Reprint **ISSN 1991-3036 (Web Version)**

International Journal of Sustainable Crop Production (IJSCP)

(*Int. J. Sustain. Crop Prod.*)

Volume: 18 **Issue: 1** **February 2023**

Int. J. Sustain. Crop Prod. 18(1): 19-23 (February 2023)

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ISSN-1991-3036 (Online)
Int. J. Sustain. Crop Prod. 18(1):19-23(February 2023)

EFFECT OF HIGH TEMPERATURE AT DIFFERENT GROWTH STAGES ON PHOTOSYNTHESIS, CHLOROPHYLL STABILITY, GRAIN GROWTH AND YIELD OF AMAN RICE VARIETIES

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Accepted for publication on 10 January 2023

ABSTRACT

Akter T, Islam MT, Baten MA, Rana MS (2023) Effect of high temperature at different growth stages on photosynthesis, chlorophyll stability, grain growth and yield of aman rice varieties. *Int. J. Sustain. Crop Prod.* 18(1), 19-23.

Changing climate rises air temperature due to increasing concentration of CO_2 and other atmospheric greenhouse gases. A pot experiment was conducted with five rice varieties *viz.*, Binadhan-4, Binadhan-7, Binadhan-11, Binadhan-12 and Binasail in the plant growth chamber at Bangladesh Institute of Nuclear Agriculture, Mymensingh to assess the effects of high temperature (36°C) at different growth stages on photosynthesis, chlorophyll stability, grain growth and yield and to find out the variety tolerant to high temperature. Five temperature treatments *viz*., Ambient, 36°C at tillering stage, 36°C at panicle initiation stage, 36°C at booting stage, and 36°C at flowering stage were imposed for seven days at each respective growth stage and then plants were allowed to grow at ambient temperature up to maturity. For grain growth studies two temperature treatments, Ambient and 30°C were applied from fertilization to grain maturity. Ten grains were harvested from selected panicles of three plants of each treatment at 3 days interval starting from fertilization to maturity. During grain growth photosynthetic rate, chlorophyll content of flag leaf and dry weights of those grains were recorded. Photosynthetic rate, chlorophyll content of flag leaf, grain dry matter accumulation, plant height, number of total tillers and effective tillers plant^{-1}, panicle length, filled and unfilled grains panicle^{-1}, panicle length, 1000-grain weight and grain yield were significantly affected by temperature treatments. However, high temperature (36°C) at flowering stage affected grain yield more compared to other temperature treatments and found to be more sensitive. Grain dry matter accumulation gradually increased but photosynthetic rate in flag leaf decreased from fertilization to maturity. The rice varieties achieved physiological maturity at 24 days and chlorophyll content in flag leaves was stable up to 16 days after anthesis. The highest photosynthetic rate, grain dry matter accumulation and grain yield were found in Binadhan-7 under the treatments. So, Binadhan-7 seems to be tolerant to high temperature compared to other varieties.

***Key words**: rice, high temperature, growth stage, photosynthesis, chlorophyll, grain growth, 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. 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 2022). Climate model predicts 33% rice yield decrease in 2100 (Karim *et al*. 2012). 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). Boro rice is transplanted in January February 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 2021a; Islam 2021b; Islam 2022). 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 September-October is very irregular and often inadequate which fails to meet the evapotranspirational demand of Aman rice consequently develops water stress and affects translocation of assimilates and grain development in rice (Rahman *et al*. 2002; Moonmoon *et al*. 2020c). Rice grain dry weight increased from fertilization to 18-24 days and temperature/water stress decreased the rate of accumulation and finally produced decreased grain weight (Islam and Gretzmacher, 2001; Islam 2010; Hafiz *et al*. 2015; Hazra *et al*. 2016; Moonmoon *et al*. 2020a). 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).

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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*. 2020b; 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). So, objectives of the study were to assess the effects of high temperature at different growth stages on photosynthesis, grain growth and yield of rice varieties and to find out the variety tolerant to high temperature.

MATERIALS AND METHODS

A pot experiment was conducted with the varieties Binadhan-4, Binadhan-7, Bimadhan-11, Binadhan-12 and Binasail in a plant growth chamber at Bangladesh Institute of Nuclear Agriculture (BINA) during June to December, 2014. The following five treatments *viz.*, T_0 (ambient temperature), T_1 (36°C at tillering stage), T_2 (36°C at panicle initiation stage), T_3 (36°C at booting stage), and T_4 (36°C at flowering stage) were applied for seven days at each respective growth stage and then plants were allowed to grow at ambient temperature up to maturity. The soil for the experiment was collected from BINA campus. The soil was silt loam, organic matter 1.05%, total N 0.07%, available P 14.3 ppm, exchangeable K 0.25 meq. per 100g soil, available S 13.2 and soil pH 6.67. The experiment was laid out on Completely Randomized Design, where each treatment was replicated 3 times. Seedlings were uprooted carefully from the seedbed and bundled with proper care. On 17 July, 2014, 30 days old seedlings were transplanted in the puddle pots. One seedling was transplanted in a pot. Soils were fertilized with urea 1.72 g pot^{-1}, TSP 1.06 g pot^{-1}, MP 0.215 kg ha^{-1}, 0.80 g pot^{-1} corresponding to urea 215 kg ha^{-1} TSP 180 kg ha^{-1}, MP 100 kg ha^{-1}, respectively. For grain growth studies two temperature treatments, T_0 (control) and 30^{o}C were applied from fertilization to grain maturity. Ten grains were harvested from selected panicles of three plants of each treatment at 3 days interval starting from fertilization to maturity. Dry weights of those grains were recorded. Photosynthetic rate were measured using Portable Photosynthetic system (Model: Li-6400XT) and chlorophyll content of flag leaves were measured using SPAD meter (Model: SPAD 502). Grain dry weight grain dry matter accumulation), chlorophyll content (SPAD reading) and photosynthetic rate of flag leaves were measured at 3 days internal from fertilization to maturity. At maturity, three pots were harvested for each treatment. After harvest data were recorded on plant height, number of total and effective tillers $plant^{-1}$, panicle length, number of filled and unfilled grains $panicle^{-1}$ and grain yield $plant^{-1}$. The collected data were analyzed statistically following two factor experimental design of CRD by MSTAT computer packages. Duncan's Multiple Range Test was done to compare the means.

RESULTS AND DISCUSSION

Temperature treatments significantly affected all the parameters (Table 1). However, high temperature (36°C) at flowering stage had more detrimental effect on yield and yield attributes compared to other temperature treatments. Rice varieties significantly varied on all the parameters (Table 1). Binadhan-4 produced the longest plants and panicles, highest number of unfilled grains $plant^{-1}$, lowest 1000-grain weight and grain yield. Binadhan-7 showed the lowest number of total and effective tillers but the highest 1000-grain weight and grain yield. Binadhan-11 and Binadhan-12 produced shorter plants with medium yield. Binasail had the highest number of filled grains $plant^{-1}$, the lowest 1000-grain weight and lower yield. Interaction of temperature treatments and varieties was significant on plant height, number of effective tillers, filled and unfilled grains and grain yield $plant^{-1}$ (Table 2). Interaction effect was not significant on total tiller $plant^{-1}$, panicle length. The highest plant height was found on Binadhan-4 at ambient temperature and the lowest plant height was found in Binadhan-11(36°C at booting stage). The highest number of tiller was found at T_4 treatment, 36^{o}C at flowering stage (12.33) and the lowest number of tillers $plant^{-1}$ at T_3 treatment, 36^{o}C at booting stage (12). The highest number of tiller was found at T_0 treatment, at ambient temperature. The lowest tiller was produced at T_3 treatment, 36^{o}C at booting stage (8.92). The longest panicles were observed at T_0V_1. The shortest panicle was observed at V_4T_2. The highest number of filled grains $plant^{-1}$was observed in V_5T_5 interaction (105.3). The lowest number of filled grains $plant^{-1}$was observed in V_1T_3 interaction (42). Here Binadhan-7 possessed the highest number of unfilled grain per panicle under T_2 (36^{o}C at PI stage). The lowest number of unfilled grains possessed by Binadhan-12. The maximum 1000-grain weight (31 g) was observed in V_2T_0 that was statistically similar with T_4V_2 (30.27 g). On the other hand, the minimum 1000-grain weight (14 g) was recorded in V_5T_4. The highest yield $plant^{-1}$(19) was observed in T_0V4. On the other hand, the minimum (7) yield $plant^{-1}$was observed in T_4V_5. High temperature at flowering stage decreased grain yield more compared to other temperature treatments. So flowering stage was more critical for high temperature stress. The highest values of grain dry weight and photosynthetic rate were found in Binadhan-7. Among the varieties Binadhan-7 produced

the highest grain yield under the temperature treatments and it showed tolerance to other rice varieties. Grain dry matter accumulation gradually increased but photosynthetic rate in flag leaf decreased from fertilization to maturity. The rice varieties achieved physiological maturity at 24 days and chlorophyll content in flag leaves was stable up to 16 days after anthesis. The highest photosynthetic rate, grain dry matter accumulation and grain yield were found in Binadhan-7 under the treatments. So, Binadhan-7 seems to be tolerant to high temperature compared to other varieties. The results agree with Islam 2013; Islam and Arefin, 2022.

Table 1. Yield and yield attributes of Aman rice under high temperature (36^{o}C) at tillering, panicle initiation, booting and flowering stages

Treatments	Plant height (cm)	Total tillers plant^{-1} (no.)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grains plant^{-1} (no.)	Unfilled grains plant^{-1} (no.)	1000-grain wt. (g)	Grain yield plant^{-1} (g)
Varieties								
Binadhan-4 (V_1)	149a	12b	9.6b	25a	486c	180a	18d	9d
Binadhan-7 (V_2)	128b	10d	7.8d	23c	482c	167b	30a	14a
Binadhan-11 (V_3)	82e	13a	10a	24b	543b	157b	24c	13b
Binadhan-12 (V_4)	87d	12ab	8.9bc	22d	482c	92c	27b	13b
Binasail (V_5)	92c	11c	8.5cd	21.9d	695a	90c	14e	10c
Temperature								
Control (T_0)	112a	12b	10a	24a	700a	87c	24a	15a
36^{0}C at tillering stage (T_1)	106bc	11c	8c	24a	607b	119b	23b	13b
36^{0}C at PI stage (T_2)	105c	11bc	8c	21c	507c	177a	23b	11c
36^{0}C at booting stage (T_3)	107bc	12b	8bc	23b	455d	129b	23b	10d
36^{0}C at flowering stage (T_4)	109b	12a	9b	23b	419e	173a	23b	9e

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

Table 2. Interaction effects of temperature and variety

Treatments	Plant height (cm)	Total tillers plant^{-1} (no.)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grains plant^{-1} (no.)	Unfilled grains plant^{-1} (no.)	1000-grain wt. (g)	Grain yield plant^{-1} (g)
V_1 T_0	156a	12	11.6a	26	706cd	121efg	19f	13 e
V_1 T_1	142b	11	8.3e-h	25	484ijk	196b	18f	9 i
V_1 T_2	146bc	12	10a-d	23	425lmn	222a	18f	7 j
V_1 T_3	150ab	13	9c-g	25	426lmn	165c	18f	7 j
V_1 T_4	153ab	13	9b-f	25	390n	197b	18f	7 j
V_2 T_0	133d	11	9a-e	25	577f	136de	31a	17 ab
V_2 T_1	126de	9	6.3h	24	528f-i	162c	30a	16 bc
V_2 T_2	130de	10	7gh	21	468jkl	228a	30a	13gh
V_2 T_3	127de	11	8e-h	24	439klm	117efg	30a	14fg
V_2 T_4	124e	11	8e-h	24	397n	192b	31a	12hi
V_3 T_0	89fgh	12	11abc	24	688cde	103ghi	24e	17bc
V_3 T_1	82hi	12	10a-e	25	658de	109fgh	23e	14ef
V_3 T_2	76i	12	9b-f	24	500hij	215ab	24e	12ij
V_3 T_3	76i	13	11ab	23	455jkl	149cd	24e	11jk
V_3 T_4	90fgh	14	11a	24	417lmn	209ab	24e	9m
V_4 T_0	87gh	12	9.6a-e	22	638e	41j	28b	19a
V_4 T_1	92fg	12	9.6a-e	23	555fg	82i	27bc	15de
V_4 T_2	83hi	13	8.6d-h	19	424lmn	115efg	27cd	11ij
V_4 T_3	87gh	12	7.3fgh	22	406mn	89hi	27d	11jkl
V_4 T_4	87gh	13	9.3b-f	22	389n	131def	26d	10klm
V_5 T_0	97f	12	11.6a	22	892a	36j	14g	13gh
V_5 T_1	90fgh	11	8.3d-h	22	810b	46j	14g	11j
V_5 T_2	92fg	11	7gh	19	719c	108fgh	14g	10lm
V_5 T_3	93fg	11	7.3fgh	23	550fgh	125efg	14g	8n
V_5 T_4	90fgh	11	8.3d-h	22	505hij	136de	14g	7n

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

Where, V_1= Binadhan-4, V_2= Binadhan-7, V_3= Binadhan-11, V_4= Binadhan-12, V_5= Binasail, T_0= Control or ambient temperature, T_1= 36°C attillering stage, T_2= 36°C at panicle initiation stage, T_3= 36°C at booting stage, T_4= 36°C at flowering stage

Table 3. Effect of temperature on grain dry weight, photosynthetic rate, and chlorophyll content of flag leaf during grain filling period of Aman rice genotypes

Treatments	Grain dry wt. grain^{-1} (mg)	SPAD reading (chlorophyll)	Photosynthetic rate ($\mu molCO_{2m}{}^{-2}s^{-1}$)
Control	16a	38a	21a
Temperature stress (30ºC)	15b	35b	14b
Varieties			
Binadhan-4	17b	39a	19b
Binadhan-7	20a	37b	22a
Binadhan-11	15d	36b	16d
Binadhan-12	16c	37b	16c
Binasail	8e	33c	15e
Days after anthesis			
0	2g	38a	22a
4	4f	38ab	20b
8	11e	37abc	19c
12	17d	37abc	18d
16	19c	36abc	17e
20	21b	35bc	16f
24	24a	35c	15g
28	23a	35c	15h

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

CONCLUSION

Photosynthetic rate, chlorophyll content of flag leaf, grain dry matter accumulation, Plant height, number of total tillers and effective tillers plant^{-1}, panicle length, filled and unfilled grains panicle^{-1}, panicle length, 1000-grain weight and grain yield were significantly affected by temperature treatments. However, high temperature (36^{o}C) at flowering stage affected grain yield more compared to other temperature treatments and found to be more sensitive. Grain dry matter accumulation gradually increased but photosynthetic rate in flag leaf decreased from fertilization to maturity. The rice varieties achieved physiological maturity at 24 days and chlorophyll content in flag leaves was stable up to 16 days after anthesis. The highest photosynthetic rate, grain dry matter accumulation and grain yield were found in Binadhan-7 under the treatments. So, Binadhan-7 seems to be tolerant to high temperature compared to other varieties.

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