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Effect of Moisture Regimes on Growth and Root characteristics of Rice Cultivars under Aerobic condition in Summer Season

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ABSTRACT: A field experiment was conducted at Regional Research Station, Gayeshpur, West Bengal to study the effect of moisture regimes on the rice cultivars under aerobic condition in summer season during 2012 and 2013. The farm is located at 22°57′N latitude, 88°20′E longitude and at an elevation of 9.75 m above sea level. The experiment was conducted on sandy clay loam soil. The experiment was laid in split plot design replicated thrice. The treatments consisted of four irrigation regimes in main plots *viz.*, I_1: scheduling of irrigation at 60-70 % field capacity (FC) throughout the season, I_2: scheduling of irrigation at 80-90 % FC throughout the season, I_3: scheduling of irrigation at 60-70 % FC at vegetative stage and at 80-90 % FC at reproductive stage and I_4: Control. (maintaining at 100% FC) and three varieties in sub plots *viz.*, V_1: Satabdi, V_2: Khitish and V_3: IR 36. The experiment was conducted to study the effect of irrigation regimes on the rice cultivars and their response under aerobic condition. The results revealed that crop under I_4 (maintaining at 100 % FC) treatment recorded higher plant height at harvest (91.85 cm), drymatter accumulation at harvest (883.47 g m^{-2}), leaf area index at flowering stage (4.33), root length (27.53 cm), root volume (14.15 cc $hill^{-1}$) and root dry weight (139.73 g m^{-2}) than that of other irrigation treatments. Among the varieties, V_2 (Khitish) registered higher plant height at harvest (100.87 cm), drymatter accumulation at harvest (796.78 g m^{-2}), leaf area index at flowering (4.11), root length (26.53 cm), root volume (13.88 cc $hill^{-1}$) and root dry weight (131.81 g m^{-2}) than that of V_1 (Satabdi) and V_3 (IR 36).

Keywords: Aerobic rice, irrigation regimes, rice varieties, growth parameters, root characteristics.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of about 3.5 billion people and demand is expected to continue to grow as population increases (GRiSP, 2013). It is an important staple cereal crop and fulfills the dietary requirement for more than of half population globally (Cordero-Lara, 2020). Half the world's population subsists wholly or partially on rice whereas 90 % of the world's rice crop is grown and consumed in Asia. Rice is the most important crop in India and extensively grown as food crop. The (DES, 2021) rice area in India 45.07 million ha with rice production of 122.27 million tonnes and yield of 2.713 t ha^{-1}. Further, rice crop is the greatest water user amongst of the crops, consuming about 80 % of the total irrigated fresh water resources in Asia (Bouman and Tuong 2001). Irrigated lowland rice usually has standing water for most of the growing season. But traditional lowland rice with continuous flooding has relatively high water inputs (Bouman, 2001) and its sustainability is threatened by increasing water shortages. By the end of the 21st century, decreasing water resources due to anthropogenic and natural factors will reduce the sustainable production of flood-irrigated rice, a heavy user of water (Joshi *et al.*, 2017; Alcamo *et al.*, 2017). The production of lowland rice, a squandering user of water, is being threatened by this increasing water scarcity. Rice production and food security largely depend on the irrigated lowland rice system, whose sustainability is threatened by fresh water scarcity, water pollution and competition for water use (Guerra *et al.*, 1998). To safeguard the food industry and conserve water, an alternate system of growing rice with less water is essentially required. Aerobic rice is a concept of growing rice where high yielding rice varieties grown in non-puddled aerobic soil under supplementary irrigation. Aerobic rice genotypes can reduce water requirement for rice production by over 44 % compared to lowland rice, by avoiding water use for seed bed and land preparation and by reducing percolation, seepage and evaporation losses, with grain yield potential of 6 mt ha^{-1} (Bouman *et al.,* 2005) which is significantly higher than traditional upland cultivars. Keeping these facts in view, a comprehensive study was therefore carried out in which three rice cultivars were evaluated under four different soil moisture regimes in summer season under aerobic condition.

MATERIAL AND METHODS

The field experiment on summer aerobic rice was conducted in the dry (boro) seasons of 2012 and 2013 at Regional Research Station, Gayeshpur of Bidhan Chandra Krishi Viswavidyalaya. The station is located in a sub-tropical region at 22°57 N latitude, 88°20E longitude and at an elevation of 9.75 m above sea level. The soil of the experimental field is sandy clay loam in texture and the depth of the soil is shallow to medium. The experiment was laid in split plot design replicated thrice. The treatments consisted of four irrigation regimes in main plots *viz*., I_1: scheduling of irrigation at 60-70 % field capacity (FC) throughout the season, I_2: scheduling of irrigation at 80-90 % FC throughout the season, I_3: scheduling of irrigation at 60-70 % FC at vegetative stage and at 80-90 % FC at reproductive stage and I_4: Control. (maintaining at 100% FC) and three varieties in sub plots *viz*., V_1: Satabdi, V_2: Khitish and V_3: IR 36. The field experiment was undertaken with four levels of the irrigation regimes wherein the treatments were imposed 15 days after sowing and upto 15 days before harvesting in the main plots and three rice varieties in the sub plots. Proper care was taken for crop management in all the experimental plots starting from land preparation and continued up to harvesting operation. Recommended dose of fertilizers was applied to the experimental field *i.e.*, 120 – 60 – 60 of N-P-K kg ha^{-1}. One-meter row length in each plot was earmarked for recording different biometrical observations and destructive samplings. Around a single plant, a block of 15cm from soil was cut. After cleaning the root properly and separating those from shoot, the longest root from all the plants of a hill was measured to get root length of each and then average was calculated. Roots of all the five hills were used for studying root volume. The roots after careful washing and cleaning were dipped in a measuring cylinder filled with cleaned water upto a certain mark. After dipping the roots within the cylinder, the water level rose. The difference in water level was taken as a measure of root volume. The roots of each hill were oven dried after thorough washing and cleaning and then weighed. The experimental data recorded on various parameters were analyzed statistically following the analysis of variance procedure described by (Gomez and Gomez 1984). Critical difference for examining treatmental means for their significance was calculated at 5% level of probability.

RESULTS AND DISCUSSION

Plant height. The results from Table 1 clearly indicated that effect of moisture regimes was non-significant on plant height at 30 DAS and 60DAS. This finding was in conformity with the findings of Nguyen *et al.* (2009) and Vairavan *et al.* (1999). But, significant influence of moisture regimes on plant height was observed at 90 DAS and at harvest. At 90 DAS, plant height under I_4 treatment (73.82 cm) was significantly higher than plant height under I_1 (68.18 cm) and I_3 (70.17 cm) but on par with plant height under I_2 (71.25 cm) and similar trend was observed at harvest that plant height under I_4 treatment (91.85 cm) was significantly higher than plant height under I_1 (84.14 cm) and I_3 (86.99 cm) but on par with plant height under I_2 (87.81 cm). Whereas, plant height recorded under I_1 treatment was significantly lower than plant height under I_2 and I_4 treatments but on par with plant height under I_3 treatment 90 DAS and at harvest. Decrease in the plant height under I_1 treatment was mainly attributed to less available water than in the other irrigation regimes. Thus, water deficit manifests many anatomical changes in the plant which includes decrease in cell size, cell division, cell elongation, inter cellular space and thickening of cell wall thereby limits overall plant growth. Similar observations have been reported by Maheswari *et al.* (2007).

Further it was recorded that, among the varieties Khitish (21.49 cm) recorded significantly higher plant height than Satabdi (16.21 cm) and IR 36 (18.56 cm) at 30 DAS. At 60 DAS, Khitish (41.89 cm) recorded significantly higher plant height than Satabdi (30.02 cm) and IR 36 (38.59 cm). Further similar trend of influence on plant height was observed at 90 DAS and at harvest. Whereas, at harvest Satabdi (74.20 cm) recorded significantly lower plant height than Khitish (100.87 cm) and IR 36 (88.03 cm) and similar trend was recorded at 30 DAS, 60 DAS and 90 DAS. Significant difference in the plant height of three rice varieties was mainly due to the genetic variability among the cultivars of the rice crop. As all the three rice varieties responded similarly to the moisture regimes, the influence of interaction effect of moisture regimes and varieties on the plant height was found non- significant at all stages of crop growth.

Drymatter accumulation. Perusal of data from Table 2 indicated that at 30DAS the drymatter accumulation under I_4 treatment (79.28 gm^{-2}) was significantly higher than drymatter accumulation under I_1 (48.00 gm^{-2}), I_2 (60.96 gm^{-2}) and I_3 (48.49 gm^{-2}) treatments. Similarly, at 60 DAS, the drymatter accumulation under I_4 treatment (225.30 gm^{-2}) was significantly higher than drymatter accumulation under I_1 (131.74 gm^{-2}), I_2 (182.86 gm^{-2}) and I_3 (129.00 gm^{-2}) treatments. Further at 90 DAS, drymatter accumulation under I_4 treatment (446.46 gm^{-2})) was significantly higher than plant height under I_1 (316.22 gm^{-2}), I_2 (374.56 gm^{-2}) and I_3 treatment (327.01 gm^{-2}). Similar trend was observed at harvest that the drymatter accumulation under I_4

treatment (883.47 gm^{-2}) was significantly higher than drymatter accumulation under I_1 (669.32 gm^{-2}), I_2 (770.34 gm^{-2}) and I_3 (747.86 gm^{-2}) treatments. The increase in the drymatter accumulation under I_4 treatment was mainly attributed to more availability of moisture throughout the crop duration. This finding was in accordance with findings of Nguyen *et al.* (2009); Peng *et al.* (2006); Belder *et al.* (2005); Ramamoorthy *et al*. (1998a). Whereas, drymatter accumulation recorded under I_1 treatment was significantly lower than drymatter accumulation under I_2 and I_4 treatments but on par with drymatter accumulation under I_3 treatment at 30DAS and 60 DAS. But, at 90 DAS and at harvest drymatter accumulation recorded under I_1 treatment was significantly lower than drymatter accumulation under I_2, I_3 and I_4 treatments.

The dry matter accumulation increased progressively from tillering to maturity stage of rice and recorded maximum at maturity. The increased dry matter accumulation in I_4 treatment at all stages of crop growth may be attributed to more availability of moisture, possible reduction in transpiration rate and normal gas exchange resulting in increased production of photosynthates and translocation to sink which in turn increased drymatter accumulation. This is in conformity with Kato *et al.* (2009). The reduction in drymatter accumulation under I_1 treatment might be due to water stress induced impaired tillering or due to accelerated leaf senescence.

Among the varieties, Khitish (373.09 gm^{-2}) recorded significantly higher drymatter accumulation than IR 36 (356.05 gm^{-2}) and on par with Satabdi (369.05 gm^{-2}) at 90 DAS. At harvest, Khitish (796.78 gm^{-2}) recorded significantly higher drymatter accumulation than Satabdi (728.71 gm^{-2}) and IR 36 (777.76 gm^{-2}). Whereas, at harvest Satabdi (728.71 gm^{-2}) recorded significantly lower drymatter accumulation than Khitish (796.78 gm^{-2}) and IR 36 (777.76 gm^{-2}) and similar trend was recorded at 90 DAS. Significant difference in the drymatter accumulation of three rice varieties was mainly due to the genetic variability among the cultivars of the rice crop. As all the three rice varieties responded similarly to the moisture regimes, the influence of interaction effect of moisture regimes and varieties on the drymatter accumulation was found non-significant at all stages of crop growth.

Leaf Area Index. The data from Table 3 revealed that, at maximum tillering stage significantly higher leaf area index was recorded in I_4 treatment (4.72) than I_1 (3.78), I_2 (4.19) and I_3 (3.82) whereas significantly lower leaf area index was registered in I_1 treatment (3.78) than under I_4 and I_2 but on par with I_3 (3.82). Similarly, at flowering stage of aerobic rice I_4 treatment (4.33) recorded significantly higher leaf area index than I_1 (3.29), I_2 (3.96) and I_3 (3.37) whereas significantly lower leaf area index was registered in I_1 treatment (3.29) than under I_4 and I_2 but on par with leaf area index under I_3 (3.37). Likewise, I_4 treatment (3.79) recorded significantly higher leaf area index than I_1 (2.89), I_2 (3.43) and I_3 (3.08) whereas significantly lower leaf area index was registered in I_1 treatment (2.89) than under I_4 and I_2 but on par with leaf area index under I_3 (3.08) at grain filling stage. The results were in accordance with the findings of Soma *et al*. (2017).

Likewise, at maximum tillering stage leaf area index of Khitish (4.55) was significantly higher than Satabdi (3.88) but on par with IR 36 (4.36). Significantly lower leaf area index was recorded in Satabdi (3.88) than Khitish (4.55) and V_3 (4.36). Whereas, at flowering stage, leaf area index of Khitish (4.11) was significantly higher than Satabdi (3.34) and IR 36 (3.56). Significantly lower leaf area index was recorded in Satabdi (3.34) than Khitish (4.11) and V_3 (3.56). Similarly, at grain filling stage, leaf area index of Khitish (3.45) was significantly higher than Satabdi (2.98) and IR 36 (3.09). Significantly lower leaf area index was recorded in Satabdi (2.98) than Khitish and IR 36.Significant difference in the leaf area index of three rice varieties was mainly due to the phenotypic and genetic variability among the cultivars of the rice crop. The effect of interaction between irrigation regimes and varieties on the leaf area index was found non-significant.

Root characteristics

Root length. Perusal of the data from Table 4 revealed that root length was significantly higher in I_4 treatment (27.53 cm) than I_1 (23.86 cm), I_2 (25.90 cm) and I_3 (24.10 cm) significantly lower root length was recorded in I_1 (22.86 cm) when compared to root length under rest of the irrigation regimes. The decrease in the root length under I_1 treatment could be attributed to increased soil mechanical impedance as the soil becomes compact and harder when compared to the soil under I_4 treatment.

Root length of Khitish (26.53 cm) was significantly higher than that of Satabdi (24.51 cm) and IR 36 (24.25 cm). Significantly lower root length was recorded in IR 36 (24.25 cm) than Khitish (26.53 cm) but on par with V_1 (24.51 cm). The difference in the root length of aerobic rice varieties is dependent on gene factor and also the environment in which crop is grown. The higher root length under higher moisture were reported by Hayat *et al.* (2017).Variations in root character by different genotypes was reported by Uphoff and Randriamiharisoa (2007). The effect of interaction between irrigation regimes and varieties on the root length was found non-significant.

Root volume. Data from Table 4 revealed that I_4 treatment (14.15 cc $hill^{-1}$) recorded significantly higher root volume than in I_1 (11.84 cc $hill^{-1}$) and I_3 (12.95 cc $hill^{-1}$) but on par root volume with I_2 (13.43 cc $hill^{-1}$). Significantly lower root volume was recorded in I_1 treatment (11.84 cc $hill^{-1}$) than root volume under I_2, I_3 and I_4 irrigation regimes.

Table 1: Pooled data of plant height (cm) of aerobic rice as influenced by irrigation regimes and varieties during 2012 and 2013.

Treatments	30DAS	60 DAS	90DAS	At Harvest
Irrigation Regimes				
I_1	17.35	36.03	68.18	84.14
I_2	19.28	36.78	71.25	87.81
I_3	18.30	35.97	70.17	86.99
I_4	20.08	38.53	73.82	91.85
S.Em±	0.49	0.63	0.76	1.13
C.D at 5%	N.S.	N.S.	2.66	4.11
Varieties				
V_1	16.21	30.02	64.53	74.20
V_2	21.49	41.89	76.44	100.87
V_3	18.56	38.59	71.60	88.03
S.Em±	0.40	0.66	0.60	0.68
C.D at 5%	1.22	1.98	1.80	2.04

Table 2: Pooled data of Drymatter accumulation (g m^{-2}) of aerobic rice as influenced by irrigation regimes and varieties during 2012 and 2013.

Treatments	30DAS	60 DAS	90DAS	At Harvest
Irrigation Regimes				
I_1	48.00	131.74	316.22	669.32
I_2	60.96	182.86	374.56	770.34
I_3	48.49	129.00	327.01	747.86
I_4	79.28	225.30	446.46	883.47
S.Em±	1.05	1.47	1.12	7.90
C.D at 5%	3.63	5.07	3.87	27.26
Varieties				
V_1	60.26	167.29	369.05	728.71
V_2	56.58	165.76	373.09	796.78
V_3	60.70	168.62	356.05	777.76
S.Em±	1.78	1.52	2.07	5.97
C.D at 5%	N.S.	N.S.	6.22	17.92

Table 3: Pooled data of Leaf Area Index of aerobic rice as influenced by irrigation regimes and varieties during 2012 and 2013.

Treatments	Maximum Tillering stage	Flowering stage	Grain filling stage
Irrigation Regimes			
I_1	3.78	3.29	2.89
I_2	4.19	3.96	3.43
I_3	3.82	3.37	3.08
I_4	4.72	4.33	3.79
S.Em±	0.16	0.10	0.08
C.D at 5%	0.53	0.28	0.24
Varieties			
V_1	3.88	3.34	2.98
V_2	4.55	4.11	3.45
V_3	4.36	3.56	3.09
S.Em±	0.06	0.05	0.06
C.D at 5%	0.21	0.19	0.26

Table 4: Pooled data of Root length (cm), root volume (cc hill^{-1}) and root dry weight (g m^{-2}) of aerobic rice as influenced by irrigation regimes and varieties during 2012 and 2013.

Treatments	Root length (cm)	Root volume (cc hill^{-1})	Root dry weight (g m^{-2})
Irrigation Regimes			
I_1	22.86	11.84	112.90
I_2	25.90	13.43	128.42
I_3	24.10	12.95	123.26
I_4	27.53	14.15	139.73
S.Em±	0.18	0.24	1.29
C.D at 5%	0.65	0.85	4.48
Varieties			
V_1	24.51	12.59	123.61
V_2	26.53	13.88	131.81
V_3	24.25	12.81	122.82
S.Em±	0.23	0.18	1.46
C.D at 5%	0.70	0.54	4.38

Decrease in the root volume under I_1 treatment might be due to deficit of soil moisture causing further reduction in Kpa under drought stress (Matsuo *et al.*, 2009) similar finds were reported by Hayat *et al.* (2017). Among the varieties, Khitish (13.88 cc hill^{-1}) was significantly higher than Satabdi (12.59 cc hill^{-1}) and IR 36 (12.81 cc hill^{-1}). Significantly lower root volume was recorded in Satabdi (12.59 cc hill^{-1}) than Khitish (13.88 cc hill^{-1}) but on par with IR 36 (12.81 cc hill^{-1}). The effect of interaction between irrigation regimes and varieties on the root volume was found non-significant.

Root dry weight. Data from Table 4 revealed that I_4 treatment (139.73 g m^{-2}) recorded significantly higher root dry weight than in I_1 (112.90 g m^{-2}), I_2 (128.42 g m^{-2}) and I_3 (123.26 g m^{-2}). Significantly lower root dry weight was recorded in I_1 treatment (112.90 g m^{-2}) than root dry weight under I_2, I_3 and I_4 irrigation regimes.

Among the varieties, Khitish (131.81 g m^{-2}) was significantly higher than Satabdi (123.61 g m^{-2}) and IR 36 (122.82 g m^{-2}). Significantly lower root dry weight was recorded in IR 36 (122.82 g m^{-2}) than Khitish (131.81 g m^{-2}) but on par with Satabdi (123.61 g m^{-2}). The effect of interaction between irrigation regimes and varieties on the root dry weight was found non-significant.

CONCLUSION

Perusal of the results on effect of moisture regimes on aerobic rice growth reveals that growth attributes of aerobic rice *viz.***,** plant height, drymatter accumulation and leaf area index was significantly influenced by the irrigation regimes. From the pooled data, it was found that aerobic rice under I_4 (maintaining at 100 % FC) treatment recorded higher plant height at harvest (91.85 cm), drymatter accumulation at harvest (883.47 g m^{-2}) and leaf area index at flowering stage (4.33) than that of under I_1 (scheduling of irrigation at 60-70 % FC throughout the season), I_2 (scheduling of irrigation at 80-90 % FC throughout the season) and I_3 (scheduling of irrigation at 60-70 % FC at vegetative stage and at 80-90 % FC at reproductive stage). Root characteristics of aerobic rice were significantly influenced by the irrigation regimes. From the pooled data, it was revealed that root length (27.53 cm), root volume (14.15 cc hill^{-1}) and root dry weight (139.73 g m^{-2}) of aerobic rice was higher under I_4 (maintaining at 100% FC) treatment than remaining irrigation treatments.

Among the three tested varieties, V_2 (Khitish) registered higher growth attributes *viz.*, plant height at harvest (100.87 cm), drymatter accumulation at harvest (796.78 g m^{-2}) and leaf area index at flowering (4.11) than that of V_1 (Satabdi) and V_3 (IR 36). Root characters were significantly different among the varieties. From the pooled data, it can be revealed that root length (26.53 cm), root volume (13.88 cc hill^{-1}) and root dry weight (131.81 g m^{-2}) of rive variety V_2 (Khitish) was significantly higher than the corresponding values in V_1 (Satabdi) and V_3 (IR 36).

FUTURE SCOPE

Inspite of promising achievements in aerobic rice cultivation, it is still necessary to have more studies for better understanding of aerobic rice cultivation under different environmental conditions and management techniques. Therefore, research work in future may be undertaken on fertilizer scheduling in aerobic rice, standardize and find the complete package of practices for aerobic rice cultivation aiming sustainable yields and studies for development of new water management strategies for improving the water use efficiency of aerobic rice.

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Conflict of Interest. None.

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