the flooded condition. The reduction in grain yield of rice can be attributed to the reduced rate of photosynthesis and assimilated translocation towards the reproductive parts and disturbed plant water relations under water deficit condition (Flexas *et al*., 2004, Farooq *et al*., 2009b, Fahad *et al.*, 2017) [47, 48, 49]. The number of productive tillers hill^{-1}, 1000 grain weight, straw yield and harvest index did not vary significantly due to different water regimes (Table 4). These results are in line with the findings of Sandhu *et al*. (2012) [8], Joshi *et al.* (2018) [14] and Phule *et al*. (2019) [7].

The interaction between genotypes and water regimes was found to be significant with respect to sterility percentage (Table 5). The genotype, Sharada recorded the least sterility percentage (8.80–9.76%) under all the water regimes followed by Prathyasa and KAU Manu Rathna under flooded and saturated condition. The highest sterility percentage was observed in Prathyasa (24.77%) and KAU Manu Rathna (22.83%) under aerobic condition. Similar result was also reported by Sandhu *et al*. (2012) [8], Jinsy *et al*. (2015) [43] and Phule *et al*. (2019) [7]. However, the presence of biofertilizer, interactions between genotypes and water regimes, genotypes and biofertilizer, water regimes and biofertilizer as well as interaction among genotypes, water regimes and biofertilizer had no significance with respect to other yield attributes and yield (Tables 4, 5 and 6).

Table 4: Effect of genotypes, water regimes and *A. lipoferum* on yield parameters of rice

Treatments	Productive tillers hill^{-1}	Filled grains panicle^{-1}	Sterility Percentage (%)	1000 grain Weight (g)	Grain yield (g m^{-2})	Straw yield (g m^{-2})	Harvest index
Genotypes (G)							
g_1 (Prathyasa)	4.39	108.47^b	20.47^a	21.75^b	287^b	333	0.47^b
g_2 (KAU Manu Rathna)	3.89	89.59^c	20.39^a	21.09^b	278^b	347	0.47^b
g_3 (Sharada)	4.44	132.89^a	9.29^b	26.68^a	311^a	324	0.49^a
SEm±	0.184	3.175	0.484	0.459	6.41	12.93	0.004
CD (*p*=0.05)	NS	9.106	1.387	1.317	18.38	NS	0.013
Water regimes (W)							
w_1 (Flooded)	4.11	117.24^a	15.14^b	23.09	324^a	333	0.48
w_2 (Saturated)	4.33	112.74^a	16.04^b	23.10	283^b	338	0.48
w_3 (Aerobic)	4.28	100.98^b	18.97^a	23.33	269^b	333	0.47
SEm±	0.184	3.175	0.484	0.459	6.41	12.93	0.004
CD (*p*=0.05)	NS	9.106	1.387	NS	18.38	NS	NS
Biofertilizer *Azospirillum lipoferum* (A)							
a_0 (Without A)	4.22	108.32	16.79	22.90	291	335	0.48
a_1 (With A)	4.26	112.31	16.64	23.45	293	335	0.48
SEm±	0.145	2.501	0.381	0.362	5.05	10.19	0.003
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 5: Interaction effect of genotypes, water regimes and A. lipoferum on yield parameters of rice

Treatments	Productive tillers hill^{-1}	Filled grains panicle^{-1}	Sterility percentage (%)	1000 grain weight (g)	Grain yield (g m^{-2})	Straw yield (g m^{-2})	Harvest index
Interaction (G×W)							
g_1w_1	4.33	117.66	18.00^b	22.09	326	334	0.48
g_1w_2	4.33	114.07	18.65^b	21.01	279	338	0.47
g_1w_3	4.50	93.70	24.77^a	22.16	256	328	0.47
g_2w_1	3.50	98.45	18.63^b	20.84	325	337	0.47
g_2w_2	4.17	91.37	19.70^b	21.29	262	355	0.46
g_2w_3	4.00	78.94	22.83^a	21.13	248	349	0.46
g_3w_1	4.50	135.60	8.80^c	26.35	320	328	0.49
g_3w_2	4.50	132.77	9.76^c	27.00	309	322	0.49
g_3w_3	4.33	130.29	9.32^c	26.71	303	321	0.49
SEm±	0.319	5.499	0.838	0.795	11.10	22.40	0.008
CD (*p*=0.05)	NS	NS	2.403	NS	NS	NS	NS
Interaction (G×A)							
g_1a_0	4.33	104.96	20.67	21.90	286	332	0.47
g_1a_1	4.44	111.98	20.28	21.61	288	334	0.47
g_2a_0	3.89	88.07	20.38	20.20	276	347	0.47
g_2a_1	3.89	91.10	20.40	21.97	280	348	0.47
g_3a_0	4.44	131.94	9.33	26.59	310	325	0.49
g_3a_1	4.44	133.84	9.25	26.78	312	322	0.49
SEm±	0.261	4.490	0.684	0.649	9.06	18.29	0.006
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS
Interaction (W×A)							
w_1a_0	4.22	115.15	15.02	22.76	323	332	0.48
w_1a_1	4.00	119.32	15.27	23.42	325	334	0.48
w_2a_0	4.00	111.35	16.37	23.29	282	338	0.48
w_2a_1	4.67	114.12	15.70	22.91	285	338	0.48
w_3a_0	4.44	98.46	18.99	22.64	267	333	0.47
w_3a_1	4.11	103.49	18.96	24.03	271	332	0.47
SEm±	0.261	4.490	0.684	0.649	9.06	18.29	0.006
CD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 6: Interaction effect of genotypes, water regimes and A. lipoferum on yield parameters of rice

Treatments	Productive tillers hill^{-1}	Filled grains panicle^{-1}	Sterility percentage (%)	1000 grain weight (g)	Grain yield (g m^{-2})	Straw yield (g m^{-2})	Harvest index
Interaction (G×W×A)							
$g_1w_1a_0$	4.33	115.46	17.53	21.91	326	331	0.48
$g_1w_1a_1$	4.33	119.85	18.47	22.26	327	337	0.47
$g_1w_2a_0$	4.00	109.95	19.97	22.22	278	340	0.47
$g_1w_2a_1$	4.67	118.18	17.33	19.80	281	335	0.47
$g_1w_3a_0$	4.67	89.47	24.50	21.56	253	327	0.47
$g_1w_3a_1$	4.33	97.92	25.03	22.76	258	330	0.47
$g_2w_1a_0$	4.00	99.09	18.87	19.82	324	339	0.47
$g_2w_1a_1$	3.00	97.80	18.40	21.85	327	335	0.47
$g_2w_2a_0$	3.67	88.77	19.30	20.81	260	353	0.46
$g_2w_2a_1$	4.67	93.97	20.10	21.76	264	358	0.46
$g_2w_3a_0$	4.00	76.35	22.97	19.96	246	348	0.46
$g_2w_3a_1$	4.00	81.53	22.70	22.30	250	350	0.46
$g_3w_1a_0$	4.33	130.90	8.67	26.55	320	327	0.49
$g_3w_1a_1$	4.67	140.30	8.93	26.15	321	329	0.49
$g_3w_2a_0$	4.33	135.33	9.83	26.83	308	323	0.49
$g_3w_2a_1$	4.67	130.21	9.68	27.16	310	321	0.49
$g_3w_3a_0$	4.67	129.57	9.50	26.39	302	326	0.49
$g_3w_3a_1$	4.00	131.01	9.13	27.02	304	317	0.49
SEm±	0.451	7.777	1.185	1.125	15.70	31.68	0.011
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

4. Conclusion
The aerobic rice variety, Sharada performed better under different water regimes with respect to growth attributes and yield, even in the absence of *Azospirillum lipoferum*. The two lowland rice genotypes *viz*., Prathyasa and KAU Manu Rathna also maintained their growth and yield under saturated and aerobic condition without drastic yield reduction.

5. Further Research
There is a need to identify more rice genotypes that can be cultivated with limited water resource without jeopardizing the economic yield. Further studies should also evaluate the effect of different plant growth promoting rhizobacterias (PGPRs) on rice under water stress condition. Development of sustainable management practices to reduce and compensate the yield decline under water deficit condition should also be addressed.

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