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GROWTH, GRAIN DEVELOPMENT AND YIELD PERFORMANCE OF BORO RICE VARIETIES UNDER WATER STRESS CONDITION

C.K. Apu[1], P.K. Biswas[2*], T.S. Roy[2], S. Shome[2] and A. Barman[3]

[1]Department of Agricultural Extension (DAE), Nasirnagar, Brahmanbaria, Bangladesh
[2]Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh
[3]Soil Science Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh
[*]Corresponding Email:parimalbiswas@hotmail.com

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Abstract

A field experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of water stress at reproductive stage on growth, grain development and yield of Boro rice. The experiment consisted of two factors: Factor A: Water stress *viz.* no water stress (W_1) and water stress (W_2) and Factor B: Variety *viz.* BRRI dhan28 (V_1), BRRI dhan29 (V_2), BRRI dhan50 (V_3), Binadhan-10 (V_4), BRRI hybriddhan3 (V_5), Aloron (V_6). In no water stress, irrigation water was maintained strictly from transplanting time to harvesting time while in water stress condition; supply of irrigation was stopped just after flowering upto harvest. Results showed that growth, grain development and yield of Boro rice were significantly affected by water stressed condition. All the tested varieties performed better under no water stress condition compared to water stress condition. About 7% panicle weight was decreased due to water stress condition at reproductive stage. Grain development of BRRI dhan29 was least affected by water stress while the most affected variety was Binadhan-10. Water deficit at reproductive stage reduced about 15-22% grain yield of tested varieties. Aloron was the least affected variety due to water stress while BRRI dhan50 was the most affected variety. The variety Aloron provided equal yield (7.31 t ha^{-1}) under stress condition as given by BRRI dhan29 under no water stress condition. So, Aloron may be a better option to cultivate in the region where irrigation water is scarce or costly.

Introduction

Rice which is the driving force of Bangladesh agriculture occupies about two-thirds of the cultivated land area and constitutes 90% of the food grain production in Bangladesh (BBS, 2020). Boro (January - May) is the single largest crop grown in Bangladesh which accounts more than 50% of total rice production (BBS, 2020). Boro rice is generally cultivated under irrigated condition when rainfall is very scanty. Irrigated rice cultivation is the most productive and plays a vital role in fulfilling global food demand. But one estimate shows that2000–5000 L of water is required to produce 1 kg of rice (Caine *et al.* 2019). But accelerated urbanization and industrialization result in decreasing freshwater resources for rice production. Therefore, time demands the production of “more rice with less water” for global food security (Maneepitak *et al.*, 2019). Water stress is one of the most restrictive factors for growing rice (Halder *et al.*, 2018). Keller (2005) reported that water flow through the soil-root-shoot pathway assists nutrient uptake by plant roots and leaf transpiration generates the tension necessary for the roots to absorb this essential solution so in a dry soil, uptake of water and nutrients becomes progressively more difficult for any crop. Moisture stress hampers photosynthesis in plants by closing stomata and destructing the chlorophyll contents and photosynthetic apparatus(Waraich *et al.*, 2011).Disturbed photosynthesis adversely affects the tiller number, leaf area, dry matter production, filled grains per panicle, 1000-grain weight and grain yield (Sabetfar *et al.*, 2013). Drought stress at vegetative phase of rice has minimal effect on subsequent growth and grain yield whereas drought during reproductive stage causes about 30% yield reduction (Fofana *et al.*, 2010).This might be due to low dry matter accumulation, delayed an thesis, reduction of the number of spikelets per panicle and decrease in numbers of filled grains (Halder and Burrage, 2003). Actually water stress during reproductive stage may reduce grain mass by 20%, no. of spikelet up to 60%, filled grains up to 40% which contribute as a whole to reduction in yield. Farmers use groundwater for boro rice cultivation as it is available in comparison with any other facilities. But, excessive and improper use of groundwater threatened soil horizon, environment as well as groundwater availability. Exploring the ways to reduce water use for rice production is therefore of great strategic value for sustainable crop production for the world facing water scarcity (Molden *et al.*, 2010).Considering the above fact , a detailed study was undertaken to explore the extent of water stress at reproductive stage affects growth and yield of rice and to find out suitable varieties providing high yield under water stress condition and saving the cost of irrigation water in boro rice production.

Materials and Methods

The experiment was conducted at Sher-e-Bangla Agricultural University (23°77′N latitude and 90°33′E longitude) which belongs to the Agro-ecological zone of The Modhupur Tract, AEZ-28 (Anonymous, 1988). Split plot design with three replications was followed to implement the experiment where water stress was put in the mainplots and variety in the sub-plots. There were two water stress conditions (W_1: no water stress and W_2: water stress) and six varieties V_1: BRRI dhan28,V_2: BRRI dhan29, V_3: BRRI dhan50,V_4: Binadhan-10,V_5: BRRI hybriddhan3 and V_6: Aloron. Water stress means absence of irrigation water from reproductive stage to harvesting stage where no water stage means no scarcity of irrigation water during rice cultivation. Before reproductive stage there is no discrimination of irrigation water among the plots. Unit plot of 4 m × 2 m was made with 0.75 m distance between plot to plot.Thirtydays old seedlings were transplanted in the main field. The experimental area was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} of N, P_2O_5, K_2O, S and Zn as per recommended method (FRG, 2012). Crop management was practiced according to necessity. Plant height, number of tillers hiil^{-1} and number of leaves hiil^{-1}were calculated from randomly pre-selected 5 hills plot^{-1}. Dry matter was recorded from the mean oven dry weight of plants from 2 hills per plot. Filled grains panicle^{-1} and unfilled grains panicle^{-1} were counted from the average number of grains from ten panicles.1000-grain weight was measured at 12% moisture content.Grain yield and straw yield were determined from the central 4 m^2 area of each plot and expressed as t ha^{-1}. Biological yield was calculated by summing up the grain and straw yield. Harvest index refers to the ratio of economic yield to biological yield and was computed with following formula (Gardner *et al*., 1985).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using STATISTIX 10 computer package program and the mean differences were calculated using least significant difference (LSD) test at 5 % level of significance.

Results and Discussion

Effect of water stress on crop growth characters

Crop growth parameters *viz.* plant height, number of tillers hill^{-1} and number of leaves hill^{-1}showed significant variation when water stress was imposed at reproductive stage (Table 1). Plants under no water stress condition were found to be a bit taller with higher number of tillers and leaves than the plants under water stress condition. Number of tillers and leaves hill^{-1} were reduced by about 8% and 12%, respectively due to water stress condition. About 12% higher stem dry weight was recorded for no water stress condition than water stress condition. On the other hand, leaf dry weight and root dry weight were not influenced by water stress condition. Sokoto and Muhammad (2014)found water stress at flowering and grain filling stage decreased plant height. Plant cannot uptake sufficient nutrients from soil due to water scarcity which consequently caused plant growth retardation (Mannan *et al.*, 2012). Mostajeran and Rahimi-Eichi (2009) documented decreased tiller number per hill due to decreased soil moisture level. Inability to produce dry matter due to inhibited photosynthesis by moisture stress might be responsible for lower tiller production. Dearth of water required for food production and cell division might be another reason (Zubaer *et al.*, 2007).

Effect of variety on crop growth characters

Varietal differences had significant impact on all growth parameters (Table 1). At harvest, tallest plant (106.98 cm) was recorded from Binadhan-10 and shortest plant (85.03 cm) was obtained from BRRI dhan50. Maximum number of tillers (14.88) and leaves (48.64) were observed in BRRI dhan50 while minimum tillers (10.50) and leaves (23.0) were recorded from Aloron. BRRI dhan50 provided lowest leaf dry weight while Binadhan-10 produced lowest stem and root dry weight at harvest. The variety BRRIdhan29 gave highest stem and root dry weight which was significantly different from other varieties. The variation in plant height among the different varieties might be due to genetic makeup of different varieties (Murshida *et al.*, 2017).

Table 1. Effect of water stress and variety on growth parameters of Boro rice at harvest

Treatments	Plant height (cm)	Number of tillers hill $^{-1}$	Number of leaves hill^{-1}	Leaf dry weight (g hill^{-1})	Stem dry weight (g hill^{-1})	Root dry weight (g hill^{-1})
Water stress						
W_1	98.35 a	12.48 a	35.05 a	16.77	31.31 a	9.39
W_2	93.68 b	11.53 b	30.79 b	15.05	27.57 b	8.23
$LSD_{(0.05)}$	4.27	0.60	2.36	NS	2.29	NS
CV (%)	3.09	23.82	12.07	13.76	5.41	21.02
Variety						
V_1	94.75 b	12.35 ab	42.81 b	19.04 a	33.24 ab	9.67 ab
V_2	95.46 b	12.47 ab	25.16 d	19.51 a	35.89 a	12.04 a
V_3	85.03 c	14.87 a	48.64 a	9.45 c	26.40 c	7.21 bc
V_4	106.98 a	10.93 b	32.93 c	16.06 a	26.04 c	6.27 c
V_5	98.29 b	10.90 b	25.00 d	14.30 b	27.06 c	8.03 bc
V_6	95.56 b	10.50 b	23.00 d	17.09 ab	27.99 bc	9.66 ab
$LSD_{(0.05)}$	3.54	2.74	5.80	4.18	5.79	2.51
CV (%)	3.06	17.92	14.63	21.81	16.34	23.63

W_1- No water stress, W_2- Water stress and V_1- BRRI dhan28, V_2- BRRI dhan29, V_3- BRRI dhan50, V_4- Binadhan-10, V_5- BRRI hybrid dhan3, V_6- Aloron.

Interaction effect of water stress and varietyon crop growth characters

Interaction effect of water stress and variety had significant influence on all crop growth parameters (Table 2). All the tested varieties performed better under no water stress condition. When there was no water stress throughout the crop duration, tallest plant (110.37 cm)was recorded from Binadhan-10 and maximum number of tillers and leaves were recorded from BRRI dhan50. At harvest, the variety BRRI dhan29 provided maximum leaf, root and stem dry weight. When water supply was stopped at reproductive stage, growth and development of all the tested varieties were hampered considerably. Tiller and leaf production of BRRI dhan50 was least affected by water stress. BRRI dhan29 and Aloron accumulated more dry matter in stem, leaves and root at harvest under water stress condition compared to other varieties. Chowdhury *et al.* (2004) observed that plant height decreased with the decrease in soil moisture levels and elucidated inhibition of cell division and cell enlargement due to water stress as the possible reason.

Table 2. Interaction effect of water stress and variety on growth parameters of Boro rice at harvest

Treatments	Plant height (cm)	Number of tillers hill $^{-1}$	Number of leaves hill^{-1}	Dry Leaf weight (g hill^{-1})	Dry stem weight (g hill^{-1})	Dry Root weight (g hill^{-1})
W_1V_1	97.25 cd	12.60 abc	46.13ab	19.74 a	35.89 ab	10.12 ab
W_1V_2	97.41 cd	13.80 ab	28.07 def	20.96 a	39.93 a	13.34 a
W_1V_3	86.68 ef	15.61 a	51.75 a	11.49 bc	27.86 bcd	9.13 bc
W_1V_4	110.37 a	11.07 bc	34.20 cd	16.27 ab	25.35 cd	5.98 cd
W_1V_5	101.17 bc	11.00 bc	25.47ef	16.91 ab	31.14 bc	8.52 bcd
W_1V_6	97.21 cd	10.80 bc	24.73 ef	15.24 ab	27.67 cd	9.26 bc
W_2V_1	92.25 de	12.10 abc	39.50 bc	18.35 a	30.58 bcd	9.22 bc
W_2V_2	93.51 d	11.13 bc	22.27 f	18.06 a	31.86 bc	10.74 ab
W_2V_3	83.39 f	14.13 ab	45.53 ab	7.41 c	24.93 cd	5.28 d
W_2V_4	103.60 b	10.80 bc	31.67 cde	15.85 ab	26.74 cd	6.56 cd
W_2V_5	95.41 cd	10.80 bc	24.53 ef	11.69 bc	22.97 d	7.53 bcd
W_2V_6	93.91 d	10.20 c	21.27 f	18.95 a	28.32 bcd	10.05 ab
$LSD_{(0.05)}$	5.009	3.790	8.20	5.910	8.190	3.490
CV (%)	3.06	17.92	14.63	21.81	16.34	23.63

W_1- No water stress, W_2- Water stress and V_1- BRRI dhan28, V_2- BRRI dhan29, V_3- BRRI dhan50, V_4- Binadhan-10, V_5- BRRI hybrid dhan3, V_6- Aloron.

Effect of water stress on yield and yield contributing characters

Filled grainspanicle^{-1}, 1000-grains weight and harvest index were not significantly influenced by different water stress condition while water stress had significant effect on unfilled grainspanicle^{-1}, grain yield, straw yield and biological yield (Table 3).All the yield and yield contributing characters achieved maximum value under no water stress condition. Water stress at reproductive stages caused about 14% yield reduction compared to no water stress condition. Mannan *et al.* (2012)reported lower number of filled grains per panicle and grain weight due to water stress at reproductive stage. Inactivation of pollen grain due to dryness, hampered pollen tube development and disturbed assimilates production and distribution might be the causes (Fofana *et al.*, 2010).Actually moisture stress obstructs photosynthesis and limits the supply of photosynthates to developing grains which eventually reduces grain yield.

Effect of variety on yield and yield contributing characters

Varietal performance had significant impact on yield and yield contributing characters (Table 3). The maximum number of filled grains panicle^{-1}(133.28)was obtained from BRRI dhan29 which was statistically at par with BRRI dhan28 and BRRI hybrid dhan3. The lowest number of filled grains panicle^{-1} (98.88) was recorded from Aloron. Maximum 1000-grain weight (26.55 g) was obtained from BRRI hybrid dhan3 and minimum (21.03 g) from BRRI dhan28. Aloron provided maximum grain yield which was 12% and 18% higher than BRRI hybrid dhan3 and BRRI dhan29. Lowest yielder BRRI dhan50 and BRRI dhan28 gave about 50% lower yield than Aloron. Aloron also had the highest straw yield and biological yield. Maximum harvest index (49.64%) was recorded from BRRI dhan29 which was statistically similar with other varieties except BRRI dhan50 and BRRI hybrid dhan3. Mannan *et al.* (2012) also documented significant variations in case of yield and yield contributing attributes due to difference in genetic makeup of varieties.

Table 3. Effect of water stress and variety on yield and yield contributing characters of Boro rice

Treat-ments	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000- grain weight	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biolo-gical yield (t ha^{-1})	Harvest index (%)

Water stress							
W_1	117.8	14.23	22.31	6.86 a	7.4 a	14.26 a	48.1
W_2	106.6	20.04	22.26	5.75 b	6.47 b	12.22 b	47
$LSD_{(0.05)}$	NS	1.87	NS	0.48	0.79	1.24	NS
CV (%)	8.14	7.59	0.54	5.31	7.91	1.95	1.95
Variety							
V_1	121.25 a	21.27 a	21.03 c	5.14 d	5.70 d	10.84 d	47.35 ab
V_2	133.28 a	20.70 a	18.37 d	6.74 b	6.84 b	13.57 c	49.64 a
V_3	102.15 bc	21.42 a	18.37 d	5.05 d	5.91 d	10.97 d	46.17 b
V_4	100.82 bc	10.48 b	25.19 b	5.85 c	6.55 bc	12.40 c	47.20 ab
V_5	117.17 ab	11.95 b	26.55 a	7.08 b	8.09 a	15.17 b	46.68 b
V_6	98.88 c	17.00 ab	25.40 b	7.98 a	8.53 a	16.51 a	48.25 ab
$LSD_{(0.05)}$	16.4	7.78	0.66	0.63	0.75	1.18	2.87
CV (%)	12.13	25.01	2.45	8.31	8.94	7.42	5.00

W_1- No water stress, W_2- Water stress and V_1- BRRI dhan28, V_2- BRRI dhan29, V_3- BRRI dhan50, V_4- Binadhan-10, V_5- BRRI hybrid dhan3, V_6- Aloron.

Interaction effect of water stress and varietyon yield and yield contributing characters

The interaction between water stress and variety significantly influenced yield and yield contributing characters (Table 4). All the tested varieties performed better under no water stress condition than water stress condition from reproductive stage to harvest. BRRI dhan29 gave the maximum filled grainspanicle^{-1}both under no water stress condition (145.43) and water stress condition(121.13). Number of unfilled grains was found minimum in Binadhan-10 under both the situation when plants faced no water stress and water stress at reproductive stage. Grain yield was considerably reduced (15-22%) due to water stress condition in case of all the varieties. Aloron provided maximum grain yield in both the cases of no water stress and water stress but water stress reduced about 15% yield of that variety. However, grain yield of Aloron was the least affected due to water stress while BRRI dhan50 (22% yield reduction) was the most affected variety by water stress. Better performance was also recorded from Aloron in case of straw yield and biological yield. Harvest index of varieties was not significantly influenced by water stress except BRRI dhan50. Sarvestani *et al.* (2008) documented that water stress at reproductive stage reduced about 50% grain yield in comparison to no water stress condition.

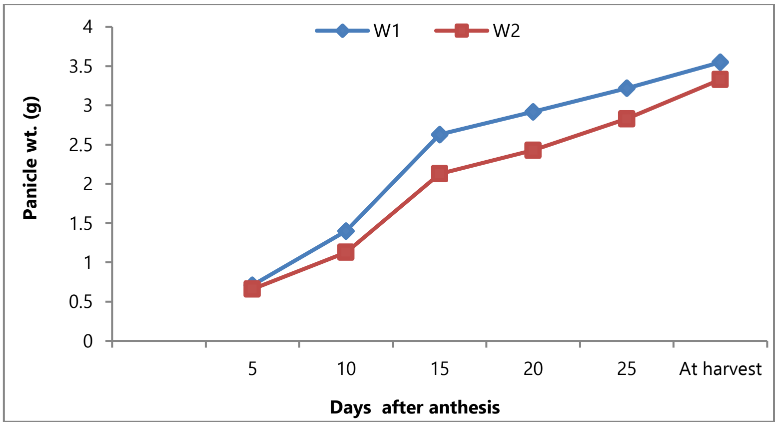
Table 4. Interaction effect of water stress and variety on yield and yield contributing characters of Boro rice

Treatments	**Filled grains panicle^{-1} (No.)**	**Unfilled grains panicle^{-1}**	**1000-grain weight (g)**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Biolo-gical yield (t ha^{-1})**	**Harvest index (%)**
W_1V_1	123.63 abc	16.40 abc	21.13 d	5.63 def	6.10 d	11.72 ef	48.01 a
W_1V_2	145.43 a	16.47 abc	18.26 e	7.31 bc	7.44 b	14.76 bc	49.55 a
W_1V_3	100.07 de	16.70 abc	17.23 f	5.59 ef	5.93 d	11.52 ef	48.68 a
W_1V_4	102.73 cde	8.40 c	25.37 bc	6.33 de	7.30 bc	13.63 cd	46.46 ab
W_1V_5	126.57 ab	9.437 c	26.10 b	7.65 b	8.73 a	16.39 ab	46.69 ab
W_1V_6	108.67 b-e	14.97 abc	25.47 bc	8.64 a	8.91 a	17.55 a	49.19 a
W_2V_1	118.87 bcd	26.13 a	25.47 bc	4.65 g	5.30 d	9.95 f	46.68 ab
W_2V_2	121.13 bcd	21.93 ab	18.49 e	6.16 def	6.23 cd	12.39 de	49.72 a
W_2V_3	104.23 b-e	26.13 a	17.10 f	4.52 g	5.90 d	10.42 f	43.66 b
W_2V_4	98.90 de	12.57 bc	25.01 c	5.36 fg	5.80 d	11.17 ef	47.94 a
W_2V_5	107.77 b-e	14.47 abc	27.00 a	6.52 cd	7.45 b	13.96 cd	46.67 ab
W_2V_6	89.10 e	19.03 abc	25.33 bc	7.31 bc	8.15 ab	15.47 bc	47.32 ab
$LSD_{(0.05)}$	23.19	12.86	0.93	0.89	1.06	1.63	4.05
CV (%)	12.13	25.01	2.45	8.31	8.94	7.42	5.00

W_1- Nowater stress, W_2- Water stress and V_1- BRRI dhan28, V_2- BRRI dhan29, V_3- BRRI dhan50, V_4- Binadhan-10, V_5- BRRI hybrid dhan3, V_6- Aloron.

Effect of water stress on grain growth pattern

Panicle weight was significantly influenced by water stress at 5, 10, 15, 20, 25 days after anthesis and at harvest (Figure 1). Panicle weight increased from 5 days after anthesis up to harvest for both no water stress and water stress condition. Panicle weight was reduced by about 7% at harvest due to water stress condition at reproductive stage. Fofana *et al.*(2010)found that effect of water stress on yield was most severe when drought occurred during panicle development. This might be associated with low dry matter production during the drought period as well as during the recovery period following the drought. When drought occurred during grain filling, the percentage of filled grain was decreased to 40% and individual grain mass decreased by 20% (Sarvestani *et al.*, 2008). Mannan *et al.* (2012) also found variation in grain development due to water deficit condition.



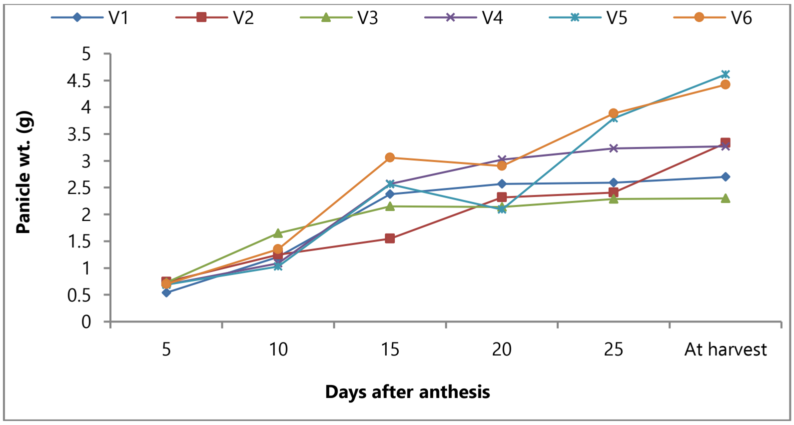
W_1-No water stress,W_2-Water stress

(LSD $_{(0.05)}$ value = 0.06, 0.33, 0.23, 0.29, 0.24 and 0.11 at 5, 10, 15, 20, 25 days after anthesis and at harvest, respectively).

Fig.1. Effect of water stress on panicle weight at different days after anthesis

Effect of variety on grain growth pattern

Varietal variances showed significant difference in anthesis development. Panicle weight was significantly influenced by different varieties at 15, 25 days after anthesis and at harvest but statistically similar at 5 and 10 days after anthesis (Figure 2). Panicle weight of all the tested varieties was increased throughout the grain development period with a little fluctuation. At harvest, maximum panicle weight was recorded in BRRI hybrid dhan3 (4.61 g) which was statistically similar with Aloron (4.42g). On the other hand, BRRI dhan50produced the minimum panicle weight at harvest (2.30 g).These findings corroborated with the findings of Murshida *et al.* (2017).



V_1- BRRI dhan28, V_2- BRRI dhan29, V_3- BRRI dhan50, V_4- Binadhan-10, V_5- BRRI hybriddhan3, V_6- Aloron
(LSD $_{(0.05)}$ = NS, NS, 0.61, 0.56, 0.46 and 0.75 at 5, 10, 15, 20, 25 days after anthesis and at harvest, respectively).
Fig. 2. Effect of variety on Panicle weight at different days after anthesis

Interaction effect of water stress and varietyon grain growth pattern

Panicle weight was significantly influenced by the interaction of water stress and variety at 15, 20, 25 days after anthesis and at harvest but statistically insignificantat 5 and 10 days after anthesis (Table 5).

Table 5. Interaction effect of water stress and variety on panicle weight at different days after anthesis

Treatments	5 Days	10 Days	15 Days	20 Days	25 Days	At harvest
W_1V_1	1.3	1.45	2.70 a-d	2.74 a-e	2.76 cd	2.78 d
W_1V_2	0.80	1.33	1.73 de	2.78 a-e	2.73 cd	3.34 bcd
W_1V_3	0.73	2.00	2.31 a-e	2.25 def	2.38 cde	2.39 d
W_1V_4	0.72	1.04	3.04 ab	3.40 a	3.50 ab	3.52 a-d
W_1V_5	0.71	1.10	2.77 abc	3.29 ab	4.01 a	4.84 a
W_1V_6	0.74	1.22	3.20 a	3.08 abc	3.95 a	4.46 ab
W_2V_1	0.52	0.97	2.05 b-e	2.40 c-f	2.41 cde	2.63 d
W_2V_2	0.68	1.17	1.36 e	1.88 f	2.08 e	3.32 bcd
W_2V_3	0.73	1.30	1.98 cde	2.047 ef	2.19 de	2.32 bcd
W_2V_4	0.66	1.13	2.10 b-e	2.64 b-f	2.96 bc	3.03 cd
W_2V_5	0.67	0.96	2.35 a-e	2.89 a-d	3.56 ab	4.39 abc
W_2V_6	0.66	1.47	2.91 abc	2.71 a-e	3.80 a	4.38 abc
$LSD_{(0.05)}$	NS	NS	1.00	0.79	0.65	1.41
CV (%)	16.49	28.80	14.05	17.34	12.54	13.67

W_1- No water stress, W_2- Water stress and V_1- BRRI dhan28, V_2- BRRI dhan29, V_3- BRRI dhan50, V_4- Binadhan-10, V_5- BRRI hybriddhan3, V_6- Aloron.

Panicle weight of all the tested varieties was reduced due to water stress at reproductive stage. Grain development of BRRI dhan29 was least affected by water stress while the most affected variety was Binadhan-10. Panicle weight of Binadhan-10 at harvest was declined by 14% due to water stress. Sokoto and Muhammad(2014)reported that applied moisture stress during reproduction phase reduced yield with the magnitude of yield reduction being 25.8% (average of reproduction in booting, flowering and grain filling stage) compared to control. Fofana *et al*. (2010)alsoshowed that stress at booting and flowering stages had the similar effect on grain yield.

Conclusion

Considering the above results, it may be concluded that water stress at reproductive stage significantly reduces the grain yield. Among the tested varieties, Aloron performed best under water stress condition. So, in the region, where the irrigation water is a matter of concern in case of cost and availability, the variety Aloron may be a better option to cultivate as it provides equal yield as mega variety BRRI dhan29 under no water stress condition.However, further experimentation will need to be executed in different agro-ecological zones with more varieties under water stress condition to reach a specific conclusion and recommendation.

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