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M.T. ISLAM

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INDIVIDUAL AND COMBINED EFFECTS OF HIGH TEMPERATURE AND DROUGHT ON YIELD OF BORO RICE VARIETIES

M.T. ISLAM

Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202, Bangladesh.

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ABSTRACT

Islam MT (2023) Individual and combined effects of high temperature and drought on yield of boro rice varieties. *Int. J. Sustain. Crop Prod.* 18(1), 05-09.

Climate is changing and air temperature is rising due to increasing concentration of CO_2 and other atmospheric greenhouse gases. The flowering stage of rice is important for high temperatures. An experiment was carried out at Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh during December 2021 to May 2022 with three Boro rice varieties *viz.* Binadhan-8, Binadhan-10 and Binadhan-14 to find out proper soil moisture level at flowering stage to reduce high temperature effect. The rice varieties were grown in pots in ambient temperature. During flowering stage 50% plants were kept in plant growth chamber at 38°C for 24 hrs under different soil moisture levels (standing water of 2 inches, 100% FC and 80% FC) in pot soil. Then those plants along with the rest 50% plants were allowed to complete the maturity under sufficient soil moisture at ambient temperature. The experiment was conducted in RCBD with three replications. High temperature (36°C) increased the number of unfilled grains panicle^{-1} and decreased yield plant^{-1}. The highest yield was found in Binadhan-8 followed by Binadhan-10 and Binadhan-14. Combined effect of high temperature and soil moisture showed that yield was significantly decreased with high temperature and soil moisture of 80% FC and 60% FC. Binadhan-8 produced the highest yield plant^{-1} with 100% FC or standing water of 2 inches and the lowest in Binadhan-14 with 60% FC. Yield and yield attributes of all the rice varieties were mainly affected by lower soil moisture rather than temperature. Binadhan-14 showed lower yield at 60 and 80% FC. Yield and yield contributing characters of the rice varieties were affected with 80 and 60% FC but not with 100% FC or standing water of 2 inches. So, maintaining soil moisture at 100% field capacity or standing water of 2 inches can reduce the high-temperature effect of the rice varieties at flowering stage.

***Key words**: high temperature, soil moisture, yield, rice*

INTRODUCTION

Changing climate rises air temperature due to increasing concentration of CO_2 and other atmospheric greenhouse gases. The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the crop varieties by affecting their phenology, physiology, and yield components (Rawson 1992; Kumar 2020; Moonmoon *et al*. 2022a, Islam 2022a). The economic yield of a plant depends mainly on leaf photosynthesis. Stomata can function as valves to control the balance of water loss and carbon gain in plants (Huang *et al*. 2021). The climate changes that are currently occurring make it necessary to understand the effects of temperature on photosynthesis. Models based on large-scale observations indicate that, in the absence of agronomic adaptation, the decrease in crop yields can reach 17% for each 1°C increase in the temperature of the growing season (Yamori *et al*. 2014). Climate model predicts 33% rice yield decrease in 2100 (Karim *et al*. 2012). Boro rice is transplanted in JanuaryFebruary and usually faces high temperature (36-39°C) at its reproductive stage in April-May (Islam 2021a). Flowering stage of rice is very important for high temperature (Islam 2011 and Islam 2013). High temperature may cause drying of pollen and stigma and ceasing pollen tube development unsuitable for fertilization. As a result, unfilled grains are produced. High soil moisture can reduce high temperature effect of boro rice at flowering stage (Islam 2021b; Islam 2022a). Rice grain dry weight increased from fertilization to 18-24 days and water stress decreased the rate of accumulation and finally produced decreased grain weight (Islam and Gretzmacher, 2001; Islam 2010; Hafiz *et al*. 2015; Moonmoon*et al*. 2020b; Moonmoon *et al*. 2020c). The yield of rice is an integrated result of various processes including canopy photosynthesis, conversion of assimilates to biomass, and partitioning of assimilates to grains (Jeng *et al*. 2006). Drought stress affects plant growth and development, and ultimately reduces grain yield of rice (Islam *et al*. 1994b; Islam *et al*. 2005a; Zohora *et al*. 2016; Moonmoon *et al*. 2017; Moonmoon *et al*. 2020a; Moonmoon *et al*. 2022b). Response of rice yield to drought varies with growth stage being most sensitive at booting followed by flowering and or grain filling stage (Islam *et al*. 1994a). The early reproductive growth period, encompassing tetrad-formation stage of miosis (i.e., about 10-15 d prior to heading), was found to be the most sensitive and critical to water deficit resulting in up to 59% grain sterility that caused similar magnitude of yield reduction (Singh *et al*. 2010). As the grain formation progressed further, the early period of grain-filling was found to be more vulnerable to water stress than the late-milk stages (Singh *et al*. 2010). For stress condition, reproductive stages are critical than vegetative stages and booting to early grain filling stages are more critical (Rahman *et al*. 2002; Islam *et al*. 2005b; Moonmoon and Islam, 2017; Islam and Arefin, 2022). So, the experiment was conducted to find out proper soil moisture level at flowering stage of Boro rice varieties to reduce high temperature effect.

Corresponding author & address: Dr. Md. Tariqul Islam, E-mail: islamtariqul05@yahoo.com
Md. Tariqul Islam

MATERIALS AND METHODS

An experiment was conducted with three rice genotypes *viz.* Binadhan-8, Binadhan10 and Binadhan-14 at pot yard and in plant growth chamber of Bangladesh Institute of Nuclear Agriculture (BINA) during December, 2021 to May, 2022. Thesoils of the experiment were collected from the field of BINA Farm. The top soil was non-calcareous Dark Grey Floodplain with loamy texture belonging to the AEZ Old Brahmaputra Floodplain. The collected soil was pulverized, inert materials, visible insect pest and plant propagules were removed. Pots are filled with top soils. The soil moisture stresses were calculated based on field capacity (FC). Gravimetric Method determined FC. Each pot contained 8 kg soil. All soils pots were fertilized with urea, TSP, MP and gypsum @ 2.08, 0.32, 0.41 and 0.21g pot^{-1} corresponding 260, 125, 180 and 80 kg ha^{-1} Urea, TSP, MoP and Gypsum, respectively. All TSP, MoP, Gypsum and one-third of the urea were applied as basal dose. The remaining two-thirds of the urea were applied in two equal splits in each pot at 25 and 45 days after transplanting (DAT). One seedling was transplanted in a puddled pot. For gap filling there were extra seedlings preserved. All necessary intercultural operations, mainly weeding, and irrigation was done as and when necessary. The experiment was set in a two factorial RCBD with three replications. The first factor was rice genotypes and the second factor was irrigations: standing water of 2 inches, 100% FC, 80% FC and in pot soil. Plants were grown in ambient temperature and during flowering stage those were kept in plant growth chamber at 38^{o}C for 24 hours under different soil moisture levels (standing water of 2 inches, 100% FC, 80% FC). Then all the plants were allowed to complete the maturity in ambient temperature. At maturity, data on yield attributes and yield were recorded. Data were analyzed statistically and DMRT was used to compare the means.

RESULTS AND DISCUSSION

Plant height, number of panicle plant^{-1}, number of filled grain panicle^{-1} and 1000-grain weight were not significantly affected by the high temperature (Table 1). High temperature (36^{o}C) increased the number of unfilled grains panicle^{-1} and decreased yield plant^{-1}. In respect of soil moisture levels, yield and yield contributing characters were affected with 80 and 60% FC but not with 100% FC or standing water of 2 inches (Table 2). In case of rice varieties, the longest plant was found in Binadhan-10 (Table 3). Number of panicle plant^{-1} was not significant among the varieties. The highest panicle length was found in Binadhan-8 and the lowest in Binadhan-14. The highest number of filled grain plant^{-1} was found in Binadhan-8 and the lowest was found in Binadhan-10 whereas unfilled grains panicle^{-1} was lower in Binadhan-8. Thousand grain weights were higher in Binadhan-8. The highest yield was found in Binadhan-8 followed by Binadhan-10 and Binadhan-14. Combined effect of high temperature and soil moisture showed that yield was significantly decreased with high temperature and soil moisture of 80% FC and 60% FC (Table 4). Binadhan-8 produced the highest yield plant^{-1} with 100% FC or standing water of 2 inches and the lowest in Binadhan-14 with 60% FC (Table 5). High temperature and ambient temperature had similar effect on all the varieties (Table 6). Binadhan-14 was affected more mainly due to lower soil moisture levels (60 and 80% FC) instead of temperature levels (Table 7). Yield and yield contributing characters of the rice varieties were affected with 80 and 60% FC but not with 100% FC or standing water of 2 inches. So, maintaining soil moisture at 100% field capacity or standing water of 2 inches can reduce the high-temperature effect of Boro rice varieties at flowering stage.The results are in conformity with many researchers (Islam 2001; Islam *et al*. 2005c; Islam *et al*. 2012; Hazra *et al*. 2016; Islam 2022b).

Based on these results, it may be concluded that yield and yield contributing characters of the rice varieties were affected with 80 and 60% FC but not with 100% FC or standing water of 2 inches. So, maintaining soil moisture at 100% field capacity or standing water of 2 inches can reduce the high-temperature effect of Boro rice varieties at flowering stage.

Table 1. Effect of temperature on morphological attributes and yield of rice varieties

Temperature level	Plant height (cm)	Panicle plant^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)
Temperature (36^{o}C)	97.92a	12.40a	25.69a	75.57a	42.61a	25.12a	18.67b
Ambient	97.72a	9.74a	23.92b	79.63a	32.67b	25.14a	19.17a
CV (%)	1.08		4.55	11.39	6.42	1.00	3.69

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Table 2. Effect of soil moisture regimes on morphological attributes and yield of rice varieties

Soil moisture regimes	Plant height (cm)	Panicle plant^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)
S_1	98.06a	15.11a	25.53a	89.85a	18.11c	25.54a	22.97a
S_2	98.17a	9.79a	24.98ab	94.29a	18.33c	25.56a	22.93a
S_3	97.89a	9.68a	24.56bc	71.89b	45.83b	24.82b	17.05b
S_4	97.17b	9.70a	24.14c	54.37c	68.28a	24.61c	12.73c
CV (%)	1.08		4.55	11.39	6.42	1.00	3.69

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT

Where, S_1= Standing water of 2 inches, S_2= 100% FC, S_3= 80% FC and S_4= 60% FC

Table 3. Effect of rice variety on morphological attributes and yield under different temperature and soil moisture regimes

Variety	Plant height (cm)	Panicle plant^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)
V_1	100.96b	8.62a	26.72a	95.79a	35.25c	27.42a	22.63a
V_2	101.71a	14.33a	24.35b	59.90c	37.04b	27.27b	17.68b
V_3	90.79c	10.27a	23.35c	77.11b	40.63a	20.71c	16.45c
CV (%)	1.08		4.55	11.39	6.42	1.00	3.69

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. Where, V_1= Binadhan-8, V_2= Binadhan-10 and V_3= Binadhan-14.

Table 4. Combined effect of temperature and soil moisture on morphological attributes and yield of rice varieties

Temperature level × Treatment	Plant height (cm)	Panicle hill^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	1000-grain weight (g)	Yield plant^{-1} (g)
T_2S_1	98.33a	20.44a	25.94a	86.04a	18.11e	25.52a	22.97a
T_2S_2	98.22ab	9.81ab	26.04a	94.18a	18.44e	25.27b	22.93a
T_2S_3	98.00abc	9.69b	25.70a	68.36b	55.56c	24.80cd	16.26c
T_2S_4	97.11c	9.64b	25.09a	53.70c	78.33a	24.59d	12.51d
T_1S_1	97.78abc	9.78ab	25.12a	93.66a	18.11e	25.57a	22.97a
T_1S_2	98.11abc	9.78ab	23.91b	94.40a	18.22e	25.34ab	22.93a
T_1S_3	97.78abc	9.67b	23.43b	75.43b	36.11d	24.84c	17.84b
T_1S_4	97.22bc	9.76ab	23.20b	55.04c	58.22b	24.63cd	12.95d
CV (%)	1.08		4.55	11.39	6.42	1.00	3.69

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Where, T_2= Temperature (36^{o}C), T_1= Ambient temperature, S_1= Standing water of 2 inches, S_2= 100% FC, S_3= 80% FC and S_4= 60% FC

Table 5. Combined effect of temperature and rice variety on morphological attributes and yield

Temperature level × Variety	Plant height (cm)	Panicle hill^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	1000-grain weight (g)	Yield plant^{-1} (g)
T_2V_1	101.00b	8.66b	26.01b	94.56a	39.67c	27.29a	22.41a
T_2V_2	102.08a	18.25a	25.21b	56.40c	42.08b	27.17a	17.39b
T_2V_3	90.67c	10.28ab	25.87b	75.74b	46.08a	20.68b	16.19c
T_1V_1	100.92b	8.58b	27.43a	97.02a	30.83e	27.37a	22.85a
T_1V_2	101.33ab	10.40ab	23.49c	63.40c	32.00e	27.19a	17.96b
T_1V_3	90.92c	10.25ab	20.83d	78.47b	35.17d	20.72b	16.70c
CV (%)	1.08		4.55	11.39	6.42	1.00	3.69

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Where, T_2= Temperature (36^{o}C), T_1= Ambient temperature,V_1=Binadhan-8, V_2= Binadhan-10 and V_3= Binadhan-14.

Table 6. Combined effect of soil moisture and rice variety on morphological attributes and yield

Moisture level× Variety	Plant height (cm)	Panicle hill^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	1000-grain weight (g)	Yield plant^{-1} (g)
S_1V_1	101.67abc	8.73b	26.77a	105.36a	16.00f	27.98a	25.74a
S_1V_2	101.67abc	26.37a	26.38a	63.99d	18.00ef	27.59b	21.58b
S_1V_3	90.83e	10.23b	23.45bc	100.20ab	20.33e	21.06d	21.58b
S_2V_1	100.83bcd	8.70b	27.18a	107.19a	16.67f	27.58b	25.71a
S_2V_2	102.50a	10.45b	24.25b	75.45c	18.50ef	27.33b	21.54b
S_2V_3	91.17e	10.23b	23.50bc	100.23ab	19.83e	21.01d	21.53b
S_3V_1	101.00bcd	8.53b	26.89a	93.15b	43.50d	26.97c	21.43b
S_3V_2	102.00ab	10.23b	23.17bc	59.96d	45.00d	26.91c	16.51d
S_3V_3	90.67e	10.27b	23.63bc	62.57d	49.00c	20.59e	13.23e
S_4V_1	100.33d	8.52b	26.03a	77.47c	64.83b	26.78c	17.66c
S_4V_2	100.67cd	10.25b	23.60bc	40.21e	66.67b	26.90c	11.08f
S_4V_3	90.50e	10.33b	22.80c	45.42e	73.33a	20.14f	9.44g
CV (%)	1.08		4.55	11.39	6.42	1.00	3.69

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Where, S_1= Standing water of 2 inches, S_2= 100% FC, S_3= 80% FC and S_4= 60% FC, V_1=Binadhan-8, V_2= Binadhan-10 and V_3= Binadhan-14.

Table 7. Combined effect of temperature, soil moisture and variety on morphological attributes and yield

Temperature level × Treatment × Variety	Plant height (cm)	Panicle hill^{-1} (no.)	Panicle length (cm)	Filled grain panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	1000-grain weight (g)	Yield plant^{-1} (g)
$T_2S_1V_1$	102.00abc	8.73b	25.90b-e	105.49a	16.00h	27.95ab	25.74a
$T_2S_1V_2$	102.33ab	42.27a	25.87b-e	53.27ghi	18.00gh	27.57b	21.58b
$T_2S_1V_3$	90.67d	10.33b	26.07a-e	99.37ab	20.33g	21.03d	21.58b
$T_2S_2V_1$	100.67bc	8.73b	26.50a-d	107.10a	16.67gh	27.93ab	25.71a
$T_2S_2V_2$	103.00a	10.4b	25.77cde	75.55de	18.67gh	27.75ab	21.54b
$T_2S_2V_3$	91.00d	10.27b	25.87b-e	99.89ab	20.00g	21.02d	21.53b
$T_2S_3V_1$	101.00bc	8.60b	26.30a-e	90.83bc	51.00e	26.93c	21.04b
$T_2S_3V_2$	102.33ab	10.20b	24.60e	57.35fgh	55.00d	26.91c	15.74d
$T_2S_3V_3$	90.67d	10.27b	26.20a-e	56.90fgh	60.67c	20.57e	12.01f
$T_2S_4V_1$	100.33c	8.57b	25.33de	74.84de	75.00b	26.78c	17.17c
$T_2S_4V_2$	100.67bc	10.10b	24.60e	39.45i	76.67b	26.88c	10.71gh
$T_2S_4V_3$	90.33d	10.27b	25.33de	46.80hi	83.33a	20.11f	9.65hi
$T_1S_1V_1$	101.33abc	8.73b	27.63ab	105.24ab	16.00h	28.01a	25.74a
$T_1S_1V_2$	101.00bc	10.47b	26.90a-d	74.71de	18.00gh	27.60b	21.58b
$T_1S_1V_3$	91.00d	10.13b	20.83gh	101.03ab	20.33g	21.09d	21.58b
$T_1S_2V_1$	101.00bc	8.67b	27.87a	107.29a	16.67gh	28.00a	25.71a
$T_1S_2V_2$	102.00abc	10.47b	22.73f	75.34de	18.33gh	27.59b	21.54b
$T_1S_2V_3$	91.33d	10.20b	21.13fgh	100.56ab	19.67gh	21.04d	21.53b
$T_1S_3V_1$	101.00bc	8.47b	27.48abc	95.47ab	36.00f	27.00c	21.82b
$T_1S_3V_2$	101.67abc	10.27b	21.73fgh	62.57efg	35.00f	26.91c	17.27c
$T_1S_3V_3$	90.67d	10.27b	21.07fgh	68.24def	37.33f	20.61e	14.44e
$T_1S_4V_1$	100.33c	8.47b	26.73a-d	80.09cd	54.67de	26.78c	18.15c
$T_1S_4V_2$	100.67bc	10.40b	22.60fg	40.97i	56.67d	26.92c	11.45fg
$T_1S_4V_3$	90.67d	10.40b	20.27h	44.05hi	63.33c	20.17f	9.23i
CV (%)	1.08		4.55	11.39	6.42	1.00	3.69

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Where, T_2= Temperature (36°C), T_1= Ambient temperature, S_1= Standing water of 2 inches, S_2= 100% FC, S_3= 80% FC and S_4= 60% FC V_1=Binadhan-8, V_2= Binadhan-10 and V_3= Binadhan-14.

CONCLUSION

Under high temperature yield and yield attributes of the Boro rice varieties were significantly decreased at 80% FC compared to 100% FC or standing water of 2 inches in pot soil. So, maintaining soil moisture at 100% field capacity or standing water of 2 inches appears to reduce the high-temperature effect of Boro rice varieties at flowering stage.

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