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SCREENING OF ELITE WHEAT GERMPLASM AGAINST NORMAL AND HEAT STRESS CONDITIONS USING AGRO-MORPHOLGICAL APPROACHES

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ABSTRACT

Alarming climate change is a worldwide documented phenomenon and increase in abiotic (temperature stress, drought, salinity) and biotic stresses (diseases, pests) have been reported worldwide in agricultural crops. Terminal heat stress is one of the yield limiting factors for wheat crop in South Asia, including Pakistan. To address this core issue, a field study was carried out at Experimental Farm of Nuclear Institute of Agriculture, Tandojam for two consecutive years 2013-14 and 2014-15 by using 20 wheat genotypes (mutants and advance lines) along with four check varieties. The breeding material was exposed to different temperature levels by sowing on two different dates viz. sowing date-1 abbreviated as SD-1 (November 15 as normal sowing $<35^0$C at grain filling) and SD-2 (December 25 as late sowing $>40^0$C temperature stress at grain filling). The observations on various important traits (days to maturity, grain yield, 1000-grain weight and harvest index) were recorded for both the years. The two years agro-morphological data revealed variable response of wheat genotypes for grain yield and other traits under normal and heat stress conditions. Grain yield under normal sowing ranged from 5050 to 6385 kg ha^{-1} in potential genotypes. Seven genotypes i.e. DH-12/1, NIA-10/8, Kiran-95, NIA-Amber, NIA-28/4, NIA-8/7 and BWS-78 were found tolerant to heat stress and produced higher grain yields (varied from 3850 to 4905 kg ha^{-1}) under heat stress conditions during both the years.

Keywords: heat stress tolerance, wheat genotypes, yield and yield attributes

INTRODUCTION

Shrinking of agricultural lands due to urbanization and industrialization is a big challenge for food security in the world (Parry *et al.*, 2011). Wheat is an important staple food crop to feed increasing population of the world. Its consumption will increase from 552 million tons in 1993 to 775 million tons by 2020. (Rosegrant and Agcaoili, 2010). Total 60% increase in wheat production will be required to

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meet the food demand of worlds population by 2050 (Rosegrant and Agcaoili, 2010). Wheat is an important cereal crop of Pakistan, grown over an area of 9.26 million hectares with production of 25.48 million tons (GoP, 2015-2016).

Globally, climate change scenario indicates that intensity and frequency of various biotic and abiotic stresses on wheat crop are increasing with the time. Beside the other factors such as drought, diseases, heat stress is likely to occur more frequently (IPCC, 2013; Hossain *et al.,* 2015). Continual heat stress affects approximately 7 million hectares of wheat grown in 50 developing countries, (Sarkar *et al*., 2001). While, terminal heat stress is a problem in 40% of temperate environments, which cover 36 million hectares (Renolds *et al.*, 2001). High temperature during wheat grain filling period is a major yield limiting stress in most parts of Asia and Africa (Ferrera *et al*., 1993; Joshi *et al*., 2007). Increase in temperature will reduce wheat yield by 20-30% in area where 66% of the wheat is produced (Lobell *et al.*, 2008; Rosegrant and Agcaoili, 2010; Talukder *et al*., 2014). Temperature increase especially at grain filling period will have a big impact on wheat productivity worldwide. In Pakistan, more than 40% of cropped area in Punjab and Sindh provinces is sown late (Farooq *et al*., 2011). The late sown wheat is affected by high temperature stress during their grain development. It affects yields and yield attributes like grain yield, plant height, days to heading, and days to maturity and grain formation period (Riaz-ud-din *et al*., 2010). It was reported that genotypes which possess stay green character and longer grain filling period under heat stress were found tolerant to high temperature stress (Nawaz *et al.,* 2013). Keeping in view the global warming and to ensure the food security of a huge increasing population of the country, it is need of the day to develop germplasm which can produce sustainable grain yield under high temperature stress (Hossain and Silva, 2012; Martre *et al.*, 2015). Therefore, present study was planned to assess various effects of heat stress on wheat grain yield and other yield contributing traits and to identify key parameters for selection of genotypes against high temperature stress tolerance. The selected, heat tolerant wheat germplasm can be efficiently used in future breeding program to meet the climate challenge, which threatens to food security.

MATERIALS AND METHODS

To address the core issue of increasing high temperature stress at grain filling period in wheat crop, a field study was carried at Experimental Farm of Nuclear Institute of Agriculture, Tandojam for two consecutive years 2013-14 and 2014-15. Twenty wheat mutants/ advance lines (BWM-3, MSH-3, MSH-36, MSH-5, NIA-8/7, NIA-AMBER, MASR-3, MASR-9, MASR-64, BWS-78, DH-3/8, DH-3/48, DH-11/3, NIA-9/5, NIA-10/8, NIA-28/4, MASR-23, MASR-7, DH-10/22 and DH-21/1) along with four check varieties (Sarsabz, TJ-83, TD-1 and Kiran-95) were exposed to different temperature regimes by sowing on two different dates viz. sowing date-1 abbreviated as SD-1 (November 15 as normal sowing $<35^0$C at grain filling) and SD-2 (December 25 as late sowing$>$ 40^0C temperature stress at grain filling). Temperature at the time of sowing of both normal and late trials was suitable during both the years. The normal sown crop completed its life cycle before onset of high temperature stress in the month of March; on the other hand the late sown crop faced high temperature shocks during its grain development processes in the month of April. Mean maximum temperature in the month of April during 2013-14 remained above optimal level of crop viz. 38^0C to 41.2^0C (data not shown) that stressed the crop during grain development whereas during 2014-15 terminal heat stress for the late sown crop further increased and ranged 39^0C to 43.8^0C in the month of April (data not shown). Experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. Each experiment was sown with 4 rows of 3 m length and row to row distance of 30 cm. Metrological data was recorded throughout crop season through October to May each year with hygrothermo-graph installed in front of wheat field of NIA office. Hygrothermograph instrument was used to record minimum, maximum temperature and relative humidity data on its sheet automatically. The sheet of the instrument changed every week. Mean minimum and maximum temperature of each week was calculated. The observations on yield and yield related traits (days to maturity, grain yield, biological yield, 1000-grain weight and harvest index) were recorded. Days to maturity were recorded at the stage, when grain filling process completed, green colour of stem turned to yellowish and grains hardly broken between the teeth. The maturity date was counted from the date of sowing to the complete filling and hardening of grains. Grain yield per plot was recorded by threshing each plot with the help of Vogel thresher. The total produce was weighed in grams with analytical balance. Thousand grains were counted by counting 1000 grains with the help of seed counter and weighed in grams with the help of electronic balance (Sartorius LA 6200S, Germany). The harvest index (%) was calculated using the formula: Harvest index (HI) = Grain yield plant^{-1}/ Biological yield plant^{-1} × 100. Data were statistically analyzed for mean square values and interaction of different factors using computer based software Statistix 8.1 (Steel *et al*., 1996).

RESULTS AND DISCUSSION

Statistical analysis of data showed that there were significant differences among genotypes and the interaction among genotypes with temperature change (sowing dates). Error mean square for different traits viz. days to maturity, grain yield, thousand kernel weight, harvest index %, years, sowing dates, genotypes, years x sowing dates, years x genotypes, sowing dates x genotypes, and years x sowing dates x genotypes are given in Table 1.

Analysis of data showed that days to maturity, years, sowing dates, genotypes, years x sowing dates, sowing dates x genotypes, years x sowing dates x genotypes all were highly significant at $P< 0.05$. Grain yield was found highly significant for years, sowing dates, genotypes and sowing dates x genotypes whereas years x sowing dates, years x genotypes and years x sowing dates x genotypes were non-significant. Thousand kernel weight (g) showed that sowing dates, genotypes, years x sowing dates and sowing dates x genotypes were highly significant while years, years x genotypes, and years x sowing dates x genotypes were non-significant for thousand grain weight. Mean square values for harvest index showed that years x sowing dates were significant while all other interactions were highly significant. This statistical analysis of various traits and their interactions showed highly significant impact of high temperature stress on various agro-morphological traits and their expression with changing environments due to change in sowing dates and years.

Table1. Mean square of various traits, sowing dates, genotypes and their interaction

Source of variation	Reps.	Years	Sowing dates	Genotypes	Years x sowing dates	Years x Genotypes	Sowing dates x Genotype	Years x sowing dates x Genotypes	Error
D.F.	2	1	1	23	1	23	23	23	190
Days to maturity	0.1	23.3**	20469.4**	179.2**	206.7**	5.4**	33.8**	7.1**	1.9
Grain yield (g plot^{-1})	537	52677**	5208109**	203304**	9169ns	4297ns	21504**	2720ns	4109
Thousand kernel weight (g)	8.9	0.00165ns	11005.2**	165.3**	13.0*	1.99167ns	83.5**	3.10713ns	2.3
Harvest index	1.6	130.4**	549.5**	243.9**	55.1*	32.3**	42.5**	21.3**	8.5

NS = Non significant, * =Significant at 0.05, **Highly Significant at 0.01%

Days to maturity

Days to maturity during 1st year of evaluation ranged from 113 days (MASR-3) to 131.7 days (DH-12/1) at normal sowing. At late sowing it ranged from 96 (MSH-3) to 110 days (NIA-10/8) (Table 2). MASR-7, MASR-64, BWS-78 was found early maturing genotypes; NIA-Amber, DH-12/1 and NIA-10/8 was identified as late maturing. Days to maturity reduced to 17.96% in 1st year of evaluation. During 2nd year of evaluation, maturity period ranged from 113.3 in MASR-3 and 129 days in DH-12/1 at normal sowing and at late sowing it ranged from 98.7 days in MASR-64 and 113 days in NIA-9/5 (Table 3) and upto 14.36% reduction was recorded in this character due to heat stress during second year of study. Punia *et al*. (2011) reported that heat stress during anthesis or grain filling period would cause force maturity which will result in reduced grain development period. In another study conducted by Nahar *et al*. (2010) had reported 15% reduction in days to maturity due to the effect of heat stress. These all studies including ours highlight the impact of heat stress and high temperature by reducing maturity period.

Grain yield

Results for the grain yield demonstrated that on the basis of desired traits and better tolerance to high temperature stress nine genotypes i.e., DH-12/1, NIA-10/8, Kiran-95, NIA-Amber, NIA-28/4, NIA-8/7, BWS-78, BMW-3 and MASR-64 produced higher grain yield (ranged from 3850 to 4722 kg ha^{-1}) under high temperature stress conditions during 1st year of evaluation (Table 2). Overall, 43.32% reduction for grain yield was observed during this year. During 2nd year, seven genotypes (DH-12/1, NIA-10/8, Kiran-95, NIA-8/7, NIA-Amber, NIA-28/4 and BWS-78) produced statistically higher grain yield (ranged from 4461 to 4905 kg ha^{-1}) than other genotypes. BWM-3 and MASR-64 could not produce sustainable yield in 2nd year. Overall 46% yield reduction was observed during 2nd year (Table 3). This showed variable response of these two genotypes with changing temperature and environment. Kaur and Behl (2010) reported that high temperature during post-anthesis, reduces duration of maturation, grain filling, grain number, 1000-kernel weight and ultimately grain yield. Sohail *et al.* (2014) in their research studies concluded that late planting could reduce grain yield by

29%. In other studies conducted by Modarresi *et al.* (2010), 43% and 44% decline in grain yield and grain weight, respectively have been reported at high temperature as compared to normal sowing.

Table 2. Performance of elite wheat genotypes for grain yield and it associated traits under normal and heat stressed conditions during 2013-14. (SD-1= Sowing date 1; November 15th, SD-2=Sowing date 2; December 25th)

Genotypes	Days to maturity SD-1	Days to maturity SD-2	Grain yield (gram) plot^{-1} SD-1	Grain yield (gram) plot^{-1} SD-2	1000 Kernel weight (gram) SD-1	1000 Kernel weight (gram) SD-2	Harvest index % SD-1	Harvest index % SD-2
BWM-3	118.7±0.3	101.3±0.9	950.0±29	763.3±15	45.5±0.8	38.0±0.5	41.0±0.7	41.8±0.7
MSH-36	118.3±0.9	99.0±0.6	706.7±7	403.3±3	41.5±0.8	29.2±0.6	34.8±0.1	25.2±0.1
MSH-3	123.0±1.7	96.0±0.6	783.3±17	573.3±47	44.9±0.7	27.6±0.3	37.0±0.4	34.1±1.6
MSH-5	123.7±0.3	98.7±0.9	753.3±9	605.0±13	45.7±1.2	29.0±0.1	34.0±0.2	34.9±0.6
NIA-8/7	124.7±0.3	103.3±0.9	946.7±26	773.3±15	49.3±0.6	43.3±0.3	40.3±0.8	45.0±0.3
NIA-AMBER	129.7±0.9	101.7±1.2	910.0±21	780.0±15	39.3±0.9	35.2±0.2	41.7±0.5	44.2±0.1
MASR-3	113.0±0.7	102.7±0.3	760.0±31	560.0±31	46.3±0.2	28.5±0.5	39.0±0.7	33.6±1.2
MASR-9	117.3±0.3	99.0±0.6	700.0±58	433.3±44	46.9±0.4	29.2±0.1	36.1±1.4	27.4±1.7
MASR-64	115.7±0.7	97.0±0.6	843.3±23	693.3±23	47.7±0.4	39.0±0.6	42.2±0.1	44.3±0.7
BWS-78	115.0±0.6	101.7±1.2	946.7±24	770.0±15	48.7±0.4	38.9±0.3	43.7±0.8	43.6±0.4
DH/3/8	121.7±0.7	107.3±0.3	766.7±17	510.0±21	46.7±1.1	23.8±0.1	39.8±0.5	34.0±0.4
DH-3/48	121.0±1.2	107.0±0.6	776.7±13	416.7±17	47.1±0.5	29.7±0.3	39.4±0.9	26.1±0.8
DH-11/3	125.0±1.0	109.3±0.9	796.7±18	500.0±29	41.5±0.8	28.7±0.2	38.5±0.3	31.7±1.3
NIA-9/5	128.3±0.9	107.7±0.6	850.0±29	523.3±15	43.9±0.2	29.0±0.5	39.0±1.2	30.8±0.5
NIA-10/8	129.0±1.0	110.0±0.9	1066.7±17	850.0±50	46.0±0.6	39.1±0.2	44.2±0.7	44.7±0.2
NIA-28/4	120.3±1.3	105.3±0.3	916.7±60	776.7±12	44.3±0.1	38.5±0.6	42.2±0.6	43.2±0.8
MASR-23	120.7±0.7	105.0±0.6	760.0±60	416.7±17	41.0±0.3	25.1±0.2	30.3±0.7	26.0±0.6
MASR-7	117.3±0.9	102.7±0.3	750.0±29	375.0±14	37.5±0.4	24.4±0.2	33.3±0.7	26.7±0.8
DH-10/22	122.3±0.9	106.7±0.3	708.3±22	366.7±17	44.4±0.4	27.2±0.2	33.7±0.5	23.2±0.5
DH-12/1	131.7±0.7	105.7±1.2	1108.3±22	858.3±30	41.5±0.4	36.3±0.3	44.1±0.8	45.2±0.3
SARSABZ	125.0±0.6	103.3±0.6	853.3±29	526.0±14	42.4±0.3	36.2±0.6	35.6±0.6	35.0±0.8
TJ-83	122.3±0.7	102.7±0.7	858.3±30	575.0±41	38.5±0.4	27.9±0.5	37.6±0.8	34.8±0.2
TD-1	124.7±0.9	98.7±0.9	930.0±35	425.0±38	47.3±0.3	31.2±0.2	44.0±0.9	28.5±1.6
KIRAN-95	126.0±0.6	106.0±0.6	1016.7±44	800.0±29	41.8±0.1	34.9±0.3	43.3±1.2	43.6±0.6

1000-kernel weight

Thousand kernel weight in germplasm under study ranged from 39.3 in NIA-Amber to 49.3 in NIA-8/7 at normal sowing during 1st year of evaluation (Table 2). At late sowing 1000-kernel weight ranged from 23.8 in DH-3/8 and 43.3 in NIA/8/7. Overall reduction in 1000-kernel weight during 1st year remained 31.4%. At late sowing, NIA-8/7, BWM-3, MASR-64, BWS-78, NIA-10/8, NIA-28/4, Sarsabz and Kiran-95 produced higher 1000-kernel weight when sown in late conditions due to heat stress. During second year of screening 1000 kernel weight ranged from 37 gram in MASR-7 to 50 gram in NIA-8/7 (Table 3). At late sowing it ranged from 20 gram in MSH-3 to 42 gram in NIA-8/7. Overall reduction during second year in this trait remained 28%. Genotypes NIA-8/7, BWM-3, MASR-64, BWS-78, NIA-10/8, NIA-28/4, DH-12/1, Sarsabz and Kiran-95 produced higher 1000-kernel weight when sown in late conditions due to heat stress (Table 3). It is reported that those wheat genotypes that produce high thousand-kernel weight (TKW) under heat stress possess great level of heat tolerance (Shefazadeh *et al.* 2012). Kaur and Behl, (2010); Modarresi *et al.* (2010) published that high temperature after period of post anthesis can significantly reduce crop duration, maturity, final grain yield, grain number and grain weight. Singha *et al*. (2006) were of view that those genotypes which can maintain their grain weight during heat stress can be considered as heat tolerant. In this study, most of the genotypes producing higher grain yield under high temperature stress possess higher thousand kernel weight as compared to low yielding or heat susceptible wheat genotypes.

Table 3. Performance of elite wheat genotypes for grain yield and it associated traits under normal and heat stressed conditions during 2014-15. (SD-1= Sowing date 1; November 15th, SD-2=Sowing date 2; December 25th)

Genotypes	Days to maturity SD-1	Days to maturity SD-2	Grain yield (gram) plot^{-1} SD-1	Grain yield (gram) plot^{-1} SD-2	1000 Kernel weight (gram) SD-1	1000 Kernel weight (gram) SD-2	Harvest index % SD-1	Harvest index % SD-2
BWM-3	116.3±0.3	103.3±0.9	950.0±29	550.0±29	46.0±0.6	38.0±0.6	42.9±2.3	35.3±2.3
MSH-36	115.3±0.9	102.0±1.0	816.7±60	436.7±32	43.0±0.6	28.3±0.9	32.8±2.2	31.1±1.2
MSH-3	119.7±1.2	99.0±0.6	800.0±58	586.7±47	46.0±0.6	20.0±1.5	38.7±2.2	38.1±2.5
MSH-5	122.3±0.7	107.3±1.5	763.3±41	600.0±29	45.0±0.6	29.3±0.9	35.8±3.2	34.6±0.8
NIA-8/7	122.7±0.7	105.7±0.9	1000.0±58	806.7±23	50.0±0.4	42.0±0.6	42.6±2.6	40.4±1.0
NIA-AMBER	125.3±0.9	106.3±0.7	1016.7±60	800.0±29	39.7±0.9	34.7±0.3	39.1±2.3	43.2±1.4
MASR-3	113.3±0.9	99.0±0.6	793.3±52	593.3±52	46.7±0.3	28.3±0.9	40.6±0.9	41.0±2.7
MASR-9	118.7±0.7	100.0±1.2	800.0±29	500.0±29	47.3±0.7	29.2±0.2	40.9±1.4	38.0±2.2
MASR-64	114.0±0.6	98.7±1.2	883.3±44	600.0±29	48.3±0.7	38.7±0.7	38.2±2.8	31.7±2.5
BWS-78	114.3±0.7	103.7±0.9	1013.3±35	803.3±32	48.3±0.7	39.0±0.6	42.7±2.5	42.2±2.5
DH/3/8	122.7±0.3	109.3±1.2	750.0±29	550.0±29	45.7±0.9	25.0±0.6	37.8±0.2	37.4±1.9
DH-3/48	123.3±0.7	107.3±0.9	780.0±44	466.7±44	47.3±0.7	29.3±0.7	38.6±2.1	39.1±1.8
DH-11/3	124.0±1.5	112.3±0.9	816.7±44	550.0±50	41.0±0.6	29.3±0.7	38.7±2.1	41.0±0.6
NIA-9/5	126.3±0.9	113.0±1.2	883.3±60	553.3±29	43.7±0.7	29.0±0.6	36.0±3.4	39.3±0.9
NIA-10/8	126.3±0.9	112.0±1.0	1083.3±44	883.3±17	45.0±0.6	39.0±0.6	45.4±1.2	44.0±1.8
NIA-28/4	117.3±0.9	106.0±2.6	966.7±60	813.3±30	44.3±0.7	37.0±0.6	39.0±3.4	45.5±0.2
MASR-23	121.3±1.2	107.7±0.9	793.3±52	483.3±44	40.3±0.3	24.3±0.3	32.3±1.1	25.5±2.8
MASR-7	117.3±0.9	105.0±0.6	800.0±58	450.0±76	37.0±0.4	24.2±0.4	35.0±2.0	31.4±2.0
DH-10/22	123.0±1.7	108.0±1.0	758.3±30	400.0±29	44.3±0.9	27.2±0.2	37.3±3.4	30.0±2.4
DH-12/1	129.0±1.2	112.0±1.0	1150.0±29	883.3±44	41.3±0.3	36.8±0.6	45.5±0.5	42.2±1.8
SARSABZ	123.7±0.9	105.0±0.6	910.0±49	526.0±14	43.3±0.7	36.3±0.7	35.0±1.6	37.1±2.9
TJ-83	121.7±0.7	103.7±1.2	916.7±60	575.0±14	38.3±0.7	28.0±0.6	40.4±1.5	41.9±2.1
TD-1	118.3±1.2	100.0±1.2	916.7±73	425.0±38	49.3±0.3	32.0±0.6	43.8±0.9	37.4±0.6
KIRAN-95	121.3±0.9	107.3±0.9	1016.7±60	816.7±17	44.3±0.9	35.0±0.6	43.8±3.2	41.4±1.8

Harvest index

During normal sowing time, harvest index % ranged from 30.3 in MASR-23 to 44.2% in NIA-10/8 whereas at late sowing under heat stress condition harvest index % was slightly increased and ranged from 23.2 in DH-10/22 to 45.2 in DH-12/1 (Table 2). Harvest index was identified as main criteria for selection under high temperature stress conditions. Those genotypes which produce higher harvest index have capability to translocate their photosynthetes efficiently for grain development. Genotypes BWM-3, NIA-8/7, NIA-Amber, MASR-64, BWS-78, NIA-10/8 NIA-28/4, DH-12/1 and Kiran-95 produced higher harvest index as compared to other genotypes under heat stress. During 2nd year of evaluation harvest index % ranged from 32.3 in MASR-23 to 45.5 % in DH-12/1 under normal sown conditions. Whereas under late sowing due to heat stress harvest index ranged from 25.5 in MASR-23 to 45.5 in NIA-28/4 (Table 3). Genotypes NIA-Amber, MASR-3, DH-11/3, NIA-9/5, Sarsabz and TJ-83 has shown slightly increase in their harvest index values under heat stress as compared to normal sowing (Table 2 and 3). Radhika and Thind (2013) had also reported significant contribution of harvest index in producing higher yield under late sowing. Those genotypes which do not have capability to utilize its photosynthetes for its grain development at reproductive stage would produce lower yield as compared to nutrient use efficient genotypes (Yine *et al*., 2009).

CONCLUSION

It can be concluded that there exists genetic variability for heat stress tolerance at grain filling period in germplasm under study. Genotypes DH-12/1, NIA-10/8, Kiran-95, NIA-8/7, NIA-Amber, NIA-28/4 and BWS-78 were found tolerant to high temperature stress during both years of study. Harvest index and 1000-grain weight were identified two key parameters for selection of genotypes for heat stress tolerance during terminal heat stress period.

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