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PHOTOSYNTHESIS, CHLOROPHYLL FLOUROSCENCE, STOMATAL CONDUCTANCE, TRANSPIRATION, WATER USE EFFICIENCY AND YIELD OF AMAN RICEGENOTYPES UNDER HIGH TEMPERATURE AT DIFFERENT GROWTH STAGES

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PHOTOSYNTHESIS, CHLOROPHYLL FLOUROSCENCE, STOMATAL CONDUCTANCE, TRANSPIRATION, WATER USE EFFICIENCY AND YIELD OF AMAN RICE GENOTYPES UNDER HIGH TEMPERATURE AT DIFFERENT GROWTH STAGES

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ABSTRACT

Islam MT, Arefin KS (2022) Photosynthesis, chlorophyll flouroscence, stomatal conductance, transpiration, water use efficiency and yield of aman rice genotypes under high temperature at different growth stages. *Int. J. Sustain. Crop Prod.* 17(1), 22-26.

Climate is changing and air temperature is rising 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. An experiment was conducted with six rice genotypes *viz*. MFG-72, RML-81, Magic-82, MFG-86, Magic-62 and RML-37 at Bangladesh Institute of Nuclear Agriculture during July-December, 2020 to assess the effect of high temperature (35^{0}C) at PI, booting and flowering stage. During PI, flowering and grain filling stage plants were kept in plant growth chamber at 35^{0}C for 5 days along with ambient temperature. Then all the plants were allowed to complete their maturity at ambient temperature. The experiment was laid out in a completelyrandomized design with three replications. Data on photosynthetic related parameters were recorded during stress imposition and yield and yield attributes were recorded at maturity. Photosynthesis, water use efficiency, yield and yield attributes decreased, stomatal conductance increased, transpiration rate varied but Fv/Fm did not vary with high temperature at different growth stage compared to ambient temperature. High temperature at flowering stage showed more detrimental effect.The rice genotypes significantly varied among the plant parameters under the treatments. The genotypes MFG-72, RML-81 and Magic-82 showed better performance under high temperature.

Key words: *high temperature, growth stage, photosynthesis, Fv/Fm, transpiration, stomatal conductance, water use efficiency, rice yield*

INTRODUCTION

Temperature is one of the most important environmental factors influencing crop growth, development, and yield processes.Temperature is becoming the major concern for plant scientists worldwide due to the changing climate. Global climate change is making high temperaturea critical factor for plant growth and productivity. It is now considered to be one of the major abiotic stresses for restricting crop production, which has a favorable and in some cases unfavorable influence on the development, growth and yield of rice. Rice being a tropical and sub-tropical plant requires afairly high temperature, ranging from 20°C to 40°C. Rice cultivation is conditioned bytemperature parameters at the different phases of growth. Climate model predicts 33%rice yield decrease in 2100 (Karim *et al*. 2012). Grain filling is the final stageof growth in cereals where fertilized ovaries develop into caryopses. Grain fillingincerealsdepends on carbon from two sources: current assimilates transferred directly to the grain and assimilates redistributed from reserve pools in vegetative tissues eitherpriorpost-anthesis (Schnyder 1993). Rice grain dry weight increased from fertilization to 18-24 days (Moonmoon *et al*. 2020a; Hafiz *et al*. 2015; Islam 2010; Islam *et al*. 2005b; Islam and Gretzmacher, 2001). 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). High temperature and drought stress affects growth and yield of rice (Islam 2021; Islam and Khatoon, 2019; Moonmoon *et al*. 2017; Islam *et al*. 2012; Islam *et al*. 2005c; Islam 2001). In Bangladesh, Boro rice often suffers with high temperature during its reproductive stages in April-May and Aman rice occasionally in September-October. Aman rice is rain fed cultivated during June-December. It passes through vegetative stage during August to September when rainfall is usually sufficient. The crop suffers from moisture stress when the rainfall usually ceases by the first week of October in Bangladesh. By this time, it passes through reproductive. The total rainfall in these two months is very irregular and often inadequate which fails to meet the evapotranspirational demand of Aman rice consequently develops water stress and affects translocation of assimilatesand grain development in rice (Moonmoon *et al*. 2020c; Rahman *et al*. 2002). Drought stressaffects plant growth and development, and ultimately reduces grain yield of rice (Moonmoon *et al*. 2020b; Moonmoon and Islam, 2017; Zohora *et al*. 2016; Islam *et al*. 2005a; Islam *et al*. 1994a; Islam *et al*. 1994b). The response of rice yield to drought varies with growth stagebeing 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. 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). With all those factors above in mind, this study was carried out to assess the effect of high temperature at PI, booting and flowering stage of ricegenotypes.

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MATERIALS AND METHODS

The experiment was conducted at the pot yard and plant growth chamber of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. The experimental site falls under the AEZ (Agro-Ecological-Zone)-9 (Old Brahmaputtra Floodplain) of Bangladesh andsituated at latitude 24.75°N and longitude of 90.50°E. The soils of the experimentwere collected from the field of BINA Farm. The top soilwas non-calcareous DarkGrey Floodplain with loamy texture belonging to the AEZ Old Brahmaputtra Floodplain. The collected soil was pulverized, inert materials, visible insect pest andplant propagules were removed. Pots are filled with top soils. The pot was 25 cm deepwith 27 cm diameter at the top. The pots were placed at the potyard of Crop Physiology Division, BINA, Mymensingh. Each pot contained 12 kg soil. All soils pots were fertilized with urea, TSP, MP and gypsum @ 3.08, 0.70, 1.12 and 0.707 g pot^{-1}, respectively. All TSP, MP, Gypsum and one-third of the urea wereapplied 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 puddle pot. For gap filling there were extra seedlings preserved. Allnecessary intercultural operations, mainly weeding, and irrigation was done as andhen necessary. The pot experiment was conducted with six rice genotypes *viz*. MFG-72, RML-81, Magic-82, MFG-86, Magic-62 and RML-37. The experiment was set in a two factorial RCBD with three replications in during Aman season (July-December) 2020. The first factor was rice genotypes and the second factor was temperature: ambient, 38^{0}C at PI, flowering and booting stage of rice genotypes for 5 hours. Then all the plants were allowed to continue maturity. Data on photosynthetic related parameters were recorded during temperature treatment imposition and yield and yield attributes were recorded at maturity. Data were analyzed statistically and DMRT was adjusted to compare the means.

RESULTS AND DISCUSSION

Results indicated that high temperature imposed at PI, booting and flowering stage had significant negative influence on plant parameters (Table 1-3). Photosynthesis, yield and yield attributes decreased but stomatal conductance and water use efficiency increased with high temperature (Table 1). Under high temperature transpiration was better at booting stage and lower at flowering stage. Water use efficiency was higher in high temperature at all the growth stages compared to control. Among the genotypes, RML-81 showed best performance in photosynthesis and its related parameters (Table 2). Plant height, number of panicles plant^{-1}, number of grains panicle^{-1}, 1000-grain weight and yield plant^{-1} decreased with high temperature (Table 3). However, high temperature at flowering stage had more negative effect.The results are in conformity with many authors (Islam 2021; Saha *et al*. 2020; Haque *et al*. 2020; Hazra *et al*. 2016; Islam 2013). Under high temperature panicle length was higher at flowering stage because panicle was already formed in its full structure at this stage. Reduced cell division under water stress may result in shorter plants. MFG-72, RML-81 and Magic-82 showed better yield performance under high temperature (Table 3) and MFG-72 had the highest yield under control condition (Table 4).

Table 1. Effect of high temperature at different growth stages on photosynthesis, stomatal conductance, transpiration and water use efficiency

Treatment	Photosynthesis (μmolCO$_2$m^{-2}s^{-1})	Stomatal conductance (mmolH$_2$Om^{-2}s^{-1})	Transpiration (mmolH$_2$Om^{-2}s^{-1})	Water use efficiency	Fv/Fm
T1	17.69 a	0.64 c	6.38 b	2.78 a	0.81 a
T2	13.94 b	0.83 a	6.77 a	2.06 b	0.82 a
T3	12.96 c	0.81 b	6.39 b	2.03 b	0.82 a
T4	12.69 d	0.81 b	6.22 c	2.04 b	0.82 a
CV (%)	2.46	2.02	2.46	2.24	2.42
Varieties					
V1	14.62 b	0.79 a	6.55 b	2.24 ab	0.86 a
V2	15.40 a	0.79 a	6.84 a	2.26 a	0.82 c
V3	14.76 b	0.78 a	6.56 b	2.26 a	0.84 b
V4	13.79 c	0.71 b	6.22 c	2.21 b	0.79 d
V5	13.59 c	0.78 a	6.26 c	2.17 c	0.79 d
V6	13.75 c	0.78 a	6.19 c	2.22 ab	0.80 d
CV (%)	2.46	2.02	2.46	2.24	2.42

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. Here, T1: Control, T2: 35^{0}C at PI stage, T3: 35^{0}C at booting stage and T4: 35^{0}C at flowering stage; V1: MFG-72, V2: RML-81, V3: Magic-82, V4: MFG-86, V5: Magic-62 and V6: Binadhan-14

Table 2. Combined effect of high temperature and rice genotypesat on photosynthesis, stomatal conductance, transpiration and water use efficiency

Genotype × Treatment	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$)	Transpiration ($mmolH_2Om^{-2}s^{-1}$)	Water use efficiency	Fv/Fm
V1T1	18.31 a	0.64 d	6.44 cde	2.84 ab	0.83 def
V1T2	14.79 e	0.85 a	7.26 a	2.04 efg	0.82 def
V1T3	12.85 hij	0.83 ab	6.38 cdefg	2.02 g	0.90 a
V1T4	12.54 ij	0.83 ab	6.12 gh	2.05 efg	0.88 ab
V2T1	18.34 a	0.64 d	6.40 cdef	2.86 ab	0.82 ef
V2T2	15.75 d	0.85 a	7.48 a	2.11 e	0.83 def
V2T3	13.99 f	0.83 ab	6.87 b	2.04 efg	0.82 def
V2T4	13.52 fg	0.83 ab	6.63 bc	2.04 efg	0.82 ef
V3T1	18.41 a	0.63 d	6.35 defgh	2.90 a	0.82 ef
V3T2	14.83 e	0.84 ab	7.23 a	2.05 efg	0.85 bcd
V3T3	13.25 gh	0.82 b	6.51 cd	2.03 efg	0.86 bc
V3T4	12.54 ij	0.83 ab	6.15 fgh	2.04 efg	0.82 ef
V4T1	17.33 b	0.63 d	6.44 cde	2.69 c	0.81 efg
V4T2	12.99 ghi	0.73 c	6.19 efgh	2.10 ef	0.82 ef
V4T3	12.40 j	0.74 c	6.09 h	2.04 efg	0.77 i
V4T4	12.45 ij	0.73 c	6.14 gh	2.03 efg	0.78 hi
V5T1	16.41 c	0.63 d	6.40 cfef	2.56 d	0.84 cde
V5T2	12.70 hij	0.85 a	6.27 defgh	2.03 efg	0.80 fghi
V5T3	12.67 hij	0.83 ab	6.24 efgh	2.03 efg	0.77 i
V5T4	12.58 ij	0.83 ab	6.14 gh	2.05 efg	0.78 hi
V6T1	17.31 b	0.63 d	6.22 efgh	2.78 b	0.77 i
V6T2	12.58 ij	0.84 ab	6.19 efgh	2.03 efg	0.78 ghi
V6T3	12.57 ij	0.82 b	6.22 efgh	2.02 fg	0.81 efgh
V6T4	12.54 ij	0.83 ab	6.12 gh	2.05 efg	0.83 def
CV (%)	2.46	2.02	2.46	2.24	2.42

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. Here, T1: Control, T2: 35^0C at PI stage, T3: 35^0C at booting stage and T4: 35^0C at flowering stage; V1: MFG-72, V2: RML-81, V3: Magic-82, V4: MFG-86, V5: Magic-62 and V6: Binadhan-14

Table 3. Effect of high temperature at different growth stages on yield and yield attributes of rice genotypes

Treatment	Plant Height (cm)	Panicle length (cm)	Panicle $plant^{-1}$ (no.)	Grains $panicle^{-1}$ (no.)	1000-grain wt.(g)	Yield $plant^{-1}$ (g)
T1	102.94 a	12.50 b	26.42 a	139.16 a	20.14 a	34.24 a
T2	98.44 c	12.78 b	23.27 c	97.26 b	19.12 b	22.88 b
T3	100.78 b	14.56 a	24.72 b	89.07 b	18.95 b	23.87 b
T4	100.06 bc	10.61 c	25.16 b	97.79 b	18.86 b	19.00 c
CV (%)	2.80	9.73	3.64	13.56	3.68	16.38
Varieties						
V1	106.58 b	11.50 b	25.57 bc	118.73 a	20.61 c	27.67 a
V2	110.75 a	11.67 b	24.87 cd	108.85 ab	23.12 a	29.36 a
V3	106.67 b	14.50 a	26.05 ab	100.38 bc	18.55 d	26.68 a
V4	96.08 c	11.33 b	24.82 d	92.67 c	21.97 b	23.22 b
V5	95.92 c	12.33 b	26.42 a	118.52 a	14.68 f	20.37 b
V6	87.33 d	14.33 a	21.63 e	95.75 c	16.66 e	22.68 b
CV (%)	2.80	9.73	3.64	13.56	3.68	16.38

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. Here, T1: Control, T2: 35^0C at PI stage, T3: 35^0C at booting stage and T4: 35^0C at flowering stage; V1: MFG-72, V2: RML-81, V3: Magic-82, V4: MFG-86, V5: Magic-62 and V6: Binadhan-14

Table 4. Combined effect of high temperature and rice genotypeson yield and yield attributes

Variety×high temperature	Plant height (cm)	Panicle length (cm)	Panicle plant^{-1} (no.)	Grains panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)
V1T1	108.67 b	27.00 abc	13.33 efgh	157.00 a	21.26 cde	43.47 a
V1T2	107.67 b	25.60 cd	9.00 l	128.67 bcd	20.07 fg	22.85 fghij
V1T3	107.67 b	25.00 de	17.67 a	89.00 fghi	20.76 def	32.18 cde
V1T4	102.33 cde	24.67 def	6.00 m	100.27 efg	20.33 ef	12.20 k
V2T1	114.00 a	25.73 bcd	11.33 hijk	147.00 ab	24.65 a	40.26 ab
V2T2	108.00 b	23.07 gh	13.00 fghi	94.93 efgh	22.80 b	27.92 defg
V2T3	110.67 ab	24.73 def	10.67 jkl	106.47 def	22.88 b	25.60 efgh
V2T4	110.33 ab	25.93 bcd	11.67 hijk	87.00 fghi	22.15 bc	23.67 fghi
V3T1	108.67 b	27.53 a	14.00 defg	137.13 abc	18.90 hi	35.69 bc
V3T2	106.67 bc	24.07 efg	16.67 abc	93.20 efgh	18.63 hij	29.02 cdef
V3T3	103.00 cd	25.53 cde	17.33 ab	81.47 ghi	17.60 j	24.48 fgh
V3T4	108.33 b	27.07 abc	10.00 kl	89.73 fghi	19.08 gh	17.54 ijk
V4T1	99.00 def	27.00 abc	13.33 efgh	108.53 def	22.95 b	33.07 cd
V4T2	94.67 fgh	22.20 hi	12.00 ghijk	82.53 ghi	21.81 bcd	21.49 ghij
V4T3	98.00 efg	24.73 def	11.00 ijkl	87.07 fghi	21.81 bcd	21.27 ghij
V4T4	92.67 hij	25.33 de	9.00 l	92.53 efgh	21.28 cde	17.04 ijk
V5T1	98.00 efg	27.93 a	10.67 jkl	160.07 a	15.25 klm	25.03 fgh
V5T2	93.00 hi	25.13 de	10.67 jkl	115.67 cde	14.98 lm	18.94 hij
V5T3	94.33 gh	25.47 cde	16.00 abcd	74.47 hi	14.20 m	16.45 jk
V5T4	98.33 efg	27.13 ab	12.00 ghijk	123.87 bcd	14.28 m	21.07 hij
V6T1	89.33 ij	23.33 fgh	12.33 ghij	125.20 bcd	17.80 ij	27.92 defg
V6T2	80.67 k	19.53 j	15.33 bcde	68.53 i	16.40 k	17.04 ijk
V6T3	91.00 hij	22.87 gh	14.67 cdef	95.93 efgh	16.40 k	23.25 fghi
V6T4	88.33 j	20.80 ij	15.00 cdef	93.33 efgh	16.05 kl	22.50 fghij
CV (%)	2.80	3.64	9.73	13.56	3.68	16.38

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. Here, T1: Control, T2: 35^0C at PI stage, T3: 35^0C at booting stage and T4: 35^0C at flowering stage; V1: MFG-72, V2: RML-81, V3: Magic-82, V4: MFG-86, V5: Magic-62 and V6: Binadhan-14

CONCLUSION

Photosynthesis, yield and yield attributes decreased but stomatal conductance and water use efficiency increased with high temperature. However, high temperature at flowering stage had more negative effect. Among the genotypes, MFG-72, RML-81 and Magic-82 showed better yield performance under high temperature.

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