SHORT COMMUNICATION

EFFECT OF HIGH TEMPERATURE STRESS ON GROWTH, BIOMASS AND YIELD OF WHEAT GENOTYPES

S.R. KUSHWAHA, P.S. DESHMUKH, R.K. SAIRAM* AND MANISH KUMAR SINGH

Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi-110012

Received on 31st May, 2010, Revised and Accepted on 12th March, 2011

Twenty four wheat genotypes were sown under normal and late sown irrigated conditions. Under late planting crop was exposed to high temperature during anthesis and grain filling stages. High temperature stress caused significant reductions in physiological parameters and yield. High temperature/late sowing induced decline in membrane stability index (31.1%), plant height (17.1%), biomass (39.2%) and seed yield (51.7%) were observed in WH 730, HI 1535, WH 896 and RR 3, respectively. Genotypes LOK-1, HI-1418, DL-788-2, Raj-3765 showed lower values of heat susceptibility index (<0.5) and higher values of yield stability index (>90%), and therefore grouped as temperature tolerant. Membrane stability index at seed development stage showed positive association with biomass and seed yield in wheat genotypes under normal and late sown conditions. The linear relationship of MSI with seed yield and biological yield showed dependence of seed yield and biomass on membrane stability index.

***Key words*: Heat susceptibility index, membrane stability index, seed yield, temperature tolerance, yield stability index.**

Late planting of wheat in North West India is common due to the intensive cropping system, which often delays the sowing of wheat up to the middle of January. In the recent past the minimum and average temperatures have been increasing significantly at the rates of 0.06 and 0.03°C per year, respectively and during the last 32 years, the minimum temperature has increased by 1.9°C (Pathak and Wassmann 2009). The yield loss of wheat in India due to rising temperature has been projected as 4-5 million tonnes per year with every degree rise of temperature throughout the growing period even after considering the benefits of carbon fertilization (Aggarwal 2007). Heat stress is a major determinant of wheat (*Triticum aestivum* L.) development and growth, decreasing yields by 3 to 5 % per 1°C increase above normal conditions (Gibson and Paulsen 1999). The late sown wheat crop gets exposed to maximum temperature of above 35 ^{0}C during grain growth period, which causes yield reduction of 270 kg ha^{-1} $degree^{-1}$ rise in temperature (Nagarajan and Rane, 2002). High temperature after anthesis up to maturity adversely affects fertilization and grain development. Rise in temperature decreases grain size due to high respiration rate and decrease in rate of starch synthesis, which reduces grain weight because of forced grain development (Stone and Nicolas, (1984), Tashiro and Wardlaw (1990), Warrington *et al*. 1977). High temperature has significant influence on physiology, growth and yield traits of wheat. High night time temperature (>14°C) decreased photosynthesis, spikelete fertility, grains per spike, grain size, and decreased grain

*Corresponding author, E-mail: rks_ppl@yahoo.co.ok

filling duration by 3 to 7 days and grain yield (>20 ^{o}C) (Prasad *et al*. 2008).

An experiment was conducted at experimental farm of Division of Plant Physiology, IARI, New Delhi during 2005-06 and 2006-07 to evaluate the effect of high temperature at grain filling stage in wheat genotypes. Twenty four genotypes of wheat (*Triticum aestivum* L.) were grown under normal (6-12-05) and late (6-01-06) conditions in split plot design with three replications. The average maximum and minimum temperature during anthesis stage were 24.8 and 26.3 under normal and 32.4 and 33.8^{0}C, respectively under late sown conditions. The observations were recorded on membrane stability index and plant height at grain filling stage.

Membrane stability index was determined by recording the electrical conductivity of leaf leachates in double distilled water at 40 and 100 ^{0}C (Sairam *et al*. 1997).

$$\text{Membrane stability index} = 100- \{[(C_1/C_2)] \times 100\}$$

C_1 = Electrical conductivity at 40^{0}C
C_2 = Electrical conductivity at 100^{0}C

At maturity stage, five plants were harvested randomly per replicate and observations were recorded on plant height, biomass per plant, seed weight per plant and harvest index.

The heat susceptibility index for seed yield was calculated as per Fisher and Maurer (1978).

$$S = (1-y_h/y_n) / (1-y_g/y_a)$$

Where,

y_h = mean yield of individual genotype under high temperature

y_n = mean yield of individual genotype under normal conditions

y_g = mean yield of all genotypes under high temperature

y_a = mean yield of all genotypes under normal conditions

The yield stability index for seed yield was calculated as per the following formula:

$$YS = \frac{GY\ (H)}{GY\ (N)} \times 100$$

where,

GY (H): Grain yield under heat stress condition

GY (N): Grain yield under normal condition.

The results on growth and yield of twenty four wheat genotypes as influenced by high temperature are presented in Table 1. The results revealed significant variations for various growth and yield traits due to high temperature stress at anthesis stage. Membrane stability index among different genotypes at grain filling stage ranged between 42.25 (WH-896) to 74.25 (9CHT-16) under normal and 37.58 (WH-896) to 58.62 (PBW-502) under late sown conditions. Due to high temperatures, highest reduction in MSI was recorded in WH-730 (31.11%) followed by HI 1531 (29.33%), GW 143 (29.63%), while genotype HI-1418 (5.40%) showed minimum reduction. High temperature stress tolerance in plants is related to membrane stability index, compatible solutes and synthesis of heat shock proteins. Plant height among different genotypes ranged between 71.80 (GW-143) to RR-3 (107.1) and 59.50 (GW-143) to 99.5 (HD-2913) under normal and late sown conditions, respectively. The significant variations in these characters were due to their genetic potential and the environmental response under normal and late sown conditions. Late sown crop results in reduced leaf area and chlorophyll content due to rise in temperature that adversely affects photosynthetic activity of plants. As a result of reduced leaf area, the crop intercepts less photosynthetically active radiant energy, resulting in reduction in yield.

The adverse effect of high temperature due to late sowing was reflected in reduction of biological yield among wheat genotypes. The biological yield varied from 10.83 g/plant (WH 896) to 25.0 g/plant (HI 1531) under normal condition and 6.58 g/plant (WH 896) to 21.0 g/

Indian J. Plant Physiol., Vol. 16, No. 1, (N.S.) pp. 93-97 (Jan.-Mar., 2011)

Table 1. Variations for membrane stability index, plant height, biological yield, seed yield and harvest index in wheat genotypes under normal and late planting conditions.

Genotypes	MSI (%)		Plant height (cm)		Biological yield (g/plant)		Seed yield (g/plant)		Harvest index (%)	
	Normal	Late	Normal	Late	Normal	Late	Normal	Late	Normal	Late
HD 2329	62.08	47.90	73.30	73.30	18.70	16.50	5.55	4.17	29.68	25.27
Lok-1	58.25	50.41	79.00	71.30	18.33	16.67	5.71	5.36	31.15	32.15
WH-896	42.25	37.58	77.20	72.80	10.83	6.58	2.40	1.67	22.16	25.38
HI 1479	63.88	46.43	84.70	78.30	16.67	14.50	6.60	4.58	39.59	31.59
HI 1531	68.42	48.35	85.70	83.00	25.00	19.50	7.02	4.69	28.08	24.05
HI 1418	55.57	52.57	82.31	73.20	15.83	12.51	6.26	5.72	39.55	45.72
HI 1535	54.26	46.85	83.20	68.30	17.50	17.00	5.92	4.62	33.83	27.18
PBW 175	60.23	50.41	93.20	81.30	15.00	13.70	5.87	4.15	39.13	30.29
C 306	50.26	44.28	103.70	94.20	16.67	14.17	5.30	3.80	31.79	26.82
HI 1454	54.68	47.62	81.70	72.50	14.67	9.17	5.45	4.36	37.15	47.55
DL 788-2	58.65	50.98	77.30	71.20	18.70	12.90	5.00	4.59	26.74	35.58
GW 143	60.61	42.65	71.80	59.50	14.17	12.65	6.47	3.66	45.66	28.93
HD 2913	60.25	55.65	104.00	99.50	19.00	18.33	6.75	5.05	35.53	27.55
RR 3	56.89	42.65	107.10	95.50	21.67	17.65	8.32	4.02	38.39	22.78
HD 2934	62.24	57.95	106.50	93.00	23.33	21.50	9.48	7.90	40.63	36.74
PBW 502	66.80	58.62	82.50	76.80	20.00	16.67	8.64	7.12	43.20	42.71
PBW 503	44.62	40.66	78.00	65.80	12.50	10.50	4.13	2.90	33.04	27.62
NW 2036	56.05	45.26	78.50	73.70	12.50	9.20	5.43	3.07	43.44	33.37
Raj 4014	71.56	51.25	76.30	70.30	18.33	16.58	8.66	4.92	47.24	29.67
Raj 3765	66.65	56.51	83.00	76.50	20.03	18.33	8.10	7.55	40.44	41.19
WH 730	64.25	44.26	80.20	72.20	15.00	10.50	6.13	2.98	40.87	28.38
K 2008	62.82	47.95	83.20	81.70	19.17	17.66	6.51	4.05	33.96	22.93
9 CHT-16	74.25	52.65	73.80	72.80	23.33	21.00	10.87	6.82	46.59	32.48
HD 2687	63.09	47.65	81.20	73.50	17.50	11.17	6.19	3.56	35.37	31.87
Mean	**59.94**	**48.63**	**84.48**	**77.09**	**17.68**	**14.79**	**6.53**	**4.64**	**36.80**	**31.58**
CD at 5%										
Planting time (P)	1.94		2.83		0.74		0.089		0.108	
Genotypes (G)	1.63		2.19		0.52		0.163		1.015	
P*G	2.81		3.89		.0.96		0.238		1.41	

plant (9CHT-16) under late sown condition. Reduction in biological yield was maximum in WH-896 (39.24%) followed by HI-1454 (37.49), HD-2687 (36.17) and DL-788-2 (31.02) while minimum reduction was recorded in HI 1535.

Significant variations were observed for seed yield, which ranged between 2.40 g/plant (WH-896) to 10.87 g/plant (9 CHT-16) under normal condition, while under late planting ranged between 1.67 g/plant (WH-896) to 7.90 g/plant (HD-2934). The greater reduction in seed yield due to high temperature was in RR-3 (51.68) followed by WH-730 (51.39%), NW-2036 (43.46), GW-143 (43.43), while smaller (less than 10%) were observed in LOK-1 (6.13), Raj-3765 (6.79), DL-788 (8.20) and HI-1418 (8.63%). At grain filling stage high temperature affected grain development and reduced seed size and grain number per plants. Decline in seed yield under high temperature at grain filling stage has also been reported by Sharma-Natu *et al.* (2006), Prasad *et al*. (2008) and Saikia *et al.* (2009).

Significant differences in harvest index occurred among genotypes under normal and late planting conditions. Among the wheat genotypes HI ranged between 22.16 (WH-896) to 47.24 (Raj-4014) under normal planting while under late planting condition harvest index ranged between 22.78 (RR3) to 47.55 (HI-1454).

The yield stability index (Fig. 1A) and heat susceptibility index (Fig. 1B) among different genotypes of wheat ranged from 48.29 (RR-3) to 93.87 (LOK-1) and 0.25 (LOK-1) to 2.10 (RR-3) respectively. Genotypes LOK-1, HI-1418, DL-788-2 and Raj-3765 showed higher temperature tolerance at grain filling stage as these genotypes showed yield high stability index (>90%) and lower values for heat susceptibility index (0.50%).

Correlation studies showed that MSI was positively and significantly correlated with seed yield (Figs. 2 A & B) and biomass (Figs. 2 C & D). Seed yield was also positively and significantly correlated with harvest index under both the conditions.

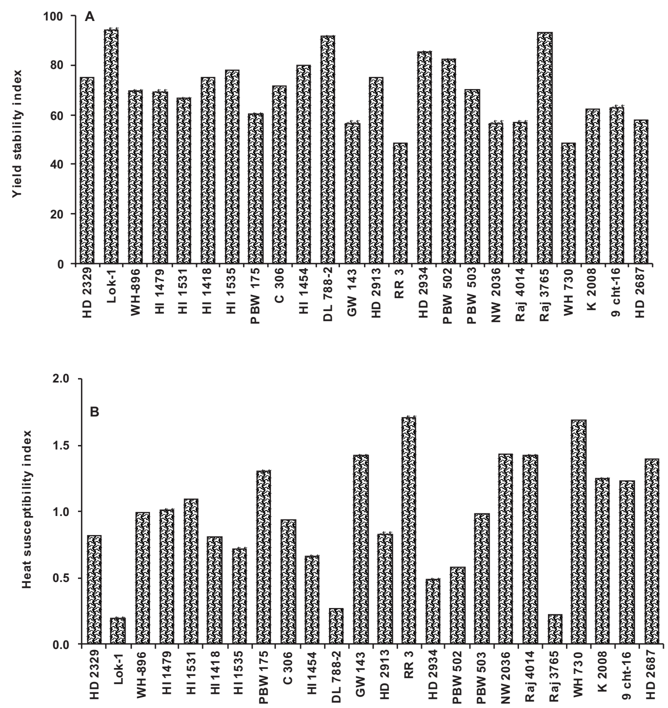

Fig. 1. Yield stability index (A) and heat susceptibility index (B) as influenced by high temperature during grain filling

The strong and linear relationship of membrane stability index with biological yield indicates the dependence of biomass production on the membrane stability index (Fig. 2). The close association between MSI and biomass and seed yield also indicate that MSI

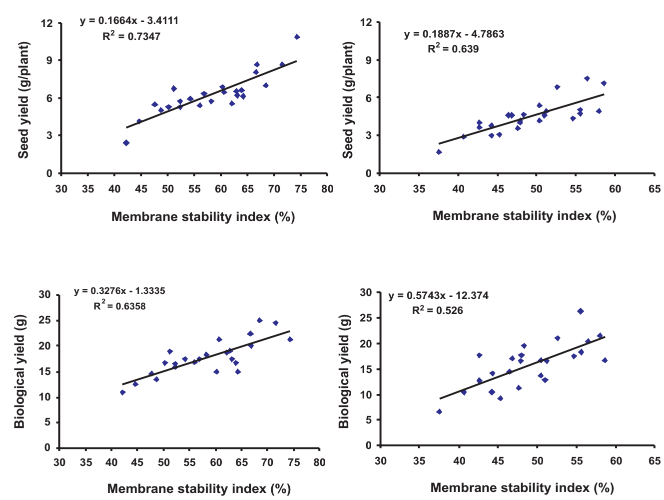

Fig. 2. Relationship of membrane stability index with seed yield (A and B) and biological yield (C and D) under normal and late planting

is more suitable trait for screening the genetic material, which will help to identify suitable parents by plant breeders in general. The traits YSI and HIS are also suitable traits for screening heat tolerant genotypes under late sown conditions.

REFERENCES

Aggarwal, P.K. (2007). Climate change: Implication for Indian Agriculture. *Jalvigyan Sameeksha.* **22:** 37-46.

Fisher, R.A. and Maurer, R. (1978). Drought resistance in spring wheat cultivars. I: Grain yield responses. *Aust. J. Agric. Res*. **29:** 897-912.

Gibson, L.R. and Paulsen, G.M. (1999). Yield components of wheat grown under high temperature stress during reproductive growth. *Crop Sci.* **39:** 1841-1846.

Nagarajan, S. and Rane, J. (2002). Physiological traits associated with yield performance of spring wheat (*Triticum aestivum* L.) under late sown conditions. *Indian J. Agric. Sci.* **72:** 135-140.

Pathak and Wassrmann, R. (2009). Quantitative evaluation of climate variability and risks for wheat yield in India. *Climate change.* **93:** 157-175.

Prasad, P.V.V., Pisiput, S.R., Ristic, Z., Bukovrik, U. and Fritz, A.K. (2008). Impact of night time temperature on physiology and growth of spring wheat. *Crop Sci.* **48:** 2372-2380.

Saikia, U.S., Rao, G.G.S.N., Rao, W.U.M., Venkateswarlu, B. and Gogai, A.K. (2009). Dynamics of wheat production and productivity in north west plains zone of India in relation to thermal regime. Research Bulletin 3:AICRP, Agro-metrology, CRIDA, Hyderabad, p. 31.

Sairam, R.K., Deshmukh, P.S. and Shukla, D.S. (1997). Tolerance to drought and temperature stress in relation to increased antioxidant enzyme activity in wheat. *J. Agron. Crop Sci.* **178:** 171-177.

Sharma Natu, P., Sumesh, K.V., Lohat, V. and Ghildiyal, M.C. (2006). High temperature effect on grain growth in wheat cultivars: an evaluation of responses. *Indian J. Plant Physiol.* **11:** 239-245.

Stone, P.J. and Nicolas, M.E. (1984). Wheat cultivars vary widely in their response of grain yield and quality to short period of post anthesis heat stress. *Aust. J. Pl. Physiol.* **21:** 887-900.

Tashiro, T. and Wardlaw, I.F. (1990). The effect of high temperature at different stages of ripening on grain set, grain weight and grain dimension in semi dwarf wheat 'Bank'. *Ann. Bot.* **65:** 51-61.

Warrington, I.J., Dunstone, R.L. and Green, L.M. (1977). Temperature effect at three developmental stages on the yield of wheat ear. *Aust. J. Agric. Res.* **28:** 11-27.