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Exploring indigenous wheat (*Triticum aestivum*) germplasm accessions for terminal heat tolerance

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ABSTRACT

Terminal heat is one of the stress factors for wheat (*Triticum aestivum* L.) production. Nearly 10 000 accessions of exotic and indigenous wheat germplasms are conserved in gene bank at DWR, Karnal. Four hundred and eighty-five indigenous wheat germplasm accessions were characterized as per DUS guidelines during 2007-08. Among these, 77 accessions, those bearing pale green colour, strong to medium waxiness and thousand grain weight more than 38 were preliminary evaluated for terminal heat tolerance under timely and late sown conditions during 2008-09. Genotypes with less than 20% reduction in thousand grain weight and more than 35g thousand grain weight under timely sown conditions were identified as tolerant and those with more than 40% reduction in thousand grain weight and more than 40g thousand grain weight under timely sown conditions were identified as susceptible. On this basis, 23 genotypes were identified. These along with two checks were finally evaluated under polyhouse as well as field conditions during 2009-10. Under polyhouse conditions, two sets of three replications of each genotype were sown in pots. One set was exposed to high temperature conditions in polyhouse during grain growth period. In field evaluation sowing was done under timely and late sown conditions. Data was recorded on phenological, morphological and grain traits. Data was recorded on phenological, morphological and grain traits. Five accessions namely; IC 29007B, IC 45437, IC 47993A, IC 55707B and IC 59534, had heat susceptibility index less than 1 and hence are confirmed as heat tolerant. Two of these accessions; IC 47993A, IC 55707B had high heat tolerance index. These genotypes could be used directly in breeding programme targeting for stressed environments.

Key words: Heat susceptibility index, Indigenous germplasm, Terminal heat tolerance, Wheat

Terminal heat is one of the stress factors for wheat (*Triticum aestivum* L.) production. A significant wheat growing area in South Asia is affected by heat stress and majority of this area lies in Eastern Gangetic Plains, central and peninsular parts of India (Joshi *et al.* 2007a, b). Heat stress also affects North Western parts of the Indian Gangetic Plains to some extent. Both the proximity to the equator and the popular rice-wheat cropping systems, which involve late sowing of wheat, are the major causes of exposure of wheat in India and other neighboring countries to high temperatures during grain filling (Rane *et al.* 2000). It is estimated that the 'cool period' for wheat crop in India is shrinking, while the threat of terminal heat stress is increasing due to global warming also (Rane *et al.* 2000, Joshi *et al.* 2007b). Indian Meteorological Department declared year 2009 as the warmest year since 1909. Sudden increase in temperature during 2nd half of March, 2010 was matter of concern for wheat production. In order to meet the challenging temperature ahead of global warming, there is need to incorporate heat tolerance into wheat germplasm and develop genotypes which are suitable to such stressed environments. The indigenous wheat germplasm accessions can be evaluated for terminal heat tolerance. Such genotypes which bear heat tolerance as well as reasonable thousand grain weight can be used directly in breeding programme targeting for stressed environments.

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MATERIALS AND METHODS

The gene bank of DWR, Karnal houses more than 10 000 accessions of exotic and indigenous nature. The characterization of these accessions for utilization in wheat improvement programme is one of the main mandate of the institute. Four hundred and eighty-five indigenous accessions those included 424 of *Triticum aestivum* and 61 of *T. durum* were selected for characterization as per DUS guidelines during 2007-08. Of these accessions, those bearing pale green colour, strong to medium waxiness and thousand grain weight more than 38 g were selected for the present study.

These genotypes comprising of seventy-seven indigenous accessions were sown along with two checks in augumented design under timely and late sown conditions. Data was recorded on phenological, morphological and grain traits. On the basis of reduction in thousand grain weight due to late sowing, terminal heat tolerant and susceptible genotypes were identified and evaluated further.

Fifteen heat tolerant and eight susceptible genotypes along with two checks were evaluated under polyhouse as well as field conditions. For evaluation under polyhouse conditions, two sets of three replications of each genotype were sown in pots. One set was exposed to high temperature conditions in polyhouse during grain growth period. For field evaluation sowing was done under timely and late sown conditions. Data was recorded on phenological, morphological and grain traits.

Phenological parameters included were days to 75% heading, days to 75% anthesis and physiological maturity. Physiological maturity was recorded when rachis of 75% spikes in each plot lost green colour. Grain filling duration was calculated by substracting days to anthesis from days to maturity. Grain yield and biomass per plot were obtained when plants were fully dry.

Daily mean maximum and mean minimum temperatures were recorded for characterization of environments. Mean minimum and maximum temperatures before and after heading were calculated by taking into consideration the minimum number of days to heading and maximum number of days to maturity.

For calculating Heat Susceptibility Index and Heat Tolerance Index, formulae given by Fisher and Maurer (1978) and Fernandez (1992) were used.

RESULTS AND DISCUSSION

Four hundred and eighty-five indigenous accessions of wheat were characterized for 33 traits during 2007-08. Dark green foliage colour was predominant among these accessions. Ninety two accessions had pale green foliage. Eighty-eight accessions had medium to strong waxy leaf blades and spikes. Thousand grain weight in 71% of the accessions was more than 38g. However, only seventy-seven accessions had pale green foliage, medium to strong waxy leaf and spikes and thousand grain weight more than 38g. Accessions with pale green foliage were included for the study as it is an indicator towards adaptation to high temperature. Pale green color and low chlorophyll content have been reported to play an important role in leaf temperature regulation in barley (Havaux and Tardy 1999). According to Tardy *et al.* (1998) light green color of leaves, which is due to a non-specific decrease in both chlorophyll and carotenoids, appears to be an adaptation to high temperature.

During 2008-09 crop season, these seventy-seven selected accessions were evaluated under timely and late sown conditions. The average maximum and minimum temperatures were higher by 5.4 and 4.0^{0}C under late sown conditions. All the parameters registered reduction under late sown conditions; however the genotypes differed with respect to their tolerance to high temperature under late sown conditions. Genetic diversity for heat tolerance in cultivated wheat is well established (Midmore *et al.* 1984, Rawson 1986, Wardlaw *et al.* 1989, Al-Khatib and Paulsen 1990, Reynolds *et al.* 1994). High temperatures (>30°C)

Table 1 Thousand grain weight under timely and late sown conditions and its % reduction

Genotype	Thousand grain weight		
	Timely sown	Late sown	% reduction
IC 28585	*46.2*	*26.33*	*43.1*
IC 28599	40.4	30.09	25.5
IC 28620 B	*47.4*	*25.52*	*46.2*
IC 28669 A	36.9	28.24	23.5
IC 28692 A	33.9	30.83	9.0
IC 28904 A	43.3	33.35	23.0
IC 28913	*46.3*	*19.26*	*58.4*
IC 28940 A	*41.3*	*22.10*	*46.5*
IC 28951 A	**38.0**	**33.41**	**12.1**
IC 29005 A	39.8	24.57	38.2
IC 29007 A	43.5	34.73	20.2
IC 29007 B	**35.3**	**31.41**	**10.9**
IC 29008	31.2	37.05	–18.8
IC 29009	35.6	26.80	24.7
IC 29010 A	43.2	34.03	21.1
IC 29013	35.4	21.00	40.7
IC 29015	30.8	36.21	–17.6
IC 29017 A	**37.8**	**33.50**	**11.3**
IC 29017 B	35.8	25.74	28.1
IC 29040	*46.1*	*26.79*	*41.9*
IC 29088	21.4	27.87	–30.1
IC 30276 B	33.9	29.90	11.9
IC 30282	27.2	36.15	–32.8
IC 30290 A	40.8	25.47	37.6
IC 31405 B	43.0	30.13	30.0
IC 31488	39.3	27.79	29.3
IC 32508 A	**36.8**	**33.20**	**9.9**
IC 32573	30.4	37.48	–23.2
IC 35037	*44.4*	*26.13*	*41.1*
IC 35117	**42.7**	**43.24**	**–1.4**
IC 35138 A	38.4	29.14	24.2
IC 35147	45.3	30.06	33.6
IC 35740 B	43.0	30.76	28.4
IC 36693 A	39.4	31.08	21.2
IC 36725	**37.0**	**34.00**	**8.1**
IC 36863 A	22.6	28.70	–26.9
IC 36882	36.6	22.65	38.1
IC 36883 A	29.1	30.74	–5.8
IC 36904	32.9	31.79	3.4
IC 41504	24.2	31.56	–30.3
IC 45437	**39.6**	**31.75**	**19.8**
IC 47011 B	43.1	32.10	25.6
IC 47013	46.3	36.25	21.6
IC 47016 A	33.7	34.51	–2.5
IC 47073 B	*45.3*	*20.50*	*54.7*
IC 47343 A	41.5	29.13	29.7
IC 47514 A	38.8	20.41	47.4
IC 47539 B	48.3	32.66	32.3
IC 47550 B	45.6	31.89	30.0
IC 47585 A	*49.9*	*23.00*	*53.9*
IC 47793 A	**40.0**	**32.72**	**18.3**
IC 47801	33.1	26.44	20.2
IC 49593	41.0	30.35	26.0
IC 55582	28.7	28.52	0.5
IC 55601	26.6	32.31	–21.4

Contd.

Table 1 *Contd.*

Genotype	Thousand grain weight		
	Timely sown	Late sown	% reduction
IC 55665	**38.3**	**30.73**	**19.8**
IC 55681 A	36.2	27.81	23.2
IC 55707 A	**45.6**	**36.71**	**19.5**
IC55707 B	**38.4**	**32.16**	**16.3**
IC 55720	30.9	28.02	9.2
IC 57579	41.4	28.70	30.7
IC 57883	32.8	27.67	15.6
IC 57889 A	35.5	28.21	20.5
IC 57889 B	34.9	29.62	15.2
IC 57983 B	25.8	31.22	–20.9
IC 57985	**37.3**	**31.03**	**16.9**
IC 59129	33.0	33.99	–3.0
IC 59131	28.4	27.74	2.3
IC 59137 B	40.6	32.08	21.0
IC 59353	23.4	26.80	–14.4
IC 59515	29.6	31.33	–5.8
IC 59534	**35.7**	**31.71**	**11.1**
IC 59572 A	36.4	28.95	20.6
IC 59575 A	38.8	28.19	27.3
IC 59579 A	34.8	31.29	10.0
IC 73598	**44.0**	**35.45**	**19.4**
IC 78094 B	**38.1**	**33.33**	**12.6**

*Accessions in bold considered as heat tolerant and accessions in italics as heat susceptible

during grain growth duration can decrease the rate of grain filling in wheat (Al-Khatib and Paulsen 1984, Randall and Moss 1990, Stone *et al.* 1995, Wardlaw and Moncur 1995). The reduction in grain filling duration ranged from -76 to 51%, in grain number/main spike -34 to 49%, grain weight/spike -53 to 74% and in thousand grain weight from -33 to 58%. This indicates that some of the accessions performed better under late sown conditions. Fifteen accessions did not suffer any reduction in thousand grain weight and eight accessions registered less than 10% reduction. Sixteen accessions had more than 30% reduction in thousand grain weight. The data on reduction in thousand grain weight is given in Table 1. There were 28 accessions which had thousand grain weight more than 40g under timely sown conditions. Of these, only four accessions suffered less than 20% reduction in thousand grain weight, 16 suffered up to 40% reduction and 8 suffered more than 40% reduction. Hence for further study, genotypes with less than 20% reduction in thousand grain weight and more than 35g thousand grain weight under timely sown conditions were identified as tolerant and those with more than 40% reduction in thousand grain weight and more than 40g thousand grain weight under timely sown conditions were identified as susceptible. As a result, 15 tolerant and 8 susceptible genotypes were selected and evaluated further under poly house as well as field conditions.

Table 2 Reduction in grain yield and grain weight/spike under late sown field conditions and grain weight/plant under polyhouse conditions

G No	Genotype	Grain yield/m^2			Grain weight (g)/spike			Grain weight (g)/plant		
		Timely sown	Late sown	% reduction	Timely sown	Late sown	% reduction	Control	Polyhouse	% reduction
G1	IC 28585	*3623*	*2850*	*213*	*24*	*18*	*266*	*63*	*42*	*330*
G2	IC 28620 B	*2875*	*1928*	*329*	*17*	*13*	*242*	*54*	*38*	*296*
G3	IC 28913	3443	2146	377	17	18	–77	45	38	142
G4	IC 28940 A	*2786*	*2140*	*232*	*21*	*16*	*238*	*57*	*44*	*230*
G5	IC 28951 A	2870	1880	345	21	16	261	**45**	**41**	**85**
G6	IC 29007 B	**2642**	**2138**	**191**	**19**	**16**	**172**	**61**	**59**	**37**
G7	IC 29017 A	3212	2434	242	17	17	–17	50	34	316
G8	IC 29040	2468	1977	199	20	17	147	*64*	*40*	*373*
G9	IC 32508 A	3647	2100	424	21	18	144	59	37	373
G10	IC 35037	2750	1858	325	15	16	–78	20	37	–879
G11	IC 35117	2952	2018	316	17	20	–181	**43**	**36**	**172**
G12	IC 36725	3750	1967	476	19	15	188	**43**	**35**	**169**
G13	IC 45437	**2424**	**2303**	**50**	**16**	**17**	**–36**	**46**	**48**	**–44**
G14	IC 47073 B	*3378*	*2034*	*398*	*18*	*12*	*342*	39	31	193
G15	IC 47585 A	3375	2901	140	19	17	94	37	40	–81
G16	IC 47793 A	**3272**	**2689**	**178**	**18**	**17**	**78**	**47**	**42**	**104**
G17	IC 55665	3297	2559	224	20	15	212	**31**	**37**	**–195**
G18	IC 55707 A	2764	2121	232	22	16	265	**30**	**33**	**–99**
G19	IC55707 B	**2992**	**2399**	**198**	**15**	**16**	**–66**	**49**	**50**	**–11**
G20	IC 57985	2723	2018	259	20	17	147	69	37	471
G21	IC 59534	**2835**	**2293**	**191**	**17**	**15**	**139**	**46**	**61**	**–336**
G22	IC 73598	**2984**	**2418**	**190**	**16**	**17**	**–46**	**32**	**34**	**–69**
G23	IC 78094 B	3818	2176	430	22	19	130	**46**	**62**	**–353**

*Accessions in bold confirmed as heat tolerant and accessions in italics as heat susceptible

Table 3 Heat susceptibility index (HSI) and Heat tolerance index (HTI)

G No	Genotype	HSI	HTI
G 1	IC 28585	072	108
G 2	IC 28620 B	*110*	058
G 3	IC 28913	*126*	077
G 4	IC 28940 A	**078**	062
G 5	IC 28951 A	116	056
G 6	IC 29007 B	**064**	059
G 7	IC 29017 A	**081**	**081**
G 8	IC 29040	067	051
G 9	IC 32508 A	142	080
G 10	IC 35037	*109*	053
G 11	IC 35117	106	062
G 12	IC 36725	159	077
G 13	IC 45437	**017**	058
G 14	IC 47073 B	*133*	072
G 15	IC 47585 A	047	102
G 16	IC 47793 A	**060**	**092**
G 17	IC 55665	**075**	**088**
G 18	IC 55707 A	**078**	061
G 19	IC55707 B	**076**	**072**
G 20	IC 57985	**087**	057
G 21	IC 59534	099	059
G 22	IC 73598	137	055
G 23	IC 78094 B	144	087

Table 4 Data on phenological and grain traits of identified heat tolerant and susceptible accessions

G No	Genotype	Days to heading (days)	Days to maturity (days)	Grain number/ spike	Grain weight/ spike	1000 grain weight (g)	Grain yield (g)/m²	Biomass (g)/m²	Remarks
G 6	IC 29007 B	943	1 387	475	19	399	264	1 376	Heat Tolerant
G 13	IC 45437	953	1 387	451	16	352	242	1 023	Heat Tolerant
G 16	IC 47793 A	913	1 382	451	18	392	327	1 485	Heat Tolerant
G 19	IC55707 B	978	1 390	397	15	372	299	1 648	Heat Tolerant
G 21	IC 59534	953	1 387	452	17	383	283	1 539	Heat Tolerant
G 2	IC 28620 B	923	1 390	426	17	401	288	1 267	Heat Susceptible

Twenty-three selected accessions were evaluated for terminal heat tolerance under polyhouse as well as field conditions during 2009-10. The post heading average maximum temperatures in the polyhouse were 8°C higher than the outside, whereas minimum temperatures were higher by 1.8°C. The plants exposed to high temperature in polyhouse registered reduction in various traits. On the basis of reduction in grain weight/plant under high temperature conditions in polyhouse, twelve out of fifteen accessions were found to be tolerant with reduction less than 20%, whereas four accessions identified as susceptible confirmed by registering more than 20% reduction in grain weight /plant (Table 2).

Under late sown conditions in field, the average maximum and minimum temperatures were higher by 5.0 and 2.4°C respectively. Grain yield of these accessions reduced from 5 to 47.6% and grain weight/spike from -18.1 to 34.2%. On the basis of reduction in these two traits, six out of fifteen accessions were tolerant and four out of eight were susceptible. However, under both polyhouse and field conditions, six accessions confirmed as heat tolerant and three as heat susceptible.

The heat susceptibility index of these genotypes is given in Table 3. Only one genotype IC 45437 had HSI less than 0.5 and hence is a heat tolerant genotype. Twelve accessions had HSI between 0.5 and 0.99, i.e. these are moderately tolerant, whereas 10 accessions with more than 1 HSI were heat susceptible. Out of six accessions identified as tolerant under polyhouse as well as field conditions, five accessions namely; IC 29007B, IC 45437, IC 47993A, IC 55707B and IC 59534, had heat susceptibility index less than 1 and hence are confirmed as heat tolerant. Two of these accessions; IC 47993A, IC 55707B had high heat tolerance index.

The morphological data of these accessions is given in Table 4.

The heat tolerant accessions identified during the present study also have thousand grain weight of more than 35g. These accessions can be used in breeding programme for terminal heat tolerance.

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