Agricultural Sciences, 2023, 14, 509-521
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Study on the Yield and Yield Contributing Characters of Aus Rice Varieties in Various Soil Moisture Levels

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How to cite this paper: Jasmine, H.S., Ahamed, K.U. and Biswas, J.K. (2023) Study on the Yield and Yield Contributing Characters of Aus Rice Varieties in Various Soil Moisture Levels. *Agricultural Sciences*, **14**, 509-521.
https://doi.org/10.4236/as.2023.144034

Received: August 25, 2022
Accepted: April 18, 2023
Published: April 21, 2023

Abstract

The experiment was conducted at the Plant Physiology Laboratory (central laboratory) and Shade house of Field Laboratory of Agricultural Botany Department, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh under a field experiment was also carried out on yield contributing parameters. There were three rice genotypes namely BRRI dhan55 (V_1), BR6976-2B-15 (V_2) and tolerant check Hashikalmi (V_3) and seven water stress were imposed as treatments. The treatments were arranged for 0 days of water stress (control) irrigated continuously throughout the experimental period (T_0). When the seedlings were 20 days old, water deficit was imposed for seven days (T_1), when the seedlings were 35 days old, water deficit was imposed for seven days (T_2), when the seedlings were 55 days old, water deficit was imposed for seven days (T_3), when the seedlings were 75 days old, water deficit was imposed for seven days (T_4). When the seedlings were 95 days old, water deficit was imposed for seven days (T_5) and when the seedlings were 115 days old, water deficit was imposed for seven days (T_6). BRRI dhan55 and Hashikalmi produced the highest tillers, grains, number of spikelets and yield. The grain sterility percentage is much higher in BR6976-2B-15 due to water stress treatment compared to other genotypes. Grain yield was the highest in BRRI dhan55 and Hashikalmi and gradually decreased with increased water stress treatment compared to other genotypes. Decreased grain yield per plant under water stress treatment reduction of tillers, panicle, filled grains, root, shoot, spikelet/panicle, panicle dry matter content, and with other causes. The harvest index was decreased due to water stress conditions in all the genotypes while less affected in BRRI dhan55 and Hashikalmi.

Keywords

Water Stress, Rice Genotypes, Tiller, Spikelet

1. Introduction

Water deficit is a major problem of growing rice, especially in low rainfall season [1]. According to the IRRI [2], water deficit is one of the major constraints to rice (*Oryza sativa* L.). Rice is more susceptible to drought than any other crops. Drought is one of the biggest enemies of Bangladeshi farmers. In 1999, Bangladesh suffered the longest drought in 50 years, with more than four months without rain and in 2010 the country recorded its lowest rainfall since 1995. It is estimated that the world needs to produce 40% more rice to feed the population by 2025 [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 rain fed ecosystem reported by [4]. [5] found that drought limits productivity and affects both quality and quantity of the yield. [6] found that in the case of rice shoots accumulate proline in water stress conditions. [7] observed that metabolic changes during drought affect reduction of nutrients. [1] stated that drought affected the growth and reduced shoot, root weights, lengths and also physiological processes. Severe water stress may result in the arrest of photosynthesis, disturbance of metabolism and finally the death of plants [8]. 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 [9]. [10] found that a significant decrease in panicle number and filled grain per plant, and an increase in the number of unfilled grain were the main causes of sterility percentage increase due to drought treatment [10]. In agriculture, mild to severe drought has been one of the major production limiting factors. The total rainfall in three months is very irregular and often inadequate which fails to meet the evapotranspiration demand. Most of the traditional aus varieties possess quite a good grade of resistance to water stress. That is why the government is thinking about growing crops in more fields in this season. According to [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. Agricultural technology related to crop production has to be developed according to specific location. Considering this, the study was undertaken to achieve the following objectives yield contributing characters of aus rice genotypes under water deficit conditions.

2. Materials and Methods

The pot experiment was conducted at the Plant Physiology Laboratory (central laboratory) and also Agricultural research field of Agricultural Botany Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh under polythene Shade house condition in controlling the intrusion of rainfall during the period from March to July 2014.

2.1. BRRI Materials

BRRI dhan55 (V_1), BR6976-2B-15 (V_2) and tolerant check Hashikalmi (V_3) were collected from BRRI (Bangladesh Rice Research Institute).

2.2. Methods, Design and Treatment

Seven drought conditions were used as treatments that started from 20 days of seedling age. The pot experiment was done with Randomized Complete Block Design (RCBD). There were seven treatments of water deficiency, three replications, and three genotypes (63 pots) were used. Seven treatments were:

T_0 = Throughout the experimental period continuously irrigated (control).

T_1 = When the seedlings were 20 days old water deficit imposed for 7 days,

T_2 =When the seedlings were 35 days old water deficit imposed for 7 days,

T_3 = When the seedlings were 55 days old water deficit imposed for 7 days,

T_4 = When the seedlings were 75 days old water deficit imposed for 7 days,

T_5 = When the seedlings were 95 days old water deficit imposed for 7 days,

T_6 = When the seedlings were 115 days old water deficit imposed for 7 days.

2.3. Seed Cured and Spreading

Uniform size and shape of seeds were cured with Bavistin (5 g in 1/2 liter of water) for 20 minutes. Cured seeds were spreading in the Petridis with water. In March, 2014 sprouted seeds were scattered in pots.

2.4. Pot Filled up and Fertilizer Use

Pots were filled up with 10 kg sandy loam soil. Earthen pots were used of 38 cm × 25 cm in size, sandy and sandy loam. The soil was fertilized 160-150-150 kg urea, triple super phosphate (TSP) and muriate of potash (MP) per hectare, respectively [11].

2.5. General Observation of the Experiment

Three uniform and vigorous seedlings were permitted to grow in the pots after seedling establishment. For confirming normal growth, the germinated seeds were usually irrigated when the seedlings were 20, 35, 55, 75, 95 and 115 days old water deficit was forced for seven days.

2.6. Detailed Procedures of Recording Data

Data were collected about yield and yield attributing character at maturity stage.

Dry matter

Total dry matter (**Figure 1**) (root, shoot, panicle etc.) was measured after oven drying for 72 hours at 72˚C.

Weight of 1000-grain

After sun and oven drying thousand cleaned grains weight (g) was calculated with an electronic weighing scale.

Filled and unfilled grain

Filled and unfilled grain was counted up.

Spikelet sterility percentage

Spikelet sterility percentage was recorded from the main stem panicle. The calculation is given below-

$$\text{Spikelet sterility}(\%) = \frac{\text{Empty spikelet/panicle}}{\text{Total spikelet/panicle}} \times 100$$

Harvest index (HI)

HI is the percentage of grain yield and biological yield [12]. HI was given below

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

2.7. Data Analysis

All the data were analyzed and the means were separated by DMRT at 5% level of significance using MSTAT-C [13].

3. Results and Discussions

Objectives were fulfilled by assessing the effects of different duration of water deficit on yield contributing characters of different genotypes. The results of this experiment with necessary discussion are in this chapter.

Figure 1. Total dry matter (root, shoot, panicle, etc.) of three rice genotypes.

3.1. Leaf Dry Mass

Leaf dry weight was presented in **Tables 1-3**. There was 0.26 g in V_1 followed by 0.25 in V_3 and the lowest was 0.23 in V_2 in varietal effect. Leaf dry weight under different treatments varied significantly and ranged from 0.17 in T_1 and T_5 to 0.21 in T_0. In the interaction effect of variety and treatment the highest leaf dry weight (0.26 g) was recorded in V_1T_0 and the lowest weight (0.1267 g) was recorded in V_2T_1. Water stress significantly decreased plant total dry mass, but the proportion of changes differed among root, stem, and leaf, whereas leaf dry mass decreased [14].

3.2. 1000-Grains Weight

Weight of thousand grains (g) was shown in **Tables 1-3**. The highest weight of thousand grains was 16 g recorded in V_1 followed by V_3 and the lowest weight of thousand grains was 11.67 g in V_2 in varietal effect. The highest weight of thousand grains 22.00 (T_0) and the lowest weight 14.76 g in T_6 In combination effect (variety and treatment) thousand grains 22.66 g in V_3T_5 and 11.67 g in V_1T_3.

Weight of a thousand grains was different which depends on the individual grain weight. In this study, BRRI dhan55 and Hashikalmi possess the highest weight of thousand grains.

Table 1. Varietal effect of leaf dry weight (g) and weight of 1000-grains (g).

Variety	Leaf dry weight (g)	Weight of 1000-grains (g)
V_1 (BRRI dhan55)	0.26 a	16.00 a
V_2 (BR 6976-2B-15)	0.23 b	11.67 c
V_3 (Hashikalmi)	0.25 ab	15.86 b
CV (%)	0.19	9.31

Values followed by some letter(s) did not differ significantly at 5% level of probability.

Table 2. Treatment effect of leaf dry weight (g) and weight of 1000-grains (g).

Drought treatment	Leaf dry weight	Weight of 1000-grains (g)
T_0 (control)	0.21 a	22.00 a
T_1 (15 to 21 days)	0.17 d	16.79 ab
T_2 (35 to 41 days)	0.20 ab	16.32 ab
T_3 (55 to 61 days)	0.19 b	19.17 a
T_4 (75 to 81 days)	0.19 b	17.79 ab
T_5 (95 to 101 days)	0.17 d	16.44 ab
T_6 (115 to 121 days)	0.18 c	14.76 d
CV (%)	0.19	9.31

Values followed by some letter(s) did not differ significantly at 5% level of probability.

Table 3. Interaction effect of variety and treatments on leaf dry weight (g) and weight of 1000-grains (g).

Interaction		leaf dry weight (g)	1000-grains wt (g)
V_1	T_0	0.26 a	22.66 a
	T_1	0.2033 ab	18.50 abcde
	T_2	0.1967 ab	14.26 def
	T_3	0.2100 ab	11.67 f
	T_4	0.1700 ab	22.00 ab
	T_5	0.1433 ab	14.78 cdef
	T_6	0.1600 ab	16.79 abcdef
V_2	T_0	0.2567 a	21.45 abc
	T_1	0.1267 b	16.32 abcdef
	T_2	0.1967 ab	19.17 abcd
	T_3	0.1700 ab	17.79 abcdef
	T_4	0.2733 a	16.44 abcdef
	T_5	0.1533 ab	16.76 abcde
	T_6	0.2000 ab	17.41 abcdef
V_3	T_0	0.2033 ab	22.66 a
	T_1	0.1700 ab	22.00 ab
	T_2	0.2067 ab	18.62 abcde
	T_3	0.2167 ab	21.00 abc
	T_4	0.1533 ab	21.33 ab
	T_5	0.2100 ab	16.67 abcdef
	T_6	0.1867 ab	15.45 bcdef
CV (%)		0.19	9.31

Values followed by some letter(s) did not differ significantly at 5% level of probability.

Considering the treatment effect the highest weight in T_0 and in combination the height weight thousand grains was in V_1T_0. Under drought conditions BR 6976-2B-15 was mostly source limited during the grain filling stage as a result, grain weight decreased.

The result has infirmity with the results of [15] that showed that weight of 1000 grains was reduced depending on soil moisture levels. [16] showed that water stress after flowering decreased the individual grain weight. [17] advocated that water stress reduced grain weight.

3.3. Number of Spikelets/Panicle

Total number of spikelets/panicles was shown in **Tables 4-6**. Total number of spikelets was 176.7 in V_1 followed by V_3 (169.0) and the lowest found 158 (V_2).

Number of spikelets was highest 158 in T_0 and was lowest 139.6 in T_1. In combination effect the spikelet 200 in V_0T_1 and 120 in V_3T_3.

When photosynthesis became lower, all the spikelets did not get sufficient assimilates, as a result decreased the number of spikelets per panicle. The spikelets recorded highest in BRRI dhan55 (V_1). The spikelets found much lower in BR 6976-2B-15. Due to drought stress, the number of spikelets was decreased. After drought conditions the tolerant genotype would quickly recover their biomass, leaves and take no longer time to recover and then develop new growth. The less tolerant genotypes would lose their biomass, leaves and take much longer time to recover. Decreased spikelet's might be due to inhibition of stomatal conductance, translocation of assimilate to the grains.

3.4. Number of Empty Grains

Number of empty grains/panicles was shown in **Tables 4-6**. The empty grains/panicle 11 in V_3 followed by 10.00 in V_2 and the lowest unfilled grain 9.58 inV_1. The highest unfilled grain was 12.38 in T_0 and the lowest 10.38 in T_1. The highest unfilled grain was found at 18.88 in V_3T_0 and the lowest at 10.27 in V_2T_3.

Table 4. Varietal effects on the total number of spikelet's/panicle, number of unfilled grains per panicle and reduction percent of filled grains.

Variety	Total number of spikelets/panicle	No of empty grains/panicle	Reduction (%) of filled grains
V_1 (BRRI dhan55)	176.7 a	9.58 c	5.42
V_2 (BR 6976-2B-15)	158.0 c	10.00 b	6.33
V_3 (Hashikalmi)	169.0 b	11.00 a	6.51
CV (%)	4.18	11	

Values followed by some letter(s) did not differ significantly at 5% level of probability.

Table 5. Treatment effects on the total number of spikelet's/panicle, number and reduction % filled grains.

Drought treatment	Total number of spikelets/panicle	No of empty grains/panicle	Reduction (%) of filled grains/panicle
T_0 (Control)	158.0 a	12.38 a	7.84
T_1 (15 to 21 days)	139.6 d	10.84 c	7.77
T_2 (35 to 41 days)	144.4 cd	10.76 c	7.45
T_3 (55 to 61 days)	149.7 bc	10.81 c	7.22
T_4 (75 to 81 days)	154.1 ab	10.38 c	6.74
T_5 (95 to 101 days)	147.4 bc	11.23 b	7.62
T_6 (115 to 121 days)	154.8 ab	12.36 a	8.00
CV (%)	4.18	11	

Values followed by some letter(s) did not differ significantly at 5% level of probability.

Table 6. Interaction effect of variety and treatments on the total number of spikelets/panicle, unfilled grains/panicle and the reduction % filled grains/panicle.

Interaction		Total number of spikelets/panicle	No. of empty grains/panicle	Reduction (%) of filled grains
V_1	T_0	200.0 a	15.45 ab	7.73
	T_1	184.0 b	11.08 d	6.02
	T_2	147.4 fgh	11.00 d	7.46
	T_3	169.0 cd	11.68 cd	6.91
	T_4	139.6 h	10.84 d	7.77
	T_5	144.4 gh	11.23 cd	7.78
	T_6	149.7 fgh	10.81 d	7.22
V_2	T_0	154.1 efg	15.19 ab	9.86
	T_1	161.2 de	12.38 bc	7.68
	T_2	154.8 efg	10.76 d	6.95
	T_3	129.4 i	10.27 d	7.94
	T_4	158.0 ef	11.00 cd	6.96
	T_5	137.1 h	11.17 cd	8.15
	T_6	124.8 i	12.36 bc	9.90
V_3	T_0	182.0 b	18.88 a	10.37
	T_1	178.3 bc	13.07 c	7.33
	T_2	178.3 bc	11.47 cd	6.43
	T_3	120.7 i	12.30 bc	10.19
	T_4	121.0 i	13.27 abc	10.97
	T_5	122.7 i	10.66 d	8.69
	T_6	121.0 i	11.95 cd	9.88
CV (%)		4.18	14.50	

Values followed by some letter(s) did not differ significantly at 5% level of probability.

In this study, it was found that drought stress greatly reduced filled grain and increased the number of unfilled grain. Due to water stress, the current stomatal conductance decreased, as a result the current photosynthesis became lower, insufficient assimilates production was seen and its distribution to grains was insufficient, all the spikelets did not get sufficient assimilates which resulted increased the number of empty grains and decreased the number of filled grains ultimately causes yield losses [15]. The results have the similarity with the results of [16] observed that after flowering increased the number of empty spikelets per panicle under water stress. Before panicle initiation water stress reduces potential spike number and decreases translocation of assimilates to the grains, which results low in grain weight and increases empty grains [9]. [15] stated that under lower soil moisture levels reduced grain yield due to inhibition of photosynthesis and less translocation of assimilates towards grain due to soil moisture stress.

3.5. Reduction Percentage of Filled Grains

Reduction percent of filled grains is in **Tables 4-6**. The reduction percent of filled grains found 6.51% in V_3 followed by 6.33% in V_2 and 5.42 in V_1. The highest reduction percent filled grain was 8.00 in T_6 and the lowest was 6.74 in T_4. In combination effect the reduction percent of filled grain 10.97% in V_3T_4 and the lowest reduction percent filled grain 6.02% in V_1T_1.

In this study, it was found that the lowest reduction percent of filled grains was 5.42 in BRRI dhan55 (V_1) and the highest reduction of filled grain was found in Hashikalmi (V_3) and in case of treatment effect the highest reduction percent of filled grains was 7.84, 8.00 in T_0, T_6 respectively.

Therefore it is suggested that sterility percentage increased with increasing drought duration and number of unfilled grains, decrease in filled grains per plant, tiller number, panicle number, leaf number, plant height. A significant decrease in panicle number and filled grain per plant, increased in number of unfilled grain were the main causes of sterility percentage increase due to drought treatment. These results conform with the results of [10], who observed increased sterility in rice under water stress conditions. This result also agrees with [16], who observed that water stress after flowering, increased the number of empty spikelets per panicle. Increased unfilled grains per panicle under lower soil moisture level occurs which decreases translocation of assimilates to the grains, ultimately which results in low gain weight and increases empty grains [9].

3.6. Total Dry Weight (Root, Shoot and Panicle)/Plant at Harvest

The data on total dry weight per plant (g) was presented in **Tables 7-9**. In varietal effect the highest dry weight was 64.79 g recorded in V_3 followed by 57.08 g in V_1 and the lowest weight was 44.82 g in V_2. In treatment effect the highest total dry weight per plant was 58.05 recorded in T_0 and the lowest was 34.79 in T_3.

Table 7. Varietal effect on total dry weight/plant, harvest index (%) and yield/plant.

Variety	Total dry weight/plant (g)	Harvest index (%)	Yield/plant (g)
V_1 (BRRI dhan55)	57.08 b	0.401 a	23.80 a
V_2 (BR 6976-2B-15)	44.82 c	0.325 b	21.33 b
V_3 (Hashikalmi)	64.79 a	0.329 b	21.77 b
CV (%)	10.52	19.88	14.50

Values followed by some letter(s) did not differ significantly at 5% level of probability.

Table 8. Treatment effect on total dry weight per plant, harvest index (%) and yield/plant.

Drought treatment	Total dry weight/plant (g)	Harvest index (%)	Yield/plant (g)
T_0 (Control)	58.05 a	0.40 a	22.08 a
T_1 (15 to 21 days)	53.97 abc	0.32 c	14.44 d
T_2 (35 to 41 days)	44.82 bc	0.33 c	15.13 cd
T_3 (55 to 61 days)	34.79 c	0.32 bc	16.33 cd
T_4 (75 to 81 days)	57.08 ab	0.34 bc	17.04 bcd
T_5 (95 to 101 days)	47.79 abc	0.34 b	17.91 bc
T_6 (115 to 121 days)	58.79 a	0.36 ab	21.00 ab
CV (%)	10.52	19.88	14.50

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

Table 9. Interaction effects of variety and treatment on total dry weight per plant, harvest index (%) and yield/plant.

Interaction		Total dry weight/plant (g)	Harvest index	Yield/plant (g)
V_1	T_0	65.05 a	0.46 a	23.80 a
	T_1	44.82 abc	0.36 cdefg	15.50 def
	T_2	34.79 bc	0.35 defg	19.11 abcde
	T_3	41.66 abc	0.39 bcd	19.40 abcde
	T_4	47.79 abc	0.42 ab	18.11 bcdef
	T_5	57.08 ab	0.41 abc	21.00 abc
	T_6	64.79 a	0.42 ab	22.04 a
V_2	T_0	65.42 a	0.29 gh	22.70 a
	T_1	35.43 bc	0.31 fgh	15.13 ef
	T_2	44.36 abc	0.34 defgh	14.44 ef
	T_3	37.04 bc	0.32 efgh	12.20 g
	T_4	28.66 d	0.31 fgh	16.33 cdef
	T_5	35.74 bc	0.34 defgh	21.77 abc
	T_6	52.33 ab	0.30 gh	21.66 abc
V_3	T_0	65.05 a	0.32 efgh	22.78 a
	T_1	36.95 bc	0.36 bcdef	17.33 bcdef
	T_2	51.66 ab	0.23 i	18.67 abcde
	T_3	53.97 ab	0.32 efgh	19.03 abcde
	T_4	54.03 ab	0.35 defg	17.55 cd
	T_5	47.86 abc	0.28 h	18.65 abcde
	T_6	65.42 a	0.37 bcde	20.33 ab
CV (%)		12.25	19.88	14.50

Values followed by some letter(s) did not differ significantly at 5% level of probability.

In combination effect the highest found 65.05 in V_1T_0 and the lowest found 28.66 in V_2T_4.

Due to drought stress conditions root, shoot, leaf and panicle dry weight decreased, as a result the total dry matter became lower. In this study, the highest total dry weight per plant was in V_1 and V_2 and the lowest weight was in V_2. This might be due to reduction in tiller number, panicle number and filled grain per plant, plant height, leaf area etc. All of this ultimately affected the grain yield under water stress treatment. The results also agree with the results of [14] who stated that drought stress significantly decreased plant total dry mass, but the proportion of changes differed among root, stem, and leaf, whereas leaf dry mass ratio was decreased. [17] stated that water stress reduced grain weight. [9] observed that 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. [15] stated that reduced grain yield under lower soil moisture levels might be due to inhibition of photosynthesis and less translocation of assimilates towards grain due to soil moisture stress. [18] advocated that drought affect rain fed rice systems. Root characteristics such as root length density, root thickness, changes in root dry matter.

3.7. Harvest Index (HI)

The results of harvest index (%) were shown in **Tables 7-9**. Significant differences found among the varieties and the treatments for harvest index. Harvest index 0.40 was recorded in V_1 followed by 0.329 in V_3 and the lowest harvest index was found as 0.325 in V_2. In treatment effect the highest harvest index 0.40 was recorded in T_0 and 0.32 in the T_1 treatment. Considering the combination effect, harvest index 0.46 was recorded in V_1T_0 and 28.66 in V_3T_3.

In this study, the highest harvest index found was 0.40 in V_1 and the lowest harvest index in V_2. The results have the similarity with the results that harvest index was significantly influenced by moisture level in all rice genotypes [15]. Where water shortages occurred, harvest index was more conservative than biomass accumulation; harvest index was reduced only when water deficits severely decreased grain-yield [19].

3.8. Grain Yield per Plant

Yield/plant (g) was shown in **Tables 7-9**. Yield/plant 23.80 g was recorded in V_1 followed by 21.77 g in V_3 and 21.33 g in V_2. Yield/plant 22.08 g was recorded in T_0 control and the lowest yield/plant found as 14.44 g in the treatment T_6. In combination effect (variety and drought treatment) the highest yield/plant was found as 23.80 in V_1T_0 and the lowest yield/plant found 12.20 g in V_2T_3.

In this study, the highest yield/plant in BRRI dhan55 followed by tolerant check Hashikalmi and the lowest yield/plant in BR 6976-2B-15. The lowest grain yield per plant was recorded in V_2 genotypes. The results also have the similarity with the results of [15] who stated that reduced grain yield under lower soil moisture levels. Yield parameters were decreased with the increase of water stress in different growth stages of the crop. As a result of drought, the stomatal conductance and gas exchange were decreased. All of this ultimately affected the grain yield under water stress treatment. The yield components like grain number and grain size were decreased in wheat [20]. Water deficit during vegetative, flowering and grain filling stages reduced grain yield.

4. Conclusion

Hashikalmi and BRRI dhan55 produced the highest number of tillers per plant. It revealed that Hashikalmi showed significantly taller plants throughout the growing period. Hashikalmi produced the largest panicle in all water stress conditions. The largest length of panicle contains more grain which is higher weight than small length of panicle. The grain yield per plant recorded was the highest at control treatment and gradually decreased with increasing water stress duration in the genotypes. But the grain yield was less affected due to water stress treatment compared to others.

Acknowledgements

The authors are grateful to acknowledge SAURES and HEQEP (Higher Education Quality Enhancement Project) for providing financial support to conduct the research work.

Authors' Contributions

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

Conflicts of Interest

The authors have declared that no competing interests exist.

References

[1] Usman, M., Raheem, Z.F., Ahsan, T., Iqbal, A., Sarfaraz, Z.N. and Haq, Z. (2013) Morphological, Physiological and Biochemical Attributes as Indicators for Drought Tolerance in Rice (*Oryza sativa* L.). *European Journal of Biological Sciences*, **5**, 23-28.

[2] International Rice Research Institute (2005) Annual Report for 2004. International Rice Research Institute, Los Banos.

[3] Food and Agriculture Organization (2002) Crops and Drops Making the Best Use of Water for Agriculture. Food and Agriculture Organization of the United Nations, Rome.

[4] Zeigler, R.S. and Puckridge, D.W. (1995) Improving Sustainable Productivity in Rice Based Rainfed Lowland Systems of South and Southeast Asia. *GeoJournal*, **35**, 307-324. https://doi.org/10.1007/BF00989138

[5] Boyer, J.S. (1982) Plant Productivity and Environment. *Science*, **218**, 443-445.

https://doi.org/10.1126/science.218.4571.443

[6] Peleg, Z. and Blumwald, E. (2011) Hormone Balance and Abiotic Stress Tolerance in Crop Plants. *Current Opinion in Plant Biology*, **14**, 290-295. https://doi.org/10.1016/j.pbi.2011.02.001

[7] Shao, H.B., Chu, L.Y., Shao, M.A., Jaleel, C.A. and Hong-Mei, M. (2008) Higher Plant Antioxidants and Redox Signaling under Environmental Stresses. *Comptes Rendus Biologies*, **331**, 433-441. https://doi.org/10.1016/j.crvi.2008.03.011

[8] Jaleel, C.A., Manivannan, P., Murali, P.V., Gomathinayagam, M. and Panneerselvam, R. (2008) Antioxidant potential and Indole Alkaloid Profile Variations with Water Deficits along Different Parts of Two Varieties of *Catharanthus roseus*. *Colloids and Surfaces B: Biointerfaces*, **62**, 312-318. https://doi.org/10.1016/j.colsurfb.2007.10.013

[9] Rice Research and Development Institute (1999) Effect of Water Deficit. Department of Agriculture, Ibbagamuwa.

[10] O'Toole, J.C. and Moya, T.B. (1981) Water Deficit and Yield in Upland Rice. *Field Crops Research*, **4**, 247-259. https://doi.org/10.1016/0378-4290(81)90076-9

[11] Bangladesh Rice Research Institute (2008) Annual Internal Review for 2007-2008. Bangladesh Rice Research Institute, Gazipur.

[12] Donald, C.M. (1963) Competition among Crops and Pasture Plants. *Advances in Agronom*, **15**, 11-18. https://doi.org/10.1016/S0065-2113(08)60397-1

[13] Russell, D.F. (1986) MSTAT-C Package Programme. Crop and Soil Science Department, Michigan University, Ann Arbor.

[14] Liu, F. and Stütze, H. (2004) Biomass Partitioning, Specific Leaf Area, and Water Use Efficiency of Vegetable Amaranth (Amaranthus spp.) in Response to Drought *Scientia Horticulturae*, **102**, 15-27. https://doi.org/10.1016/j.scienta.2003.11.014

[15] Zubaer, M.A., Chowdhury, A.K.M.M.B., Islam, M.Z., Ahmed, T. and Hasan, M.A. (2007) Effects of Water Stress on Growth and Yield Attributes of Aman Rice Genotypes. *International Journal of Sustainable Crop Production*, **2**, 25-30.

[16] Begum, F.A. (1992) Effect of Different Levels of Light and Drought Stress on Individual Spikelet Filling in Rice. Ph.D. Thesis, The University of the Philippines, Los Banos.

[17] Tsuda, M. and Takami, S. (1991) Changing Heading Date and Panicle Weight in Rice Subjected to Water Stress during the Early Stage of Panicle Development. *Japanese Journal of Crop Science*, **60**, 241-264. https://doi.org/10.1626/jcs.60.241

[18] Asch, F., Dingkuhn, M., Sow, A. and Audebert, A. (2005) Drought-Induced Changes in Rooting Patterns and Assimilate Partitioning between Root and Shoot in Upland Rice. *Field Crops Research*, **93**, 223-236. https://doi.org/10.1016/j.fcr.2004.10.002

[19] Muchow, R.C. (1989) Comparative Productivity of Maize, Sorghum and Pearl Millet in a Semi-Arid Tropical Environment II. Effect of Water Deficits. *Field Crops Research*, **20**, 207-219. https://doi.org/10.1016/0378-4290(89)90080-4

[20] Edward, D. and Wright, D. (2008) The Effects of Winter Waterlogging and Summer Drought on the Growth and Yield of Winter Wheat (*Triticum aestivum* L.). *European Journal of Agronomy*, **28**, 234-244. https://doi.org/10.1016/j.eja.2007.07.010