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Association of Morpho-physiological Traits in Different Wheat Species Under Heat Stress Condition

Kavita*, Renu Munjal[1], S.S.Dhanda**, Naveen Kumar** and Sunita***

ABSTRACT: Wheat plants are exposed to numerous biotic and abiotic stresses which significantlyaffect the growth and cause changes in the normal physiological functions of the plants. Temperature is one of the most important environmental factors that affects growth and development of plants and adversely affects wheat growth particularly at the reproductive stage and is a major limitation to wheat productivity worldwide. Transitory or constantly high temperature cause an array of morpho-anatomical, physiological and biochemical changes in plants, which affect plant growth and development and may lead to a drastic reduction in economic yield. Keeping in view, eighty wheat genotypes, twenty each from Triticumaestivum, Triticum durum, Triticumdicoccumand Synthetic T. aestivum were evaluated for terminal heat tolerance.Hence, it would be rewarding to lay stress on these characters in selection programme for increasing yield.

Keywords: *Heat stress, morpho-physiological traits, temperature,wheat species.*

INTRODUCTION

Wheat is the second most widely grown and consumed cereal globally after rice with over 600 million tones being harvested annually. But wheat plants are exposed to various biotic and abiotic stresses which significantly affect the growth and cause changes in the normal physiological functions of the plants. Temperature is one of the most important environmental factors that affects the growth and development of plants and adversely affects wheat growth particularly at reproductive stage. Increasing temperature causes the reduction in growth phase such as grain filling duration by accelerating phenological development. Although wheat possesses some adaptive plasticity, yet the heat stress has become the common limiting factor for wheat grown in temperate regions which accounts for 40% of total wheat production in world [1, 2]. The optimum temperature for wheat is in the range of 25-35°C[3] but it differs with various growth phases, species and also for different cultivars.By year 2100 there will be an increase in the mean annual temperature between 1.5-6.0°C (IPCC, 2013). There is 3 to 4% yield reduction with every 1°C rise above 15-20°C temperature [1]. Transitory or constantly high temperature cause an array of morpho-anatomical, physiological and biochemical changes in plants, which affect plant growth & development; and may lead to drastic reduction in economic yield. Yield is a complex interaction between various phenological stages, timings and sensitivities of different growth phases to environmental conditions.For screening the heat tolerant genotypes we have to study the various physiological and morphological traits that are most affected by heat stress. There is a considerable attention towards a number of high temperature stress-related traits particularly membrane thermostability [5], canopy temperature depression [6], heat susceptibility index, thousand grain weight [7], and these can be considered as possible criteria for heat stress tolerance.

MATERIALS AND METHODS

In the present investigation 80 wheat genotypes of *Triticumaestivum*, *Triticum durum*, *Triticumdicoccum* and Synthetic *T. aestivum* were screened against heat

* Department of Botany and Plant Physiology, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004

** Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004

1 *E-Mail : munjalrenu66@gmail.com , nimbhal@gmail.com*

stress. Genotypes were obtained from Wheat and Barley section, CCS Haryana Agricultural University, Hisar, and Indian Institute of Wheat and Barley Research, Karnal. The material was grown in factorial RBD design with three replications at the experimental area of Wheat and Barley section, Department of Genetics and Plant Breeding, CCS HAU, Hisar. Each plot consisted of 2 rows of 1.5m length with a 20 × 5 cm spacing within rows and between plants. These wheat accessions were evaluated for two consecutive crop seasons during 2012-13 and 2013-14 and under two conditions; timely sown (second week of November) and late sown (last week of December).

Data on various morpho-physiological parameters viz.days to heading, days to maturity, spikelets per spike, number of productive tillers per meter row length,number of grains per spike, grain weight per spike, grain yield (kg)/m^2, biomass (kg)/m^2, harvest index,canopy temperature depression and membrane thermostability, was recorded to assess the effect of terminal heat stress on yield and yield contributing traits.

Cell Membrane Thermostability (CMS)

To measure membrane thermostability, method of Sullivan [8], modified later on by Ibrahim and Quick [9] was followed. Membrane thermostability was expressed in %. Membrane thermostability was measured by the formula given below

$$\text{MTS (\%)} = 1 - (T_1)/T_2 \times 100$$

Where T_1 = conductivity reading after heat treatment

T_2 = conductivity reading after autoclaving

Canopy Temperature Depression (CTD)

A hand held infrared thermometer (IRT), LT 300 sixth sense was used for instantaneous measurement of canopy temperature. Measurement were taken when IRT viewed 100 per cent canopy cover and held at an angle of 30°, approximately 50 cm above the canopy from horizontal and at 1m distance from the edge of the plot end. Data was recorded between 12:00 to 14:00 hrs.

HARVEST INDEX (HI)

HI was calculated by using the following formula

$$\text{HI} = \frac{\text{(Grain yield in grams)}}{\text{(Biomass in grams)}}$$

RESULTS AND DISCUSSION

Analysis of Variance

Mean sum of squares due to genotypes, environment and years were significant for canopy temperature, cell membrane thermostability, days to heading, days to maturity, biomass (kg)/m^2, harvest index, , grain yield (kg)/m^2and1000-grain weight (g) in all the species *T. aestivum*, *T. durum*, *T. dicoccum* and Synthetic *T. aestivum* (Table 1, 2, 3 and 4). Significant variation for environment and genotype for grain yield and days to heading indicated differential responses of genotypes over the normal and heat stressed conditions.

Mean Performance

Mean values for grain yield (kg)/m^2 under heat stress were lower than that under normal sown condition in all four species of wheat *i.e. T. aestivum*, *T. durum*, *T. dicoccum* and Synthetic *T. aestivum*which indicated the considerable influence of heat stress. Similarly days to heading revealed a significant impact of heat stress on anthesis as the mean days to heading was less under heat stress than normal sown condition. When only grain yield was taken in account the mean performance of *T. aestivum*was better than other three wheat species under late sown conditions, as it had more yield (0.37-0.58 (kg)/m^2). But, if days to heading were taken into account, then better performer was *T. dicoccum*under heat stress as compared to other three wheat species. So, the mean performances for physiological traits (canopy temperature and cell membrane stability) of genotypes of these two species *i.e. T. aestivum* and *T. dicoccum*are shown in Table 5.

Mean valve of canopy temperature for *T. dicoccum* (25.98°C) was less as compared to that of *T. aestivum* (29.3°C) under heat stress indicating better performance of *T. dicoccum* than *T. aestivum*. DI88 genotype of *T. dicoccum* had less CT (22.8°C) under late sown. Mean valve for cell membrane thermostability was 48.4% for *T. aestivum*and 39.70% in *T. dicoccum*showing that *T. aestivum*is better performer under late showing conditions. The performance of various genotypes of different species was not associated with a single trait but it depends upon many traits.Canopy temperature of genotypes WH730 (26.3°C), WH1105 (26.1°C), UP2425 (26.5°C), Raj 3765 (26.6°C) and WH1021 (27.0°C) of *T. aestivum*was less than the mean valve of canopy temperature (29.3°C) of all genotypes,so

Table 1
Mean sum of squares for canopy temperature and cell membrane stabilityin wheat species over the years and environments

Source	*DF*	*T. aestivum*		*T. durum*		*T. dicoccum*		*Synthetic T. aestivum*	
		CT (°C)	*CMS*	*CT (°C)*	*CMS*	*CT (°C)*	*CMS*	*CT (°C)*	*CMS*
Replication	2	37.31**	228.3**	43.58*	382.2**	11.69**	290.9**	11.37*	84.9*
Genotypes (G)	19	74.63**	456.7**	87.16**	764.5**	23.38**	581.8**	22.75**	169.8**
Environment (E)	1	38.75**	5542.0**	2241.8**	14484.0**	387.48**	12113.1**	33.96*	9170.3**
G × E	19	79.05**	443.0**	87.79**	792.4**	4.161**	352.3**	37.11*	457.5**
Year (Y)	1	154.95**	368.8**	228.82**	1430.5**	105.19**	1937.9**	0.98	2983.1**
G × Y	19	57.21**	231.2**	66.33**	293.5**	17.30**	386.8**	32.13**	801.6**
E × Y	1	205.21**	2118.3**	2627.3**	1961.1**	21.97**	3005.5**	285.76**	2158.6**
G × E × Y	19	51.05**	260.8**	66.61**	315.5**	2.58*	550.3**	39.51**	599.6**
Error	158	74.63**	16.6	87.16**	31.5	23.38**	9.8	22.75**	41.8
Total	239								

*, **: Significant at 5% and 1% probability level, respectively

Table 2
Mean sum of squares for days to heading (DTH) anddays to maturity (DTM) in wheat species over the years and environments

Source	*DF*	*T. aestivum*		*T. durum*		*T. dicoccum*		*Synthetic T. aestivum*	
		DTH	DTM	DTH	DTM	DTH	DTM	DTH	DTH
Replication	2	131.43**	247.53**	34.86*	364.61**	238.77**	310.74**	62.61**	224.96*
Genotypes (G)	19	262.87**	495.06**	69.72**	729.22**	477.55**	621.48**	125.23**	449.92*
Environment (E)	1	3164.48**	21303.52**	2362.96**	20075.1**	2611.11**	17194.73**	2668.42**	24843.86**
G × E	19	89.95**	198.12**	47.75	141.56**	144.28**	561.68**	49.94**	173.15
Year (Y)	1	466.86**	215.43**	2695.86**	1131.00**	1089.00**	10.1	1685.96**	1213.49**
G × Y	19	27.13**	63.84**	24.49*	102.74**	69.25**	154.43**	85.59**	183.62
E × Y	1	340.67**	683.43**	19.10*	1246.70**	194.56**	71.86**	76.42**	1774.10**
G × E × Y	19	19.49**	43.78**	21.05**	88.72**	51.60**	157.08**	26.32**	137.45
Error	158	3.55	2.9	10.16	4.54	2.57	5.39	6.62	109.25
Total	239								

*, **: Significant at 5% and 1% probability level, respectively.

Table 3
Mean sum of squares for biomass (kg)/m² and harvest index (HI) in wheat species over the years and environments

Source	*DF*	*T. aestivum*		*T. durum*		*T. dicoccum*		*Synthetic T. aestivum*	
		Biomass (kg)/m²	*HI*	*Biomass (kg)/m²*	*HI*	*Biomass (kg)/m²*	*HI*	*Biomass (kg)/m²*	*HI*
Replication	2	1.16**	86.98**	0.54*	101.76*	3.51**	90.36*	1.42**	38.12**
Genotypes (G)	19	2.32**	173.96**	1.08**	203.53**	7.02**	180.72**	2.84**	76.25**
Environment (E)	1	224.46**	22897.16**	65.62**	48415.10**	43.61**	2756.54**	67.11**	8681.86**
G × E	19	1.83**	169.25**	1.54**	206.42**	3.58**	177.18**	4.75**	63.57**
Year (Y)	1	12.56**	23.09**	19.32**	33.74	3.52**	37.24	21.53**	33.28**
G × Y	19	1.12**	1.15	0.68*	1.62	0.57**	0.23	0.55*	0.98
E × Y	1	18.73**	0.2	18.09**	15.95	4.05**	11.1	20.78**	5.74
G × E × Y	19	0.62**	1.23	0.75*	1.61	0.45**	0.54	0.50*	1.06
Error	158	0.22	7.2	0.21	22.47	0.06	23.12	0.16	4.42
Total	239								

*, **: Significant at 5% & 1% probability level, respectively

according to their CT valve, these were superior genotypes. In case of *T. dicoccum*, superior genotypes based on canopy temperaturewere DI88 (22.8°C), DI67 (23.4°C), DI65 (23.9°C), DI69 (23.3°C) and DI70 (23.3°C), which had less CT value than mean value of CT (25.98°C) of all genotypes.

T. aestivum genotypes *viz.* DBW17 (56.7%), WH1021 (53.4%), WH1105 (51.4%), PBW550 (51.4%) andSonalika (51.3%) had more CMS value than mean value of CMS of all genotypes of wheat species which indicated their superiority based on CMS. The genotypes DI43 (42.4%), DI26 (41.4%), DI59 (41.4%),

Table 4
Mean sum of squares for grain yield (kg)/m² and thousand grain weight (g) (TGW) in wheat species over the years and environments

Source	*DF*	*T. aestivum*		*T. durum*		*T. dicoccum*		*Synthetic T. aestivum*	
		GY(kg)/m²	*TGW (g)*	*GY(kg)/m²*	*TGW (g)*	*GY(kg)/m²*	*TGW (g)*	*GY(kg)/m²*	*TGW (g)*
Replication	2	47.53**	143.48**	64.61**	93.86**	50.74*	962.08**	24.96*	207.97**
Genotypes (G)	19	95.06**	286.96**	29.22**	187.72**	90.48**	1924.17**	49.92*	415.94**
Environment (E)	1	303.52**	1078.26**	475.1**	11060.41**	794.73**	11004.84**	443.86**	12911.34**
G × E	19	28.12**	131.50**	41.56**	33.04**	61.68**	43.27*	50.15	33.77
Year (Y)	1	105.43**	4.57	31.00**	92.35**	10.1	14.01	213.49**	47.69*
G × Y	19	63.84**	174.2**	102.74**	38.96**	41.43	36.25**	83.62	42.90**
E × Y	1	183.43**	1.3	246.70**	11.71	41.86**	153.36**	774.10**	21.15
G × E × Y	19	23.78	116.26**	38.72	28.71**	57.08**	19.07	17.45	45.07**
Error	158	2.9	12.16	4.54	12.41	5.39	14.49	109.25	11.66
Total	239								

Table 5
Mean performance of ***T. aestivum*** **and** ***T. dicoccum*****genotypes for canopy temperature andcell membrane thermostabilityunder timely and late sown environment (mean of 2012–13 and 2013–14)**

	Triticumaestivum							*Triticumdicoccum*					
	Canopy temperature (CT)			*Cell membrane stability (%)*				*Canopy temperature (CT)*			*Cell membrane stability (%)*		
Genotypes	*TS*	*LS*	*% Reduction*	*TS*	*LS*	*% Reduction*	*Genotypes*	*TS*	*LS*	*% Reduction*	*TS*	*LS*	*% Reduction*
DBW 16	26.7	29.2	–9.4	54.0	44.5	17.6	DI 119	24.5	26.6	–8.9	42.3	40.7	3.8
DBW 17	27.0	28.8	–6.7	63.5	56.7	10.7	DI 124	21.6	25.8	–19.4	43.4	39.9	8.1
HD 2285	24.7	29.0	–17.6	57.6	47.7	17.2	DI 26	21.5	26.8	–25.0	46.4	41.4	10.8
HD 2733	27.6	32.4	–17.6	65.7	47.6	27.5	DI 30	21.8	26.1	–19.9	42.5	39.8	6.4
HD 2987	29.4	30.2	–2.7	59.7	45.6	23.6	DI 43	24.6	28.0	–13.9	44.5	42.4	4.7
HD 2967	26.8	29.4	–9.8	69.7	43.5	37.6	DI 52	25.1	26.5	–5.4	45.4	41.3	9.0
PBW 343	23.6	27.6	–16.9	62.4	45.5	27.1	DI 59	25.7	27.4	–6.5	43.3	41.4	4.4
PBW 373	24.3	29.1	–19.6	53.5	48.6	9.1	DI 60	23.7	28.1	–18.9	42.3	39.7	6.1
PBW 550	26.2	30.5	–16.3	56.5	51.4	9.0	DI 61	21.6	27.9	–29.3	45.4	37.6	17.2
Raj 3765	23.6	26.6	–12.9	52.4	46.4	11.5	DI 62	23.6	26.1	–10.6	42.4	37.6	11.3
Sonak	25.3	29.3	–15.7	68.5	48.6	29.1	DI 63	23.6	26.4	–11.8	43.0	37.6	12.6
Sonalika	25.2	29.9	–18.5	56.5	51.3	9.2	DI 65	21.5	23.9	–11.4	45.4	41.4	8.8
UP 2425	25.9	26.5	–2.3	53.4	47.5	11.0	DI 67	24.5	23.4	4.2	43.4	38.7	10.8
WH 1021	23.6	27.0	–14.6	56.4	53.4	5.3	DI 69	22.0	25.3	–15.2	41.3	37.6	9.0
WH 1105	22.3	26.1	–17.0	60.4	51.4	14.9	DI 70	27.5	25.3	7.9	43.4	41.3	4.8
WH 1123	26.8	29.4	–9.7	63.6	48.5	23.7	DI 78	24.8	26.2	–5.9	46.7	39.7	15.0
WH 1124	25.7	32.6	–27.0	60.4	48.7	19.4	DI 84	21.6	25.8	–19.6	44.3	39.7	10.4
WH 711	25.7	30.0	–16.9	54.5	48.9	10.3	DI 86	24.6	25.6	–4.1	43.3	39.7	8.3
WH 730	23.7	26.3	–11.0	62.4	46.6	25.4	DI 87	23.5	25.7	–9.5	44.4	36.7	17.3
WH 1129	28.9	37.5	–29.8	62.4	46.0	26.3	DI 88	21.5	22.8	–6.5	42.4	39.7	6.4
Mean	25.6	29.3		59.7	48.4		Mean	23.41	25.98		43.77	39.70	
Range	22.3 –29.4	26.1 –37.5		52.4 –69.7	43.5 –56.7		Range	21.4 –27.5	22.8 –28.1		41.3 –46.7	36.7 –42.4	

Table 6

Mean performance of *T. aestivum*, *T. durum*, *T. dicoccum* andSynthetic *T. aestivum* forvarious morpho-physiological characters under timely and late sown environments

Genotypes	*Duration*	*Days to heading*	*Days to maturity*	*Spike lets per spike*	*No. of productive tillers/mrl*	*No. of grains /spike*	*Grain weight (g)/spike*	*Grain yield (kg)/m²*	*Biomass (kg)/m²*	*Harvest index*
Triticumaestivum	TS	98.7-115.6	103.5-159.6	18.3-24.8	66.00-97.6	63.4-69.7	2.26-3.21	0.54-0.67	1.00-1.90	26.7-47.9
	LS	78.3-97.7	104.6-128.1	15.5-23.5	61.4-93.4	60.8-66.3	1.67-3.19	0.37-0.58	1.00-1.43	23.4-45.8
T.durum	TS	94.1-98.6	132.1-152.6	16.00-22.5	73.4-78.6	54.00-77.17	1.52-3.79	0.55-0.67	1.00-1.40	34.8-57.00
	LS	81.3-91.7	110.1-143.00	17.1-20.5	54.8-64.8	53.54-71.00	1.22-3.03	0.41-0.51	1.00-1.67	29.8-49.8
T.dicoccum	TS	94.3-114.5	145.00-164.00	19.8-24.7	77.8-83.4	39.00-55.1	1.02-1.76	0.15-0.59	1.00-1.58	0.64-0.74
	LS	84.5-106.00	116.1-155.6	16.3-21.6	73.4-84.00	40.2-50.7	0.78-1.92	0.13-0.26	1.00-1.05	0.57-0.65
Synthetic *T.aestivum*	TS	94.8-113.6	145.0-165.1	17.6-24.3	68.6-98.5	64.8-72.3	1.35-1.76	0.40-0.72	1.23-1.64	21.2-25.4
	LS	85.00-105.7	118.8-142.6	14.7-21.7	63.5-93.00	63.6-71.3	1.20-1.57	0.32-0.50	1.42-1.86	18.6-22.3

DI65 (41.4%), DI70 (25.3%) and DI52 (41.3 %), had CMS value greater than mean value of CMS of all genotypes, indicated their superiority over other genotypes.

When both CT and CMS value were taken into account, the genotypes WH1021 and WH1105 of *T. aestivum* and DI65 and DI70 of *T. dicoccum*were superior as they had low CT and high CMS values.

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