Journal BiNET
Scientific Publication

Published with Open Access at Journal BiNET
Vol. 07, Issue 01: 600-607

Journal of Bioscience and Agriculture Research

Home page: www.journalbinet.com/jbar-journal.html

Effect of high temperature on some physiological parameters of grain growth and yield of boro rice varieties

P. Hazra[a], M. T. Islam[b] and G. C. Das[c]

[a]Dept. of Environmental Science, Patuakhali Science & Technology University, Patuakhali
[b]Physiology Division, Bangladesh Institute of Nuclear Agriculture, Bangladesh and
[c]Dept. of Agronomy, Patuakhali Science & Technology University, Patuakhali, Bangladesh

ABSTRACT

A pot experiment was conducted with four varieties viz. Binadhan-5, Binadhan-6, Binadhan-8 and Iratom-24 in the plant growth chamber at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh to assess the effects of high temperature at different growth stages on yield and yield attributes and photosynthetic rate, transpiration rate, leaf conductance and water use efficiency during grain growth period. For yield and yield attributes the following five treatments 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. Two temperature treatments T_0 (Ambient temperature) and T_1 (30°C) were also maintained during grain growth period. Temperature treatments significantly decreased number of total tillers and effective tillers per plant, filled and unfilled grains per panicle, 1000-grain weight, grain yield per plant and harvest index but plant height, non-effective tiller number and panicle length were not affected by temperature treatments. High temperature stress (36°C) at panicle initiation reduced grain yield more compared to other treatments. The grain dry weight, photosynthetic rate, leaf conductance, transpiration rate decreased but water use efficiency of flag leaf increased with temperature treatments. Binadhan-6 showed the highest grain dry matter accumulation under temperature treatments during grain growth period. Binadhan-6 seems to be tolerant to high temperature.

Key words: *Temperature, Photosynthetic rate, Transpiration rate, Leaf conductance, Water use efficiency and Rice yield*

Please cite this article as: Hazra, P., Islam, M. T. & Das, G. C. (2016). Effect of high temperature on some physiological parameters of grain growth and yield of boro rice varieties. *Journal of Bioscience and Agriculture Research,* 07(01), 600-607.

I. Introduction

Climate variability and change, its impacts and vulnerabilities are growing concern worldwide. The climate of Bangladesh is changing and it is becoming more unpredictable every year. Global

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)
EISSN: 2312-7945, © Hazra et al. (2016), Research paper

warming induced changes in temperature and rainfall are already evident in many parts of the world, as well as in our country (Ahmed and M. A. 1999). These entire have profound impact on agriculture (McCarthy *et. al*., 2001). As the great majority of the people of Bangladesh depend on agriculture for their livelihood, crop agriculture in this region is highly susceptible to variations in climate system. It is anticipated that crop production would be extremely vulnerable under climate change scenarios, and as a result, food security of the country will be at risk (Karim *et al*., 1996). Continuing changes in weather variables such as seasonal rainfall and temperature, and increased concentrations of greenhouse gases in the atmosphere, will affect rice production (Roy *et al*., 2009). There is a major consensus among scientists, except for some minor disagreements, that the climate is changing and the air temperature is raising due to increasing concentration of CO_2 and other atmosphere greenhouse gases (Weiss *et al*., 2003; Kerr, 2005; IPCC, 2007). Emission of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from agricultural systems is one of the major sources contributing to this global increase of temperature (Maraseni *et al*., 2009; Smith and Olesen, 2010). By the end of the 21st Century, the earth's climate is predicted to warm by an average of 2–4°C (IPCC, 2007), due to both anthropogenic and natural factors (Eitzinger *et al*., 2010). Model predicted that temperature of the globe will increase 3-4^{0}C by 2021 and yield of rice and maize will decrease by 25% (Lawlor, 1997). Increasing CO_2 as a result of global warming reduced fertility rates and the number (30-50%) of panicles per bush (Shen *et al*., 2000). Another model predicted that rice yield would decrease by 39-47% due to temperature increase of 4^{0}C (Costa, 2000). Agriculture in Bangladesh is already under pressure both from huge and increasing demand for food and from problems of agricultural land and water resources depletion. The prospect of global climate change makes the issue particularly urgent (Huq, 2003). In Bangladesh the temperature remains low at early vegetative stage and high at the reproductive stage. Due to trend of global warming, obviously the atmospheric temperature of the *Boro* season would be higher but its effect on rice production by the different varieties is not sufficiently studied.

Keeping in view the significance of climatic variability on the growth and yield of the rice crop, a pot experiment was conducted with four *Boro* rice genotypes to assess the effects of high temperature at different growth stages. The objectives were to study the effect of temperature on the photosynthesis, leaf conductance transpiration, water use efficiency, grain growth and yield of *Boro* rice and to find out temperature tolerant rice variety, if any.

II. Materials and Methods

A pot experiment was conducted with the varieties Binadhan-5, Binadhan-6, Bimadhan-8, and Iratom-24 in a plant growth chamber at Bangladesh Institute of Nuclear Agriculture (BINA) during December, 2013 to May, 2014 to assess of high temperature at different growth stages on yield and yield attributes and photosynthetic rate, leaf conductance, transpiration and water use efficiency during grain growth period. For yield and yield attributes the following five treatments *viz.* T_0 (control 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. For grain growth studies two temperature treatments, T_0 (control), and 30^{o}C were applied from fertilization to grain 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 collected soil was dried under the sun. Then the soil was crashed and sieved. A total of 84 pots were prepared and their individual weight was recorded. Each pot contained 11 kg of soils. It contained a surface area of 846.23 cm^2 with depth of the soil in each pot being 34 cm. The pots were placed at the pot yard of Crop Physiology Division, BINA, Mymensingh. Seeds were sown

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)

on seedbed on 18 December 2013. Seedlings were uprooted carefully from the seedbed and bundled with proper care. Soils were fertilized with urea 1.72g/pot, TSP 1.06 g/pot, MP 0.215 kg/ha, 0.80 g/pot corresponding to urea 215kg/ha TSP 180kg/ha, MP 100kg/ha, respectively. All TSP, MP 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 30 and 50 days after transplanting. On 18 January, 2014, 30 days old seedlings were transplanted in the puddle pots. One seedling was transplanted in a pot. The experiment was laid out on Completely Randomized Design, where each treatment was replicated 3 times. 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, transpiration rate and leaf conductance 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, 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 effective tillers, grain yield, total dry matter and harvest index. The plant parts were separated into stem, leaves, roots and oven dried at 80°C for 72 hours. After drying their weights were recorded. The collected data were analyzed statistically following two factor experimental design of CRD by MSTAT computer packages (Freed, 1992). The mean differences among the treatments were calculated with Duncan's Multiple Range Test.

III. Results and Discussion

During phonological data observation, Binahan-8 had shortest life span (seed to seed) and Binadhan-5, Binadhan-6 and Iratom-24 also had shorter life span (seed to seed) under temperature stress (Table 01). The maturity of all varieties found 5 to 14 days earlier in temperature stress and the life span became shorter (6 to 12 days) than those at control condition. It might be due to temperature stress caused faster vegetative growth and development. This is conformity with Tashiro and Wardlaw (1989); Chowdhury and Wardlaw (1978). Plant height, non-effective tillers plant^{-1}, panicle length, number of panicles plant^{-1}, number of grains panicle^{-1} were not affected by the temperature treatments. But number of total tillers plant^{-1}, number of effective tillers plant^{-1}, filled and unfilled grains panicle^{-1}, 1000-grain weight, yield and harvest index were significantly affected by the temperature treatments (Table 2). Number of total and effective tillers plant^{-1} was the highest in T_2 (36^{o}C at tillering stage) and T_4 (36^{o}C at flowering stage). The lowest filled grains per panicle was found in T_3 (36^{o}C at booting stage) temperature treatments. The maximum 1000-grain weight was recorded in T_4 (36^{o}C at flowering stage) and minimum 1000-grain weight was recorded in T_3 (36^{o}C at booting stage) which was statistically similar with T_1 (36^{o}C at tillering stage) treatments. The maximum grain yield per plant was recorded from T_2 treatment, (36^{o}C at panicle initiation stage) condition which was statistically similar with T_4 treatment, (36^{o}C at flowering stage), and minimum was recorded from T_3 (36^{o}C at booting stage) temperature condition. The highest harvest index was found at temperature stress T_2 (36^{o}C at panicle initiation stage) and T_4 (36^{o}C at flowering stage). Manalo *et al.* (1994) stated that increasing temperature from 29/21 to 37/29°C (day/night temperature) reduced tillering number by 10%. Filled grain percentage was affected by high temperature at different stages (Haque *et al.*, 1983). Similar result was obtained from Yang and Heilman (1983) who reported that high temperature during grain filling stage decreased the percentage of filled spikelet. Reduced grain yield by high temperature was observed by Shi *et al.* (2001); Shen *et al.* (2000) and Islam (2011). However, some varieties in this study resulted in positive response to temperature in increasing the filled grains per panicle. Under the temperature treatments, Binadhan-5 produced the longest plants, the highest number of total and effective tillers, panicles per plant,

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)
EISSN: 2312-7945, © Hazra et al. (2016), Research paper

filled grains per panicle, grain yield and harvest index (Table 03). Binadhan-6 also produced the longest plants, panicles and statistically similar number of filled grains per panicle compared to Binadhan-5. Binadhan-8 had the highest number of panicles per plant, unfilled grains per panicle and medium grain yield and harvest index. Iratom-24 produced the shortest plants, panicles, the lowest number of filled grains, grain yield and harvest index.

The grain dry weight, photosynthetic rate, leaf conductance, transpiration rate decreased but water use efficiency of flag leaf increased with temperature treatments (Table 05). The highest grain dry weight and transpiration rate but low photosynthesis, leaf conductance and water use efficiency were found in Binadhan-6. The highest photosynthetic rate and water use efficiency but the lowest grain dry weight, leaf conductance and transpiration rate were found in Binadhan-5. The highest leaf conductance, but medium photosynthesis, transpiration rate; low grain dry weight and the lowest water use efficiency were found in Binadhan-8. Iratom-24 showed better grain dry weight, leaf conductance, water use efficiency, transpiration rate and the lowest photosynthetic rate. Grain dry weight gradually increased from fertilization to 24 days; thereafter it did not increase significantly. Photosynthetic rate, leaf conductance and transpiration rate gradually decreased from fertilization to maturity. But water use efficiency was almost unchanged during grain growth period. The results are in conformity with Islam (2011).

Table 01. Phenological data recorded during experimental period

Temperature	Variety	Date of sowing	Date of transplanting	Days to tillering (DAT)	Days to booting (DAT)	Days to heading (DAT)	Days to maturity (DAT)	Lifespan (Seed to seed)
Control temperature	Binadhan-5	18.12.13	18.01.14	20	63	93	126	154
	Binadhan-6	,,	,,	14	61	98	135	162
	Binadhan-8	,,	,,	13	54	85	115	142
	Iratom-24	,,	,,	15	57	90	125	154
Temperature stress	Binadhan-5	,,	,,	20	58	79	113	142
	Binadhan-6	,,	,,	14	54	84	121	150
	Binadhan-8	,,	,,	13	50	76	103	135
	Iratom-24	,,	,,	15	52	79	113	142

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)
EISSN: 2312-7945, © Hazra et al. (2016), Research paper

Table 02. Effect of temperature at different growth stages on yield and yield attributes

Treatment	Plant height (cm)	Total tillers (no.)	Effective tillers (no.)	Non-effective tillers (no.)	Panicle length (cm)	Panicles plant^{-1} (no.)	Grains panicle^{-1} (no.)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)	Harvest index (%)
T_0 (control or ambient)	107.0a	11.17b	11.17b	1.25a	22.22a	5.42a	140.0 a	98.92 a	38.58 b	24.41 c	18.64 ab	40.42 b
T_1 (36°C at tillering stage)	106.8a	10.17c	10.17c	0.92a	22.23a	5.67a	134.8 a	97.42ab	41.08a	23.33 d	17.65 ab	38.58 c
T_2(36°C at panicle initiation stage)	106.9a	12.08a	12.08a	1.25a	22.24a	5.42a	138.9 a	96.58ab	40.58ab	25.58 b	19.19 a	42.83 a
T_3 (36°C at booting stage)	107.1a	8.92d	8.92d	1.00a	22.07a	5.33a	137.0 a	96.33 b	41.33 a	23.20 d	16.87 b	37.25 d
T_4(36°C at flowering stage)	107.2a	12.33a	12.33a	1.17a	22.25a	5.33a	139.3a	97.92ab	39.75ab	25.99 a	19.10 a	35.33e
CV (%)	*0.35%*	*3.34%*	*3.86%*	*43.77%*	*1.14%*	*11.14%*	*8.94%*	*2.46%*	*5.53%*	*0.57%*	*10.53%*	*2.20%*

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

Table 03. Varietal responses on yield and yield attribute due to temperature treatments at different growth stages

Treatment	Plant height (cm)	Total tillers (no.)	Effective tillers (no.)	Non-effective tillers (no.)	Panicle length (cm)	Panicles plant^{-1} (no.)	Grains panicle^{-1} (no.)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain wt. (g)	Yield plant^{-1} (g)	Harvest index (%)
V_1 (Binadhan-5)	122.1a	12.53 a	11.80 a	0.80b	21.50 c	6.200 a	141.7 a	103.0a	39.07 b	24.68 a	21.47 a	45.07 a
V_2 (Binadhan-6)	122.1 a	11.87 b	10.73 c	1.13ab	24.23 a	5.267 b	141.2 a	101.5 a	39.93 b	24.71 a	18.53 b	42.40 b
V_3 (Binadhan-8)	93.11 b	12.53 a	11.13 b	1.40 a	21.98 b	5.200 b	142.9 a	97.47 b	44.73a	24.63 a	17.74 b	39.13 c
V_4 (Iratom-24)	90.68 c	11.20 c	10.07 d	1.13ab	21.10 d	5.067 b	126.3 b	87.80 c	37.33 c	23.98 b	15.43 c	35.33 d
CV (%)	*0.35%*	*3.34%*	*3.86%*	*43.77%*	*1.14%*	*11.14%*	*8.94%*	*2.46%*	*5.53%*	*0.57%*	*10.53%*	*2.20%*

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

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)

Table 04. Interaction effects of temperature and variety on yield and yield attributes

Treatments	Plant height (cm)	Total tillers (no.)	Effective tillers (no.)	Non-effective tillers (no.)	Panicle length (cm)	Panicles plant^{-1} (no.)	Grains panicle^{-1} (no.)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 grain wt. (g)	Yield plant-1 (g)	Harvest index (%)
T_0V_1	122.2 a	12.67cde	11.33efg	1.67ab	21.42def	6.00ab	144.0 ab	101.0abcde	40.00cdefg	24.57 d	21.13 abcd	43.33 cd
T_0V_2	122.1 ab	12.33de	11.00 fg	1.33abc	24.33 a	5.33 b	143.7 ab	105.3 a	36.33 gh	24.60 d	19.80abce	42.67cde
T_0V_3	93.00 cd	13.33bc	12.33 cd	1.00bcd	22.03 bc	5.33 b	142.3 ab	102.3 abc	43.33 bc	24.53 d	18.10 cdef	40.67 f
$T_0 V_4$	90.53 e	11.00gh	10.00 h	1.00bcd	21.10 fg	5.00 b	130.0 abc	87.00 gh	34.67 h	23.93 e	15.53 fgh	35.00 i
T_1V_1	121.4 b	11.33fg	10.67 gh	0.67cd	21.58cde	7.00 a	133.0 abc	104.3 ab	38.00 efgh	23.50 f	21.77 abc	42.00def
T_1V_2	122.0 ab	11.00gh	10.00 h	1.00bcd	24.33 a	5.33 b	146.3 a	100.7bcde	41.33 cdef	23.47 f	18.27 cdef	41.33ef
T_1V_3	93.20 cd	12.00ef	11.33efg	0.67cd	22.10 b	5.33 b	146.3 a	95.67 f	48.00 a	23.53 f	17.60 def	37.00 h
T_1V_4	90.57 e	10.00ij	8.667 i	1.33abc	20.90 g	5.00 b	113.7 c	89.00 gh	37.00 fgh	22.80 g	12.97 h	34.00 i
T_2V_1	122.3 a	14.33 a	13.67 a	0.67cd	21.92 bc	6.00ab	146.0 a	103.3 abc	38.33defgh	25.70 b	22.37 a	48.67 a
T_2V_2	122.1 ab	12.00 ef	11.00 fg	1.00bcd	24.13 a	5.33 b	143.0 ab	99.33cdef	40.33cdefg	25.77 b	19.60 bcde	43.67 c
T_2V_3	92.57 d	14.00 ab	12.00cde	2.00 a	21.82bcd	5.33 b	137.0 abc	95.00 f	46.33 ab	25.60 b	18.43bcdef	41.67 ef
T_2V_4	90.73 e	13.00 cd	11.67def	1.33abc	21.10 fg	5.00 b	129.7 abc	88.67 gh	37.33 fgh	25.23 c	16.37 efgh	37.33 h
T_3V_1	122.1 ab	10.33 hi	10.00 h	0.33 d	21.00 fg	6.00ab	144.7 a	103.3 abc	38.67defgh	23.37 f	20.07abce	42.33cdef
T_3V_2	122.3 a	10.00 ij	9.000 i	1.00bcd	24.13 a	5.33 b	137.7 ab	100.7abcde	42.00 cde	23.40 f	17.17 efg	39.00 g
T_3V_3	93.23 cd	10.00ij	8.333 i	1.67ab	22.05 bc	5.00 b	145.7 a	96.67 ef	43.33 bc	23.30 f	16.57 efg	35.33 i
T_3V_4	90.67 e	9.333 j	8.333 i	1.00bcd	21.12 fg	5.00 b	120.0 bc	84.67 h	41.33 cdef	22.73 g	13.67 gh	32.33 j
T_4V_1	122.2 a	14.00 ab	13.33 ab	0.67cd	21.60cde	6.00ab	140.7 ab	103.0 abc	40.33cdefg	26.27 a	22.00 ab	49.00 a
T_4V_2	122.0 ab	14.00 ab	12.67bc	1.33abc	24.23 a	5.00 b	135.3 abc	101.3 abcd	39.67cdefg	26.30 a	17.80 def	45.33 b
T_4V_3	93.57 c	13.33 bc	11.67def	1.67ab	21.90 bc	5.00 b	143.0 ab	97.67 def	42.67bcd	26.20 a	18.00 def	41.00 ef
T_4V_4	90.90 e	12.67cde	11.67def	1.00bcd	21.27efg	5.33 b	138.3 ab	89.67 g	36.33gh	25.20 c	18.60bcdef	38.00 gh
CV (%)	*0.35%*	*3.34%*	*3.86%*	*43.77%*	*1.14%*	*11.14%*	*8.94%*	*2.46%*	*5.53%*	*0.57%*	*10.53%*	*2.20%*

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. Where, T_0= control or ambient,T_1= 36°C at tillering stage, T_2= 36°C at booting stage,T_3= 36°C at panicle initiation andT_4= 36°C at flowering stage; V_1= Binadhan5,V_2=Binadhan6,V_3=Binadhan8 and V_4=Iratom24.

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)
EISSN: 2312-7945, © Hazra et al. (2016), Research paper

Table 05. Effect of temperature on grain dry weight, photosynthetic rate, leaf conductance, transpiration rate and water use efficiency of flag leaf during grain filling period

Treatments	Dry wt. grain_1 (mg)	Pn	Cond.	Tr	WUE
Control	17.14 a	22.12 a	0.99a	7.33 a	2.52 c
Temperature stress (30ºC)	15.63c	14.61c	0.43c	6.03c	2.83 b
Varieties					
Binadhan5	15.30d	19.44 a	0.61 b	5.86 c	4.12 a
Binadhan6	17.82 a	17.98 b	0.68 b	8.31 a	2.35 c
Binadhan8	15.93 c	18.48 b	0.83 a	6.61 bc	2.20 c
Iratom24	16.49 b	17.56 b	0.71b	6.92 b	3.06 b
Days after anthesis					
0	3.07g	23.22a	1.33a	8.77a	2.98b
4	4.67f	20.79b	1.09ab	8.50a	2.78b
8	12.51e	19.59c	0.59c	6.73b	3.38ab
12	18.37d	18.78d	0.71bc	6.31bc	3.89a
16	21.31c	17.77a	0.64c	6.86b	2.85b
20	22.67b	16.95f	0.46c	6.38bc	3.06b
24	24.50a	15.52g	0.47c	6.00c	3.46ab
28	24.55a	14.76h	0.38c	5.48d	3.13b

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT. Where, Pn= Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$), Cond= Conductance ($molH_2Om^{-2}s^{-1}$), Tr= Transpiration rate ($molH_2Om^{-2}s^{-1}$) and WUE= Water use efficiency

IV. Conclusion

Based on the results of the present study, it may be concluded that higher temperature showed higher yield potential than lower temperature. Experiment finding also indicates that Binadhan-6 is tolerant to high temperature. Although further studies in different areas at larger scale are suggested to deliberately confirm these results; before start to practice and extension of these studies.

Acknowledgements

We thank Dr. Md. Abdul Baten, Dept. of Environmental Science, Bangladesh Agricultural University for his inspiration and guidance throughout this work. We also thanks to the staffs of the Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh & Department of Environmental Science, Bangladesh Agricultural University for their assistance.

V. References

[1]. Ahmed, A. U. & M. A. (1999). Development of climate change scenarios with general circulation models, In: Vulnerability and Adaptation to Climate Change for Bangladesh. S. Huq, Z. Karim, M. Asaduzzaman and F. Mahtab (Eds.), 13-20. http://dx.doi.org/10.1007/978-94-015-9325-0_2

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)
EISSN: 2312-7945,

[2]. Chowdhury, S. I. & Wardlaw, I. F. (1978). The effect of temperature on kernel development in cereals. *Australia Journal of Agricultural Resources*, 29(1), 205-223. http://dx.doi.org/10.1071/AR9780205

[3]. Costa, W. A. J. M. (2000). Prediction of the effects of elevated CO_2 and temperature on irrigated rice yields in the low country dry zone of Sri Lanka using a process based simulation model. *Journal of National Science Foundation*, Sri Lanka, 28(3), 165-184.

[4]. Eitzinger, J., Orlandini, S., Stefanski, R. & Naylor, R. E. L. 2010. Climate change and agriculture: introductory editorial. *Journal of Agricultural Science*, Cambridge, 148, 499–500. http://dx.doi.org/10.1017/S0021859610000481

[5]. Freed, R. D. (1992). MSTAT-C. Crop and Soil Science Department, Michigon University, USA.

[6]. Haque, M. Z., Hossain, M. M., Gomosta, A. R. & Islam, M. S. (1983). The effect of high temperature on spikelet sterility in several rice varieties of Bangladesh. *Bangladesh J. Agric.*, 8(1-14), 50-56.

[7]. Huq, S. (2003). Climate Change and Bangladesh: the way forward. Tiempo, Global Warming and the Third world., 47, 13-16.

[8]. IPCC Climate Change (2007). The physical science basis: contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge: Cambridge University Press.

[9]. Islam, M. T. (2011). Effect of temperature on photosynthesis, yield attributes and yield of aromatic rice genotypes. *Int. J. Sustain. Crop Prod.*, 6(1), 14-16.

[10]. Karim, Z., Hussain, S. G. & Ahmed, M. (1996). Assessing impact of climatic variations on food grains production in Bangladesh. *Journal of Water, Air, and Soil Pollution*, 92, 53-62.

[11]. Kerr, R. A. (2005). Millennium's hottest decade retains its title, for now. *Science*, 307, 828-829. http://dx.doi.org/10.1126/science.307.5711.828a

[12]. Lawlor, D. W. (1997). Response of crops to environmental change conditions: Consequences for world food production. *Journal of Agricultural Meteorology*, 52(5), 769-778. http://dx.doi.org/10.2480/agrmet.52.769

[13]. Manalo, P. A., Ingram, K. T., Pamplona, R. R. & Egeh, A. O. (1994). Atmospheric CO_2 and temperature effect on development and growth of rice. *Agriculture, Ecosystems and Environment*, 51(3), 339-347. http://dx.doi.org/10.1016/0167-8809(94)90145-7

[14]. Maraseni, T. N., Mushtaq, S. & Maroulis, J. (2009). Greenhouse gas emissions from rice farming inputs: a cross-country assessment. *Journal of Agricultural Science*, Cambridge, 147, 117–126. http://dx.doi.org/10.1017/S0021859608008411

[15]. McCarthy, J. J., O. F. Canziani, N. A., Leary, D. J. Dokken & K. S., White (eds.). (2001).Climate change: Impacts, Adaptation and Vulnerability, Inter-Governmental panel on climate change (IPCC), Work Group II, Input to the Third Assessment Report, Cambridge University Press.

[16]. Roy, K., Rahman, M. & Kumar, U. (2009). Future Climate Change and Moisture Stress: Impact on Crop Agriculture in South-Western Bangladesh, 1(1), 1-8 Dhaka, Unnayan Onneshan.

[17]. Shen, Y. A., Yu, W. S. & Lee, J. F. (2000). Effects of global climate change to rice production. *Chinese Journal of Agrometeorology*, 7(4), 69-85.

[18]. Shi, C. L., Jin, Z. Q., Ge, D. K. & Su, G. L. (2001). Effects of climate change on crop yields and adaptation strategies in the middle and lower valleys of the Yangtze river. *Jiangsu Journal of Agriculture Science*, 17(1), 1-6.

[19]. Smith, P. & Olesen, J. E. (2010). Synergies between the mitigation of, and adaptation to, climate change in agriculture. *Journal of Agricultural Science*, Cambridge, 148, 543–552. http://dx.doi.org/10.1017/S0021859610000341

[20]. Tashiro, T. & Wardlaw, I. F. (1989). A comparison of the effect of high temperature on grain development in wheat and rice. *Annual Botany*, 64(1), 59-65.

[21]. Yang, C. M. & Heilman, J. L. (1993). Response of rice (*Oriza sativa* L.) to short term high temperature growth development and yield. *Journal of Agricultural Resources*, 42(1), 1-11.

[22]. Weiss, A., Hays, C.J. & Won, J. (2003). Assessing winter wheat responses to climate change scenarios: a simulation study in the U.S. Great Plains. *Climatic Change*, 58, 119-147. http://dx.doi.org/10.1023/A:1023499612729

Corresponding author email: ph7.bau@gmail.com (Hazra, P.)
EISSN: 2312-7945,