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Research Paper

Evaluation of Wheat Genotypes Suitable for Terminal Heat Stress

Md. Monwar Hossain[1], Akbar Hossain[1], Md. Ashraful Alam[1], Md. Zaherul Islam[1] and Sagar Maitra[2*]

[1]Bangladesh Wheat and Maize Research Institute, Dinajpur, Bangladesh
[2]Centurion University of Technology and Management, Odisha, India

*Corresponding author: sagar.maitra@cutm.ac.in (**ORCID ID:** 0000-0001-8210-1531)

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ABSTRACT

Rising temperature and consequent variations in climate unfavorable affect plant growth and development and catastrophic result loss of wheat productivity. In temperature for each degree increase, wheat production decrease by 6% is estimated. Responses of wheat to stress of heat morphophysiological may help formulating appropriate strategies for heat-stressed to improvement of wheat yield. Additionally, examining for probable management technique may raise productivity and sustainability of growing wheat. The main findings from this observation causes of heat stress significantly decrease seed germination and seedling growth, cell turgidity, and plant water-use ability, at a cellular level, stress of heat disarrange cellular functions by generating more reactive oxygen species, leading to oxidative stress; wheat main response to heat stress include the raise of leaf senescence decrease of photosynthesis, deactivation of photosynthetic enzymes, and increase of oxidative harm to the chloroplasts; heat stress also decrease number of grain and size by affecting grain setting, include translocation and duration and growth rate of grains; a well-mobilized genetic and agronomic management option may improve wheat tolerance to heat. However, all the genotypes were affected adversely due to delayed sowings, It has been stated that wheat has adaptive effiicient to be cultivated in warm-dry tropical weather with irrigation and particular genotypes may be used for a breeding program of wheat with stress of abiotic tolerance. The nursery was consisted of 27 elite genotypes of wheat. It was grown under late sowing condition. Considering yield and other yield contributing characters along with different morphophysiological traits, five genotypes, viz., E-16, E-20, E-23, E-25 and E-27 were selected for further evaluation.

HIGHLIGHTS

- Terminal heat stress is a major problem for wheat cultivation in Bangladesh. To overcome the problem, suitable genotypes that can tolerate heat stress are to be brought under cultivation.
- The study suggested that out of 27 elite genotypes, five genotypes, viz., E-16, E-20, E-23, E-25 and E-27 can be suggested for further evaluation.

Keywords: Climate, productivity, enzymes, growth rate, wheat, yield, oxygen, Bangladesh

Bread wheat (*Triticum aestivum* L.) cultivated the most widely cereal crop, cold climate or temperate and sub-tropical yet a tropical crop (Midmore *et al.* 1984). It follows dissimilar patterns of the growing season in other parts of the world. In countries as Bangladesh where wheat is planted in November and harvested around March and April, China is sown in March-April and harvested in July-August (Leff *et al.* 2004). Such changing in the planting

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pattern predict a phenological succession from the crop resulting in a concise growing season. In case the sowing is late for any reason stress of high-temperature at anthesis and during the grain filling period affect the wheat yield adversely. Particularly, the wheat plant may have to go widely all the growth and development period in a decreased duration towards high temperatures (Akter and Islam, 2017). The stress of high-temperature may lesion plant development at early vegetative, flag-leaf appearance, flowering, anthesis and duration of grain filling or may go to lesion at more than one or all stages (Rezaei *et al*. 2018; Aiqing *et al*. 2018: Gaikwad *et al*. 2022). Abiotic stresses tolerance in *Triticum aestivum* L. has constantly been a hard proposition that include numerous agronomical and physiological traits in more phonological coordination (Bala and Sikder, 2018; Billah *et al*. 2021). When strikes high-temperature earlier the anthesis vegetative features and consequently adversely affected of grain yield (Calderini *et al*. 1999). High temperatures result after the anthesis reduction in the rate of grain filling, development of grain and at last yield and quality (Lyman *et al*. 2013). Components of yield contributing including the number of spikes per plant, number of grains per spikes, and weight of 1000-grain directly yield contribute (Wu *et al*. 2012; Panda *et al*. 2022).

During the development of reproductive, stress of high-temperature break photosynthesis and early senescence give to rise (Siebert *et al*. 2014). the flag leaf stocks key to photosynthetic assimilates which contribute to the yield of grain (Sanchez-Bragado *et al*. 2014). Diminishes the photosynthetic capacity of a leaf before and after the anthesis causes of high temperatures (Nandi *et al*. 2022). Comperative greater yield decline notice was due to the higher temperature (Challinor *et al*. 2014). Mondal *et al*. (2013) indicated that, the heat stress effects of plants are highly difficult resulting in exchanges of growth and development, functional changes in physiological, and decreased the formation of grain and yield .Causes of heat stress interchange of plant water relations (Hasanuzzaman *et al*. 2012, 2013), shortage of photosynthetic capacity (Ashraf and Harris 2013), reduce of metabolic activities (Farooq *et al*. 2011) and alternation of hormones (Krasensky and Jonak 2012), creation of oxidative reactive species, improvement of ethylene production (Hays *et al*. 2007), development of pollen tube decrease, and improvement of pollen mortality (Oshino *et al*. 2011) in wheat. during the time since 1880 to 2012, the Earth's system promote by 0.85°C (IPCC 2014). This warming time will carry on and calculate to increase between the range of 1.5–4.0°C in the future (Wheeler and Von Braun 2013). The factors of climate as variation in temperature, precipitation, CO_2, variability weather, and scarcity of soil moisture would have positive or negative outcome on crop production. impacts of climate change deleterious on crop production the food security are challenging of the world, and it is forecast that promise wheat production will be more influence by rising temperature (Tripathi *et al*. 2016). Change of climate wheat production could strongly affect, accounting for 21% of food and 200 million hectares of farmland worldwide (Ortiz *et al*. 2008). Impacts of climate change on crops under stress of heat elevated CO_2 environment, Deryng *et al*. (2014) contributed highly to current realiazation. affects of high temperature, crops in different ways along poor germination and plant establishment, photosynthesis reduced, leaf senescence, shortened pollen viability, and accordingly production of short grains with smaller grain size (Asseng *et al*. 2011).

Due to worldwise warming and alternative in the climate pattern, it is vital to determine the effects of heat stress and possible ways of progressing heat tolerance for the advancement of wheat production under environment of heat stress. Reidsma *et al*. (2010) approached various models of adaptation measures based on climate impact assessment. Such a condition over the season of crop growing has already been stated to decrease wheat productivity in the many causes of the world (Mueller *et al*. 2015). Abiotic stress is major yield limiting factor in wheat under changing climatic condition. Now emphasis should be given to develop stress tolerant varieties to boost up and sustain wheat yield and production. To develop stress tolerant varieties it is important to find out some physiological traits along with yield potentiality which can contribute to avoidance and tolerance mechanism against stress. In this regard, CIMMYT has designed different nurseries to test advanced genotypes in different stress environments around the world and to find out potential stress adaptive traits. However, improvement of heat-tolerant varieties of wheat generation to development pre-breeding component for any breeding program is crucial in meeting for future in food security (Ortiz *et al.* 2008). The SATYN constituting lines selected from genetic resource collections that show favorable expression of heat adaptive traits.Therefore, this nursery was tested in three locations of Bangladesh to find potential stress adaptive traits under heat stress and to select promising genotypes that perform better under the stress condition.

MATERIALS AND METHODS

The nursery consist of 27 genotypes was tested at BWMRI, Dinajpur; RWRC, Joydebpur, Gazipur and RWRC, Rajshahi. The nursery was shown on 22 December in Dinajpur, 21 December in Rajshahi and Joydebpur 21 December. The experiment was laid out in Alpha-lattice design with two replications. The unit plot size was 2.5 m long with 6 rows spaced at 20cm. Fertilizers were applied @ N_{100} P_{26} K_{50} S_{20} B_1 kg ha^{-1}.

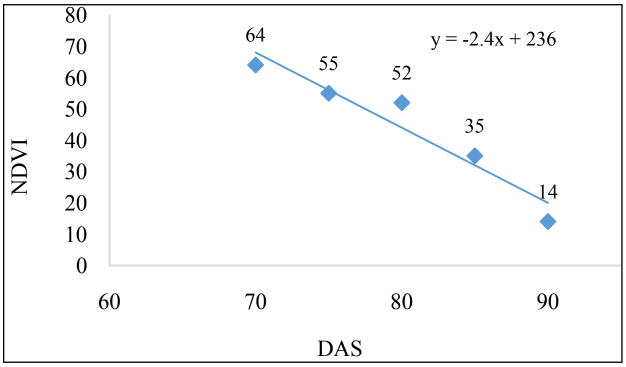

Fig. 1: Calculating senescence rate of wheat germplasm from the NDVI data in 6th SATYN 2017

All the fertilizers and two-third of urea were applied during final land preparation and one-third of urea was top dressed after first irrigation. All agronomic practices have been done proper time for better yield performance.

The data were recorded on Canopy temperature at vegetative stage (CT.VG) and Grain feeing stage (CT.GF), Leaf chlorophyll content (CHL), Senescence rate (SR) was calculated as equivalent to the slope of the trend lines of NDVI value, plotted against days after planting which is expressed as % per day. Heading days (HD), Maturity days (MD), Plant height in cm (PH), number of spikes per plot (SP. PL), Number of grains per Spike (GR.SP), Spikelet per spike (SPL.SP), 1000-grain weight in grams (TGW) and. Canopy temperature was measured by a hand held Infrared thermometer (IRT). Leaf chlorophyll was measured by hand held SPAD meter (Spectrum Technologies Inc., Plainfield,IL, USA). The GreenSeeker® handheld crop sensor is an active light source optical sensor that is used to measure plant biomass and display as NDVI. At maturity, the whole plot was harvested to estimate grain yield. Data were analyzed by ANOVA using STAR, version 2.0.1. (2014) and CropState 7.2 (2007).

RESULTS AND DISCUSSION

The mean effect of location on the genotypes for yield and yield contributing characters were presented in table. All the studied traits showed significant variation in three different locations. In Dinajpur, the genotypes took longer time for heading and maturity and were taller than genotypes grown in Joydebpur and Rajshahi. Thousand grain weight and yield were also higher in Dinajpur than other locations.

The mean performance of genotypes was presented in Table 1. All the selected genotypes headed and matured later than the check variety Shatabdi but shorter plant height than check except Entry 20. The Thousand grain weights (g) were higher in E-20 than check variety Shatabdi. The highest yield (4030 kg ha^{-1}) was recorded in Entry 3 but this entry was rejected due to poor grain quality.

Responses of plant to heat stress

Heat stress affects different processes of plant to lead morphophysiological exchanges in wheat plants, blocking the processes of development and result eventually loss into great yield (Grant *et al.* 2011). Plant responses to stress of heat significantly differ with the expand and term of temperature, and the stage of growth face with the stress (Ruelland and Zachowski 2010). Effects some common heat stress on growth and productivity, development of grain, and yield of wheat.

Responses to morphological and growth stage

Effect of initial heat stress is the barrier of seed germination and little stand incorporation in many crops including wheat (Hossain *et al.* 2013). Periphery temperature around 45°C crucial affects embryonic cell in wheat which decrease crop keep through break seed germination and emergence

Table 1: Mean effect of location on yield and yield contributing characters in SATYN in 2016-17

Location	Heading (days)	Maturity (days)	Height (cm)	TGW (g)	Yield (kg ha^{-1})
Dinajpur	73	115	105	45.0	4481
Joydebpur	65	90	88	45.6	2703
Rajshahi	71	108	98	39.0	3436
F-test	**	**	**	**	**
LSD (0.05)	0.36	0.55	1.36	0.75	135.80
CV	1.4	1.4	3.7	4.5	10

Table 2: Mean performance of genotypes for yield and yield contributing character of wheat genotypes in SATYN, 2016-17

Entry	Heading (days)	Maturity (days)	Height (cm)	TGW(g)	Yield (kg ha^{-1})	SR(Din) % per day
Shatabdi	63	102	96	48.9	3879	2.45
2	69	104	95	40.8	3485	2.28
3	69	105	92	40.8	4030	2.19
4	71	105	97	43.1	3654	2.06
5	71	106	101	47.8	3542	2.34
6	74	109	95	37.2	3275	1.96
7	66	102	89	38.6	3654	2.17
8	70	106	101	38.8	3323	2.16
9	73	108	93	39.7	3646	2.02
10	69	106	101	42.4	3579	2.1
11	72	106	102	41.8	3446	1.87
12	72	106	100	49.9	3479	2.4
13	69	104	99	42.5	3595	1.62
14	73	105	96	45.2	3396	2.17
15	69	101	98	41.2	2668	1.31
16*	73	106	96	40.6	3564	1.85
17	70	104	93	39.2	3276	2.15
18	74	108	97	41.8	3648	1.98
19	70	105	100	47.0	3545	1.98
20*	69	102	101	51.0	3707	2.26
21	72	104	98	45.9	3757	1.77
22	68	102	98	39.8	3626	2.15
23*	62	100	97	41.1	3198	2.12
24	72	105	101	45.3	3715	1.83
25*	68	101	92	44.4	3774	2.46
26	71	103	95	45.8	3293	2.19
27*	68	102	94	46.2	3820	1.96
F-test	**	**	**	**	**	**
LSD (0.05)	1.09	1.66	4.07	2.24	407.39	0.348
CV%	1.4	1.4	3.7	4.5	10	8.19

**Selected entries.*

(Essemine *et al*. 2010). mostly affects heat stress the plant meristems and decrease plant growth by raising leaf senescence and abscission, and by shorten photosynthesis (Kosova *et al*. 2011). 28 to 30°C ranging from heat stress may change the duration of plant growth by decrease seed germination and periods of maturity (Yamamoto *et al*. 2008). temperature almost 30 and 25°C day and night gradually, may have acute effects on leaf progress and productive tiller formation in wheat (Rahman *et al*. 2009) though, the advancement of reproductive stage heat stress has been build to be more noxious in wheat production (Nawaz *et al*. 2013). temperature increase in 1–2°C decrease seed weight by accelerating seed growth rate and by reduction the grain-filling periods in wheat (Nahar *et al*. 2010).

Interaction effect of location and genotype on heading, plant height, TGW and Yield for selected entries has been presented in table. Significant variation among the genotypes, locations and their interaction was observed for all traits. None of the selected genotypes had earlier days to heading than Shatabdi except E-23 at Dinajpur and Joydebpur locations. The vegetative plant height was shorter than check for all selected genotypes at Dinajpur and Joydebpur. The E-20 had higher thousand grain weight than the check at Dinajpur and Rajshahi. The highest grain yield (5005 kg ha^{-1}) was obtained in E-25 followed by E-16 (4923 kg ha^{-1}) at Dinajpur location. In Joydebpur, Entry-27 produced highest grain yield (3270 kg ha^{-1}) and E-20 produced highest grain yield (4029 kg ha^{-1}) at Rajshahi.

Heat stress responses to grain growth and development

The optimum ranges of temperature 12 to 22°C for wheat anthesis and grain filling (Shewry 2009). during reproductive stage plants exposed to temperatures above >24°C significantly decrease grain yield and yield, decrease continued with raising duration of exposure temperature of high (Prasad and Djanaguiraman 2014).

Effect of heat stress on Grain number, grain filling, and quality of grain

Heat stress decrease the grains number leading to lower harvest index in wheat (Lukac *et al*. 2011). However, influence the heat stress both the number and size of grains different with the growth stages faceing to heat stress temperatures above 20°C among spike formation and anthesis speed up the improvement of the spike but decrease the number of spikelets and grains per spike (Semenov 2009). pollen cell and microspore adversely affects heat stress resulting among male sterility (Anjum *et al*. 2008). yet temperature of high above 30°C during floret advancement may reason complete sterility in wheat depending on genotypes (Kaur and Behl 2010). in wheat, the anther made under 3 days stress of heat during anthesis was establish to be form abnormal and nonfunctional florets. cause of day/ night high temperature of 31/20°C may also shrinking of grains resulting from variation form of the aleurone layer and cell endosperm (Dias *et al*. 2008). grain-filling period high temperature in

Table 3: Interaction effect of location and genotype on heading, plant height, thousand grain weight and yield in SATYN, 2016-17

Entry	Heading (days)			Plant Height (cm)			TGW (g)			Yield (kg ha^{-1})			AUDPC
	Din	Gaz	Raj	Din	Gaz	Raj	Din	Gaz	Raj	Din	Gaz	Raj	
Shatabdi	70	60	60	108	90	90	48.9	52.8	45.1	4840	2998	3800	65
16	76	68	74	105	87	97	40.3	42.3	39.3	4923	2713	3058	115
20	71	65	72	108	91	104	55.2	52.1	45.7	4560	2531	4029	58
23	64	56	65	105	88	98	43.2	43.0	37.1	3113	2757	3726	99
25	71	64	68	102	83	92	45.8	46.9	40.5	5005	2894	3424	71
27	71	63	69	103	87	93	45.5	48.0	45.0	4675	3270	3514	94
Mean	71	63	68	105	88	96	46.5	47.5	42.1	4519	2861	3592	
CV%		1.4			3.7			4.5			10		
LSD(0.05)		1.89			7.04			3.88			705.62		

wheat is very sensitive (Farooq *et al*. 2011). However, the growth rate of grain and duration reduced in plants having various grain weight stability (Vijayalakshmi *et al*. 2010). In wheat, duration of grain-filling may be reduced by 12 days with the raise of 5°C temperature above 20°C (Yin *et al*. 2009). raise in night temperature is also responsive, reduce the grain filling stage, and decrease the grain yield than that temperature of day. 20°C and 23°C Night temperatures decrease the grain-filling time by 3 to 7 days (Prasad *et al*. 2008a). Song *et al*. (2015) indicated a significant decrease in the rate of grain filling in wheat cultivars at 32/22°C day/night temperature when compared with that 25/15°C. Affects of heat stress grain quality most of cereals and legumes, basically because of limitation of assimilates and low remobilization of nutrients.

However, the improvement of the quality of grain and yield wheat plants are able to receiving a heat shock by improving thermo-tolerance (Sharma-Natu *et al*. 2010). wheat plants suffer stress of heat early in filling of grain were begin to have high content of grain protein (Castro *et al*.2007)

CONCLUSION

The main findings from this observation causes of heat stress significantly decrease seed germination and seedling growth, cell turgidity, and plant water-use ability, at a cellular level, stress of heat disarrange cellular functions by generating more reactive oxygen species, leading to oxidative stress; wheat main response to heat stress include the raise of leaf senescence decrease of photosynthesis, deactivation of photosynthetic enzymes, and increase of oxidative harm to the chloroplasts; heat stress also decrease number of grain and size by affecting grain setting, include translocation and duration and growth rate of grains; a well-mobilized genetic and agronomic management option may improve wheat tolerance to heat. However all the genotypes were affected adversely due to delayed sowings, It has been stated that wheat has adaptive effiicient to be cultivated in warm-dry tropical weather with irrigation and particular genotypes may be used for a breeding program of wheat with stress of abiotic tolerance. Considering yield and other yield contributing characters along with different morphophysiological traits five genotypes viz. E-16, E-20, E-23, E-25 and E-27 were selected for further evaluation.

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