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Yield and Yield Attributes of Aus Rice Genotypes as Influenced by Different Levels of Water Stress

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Abstract

This paper aims to yield and yield attributes characters of aus rice genotypes under different levels of water stress conditions. The ten rice genotypes were used as treatment, *i.e.* BR21, BR24, BRRI dhan42, BRRI dhan43, BRRI dhan48, BRRI dhan55 and lines BR6976-11-1, OM1490, BR6976-2B-15 and water stress tolerant variety Hashikalmi were treated with different durations of water deficiency such as continuously irrigated throughout the experimental period, normal irrigation up to 30 days and after that no irrigation for 7 days, then irrigated continuously and normal irrigation up to 30 days and after that no irrigation for 15 days and then irrigated continuously. Plants were grown in the rain-protected polyethylene shelter or shed to avoid rain under natural conditions in the earthen pots. The results of the experiment that the grain yield per plant recorded were the highest at control treatment and gradually decreased with increasing water stress duration in the genotypes. However, the grain yield was less affected due to water stress treatment in BRRI dhan55 and Hashikalmi compared to other genotypes. Decreased grain yield per plant under water stress conditions was due to a reduction of effective tillers, panicle number, filled grains, root-shoot and panicle dry matter content, etc. while less affected due to water stress treatment in BRRI dhan55 and Hashikalmi compared to other genotypes. BRRI dhan55 and Hashikalmi showed better performance in all days of water stress conditions. It was revealed that BRRI dhan55 and Hashikalmi produced the highest number of tillers, effective tillers and number of filled grains, number of spikelet per panicle and yield per plant. The grain sterility percentage was much higher in BR6976-2B-15 due to water stress treatment compared to other genotypes. Hashikalmi and BRRI dhan55 produced the highest number of tillers per

plant.

Subject Areas

Agricultural Science

Keywords

Water Deficit, Genotypes, Dry Matter, Aus, Rice

1. Introduction

Water deficit is a major problem in growing rice as it affects directly the growth and development of rice, especially in low rainfall season (Usman *et al*., 2013) [1]. According to the IRRI (2005) [2], water deficit is one of the major constraints to rice (*Oryza sativa* L.) cultivation and production. Rice is more susceptible to drought than any other crops. Worldwide drought stress is responsible for reducing crop productivity and yield. It is estimated that the world needs to produce 40% more rice to feed the population by 2025 (FAO, 2002) [3].

Water stress is one of the major abiotic stresses that severely affect and reduce the yield and productivity of rice. It has been identified as the key factor for low productivity in the rainfed ecosystem reported by Zeigler and Puckridge (1995) [4]. Boyer (1982) [5] found that drought limits productivity and affects both the quality and quantity of the yield. Shao *et al.* (2008) [6] observed that metabolic changes during drought affect the reduction of nutrients such as carbohydrates, nitrates, and potassium concentration decreases. Usman *et al*. (2013) [1] stated that drought affected the growth and reduced shoot, root weights, lengths and physiological processes.

Severe water stress may result in the arrest of photosynthesis, disturbance of metabolism and finally the death of plants (Jaleel *et al*., 2008) [7]. Water stress at or before panicle initiation reduces potential spike number and decreases translocation of assimilates to the grains, which results low in grain weight and increases empty grains (RRDI, 1999) [8]. O'Toole and Moya (1981) [9] found that a significant decrease in panicle number and filled grain per plant, and an increase in the number of unfilled grains were the main causes of sterility percentage increase due to drought treatment. Peleg and Blumwald (2011) [10] found that in the case of rice shoots accumulate proline in water stress conditions and also ABA accumulates in water stress conditions. In agriculture, mild to severe drought has been one of the major production-limiting factors. Most traditional aus varieties possess quite a good grade of resistance to water stress. That is why government thinking about growing aus crops in more fields in this season. According to FAO (2002) [3], there is an urgent need to increase rice production to meet global demand. Hence, water stress management strategies need to be taken for better yield and improved varieties that are more resilient to abiotic stresses. Considering the above-mentioned facts, the present research work was undertaken to achieve the following objectives to find out the yield and yield contributing characteristics of aus rice genotypes under different levels of water stress conditions.

2. Materials and Methods

The experiment was conducted at the Agricultural Botany Research Field and Plant Physiology Laboratory (Central Laboratory), Deppartment of Agricultural Botany of Sher-e-Bangla Agricultural University, Dhaka-1207 under polythene shed controlling the intrusion of rainfall. The experiment was conducted during the period from March 2013 to July 2013.

2.1. Materials

A total of ten rice genotypes as BR21, BR24, BRRI dhan42, BRRI dhan43, BRRI dhan48, BRRI dhan55 and lines BR6976-11-1, OM1490, BR6976-2B-15 and water stress tolerant variety Hashikalmi were collected from Genetic Resource and Seed Division, Bangladesh Rice Research Institute (BRRI). Ten genotypes used as treatments.

2.2. Methods

2.2.1. Experimental Design, Replications

The experiment was designed in Randomized Complete Block Design and three replications were used.

Seed treatment and sowing: Seeds of uniform size and shape of each genotype were treated with Bavistin 5 gm for 20 minutes. The solution was prepared by dissolving 5 g of Bavistin in 1/2 liter of water. Treated seeds were place in the Petridis with water. Pre-soaked sprouted seeds were sown on March, 2013 in earthen pots under the rain-protected polyethylene shade.

Pot preparation and fertilizer management: Earthen pots of 38 cm × 25 cm in size were used and filled up with 10 kg sandy loam soil. The soil of the experimental area was sandy and sandy loam. The soil of the pot was fertilized uniformly with 0.9, 0.8, 0.8 g urea, triple super phosphate and muriate of potash corresponding to 160-150-150 kg urea, triple super phosphate and muriate of potash per hectare, respectively (BRRI, 2008) [11].

General observation and detailed procedures of the experiment: All the pots were irrigated up to thirty days of seedlings age for ensuring normal growth. Water deficit was imposed on 31 days old seedlings. A total of ten rice genotypes were used as treatment. Ten treatments with different durations of water deficiency, *i.e.* 1) Normal irrigation throughout the experimental period, water deficit was imposed for 7 days on 31 days old seedlings in 10 genotypes and after that irrigation was done continuously until harvest; 2) Water deficit was imposed for 15 days in 10 genotypes on 31 days old seedlings; 3) Plants were irrigated continuously until harvest that was control.

2.2.2. Detailed Procedures of Recording Data

Different yield attribute parameters: length of panicle, number of tillers, weight of 1000-grains, effective tillers and number of filled grains, number of spikelet per panicle and yield per plant, total dry matter (root, shoot and panicle) were recorded at different stages of plant.

Length of panicle: Length of panicle (cm) was taken from basal node of the rachis to apex of each panicle.

Number of total, effective and ineffective tillers per plant: Number of total and effective tillers and panicle dry weight per plant was counted. The panicles which had at least one grain was considered as effective tillers. The tiller having no panicle was regarded as ineffective tillers.

Weight of 1000-grain: After sun drying and oven drying for 72 hours at 72˚C, thousand cleaned grains weight (g) were counted. One thousand cleaned oven dried grains were counted randomly from each sample and weighed by using digital electronic balance and the mean weight was expressed in gram.

Total dry matter: Total dry matter (root, shoot and panicle) was measured after oven drying for 72 hours at 72˚C.

Harvest index (%): It denotes the percentage of economic yield and biological yield. Harvest Index (HI) was calculated with the following formula (Donald, 1963) [12].

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

Biological yield: Biological yield was calculated with the formula (Biological yield = Grain yield + Straw yield).

2.2.3. Data Analysis

The data were statistically analyzed following MSTAT-C (Michigan State Statistics-C) software package and the mean differences were adjusted by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Russell, 1986) [13].

3. Results and Discussion

The objectives of the study were to assess the effects of different durations of water stress on yield and yield attribute characters of different rice genotypes and the results of this experiment have been presented in the form of tables and figures along with necessary discussion in this chapter.

3.1. Length of Panicle at Mature Stage

In this study, lengths of panicle (cm) of different rice genotypes under water stress condition have been shown in Table 1. Significant differences were found among the varieties and the treatments for panicle length. At 7 days stress, the highest panicle length found was 20.00 cm in BRRI dhan55 and the lowest found was 17.33 cm in BR21. At 15 days stress, the highest panicle length found was 18.70 cm in Hashikalmi and the lowest found was 14.57 cm and 14.92 cm BR 6976-2B-15. At control, the highest panicle length found was 23.76 cm in Hashikalmi and the lowest found was 20.80 cm in BRRI dhan42. Under water stress

Table 1. Lengths of panicle (cm) of different rice genotypes under water stress conditions.

Genotypes	Length of panicle (cm)			Reduction (%) of panicle length (cm)	
	Control	7 days stress	15 days stress	7 days stress	15 days stress
BR21	21.9 abc	17.33 b	14.57 c	20.87	33.47
BR24	21.57 abc	19.10 ab	17.17 abc	11.45	20.40
BRRI dhan42	20.80 c	19.36 a	17.60 ab	6.92	15.38
BRRI dhan43	20.83 c	19.20 ab	16.03 abc	7.83	23.04
BRRI dhan48	21.86 abc	19.78 a	17.20 abc	9.52	21.32
BRRI dhan55	23.53 ab	20.00 a	17.36 abc	15.0	26.22
OM 1490	21.03 bc	18.99 ab	17.00 abc	9.70	19.16
BR 6976-2B-15	20.83 c	19.50 a	14.92 bc	6.39	28.37
BR 6976-11-1	21.26 abc	19.77 a	16.07 abc	7.01	24.41
Hashikalmi	23.76 a	19.83 a	18.70 a	16.54	21.30
CV (%)	7.98	5.82	8.65		

Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

condition, there were remarkable differences on panicle length among the genotypes. At 7 and 15 days stress, BRRI dhan55, Hashikalmi produced the largest panicle (reduction percent was 15 and 26.22 in BRRI dhan55 and 16.54, 21.30 in Hashikalmi, respectively).

Largest length of panicle contains more grain which was of high weight of panicle than small length of panicle. At 15 days stress, the smallest panicle length showed in BR21 and BR 6976-2B-15 (the reduction percent was 33.47, 28.37, respectively) and the highest panicle length found was 20.00 cm in BRRI dhan55 at 7 days stress. As a result, yield losses. Similar result was obtained by Islam *et al.* (1994) [14] who reported that moisture stress reduced the length of panicle. The results have also the agreement with the results of Bokul *et al.* (2009) [15] who found that panicle length was decreased due to drought conditions at reproductive stage.

3.2. Weight of 1000-Grain

In this study, thousand weights of grain (g) of different rice genotypes under water stress condition have been shown in Table 2. Significant differences were found among the varieties and the treatments for this character. At 7 days stress, the highest thousand grain weight was in 20.33g BRRI dhan48 and the lowest thousand grain weight found was 14.10 g in BRRI dhan42. At 15 days stress, the highest thousand grain weight was 15.55 g in BRRI dhan55 and the lowest was 11.04 g in BR24. At control, thousand grain weight was 23.93 g in BRRI dhan43.

In this study, the highest thousand grain weight was found 20.33g in BRRI dhan48 at 7 days stress, 15.55 g was found in BRRI dhan55 at 15 days stress and the lowest was 11.04 g in BR24. This result has the similarity with the results of

Table 2. 1000-grains weight of different rice genotypes under water stress conditions.

Genotypes	1000-grain weight (g)			Reduction (%) of 1000 wt. of grains	
	No stress	7 days stress	15 days stress	7 days stress	15 day stress
BR21	19.16 cd	15.03 b	14.10 abc	21.56	24.58
BR24	19.11 cd	15.56 b	11.04 d	18.58	42.23
BRRI dhan42	15.36 e	14.10 b	12.00 cd	8.20	21.88
BRRI dhan43	23.93 a	16.20 b	12.59 bcd	32.30	47.39
BRRI dhan48	23.37 ab	20.33 a	14.45 ab	13.01	33.03
BRRI dhan55	16.75 e	15.65 b	15.55 a	6.57	7.16
OM 1490	21.25 bc	16.15 b	11.67 d	24.00	45.08
BR 6976-2B-15	21.69 ab	14.50 b	11.31 d	33.15	47.86
BR 6976-11-1	22.74 ab	15.04 b	11.59 d	33.86	49.03
Hashikalmi	18.53 d	17.07 ab	13.96 abc	7.88	24.66
CV (%)	6.61	12.86	9.49		

Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

Zubaer *et al.* (2007) [16] who showed that 1000-grain weight was reduced with reduced soil moisture levels. The RRDI (1999) [8] stated that stress during grain filling stage decreased grain weight. Begum (1992) [17] conducted that water stress after flowering decreased the individual grain weight. Islam *et al.* (1994) [14] also stated that water stress reduced grain weight.

3.3. Total Number of Tillers per Plant

In this study, total number of tillers per plant of different rice genotypes under water stress condition has been shown in Table 3. Significant differences were found among the varieties and the treatments for this character. At 7 days stress, the highest number of tillers per plant found was 35.00 in Hashikalmi, the second highest was found 34.60 in BRRI dhan55 and the lowest number of tillers per plant found was 20.33 in BR24. At 15 days stress, BRRI dhan55 produced the highest numbers of tillers (24.33) followed by Hashikalmi (24.00) and the lowest number of tillers per plant found was 16.69 in BRRI dhan43, 16.87 in OM1490, 17.00 in BRRI dhan42, 17.21 in BR21. Under control condition, plant produced the highest numbers of tillers was found in BRRI dhan55 (36.33), Hashikalmi (36.05) and the lowest numbers of tillers were produced in 23.33 in BRRI dhan43, OM1490 (23.69).

Total number of tillers varied significant among the genotypes at different stress conditions. In this study, among the genotypes it was found that the total number of tillers was reduced under water stress condition at vegetative stage. In all water stress duration tiller production were the highest in BRRI dhan55 and Hashikalmi compared to other genotypes. In this result, at 7 days stress, the highest number of tillers per plant was found in BRRI dhan55 (the reduction

Table 3. Total numbers of tiller/plant of different rice genotypes under water stress conditions.

Genotypes	Total number of tiller/plant			Reduction of total No. of tiller/plant (%)	
	Control	7 days stress	15 days stress	7 days stress	15 days stress
BR21	27.33 bc	21.33 de	17.21 c	21.95	37.03
BR24	25.88 c	20.33 e	17.33 cd	21.45	33.04
BRRI dhan42	24.04 cd	20.43 e	17.00 cd	15.02	29.28
BRRI dhan43	23.33 d	21.00 de	16.69 c	9.99	34.11
BRRI dhan48	33.78 abc	24.33 cde	19.54 bc	7.25	42.16
BRRI dhan55	36.33 a	34.60 b	24.33 a	4.76	33.93
OM 1490	23.69 d	22.33 de	16.87 c	5.74	28.79
BR 6976-2B-15	26.65 bc	24.00 cde	17.08 cd	9.94	35.91
BR 6976-11-1	25.67 c	24.33 cde	18.00 bc	5.22	29.88
Hashikalmi	36.05 a	35.00 a	24.00 ab	2.91	33.43
CV (%)	13.08	17.38	10.00		

Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

percent was 4.76), followed by Hashikalmi (2.91). At 15 days stress, BRRI dhan55 produced the highest numbers of tillers followed by Hashikalmi which was statistically similar. It might be due to less amount of water uptake to prepare sufficient food and inhibition of stomatal conductance, dry matter production, leaf area and photosynthesis (Ekanayake *et al*., 1987) [18]. Similar results also agree with the results of Boonjung and Fukai (1996) [19] who observed that early drought may reduce tiller number and reductions were often minimal yield. Islam *et al*. (1994) [14] reported reduced tillering during vegetative stages under water stress.

3.4. Effective Tillers/Plant

In this study, total number of effective tillers/plants of different rice genotypes under water stress condition has been shown in **Table 4**. Significant differences were found among the varieties and the treatments for this character. At 7 days stress, the highest number of effective tillers found was 12.83 in Hashikalmi followed by 12.22 in BRRI dhan55 and the lowest number of tillers was 7.02 in BRRI dhan48. At 15 days stress, the highest number of effective tillers was 10.35 in BRRI dhan55 and the lowest numbers of tillers was 5.13 in BRRI dhan42. At no stress condition, tolerant genotype Hashikalmi (14.40) and BRRI dhan55 (15.87) produced the highest number of effective tillers which was statistically similar and the lowest number was found 7.89 in BRRI dhan42.

Tolerant check Hashikalmi and BRRI dhan55 produced the highest number of effective tillers at 7 days. Number of effective tillers per plant of different rice genotypes decreased with the increase in water stress condition. It might also be happened for less amount of water uptake to increased plant growth, leaf area

Table 4. Effect of different durations of water stress on effective tiller/plant of rice genotypes.

Genotypes	Effective tiller/plant		
	Control	7 days stress	15 days stress
BR21	9.62 c	8.68 c	7.00 cd
BR24	10.10 c	9.07 bc	8.12 bc
BRRI dhan42	7.893 c	7.36 c	5.13 d
BRRI dhan43	8.900 c	7.85 c	6.07 d
BRRI dhan48	14.28 ab	7.02 c	5.67 d
BRRI dhan55	15.87 a	12.22 a	10.35 a
OM 1490	8.227 c	10.13 ab	10.33 a
BR 6976-2B-15	12.63 b	10.90 ab	10.00 a
BR 6976-11-1	9.180 c	8.350 c	7.04 cd
Hashikalmi	14.40 ab	12.83 a	8.93 ab
CV (%)	10.96	11.87	12.99

Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

and to prepare sufficient food and inhibition cell division. This result has showed Ekanayake (1987) who observed the percentage of fertile tiller is severely affected by moisture stress. Kramer and Boyer (1995) [20] stated that drought stress suppresses and number of effective tillers means number of panicles per plant cannot increase due to early senescence.

3.5. Number of Panicle/Plants at Harvest

Number of panicle per plant of different rice genotypes under drought condition has been shown in **Figure 1**. Significant differences were found among the varieties and the treatments for this character. At 7 days drought stress, the highest number of panicle/plants found was 21 and 17 in BRRI dhan55 and Hashikalmi respectively and the lowest number of panicle/plants found was BR21, OM1490. At 15 days drought stress, the highest number of panicle/plants found was 18 and 14 in BRRI dhan55 and Hashikalmi respectively and the lowest number of panicle/plants found were 7 in BR21, 6976-11-1. At no stress, the highest number of panicle/plants found was 31 in Hashikalmi and the lowest number of panicle/plants was found in OM1490.

Decreased number of panicle/plant under water stress treatment was due to reduction in tiller number. Water deficit just before flower initiation may also decreased the number of spikelet primordial (Oosteruis & Cartwright, 1983) [21].

3.6. Panicle Dry Weight per Plant

In this study, panicle dry weight per plant of different rice genotypes under drought condition has been shown in **Figure 2**. Significant differences were

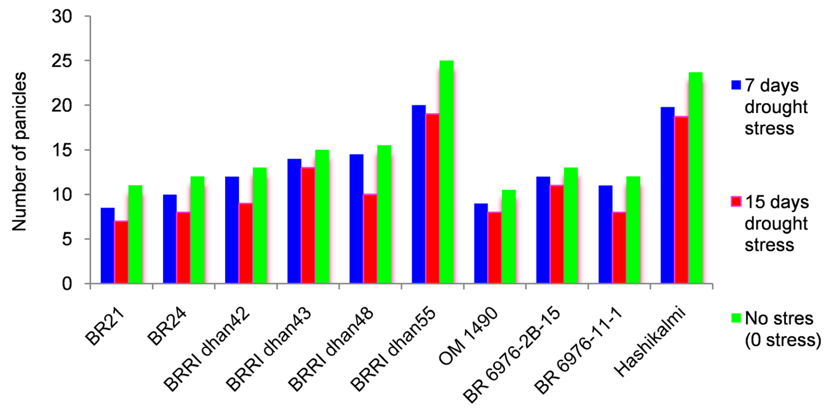

Figure 1. Number of panicles at 7 days stress (blue colour), 15 days stress (red colour) and no stress (green colour) of different genotypes under drought.

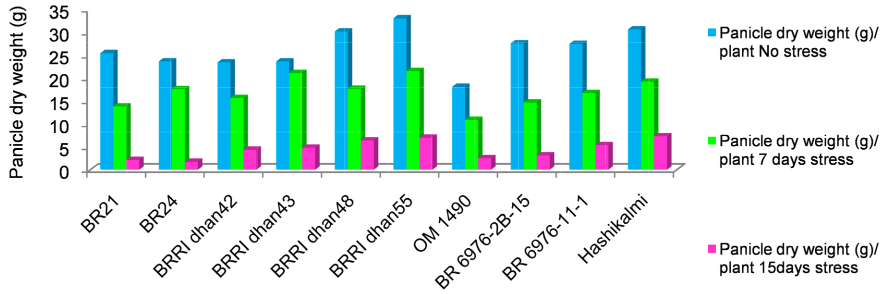

Figure 2. Effect of different durations (days) of water stress on panicle dry weight of rice genotypes.

found among the varieties and the treatments for dry weight of panicle per plant. At 7 days drought stress, the highest dry weight of panicle per plant was 21.56 g in BRRI dhan55 and the lowest weight dry weight of panicle per plant was found 10.88 g in OM1490. At 15 days drought stress, the highest panicle dry weight was found 7.29 g in Hashikalmi and the lowest dry weight of panicle per plant was found 1.75 g in BR24. At no stress, the highest panicle dry weight was found 33.08 g in BRRI dhan55 and the lowest panicle dry weight per plant was found 18.12 g in OM1490, 23.46 g in BRRI dhan42.

There were remarkable differences on dry weight of panicle among the genotypes under drought condition. BRRI dhan55 produced the highest dry weight of panicle at 7 days stress condition and at 15 days stress. As a result, yield losses occurred. The results have the similarity with the results of. Islam *et al.* (1994) [14] who observed that yield losses resulting from water deficit are severe at booting stage. Water stress at or before panicle initiation reduces potential spike number, decreases translocation of assimilates to the grains, which results low in grain weight and increases empty grains (RRDI, 1999) [8].

3.7. Total Dry Matter/Plant at Harvest

The total dry matter (g) per plant of different rice genotypes under drought condition has been shown in **Figure 3**. Significant differences were found among

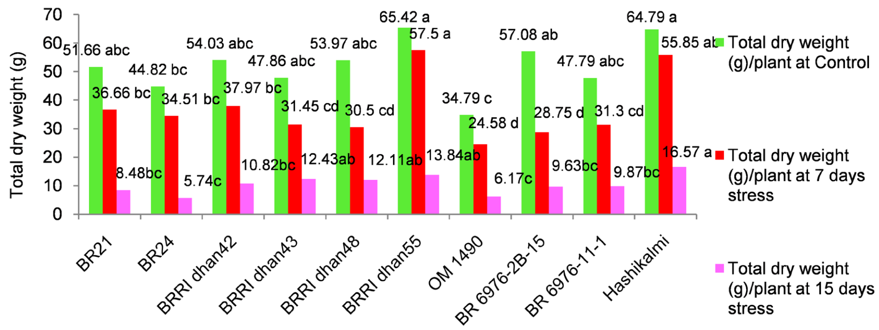

Figure 3. Effect of different days water stress on total dry weights/plant of rice genotypes. Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

the varieties and the treatments for the characters of total dry matter (g) per plant. At 7 days stress, the highesttotal dry matter per plantfound was 57.50 g in BRRI dhan55 followed by 55.85 g in Hashikalmi and the lowest total dry matter per plant was found 24.58 g in OM1490. At 15 days stress, the highest total dry matter per plantwas found 16.57 g in Hashikalmiand the lowest total dry matter per plant was 5.74 g in BR24. At control, the highest total dry matter per plant-was 65.42 g in BRRI dhan55, the second highest total dry matter per plant was 64.79 g in Hashikalmi and the lowest dry matter per plantfound was 34.79 g in OM1490.

Due to water deficit conditions root, shoot, leaf and panicle dry weight decreased, as a result the total dry matter became lower. In this study, it was found that at 7 and 15 days stress, the highest total dry matter per plant was in BRRI dhan55 and the second highest total dry matter per plant was in Hashikalmi. It-was observed that the total dry matter is decreased with the decreased of morphological characters including shoot root dry weight, tiller and leaf dry weight under drought stress condition. The results have the conformity with the results of Lum (2014) [22] who reported that in the activities of shoot length, root length and dry matter yield and biochemical parameters were decreases under drought condition. Acosta-Gallegos and Adams (1991) [23] reported that leaf expansion rate and crop growth rate at mid-pod-filling were greatly reduced by drought stress, resulting in significant reductions in total dry matter.

3.8. Yield/Plant

In this study, yield/plant of different rice genotypes under drought condition has been shown in Table 5. Significant differences were found among the varieties and the treatments for yield/plant. At 7 days drought stress, the highest yield/plant found was 19.77 g in BRRI dhan55, followed by 19.21 g in Hashikalmi and the lowest yield/plant found was 9.63 g in BR24. At 15 days stress, the highest yield/plant was found 10.7 g in BRRI dhan55 followed by 10.23 Hashikalmi and the lowest yield/plant was 1.68 g in BR24. At control, the highest yield/plant was found 34.17 g in BRRI dhan55 and the lowest yield/plant was found 20.17 g in BRRI dhan43.

Table 5. Effect of different days water stress on yield/plant of different rice genotypes.

Genotypes	Yield/plant (g)			Reduction (%) of yield/plant	
	No stress	7 days stress	15 days stress	7 days stress	15 days stress
BR21	25.67 bc	13.0 de	2.32 ef	49.36	90.96
BR24	24.58 bcd	9.63 f	1.68 f	60.82	93.15
BRRI dhan42	21.77 cde	12.93 de	4.23 cde	40.61	80.56
BRRI dhan43	20.17 e	14.19 d	6.03 bcd	29.65	70.12
BRRI dhan48	21.00 de	16.85 bc	7.32 b	19.76	65.13
BRRI dhan55	34.17 a	19.77 a	10.7 a	42.14	68.77
OM 1490	21.49 de	10.36 ef	4.16 cde	51.79	80.64
BR 6976-2B-15	24.96 bcd	14.12 cd	4.00 def	43.43	83.97
BR 6976-11-1	28.00 b	14.03 de	6.47 bc	49.89	76.90
Hashikalmi	32.33 a	19.21 ab	10.23 a	40.58	68.36
CV (%)	8.66	10.74	22.7		

Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

In this study, it was found that the highest yield/plant was found in BRRI dhan55 followed by Hashikalmi at 7, 15 days water stress (the reduction percent) was 42.14, 40.58, respectively. These results are consistent with the observed parameters of total dry matter, total number of tillers, effective tillers and plant height and leaf area of these varieties. Therefore, it was observed that yield/plant was decreased when decreased number of tillers per plant, total dry weight and plant height and leaf area were decreased under drought stress condition. On the other hand, yield is depended on the genotypes and the severity and the length of drought under drought condition. It might be due to inhibition of photosynthesis and less translocation of assimilates towards grain. The sensitive genotypes could lose their leaves, dry matter, and number of tillers and take much longer time to recover and develop new organ under drought condition. This result has the agreement with the results of Zubaer *et al.* (2007) [16] who stated that reduced yield under lower soil moisture levels might be due to inhibition of photosynthesis and less translocation of assimilates towards grain. Edward and Wright (2008) [24] also observed that the yield per plant was decreased under drought stress treatment in wheat.

3.9. Harvest Index (HI)

The results of harvest index of different rice genotypes under drought condition have been shown in Table 6. Significant differences were found among the varieties and the treatments for harvest index. At 7 days drought stress, the highest harvest index was found 38.33 in BRRI dhan55 and the lowest was 27.56 in BR24. At 15 days stress, the highest harvest index was 35.67 in BRRI dhan55 and the lowest was found 25.33 in BR24. At control, the highest harvest index was found 44.67 in BRRI dhan55 and the lowest was 34 in BR6976-11-1, 34.9 in BR24.

Table 6. Effect of different days water stress on Harvest Index (HI) of different rice genotypes.

Genotypes	Harvest index (%)			Reduction (%) of HI	
	Control	7 days stress	15 days stress	7 days stress	15 days stress
BR21	38.05 ab	30.45 cd	27.00 d	19.97	29.04
BR24	34.90 b	27.56 d	25.33 d	21.03	27.42
BRRI dhan42	35.00 b	33.00 abcd	29.67 cd	5.71	15.23
BRRI dhan43	37.67 ab	32.67 abcd	29.67 cd	13.27	21.24
BRRI dhan48	44.67 a	37.33 ab	33.33 abc	16.43	25.39
BRRI dhan55	44.67 a	38.33 a	35.67 a	14.19	20.15
OM 1490	40.30 ab	36.67 ab	34.67 ab	9.01	13.97
BR 6976-2B-15	34.67 b	31.67 bcd	29.00 cd	8.65	16.35
BR 6976-11-1	34.00 b	34.33 abc	28.67 cd	2.97	15.68
Hashikalmi	39.38 ab	35.33 abc	30.00 bcd	10.28	23.82
CV (%)	18.90	9.18	8.61		

Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

At 7 days drought stress, the highest harvest index was found in BRRI dhan55 (reduction percent was 14.19 and the highest reduction percent was 21.03% in BR24). At 15 days stress, the highest harvest index was found in BRRI dhan55 (the reduction percent was 20.15 and the highest reduction percent was 29.04% in BR24). The results of the study agreed with the finding of Zubaer *et al.* (2007) [16] who stated that harvest index was significantly influenced by moisture level in all rice genotypes. It might be due to the fact that water stress affects the translocation towards the grain. But the degree of reduction in HI value under lower moisture level was different in different genotypes. It was higher in Basmoti (13.15% to 36.84%) and RD2585 (12.5% to 28.12%) than that in Binadhan 4 (11.11% to 20.0%).

3.10. Biological Yield

The results of biological yield of different rice genotypes under drought condition have been shown in **Table 7**. Significant differences were found among the varieties and the treatments for biological yield. At 7 days drought stress, the highest biological yield found was 63.33 in BRRIdhan55 and 62.00 in Hashikalmi and the lowest biological yield was found 28.00 in BR24. At 15 days stress, the highest biological yield was found 60 in Hashikalmi and BRRI dhan55 and the lowest biological yield was found 24.33 in BRRI dhan43. At control, the highest biological yield was found 66.00 in BRRI dhan55followed by 63.33 in Hashikalmi and the lowest biological yield was found 39.67 in BR24.

In this study, at 7 days drought stress, the highest biological yield was found in BRRI dhan55, Hashikalmi (the reduction percent was the lowest 4.55% in BRRI dhan55, 1.59% in Hashikalmi) and the highest reduction percent was 36.84% in

Table 7. Effect of different days water stress on biological yield of different rice genotypes.

Genotypes	Biological yield (g)/plant			Reduction (%) of biological yield/plant	
	Control	7 days stress	15 days stress	7 days stress	15 days stress
BR21	53.33 ab	43.00 ab	26.00 d	19.32	51.22
BR24	39.67 b	28.00 c	27..00 d	29.42	31.94
BRRI dhan42	49.33 ab	34.67 bc	28.00 d	31.08	43.24
BRRI dhan43	48.00 ab	36.67 bc	24.33 d	25.00	50.00
BRRI dhan48	53.67 ab	43.00 ab	25.00 d	19.88	53.42
BRRI dhan55	66.00 a	63.00 a	60.00 a	4.55	9.09
OM 1490	51.67 ab	47.33 ab	40.33 bcd	8.40	21.95
BR 6976-2B-15	50.33 ab	44.33 ab	34.00 cd	12.58	32.45
BR 6976-11-1	57.00 ab	36.00 bc	35.67 bcd	36.84	38.60
Hashikalmi	63.33 a	62.00 a	60.00 a	1.59	4.76
CV (%)	13.86	18.15	5.35		

Values followed by different letter(s) indicate significantly different from each other by DMRT at 5% level.

BR 6976-11-1. At 15 days water stress, the lowest reduction percent was 9.09% in BRRI dhan55, 4.76% in Hashikalmi and the highest reduction percent was 51.22, 53.42 in BR21 and BRRI dhan48, respectively. The results have the conformity with the results of Prabhudeva (1998) [25] who reported that exposure of sunflower plants to drought stress at bud initiation stage was more detrimental to seed and biological yield.

3.11. Dry Matter Accumulation of Root

The results of dry matter accumulation of different rice genotypes under drought condition have been shown in **Figure 4**. Significant differences were found among the varieties and the treatments for this character. At 7 days drought stress, the highest dry matter accumulation (root) found was 7.59 g in Hashikalmi, the second highest dry matter accumulation found was 4.90 g in BRRI dhan55 and the lowest dry matter accumulation was 0.89 g in BRRI dhan48 which was not significantly different. At 15 days stress condition, the highest dry matter accumulation was found 5.37 in Hashikalmi, the second highest dry matter accumulation was found 4.53 g in BRRI dhan55 and the lowest was found 0.64 g in BR24. At no drought stress, the highest dry matter accumulation was found 8.19 in BRRI dhan55 followed by 8.07 g in Hashikalmi and the lowest was found 2.61g in BRRI dhan43 which was not significantly different.

The results have the informity with the results of Kage *et al.* (2004) [26], who reported that plant productivity under drought stress is strongly related to the processes of dry matter accumulation and temporal root distribution. Asch *et al.* (2005) [27] stated that drought effect assimilate accumulation between root and shoot. Asch *et al.* (2005) [27] also advocated that rice reacted to drought stress with reductions biomass production, changes in root dry matter and rooting depth and a delay in reproductive development.

3.12. Reduction Percent of Total Dry Weights/Plant

The reduction percent of total dry weights/plant (g) of different rice genotypes under drought condition has been shown in Figure 5. In this study, at 7 days drought stress, the reduction percent was the lowest 8.99% in BRRI dhan55, 12.25% in Hashikalmi and the highest reduction percent was 53.56% in BRRI dhan42. At 15 days water stress, the lowest reduction percent was 7.31% in BRRI dhan55, 5.94% in Hashikalmi and the highest reduction percent was 19.02, 17.65 in BR24 and OM 1490, respectively.

4. Conclusion

Based on the above discussion, the conclusion may be drawn as the grain yield per plant recorded was the highest at control treatment and gradually decreased with increasing water stress duration in all the genotypes. There were remarkable

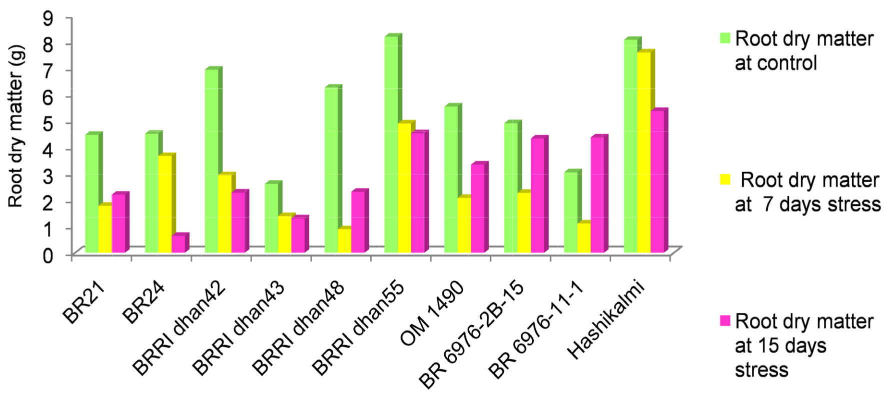

Figure 4. Effect of different durations (days) of water stress on root dry matter accumulation of different rice genotypes.

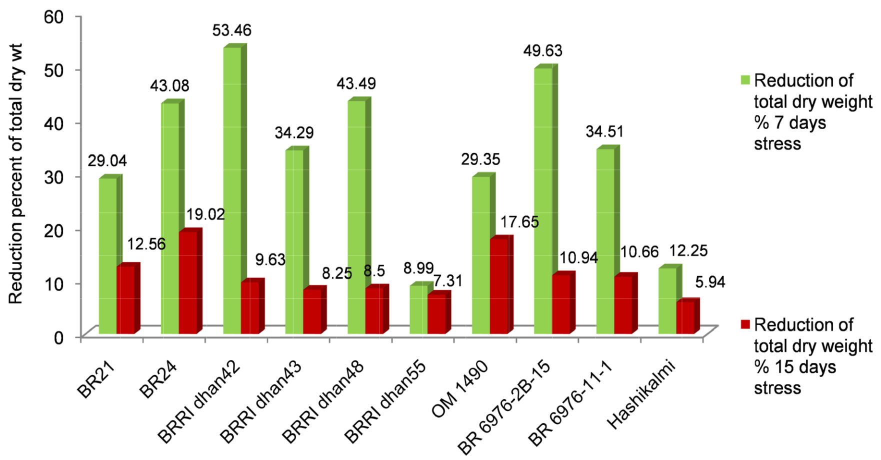

Figure 5. Effect of different durations (days) of water stress on reduction percent of total dry weights/plant (g) of different rice genotypes.

differences in grain yield and panicle length among the genotypes under water stress conditions. The largest length of panicle contains more grain that was higher weight than small length of panicle. Hashikalmi and BRRI dhan55 produced the highest number of tillers per plant and the largest panicle in all water stress conditions. However, the grain yield was less affected in BRRI dhan55 and Hashikalmi due to water stress treatment compared to other genotypes. It revealed that Hashikalmi showed significantly taller plants throughout the growing period.

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Authors' Contributions

HSJ conducted the research work, KUA designed and supervised the study and edited the manuscript, HSJ managed the literature searches and JKB collected genotypes from Bangladesh Rice Research Institute.

Conflicts of Interest

The authors declare no conflicts of interest.

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