CORRELATION AND HEAT SUSCEPTIBILITY INDEX ANALYSIS FOR TERMINAL HEAT TOLERANCE IN BREAD WHEAT

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ABSTRACT

Six generations namely, P_1, P_2, F_2, F_3, BC_{1s} and BC_{2s} (2006-07) and P_1, P_2, F_3, F_4, BC_{1ss} and BC_{2ss} (2007-08) developed from four parental genotypes viz. DBW 14 (heat tolerant), NP 846 (heat and drought tolerant), WH 147 and Raj 4014 (heat susceptible for late sown). All the six generations from four crosses were evaluated during Rabi 2006-07 and Rabi 2007-08 in a compact family block design with three replications on two sowing dates. Heat susceptibility index values revealed reduction in grain yield in both the years for all the generations of the four crosses. Significant estimates of correlation of grain yield with days to heading, days to anthesis and days to maturity were recorded in late sown condition during first year. While under timely sown condition spike length has high estimate correlation with grain yield in first year itself. Significant estimated were recorded for tillers per plant in both the environments in second year. Lowest yield loss was reported in backcross populations of Cross I in both years and among segregating populations of Cross IV observed to be least affected and therefore suggested to be forwarded to further generations and further selection of heat tolerant genotypes.

Keywords: correlation, heat tolerance, quantitative traits

INTRODUCTION

Incidences of high temperatures at the time of grain filling are more pronounced in Northern Western Plains Zone (NWPZ) which is known as wheat bowl of the country. Heat stress affects the crop at grain filling when sowing of wheat is delayed due to delay in harvest of highly remunerative preceding crops such as scented rice [13] or sugarcane. The reason of terminal heat is the geographical location of this region where western wind flow becomes intensive over the wheat crop and increases with the temperature. The fast western wind flow and increasing temperature causes poor grain filling by affecting the wheat physiological mechanisms. Exposure of late sown crop to high temperature and water deficit during reproductive growth stage also reduces grain filling period and remobilization of photosynthates to developing grains.

Global warming is likely to impact agriculture by increasing variability in temperature extremes, thereby reducing wheat yields [1]. There is need of paradigm shift in crop improvement programme with major emphasis on development of wheat variety tolerant to heat stress in general and to terminal heat stress in particular. The correlation analysis and heat susceptibility index analysis of quantitative traits is a potent way to detect their significance and direction of effects.

MATERIALS AND METHODS

The present investigation was done during Rabi 2006-07 and Rabi 2007-08 with the planting of parents and segregating generations at Crop Research Centre of GBPUA &T, Pantnagar, India. The experimental materials for the present study were developed from four parental genotypes of wheat out of which three genotypes were released varieties viz., DBW 14 (heat tolerant), NP 846 (heat and drought tolerant) and WH 147 (heat susceptible for late sown) and one advanced line RAJ 4014 (heat susceptible for late sown) and their six generations namely, P_1, P_2, F_2, F_3, BC_{1s} and BC_{2s} (2006-07) and P_1, P_2, F_3, F_4, BC_{1ss} and BC_{2ss} (2007-08) of each of the 4 crosses viz., RAJ 4014 × DBW 14; WH 147 × NP 846 normal and their reciprocal crosses DBW 14 × RAJ 4014; and NP 846 × WH 147. Six generations namely, P_1, P_2, F_2, F_3, BC_{1s} and BC_{2s} (2006-07) and P_1, P_2, F_3, F_4, BC_{1ss} and BC_{2ss} (2007-08) of each of these four crosses were evaluated during Rabi 2006-07 and Rabi 2007-08 in a compact family block design with three replications. The experiments were planted on November 18 for timely sown (TS) condition; December 18 for late sown (LS) condition during Rabi 2006-07 and on November 20 for timely sown (TS) condition and December 20 for late sown (LS) condition during Rabi 2007-08. Late sown panting was done 30 days after TS planting to subject the late sown experiment to terminal heat at grain filling stage. The number of rows was different for different progenies as per their heterozygosity level (depending upon the variability), differential numbers of competitive plants were randomly selected in each generation from each replication. The selected plants were tagged before the flowering and subsequent observations were recorded on them. The plot means were used for statistical analysis that is obtained on the basis of average of randomly selected plants of the different progenies of each generation in each replication separately.

RESULTS AND DISCUSSION

Correlation analysis

The result of association analysis in different crosses as presented in Table 1 and Table 2 for the years 2006-07 and 2007-08 respectively showed that high correlation of grain yield with days to heading was present in Cross IV under timely sown and in Cross II and Cross III under late sown conditions in first year. Lower estimates were recorded in second year for all crosses except Cross I under both the environments. Character association of grain yield with days to heading in Cross II increased significantly from timely sown (-0.214) to late sown (0.854) in first year and from timely sown (-0.144) to late sown (0.374) in second year indicating that the parent involved in these crosses could perform better in respect of days to heading under late sowing.

Table 1. Correlation coefficient of different characters with grain yield per plant (2006-07)

Characters	Timely sown				Late sown			
	C-I	C-II	C-III	C-IV	C-I	C-II	C-III	C-IV
Days to heading	-0.33	-0.21	0.09	-0.72	0.31	0.85*	-0.78	-0.19
Days to anthesis	-0.30	0.01	-0.01	-0.60	0.29	0.87*	-0.80	-0.16
Tillers per plant	0.64	0.55	0.95**	0.69	-0.41	0.42	-0.34	0.54
Spikelets per spike	-0.59	-0.29	-0.18	-0.81	-0.50	0.01	-0.03	-0.47
Spike length (cm)	-0.88*	-0.06	0.88*	-0.83*	-0.62	0.30	0.26	-0.38
Plant height (cm)	-0.48	0.68	0.61	0.39	0.15	-0.25	0.58	0.39
Days to maturity	-0.41	-0.20	0.71	-0.39	-0.82*	0.13	0.62	-0.30

Table 2. Correlation coefficient of different characters with grain yield per plant (2007-08)

Characters	Timely sown				Late sown			
	C-I	C-II	C-III	C-IV	C-I	C-II	C-III	C-IV
Days to heading	-0.52	-0.14	-0.05	-0.11	-0.44	0.37	-0.16	-0.15
Days to anthesis	-0.36	-0.13	-0.06	-0.03	-0.55	0.26	-0.14	0.21
Tillers per plant	0.24	-0.37	0.25	0.83*	0.12	0.90*	0.24	0.02
Spikelets per spike	-0.74	-0.42	-0.71	-0.39	-0.48	-0.03	0.10	-0.61
Spike length (cm)	-0.74	-0.30	-0.73	0.04	0.09	0.36	0.56	0.02
Plant height (cm)	-0.48	0.08	0.60	-0.37	-0.15	0.48	-0.60	0.25
SPAD 1	0.42	0.17	-0.19	0.76	-0.33	0.39	0.29	-0.55
SPAD 2	0.29	0.09	0.74	0.72	-0.29	0.60	0.23	-0.24
Days to maturity	-0.33	0.12	0.72	0.59	-0.67	-0.21	0.41	0.51

*, **Significant at 0.05 and 0.01 probability levels respectively.

C-I (Raj 4014 X DBW 14), C-II (DBW 14 X Raj 4014), C-III (WH 147 X NP 846), C-IV (NP 846 X WH 147)

The result of association analysis in different crosses showed that high correlation of grain yield with days to anthesis was present in Cross IV under timely sown and in Cross II and Cross III under late sown conditions in first year. Lower estimates were recorded during second year for all crosses except Cross I under both the environments. Character association of grain yield with days to heading in Cross II increased significantly from timely sown (0.008) to late sown (0.871) in first year and from timely sown (-0.134) to late sown (0.268) in second year indicating that the parent involved in these crosses could perform better in respect of days to anthesis under late sowing. These types of result are also obtained for days to anthesis [5, 9, 10].

Tillers per plant exhibited highly significant association with grain yield per plant in Cross III (0.950) under timely sown condition in first year and in Cross IV (0.835) under timely sown and in Cross II (0.903) under late sown condition during second year. Although tillers per plant exhibited highly significant correlation with grain yield but their magnitude declined in the late sown in all the crosses in both environments except Cross II where it was increased from timely sown (-0.377) to late sown (0.903) in second year. It is supposed that at Crown Root Initiation (CRI) stage normally the low temperature had its less drastic effect on the number of tillers, but lead to the decreased number of effective tiller under late sown condition. Findings related to the reduction in the number of tiller and grain yield due to higher temperature are supported [6, 7, 11, 12]

Number of spikelets per spike has negative association with grain yield in all the crosses under both environments in both years. However the magnitude increases in all the crosses except Cross IV in second year. As highly significant association is not observed in any of the Cross it might not be useful to be used for selection of plants under late sown condition. However, the results are not in agreement [4].

Correlation of spike length with grain yield revealed high association with Cross III (0.885) under timely sown condition in first year and Cross III (0.568) under late sown condition in second year. The magnitude of association increased in all the crosses in first year except Cross III and in second year except Cross IV. A high change in magnitude with Cross III in second year shows that spike length can be used as a criterion for selecting plants in Cross III. Positive association of spike length is observed in late sown condition in second year. Positive association of spike length with grain yield is in agreement [4, 5, 6].

The correlation of plant height with grain yield was high in Cross II (0.682) and Cross III (0.613) under timely sown and Cross III (0.589) under late sown condition in first year and Cross III under timely and late sown conditions in second year. Magnitude of association increased under late sown condition in Cross I in first year and Cross I, Cross II and Cross IV in second year. However, significant association is not obtained but the increase in magnitude of association in late sown condition revealed the importance of plant height in selecting plants. The results are in agreement with the findings [5, 6].

Flag leaf senescence (SPAD 1) exhibited high positive association with grain yield in Cross IV (0.761) and SPAD 2 in Cross III (0.748) and Cross IV (0.729) under timely sown condition. SPAD 2 exhibited high value in Cross II (0.605) under late sown condition. Magnitude of association decreased in late sown condition in majority of the crosses indicating chlorophyll loss associated with grain yield. However, increase in magnitude in late sown condition is observed with Cross III in SPAD 1 and Cross II in SPAD 2 indicating their ability to cope up with heat stress. SPAD reading can be used as a selectable agent for terminal heat tolerance in these crosses. SPAD value is negatively associated in both Cross II and Cross IV where susceptible parent and tolerant parent respectively were taken as female. Both of the other crosses have positive association indicating reciprocal differences in SPAD values in wheat crosses. Loss in chlorophyll content during heat stress associated with yield loss has been reported [3, 8].

The result of association analysis in different crosses showed that high correlation of grain yield with days to maturity was present in C-III (0.711) under timely sown and in Cross I (-0.824) and Cross III (0.620) under late sown conditions in first year. Cross III (0.727) under timely sown and Cross I (-0.676) under late sown condition in second year also exhibited high association of days to maturity with grain yield. Higher negative estimates in Cross I in first year and Cross I and Cross II in second year late sown conditions recommends these crosses to be used for selection for terminal heat tolerance. Similar results were obtained for days to maturity [9, 14].

Heat susceptibility index

The concept of heat susceptibility index was given by [2] to determine the total effect of heat in terms of reduction in the grain yield. Heat susceptibility index was calculated for all the characters recorded namely days to heading, days to anthesis, tillers per plant, spikelets per spike, spike length, plant height, days to maturity, grain yield per plant and flag leaf senescence (2007-08 only).

The heat susceptibility index (HSI) estimated for the all the characters to determine the effect of terminal heat in the progenies of six generations of the respective crosses have been presented in Table 3 and Table 4. The results of HSI revealed that for all the characters in all the generations the values lie below 0.6, which indicates that most of the generations represent relatively less decrease in yield and other yield contributing characters. Parent 2 (P_2) in Cross II, P_2 in Cross III and P_1 in Cross IV showed maximum yield loss between timely and late sown conditions (2006-07) representing their susceptibility. P_1 in Cross I, P_2 in Cross II, P_2 in Cross III and P_2 in Cross IV showed maximum yield loss between two sowings revealing the susceptible to terminal heat tolerance.

During year 2006-07
The HSI values of days to heading, days to anthesis and days to maturity were nearly same for all the generations of all the crosses representing that most of the plants selected for observations had nearly same days to anthesis and days to maturity. In all other characters, differences were observed in the HSI values indicating their role in terminal heat tolerance. Number of tillers increase in P_2, F_3 and BC_{1S} in Cross I and P_1 in Cross III while a slight increase in number of tiller is observed in all the generations in Cross II. Maximum decrease in tillers is observed in parental generations of Cross IV with no change in F_3 generation.

The HSI values of number of spikelets per spike increased in all the generations of all the crosses with maximum increase in P_1 of Cross I and P_1 of Cross II. Slight increase in spike length was observed in all generations of Cross I, P_1, F_2, F_3 & BC_{1S} of Cross II, P_1, P_2 & F_3 of Cross III, P_1, F_3 & BC_{1S} of Cross IV.

Table 3. Heat Susceptibility Index (HSI) for wheat crosses grown in Rabi 2006-07 under timely and late sown conditions

	Characters*							
	1	2	3	4	5	6	7	8
Cross I (Raj 4014 x DBW 14)								
P_1	0.11	0.12	0.06	-0.21	-0.20	-0.05	0.15	0.30
P_2	0.10	0.10	-0.33	-0.13	-0.07	-0.09	0.14	0.30
F_2	0.13	0.13	0.03	-0.16	-0.08	-0.12	0.15	0.34
F_3	0.16	0.18	-0.07	-0.14	-0.09	0.01	0.17	0.30
BC_{1S}	0.10	0.10	-0.05	-0.15	-0.03	-0.08	0.17	0.11
BC_{2S}	0.12	0.12	0.06	-0.05	-0.05	-0.04	0.17	0.19
Cross II (DBW 14 x Raj 4014)								
P_1	0.06	0.09	-0.04	-0.18	-0.12	-0.10	0.12	0.14
P_2	0.11	0.13	-0.07	-0.02	0.05	-0.07	0.09	0.35
F_2	0.10	0.13	-0.14	-0.10	-0.05	-0.17	0.14	0.23
F_3	0.16	0.18	-0.16	-0.16	-0.05	-0.06	0.15	0.43
BC_{1S}	0.16	0.16	-0.18	-0.11	-0.05	-0.26	0.17	0.24
BC_{2S}	0.11	0.14	-0.04	-0.02	0.06	-0.17	0.13	0.27
Cross III (WH 147 x NP 846)								
P_1	0.04	0.09	-0.78	-0.12	-0.12	-0.21	0.14	0.31
P_2	0.09	0.12	0.07	-0.02	-0.04	-0.05	0.17	0.45
F_2	0.15	0.16	0.23	-0.10	0.01	-0.09	0.14	0.38
F_3	0.16	0.17	0.18	-0.18	-0.07	-0.13	0.13	0.30
BC_{1S}	0.11	0.15	0.10	-0.17	0.06	-0.03	0.15	0.49
BC_{2S}	0.15	0.18	0.07	-0.07	0.05	-0.26	0.14	0.37
Cross IV (NP 846 x WH 147)								
P_1	0.10	0.11	0.36	-0.06	-0.02	0.01	0.15	0.38
P_2	0.10	0.11	0.35	-0.04	0.09	-0.04	0.14	0.32
F_2	0.08	0.11	0.17	-0.05	0.01	-0.08	0.13	0.31
F_3	0.12	0.13	0.00	-0.10	-0.01	-0.12	0.16	0.26
BC_{1S}	0.15	0.18	0.04	-0.08	-0.07	-0.19	0.17	0.37
BC_{2S}	0.14	0.16	0.05	-0.04	0.03	0.07	0.16	0.04

*Character 1 (days to heading), character 2 (days to anthesis), character 3 (number of tillers per plant), character 4 (number of spikelets per spike), character 5 (spike length), character 6 (plant height), character 7 (days to maturity), character 8 (grain yield per plant)

The HSI values of plant height increased in all the generations of Cross I, Cross II and Cross III while F_3 of Cross I showed minimum change. Slight increase in height was observed in P_2, F_2, F_3 and BC_{1S} of Cross IV.

Table 4. Heat Susceptibility Index (HSI) for wheat crosses grown in Rabi 2007-08 under timely and late sown conditions

	Characters*									
	1	2	3	4	5	6	7	8	9	10
Cross I (Raj 4014 x DBW 14)										
P_1	0.10	0.15	0.14	0.12	0.06	0.15	0.18	0.26	0.16	0.35
P_2	0.07	0.09	0.17	0.05	0.14	0.11	0.15	0.25	0.16	0.29
F_3	0.07	0.10	0.09	0.04	0.14	0.02	0.19	0.32	0.16	0.36
F_4	0.10	0.13	0.06	0.04	0.14	0.08	0.26	0.35	0.17	0.32
BC_{1SS}	0.12	0.14	0.15	0.09	0.15	0.16	0.25	0.29	0.16	0.13
BC_{2SS}	0.10	0.12	0.04	0.08	0.16	0.10	0.25	0.31	0.15	0.21
Cross II (DBW 14 x Raj 4014)										
P_1	0.13	0.15	0.18	0.07	0.07	0.16	0.19	0.26	0.15	0.17
P_2	0.15	0.18	0.27	0.12	0.11	0.13	0.22	0.23	0.14	0.32
F_3	0.05	0.09	0.00	0.02	0.12	0.04	0.20	0.28	0.15	0.22
F_4	0.07	0.11	0.06	-0.07	0.14	0.11	0.16	0.31	0.14	0.31
BC_{1SS}	0.08	0.11	0.25	0.10	0.16	0.13	0.21	0.31	0.15	0.22
BC_{2SS}	0.11	0.14	0.14	0.09	0.17	0.12	0.20	0.29	0.14	0.26
Cross III (WH 147 x NP 846)										
P_1	0.11	0.13	0.24	0.13	0.29	0.02	0.13	0.10	0.16	0.16
P_2	0.11	0.14	0.50	0.19	0.23	0.17	0.19	0.18	0.16	0.46
F_3	0.14	0.15	0.12	0.09	0.13	0.19	0.08	0.26	0.13	0.45
F_4	0.17	0.18	0.08	0.07	0.14	0.11	0.10	0.30	0.11	0.34
BC_{1SS}	0.14	0.15	-0.07	0.07	0.21	-0.06	0.12	0.33	0.14	0.47
BC_{2SS}	0.21	0.21	0.08	0.06	0.16	0.04	0.09	0.31	0.14	0.38
Cross IV (NP 846 x WH 147)										
P_1	0.14	0.14	0.02	0.10	0.09	-0.18	0.58	0.37	0.12	0.32
P_2	0.09	0.11	-0.09	0.07	0.31	0.02	0.13	0.38	0.16	0.34
F_3	0.18	0.18	0.35	0.09	0.27	0.03	0.16	0.37	0.15	0.27
F_4	0.16	0.16	0.30	0.09	0.22	0.08	0.13	0.33	0.15	0.18
BC_{1SS}	0.17	0.18	0.18	0.09	0.16	0.01	0.04	0.27	0.14	0.33
BC_{2SS}	0.16	0.17	0.05	0.12	0.19	0.04	0.09	0.28	0.15	0.14

*Character 1 (days to heading), character 2 (days to anthesis), character 3 (number of tillers per plant), character 4 (number of spikelets per spike), character 5 (spike length), character 6 (plant height), character 7 (SPAD 1), character 8 (SPAD 2), character 9 (days to maturity), character 10 (grain yield per plant)

F_2 of Cross I recorded highest yield decrease followed by F_3 while both P_1 and P_2 showed equal yield reduction. Maximum yield decrease was observed in F_3 generation of Cross II followed by P_2. BC_{1S} of Cross III touches the susceptibility mark in Cross III followed by P_2. Nearly similar yield decrease was observed in P_1 and BC_{1S} of Cross IV with minimum decrease in BC_{2S} generation.

During year 2007-08
A similar trend for days to heading, days to anthesis and days to maturity was observed with nearly similar data for all the generations in all the crosses. Number of tillers increased slightly in BC_{1SS} of Cross III and P_2 of Cross IV.

Effect of heat on number of tillers was most severe in F_3 and F_4 of Cross IV. Least effect was observed in Cross I and Cross II and a slight reduction in number of tillers was observed in Cross III. However, susceptibility mark was attained by P_2 in Cross III.

The HSI values for number of spikelets per spike increased slightly in F_4 of Cross II. However, maximum reduction was observed in parental generations of Cross III. Effect of heat was much severe on parental generations of Cross III and P_2 of Cross IV for spike length. Maximum reduction was observed with F_3 and F_4 of Cross IV.

Increase in height was observed with BC_{1SS} of Cross III and P_1 of Cross IV as observed by the negative values of HSI. Maximum reduction of height was observed with P_2, F_3 and F_4 of Cross III. Minimum yield decreased in F_4 of Cross IV followed by F_3 of Cross II. Maximum yield decrease was observed with P_2, F_3 and BC_{1SS} of Cross III. Among parentals lowest yield reductions were observed with P_1 of Cross II and P_1 of Cross III revealing their tolerance to terminal heat stress.

Perusal of Table 3 and Table 4 revealed that DBW 14 was heat tolerant and Raj 4014 was late heat susceptible as suggested by low and high HSI values. WH147 observed be late heat susceptible and NP 846 as late heat tolerant, but in some cases high yield loss was observed in NP 846 than WH147 which might be due to more plant height and lodging conditions attained by NP 846. The heat susceptible index for grain yield revealed that grain yield was affected when temperature raises ±4.5 - 6.8 ºC [10, 11, 12]. Lowest yield loss was reported in backcross populations of Cross I in both years and among segregating populations Cross IV proved to be least affected and therefore, suggested to be forwarded to further generations for further selection of heat tolerant genotypes. The result indicated that increasing temperature decreases grain yield per plant under both conditions.

REFERENCES

Ferris, R., Ellis, R. H., Wheeler, T. R., Hadley, P., Effect of high temperature stress at anthesis on grain yield and biomass of field grown crops of wheat. Ann. Bot. (1998) 82: 631-639.

Fisher, R. A. and Maurer, R., Drought resistance in wheat cultivars I. Grain yield response. Aust. J. Agic. Res. (1978) 29: 897-907.

Hafsi, M., Pfeiffer, W. H., Monneveux, P., Flag leaf senescence, carbon content and carbon isotope discrimination in durum wheat grown under semi-arid conditions. Cereal Res. Commun. (2003) 31(1-2): 161-168.

Hanchinal, R. R., Tandon, J. P., Salimath, P. M., Variation and adaptation of wheat varieties for heat tolerance in peninsular India. In: Saunders, D. A. and Hettel, G. P. eds. Wheat in Heat Stressed Environments: Irrigated, Dry Areas and Rice Farming Systems. Proceedings of the International Conference, Wheat in Hot, Dry, Irrigated Environments. (1994) pp 175-183. CIMMYT, Mexico.

Omara, M. K., El-Defrawy, M., Tammam, A. M., Kassem, A. A. F., Genetic control of preanthesis attributes of wheat plant and their associations with yield under heat stress. Assiut. J. Agric. Sci. (2004) 35(4): 97-155.

Pathak, N. N., Nema, D. P., Pillai, P. V. A., Correlation and path analysis in wheat under high temperature and moisture stress conditions. Wheat Information Service. (1986) 61/62: 68-73.

Renu Munjal, Dhanda, S. S., Rana, R. K., Iqbal Singh., Memberane thermostability as an indicator of heat tolerance at seedling stage in bread wheat. Natl. J. Pl. Imp. (2004) 6(2): 133-135.

Reynolds, M. P., Summary of data from the 1st and 2nd International Heat Stress Genotype Experiment. In: Saunders, D. A. and Hettel, G. P. eds. Wheat in Heat Stressed Environments: Irrigated, Dry Areas and Rice Farming Systems. Proceedings of the International Conference, Wheat in Hot, Dry, Irrigated Environments. (1994) CIMMYT, Mexico.

Reynolds, M. P., Singh R. P., Ibrahim, A., Ageeb, O. A. A., Larqué-Saavedra, A., Quick, J. S., Evaluating physiological traits to complement empirical selection for wheat in warm environments. Euphytica. (1998) 100: 84-95.

Sandeep Kumar, Singh, M., Verma, R. S., Studies on heat tolerance in wheat genotypes. Gujrat Agric. Univ. Res. J. (2000) 26(1): 16-22.

Singh, N. B., Ziauddin, A., Ahmad, Z., Response of wheat (*Triticum aestivum*) varieties to different dates of sowing. Indian J. Agric. Sci. (1997) 67(5): 208-211.

Singh, N. B., Singh, Y. P., Singh, V. K., Javed, Bahar, Singh, V. P. N., Early growth vigour, phenology, seed size, seed hardness as a parameter for assessing terminal heat tolerance in wheat under late sown irrigated condition. Farm Sci. J. (2005) 14(2): 25-28.

Tandon, J. P., Wheat cultivation, research organization and production technology in the hot dry regions of India. In: Saunders, D. A. and Hettel, G. P. (eds.). Wheat in Heat-Stressed Environments: Irrigated, Dry Areas and Rice-Wheat Farming Systems, (1994) pp 17-23. CIMMYT, Mexico.

Verma, R. S., Pandey, C. S., Sandeep Kumar, Ombir Singh, Screening of heat tolerant wheat genotypes for late sown conditions. Intntl. J. Agric. Sci. (2006) 2(1): 157-159.