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COMBINING ABILITY FOR HEAT TOLERANCE TRAITS IN BREAD WHEAT (*TRITICUM AESTIVUM* L. EM. THELL)

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ABSTRACT

Two experiments under normal and late sown conditions consisting of forty five crosses, ten parents and standard check, were conducted at Wheat Research Unit, M.A.U. Parbhani. The results indicated that parents HI 977, PBN 3235 and PBN 1607-2 are good combiners for heat tolerance, while Sonalika for proline content. NI 5439 and CC 464 were good combiner for chlorophyll content and stomatal frequency. Kalyansona had high gca effect for yield per plant under normal and pooled analysis, whereas Parbhani-51 had high gca under late sown conditions.

The studies revealed that crosses viz., PBN 3375 × Sonalika and PBN 3963 × PBN 3235 for chlorophyll stability index, MACS 2496 with PBN 3235 and PBN 3324 and Sonalika × PBN 1607-2 for heat injury per cent, PBN 3963 × Kalyansona and HI 977 × PBN 3235 for proline content; had high sca effects for heat tolerant parameters. The crosses Hindi 62 × Ajantha, Hindi 62 × CC 464 and Kalyansona × NI 5439 were found to be heat tolerant. The studies also revealed that parents like OC 464, NI 5439, Parbhani 51, PBN 1607-2, MACS 2496 could be utilized in multiple crossing programme and further biparantal matings for selection of high yielding progenies for heat tolerance.

Key Words : Heat tolerant parameters, proline content, chlorophyll, grain yield, combining ability

Wheat improvement for heat tolerance depends on intensive hybridization using heat tolerant donors and high yielding commercial cultivars. To evolve an effective hybridization programme combining ability analysis is used to test the performance of parents in different cross combinations and characterize the nature and magnitude of gene effects in the expression of various heat tolerant parameters. There are scanty references for genetic studies of heat tolerant parameters. Thus, the main objective of present studies was to identify the best combining parent and their crosses on the basis of their general and specific heat tolerant parameters viz., heat injury percent, proline content, nitrate reductase activity, chlorophyll contents, stomatal frequency alongwith developmental and agronomic characters, under normal and late sown environments.

MATERIALS AND METHODS

A set of 45 hybrids involving ten diverse parents (Kalyansona PBN 3375, PBN 3963, Parbhani 51, MACS 2496, Sonalika, HI 977, PBN 3324, PBN 3235 and PBN 1607-2) were made by using diallel mating system without reciprocals during winter 1993-94. Two hybrids, 10 parents and one standard check Kailash (PBN 142), were grown in a randomised block design with two replications, at Wheat Research Unit, M.A.U. Parbhani during Rabi 1994-95. One trial was planted under normal on 15 November, second on 25 December, 1994 under late sown situations. This has provided the natural exposure for normal and high temperature conditions. Each treatment was sown in a double rows plot of 2 m. length spaced 45 cm. and plant to plant 15 cm. apart in both the seasons. The seed was planted by dibbling a single seed per will followed by gap filling after 10 days, of planting.

Heat injury percent was measured as per Sulluvian's [1] heat tolerance test which was further modified by Blum and Ebercon [2] in wheat. The electrical conductance was recorded in normal and in high temperature incubated at 50°c. Conductance was converted to conductivity by multiplying it with a cell constant. The heat injury was calculated by the formula given below.

$$\text{Percent heat injury} = 1 - \frac{1 - T_1/T_2}{1 - C_1/C_2} \times 100$$

Where T_1 and T_2 initial and final reading of treated sample, and C_1 and C_2 initial and final reading of control sample. Heat injury was classified as tolerant (below 35%) mid tolerant (35-50 %) and susceptible 50% and above.

The proline content of 60 days old seedling was determined as per Bates *et al.* [3], while procedures for chlorophyll was adapted as recommended by Arnon [4]. A quick method of stomatal count described by Nayeem and Dalvc [5] was used for stomatal print. Nitrate reductase activity (μ moles NO_2/g of fresh weight/hr) in leaves of wheat was estimated as per the Klepper [6].

Five plants in each line were randomly selected and observations were recorded for six physico-chemical, three developmental and four spike and grain characters. Combining ability analysis was performed by following Griffing [7] Method I Model II.

RESULTS AND DISCUSSION

The high temperature prevailing during winter season hinders the productivity of wheat. Various physico-chemical processes are responsible for heat tolerance in wheat genotypes. The genetic variation with regards to these parameters among certain genotypes and their crosses in wheat would be of great value in developing heat tolerant wheat genotypes. The negative gca and sca for chlorophyll, heat injury% and stomatal frequency showed their role in heat tolerant mechanism in wheat.

Significant mean squares (Table 1) due to general combining ability and specific combining ability in pooled analysis revealed significance of both additive and dominance gene effects in inheritance of all the physico-chemical, developmental, grain and spike characters. The ratio of additive to total genotypes variance revealed that all the characters studied were predominantly controlled by non- additive genes action.

Table 1. ANOVA for combining ability for heat tolerantraints in wheat

Source of variation	d.f.	Mean squares					
		Chlorophyll content	Chlorophyll stability index	Heat injury (%)	Proline content	Stomatal frequency	
						Upper	Lower
Gca	9	0.166**	0.0761*	120.77**	3.032**	65.05**	43.89
Sca	45	0.110**	0.072**	59.01**	1.361*	30.46*	38.19*
Error	54	0.034	0.033	17.75	0.861	21.73	22.86
$\frac{2\sigma_g^2}{2\sigma_g^2+\sigma_s^2}$		0.095	0.149	0.199	0.420	0.390	0.271

Table 2 represents the selected best general combiners for various characters. None of the parents was found excellent combiners for all the characters. The parents PBN 1607-2 and Sonalika showed high gca effects for chlorophyll content under normal and late sown conditions. The parents HI 977, PBN 3235 and PBN 1607-2 had highly negative desirable gca effects for heat injury percent. The parent Sonalika was observed exceptionally good combiner for proline content. However the parents MACS 2496 and Kalyansona were good general combiners for nitrate reductase activity. Though the mean squares for nitrate reductase activity was non-significant in early sown crop and pooled analysis, the parent MACS 2496 had positive gca effects for nitrate reductase activity at all stages under normal sown situation as well as pooled analysis. The negative significant gca effect for stomatal frequency

Table 2. Parents showing maximum gca effects for different characters in normal, and late plantings and in pooled analysis

Characters	Normal planting	Late planting	Pooled
A. Physio-chemical parameters :			
Chlorophyll content	PBN-1607-2, PBN-3963 Sonalika	PBN-1607-2, MAC S-2496 Sonalika	PBN-1607-2, Sonalika PBN-51
Chlorophyll stability index	Kalyansona	PBN-3375, PBN-3963	Kalyansona
Heat injury	HI-977, PBN-3235, PBN-1607-2, PBN-3963	HI- 977,PBN3324, PBN-1607-2, PBN-3235	HU-977, PBN-3235, PBN-1607-2
Proline content	Sonalika, PBN-3324	HI-977, Sonalika	Sonalika, PBN-51
Nitrate reductase activity at 60 days	Non-significant	MACS-2496, Kalyansona	Non-significant
		Kalyansona,	Non-significant
at 90 days	Non-significant	MACS-2496 PBN-51,	
at 120 days	Non-significant	Kalyansona, PBN-1607-2	Non-significant
Stomatal frequency Upper	PBN-3963, MACS-2496, PBN-3375, MACS-2496, HI 977 PBN-3375	PBN-51, Sonalika, HI-977	PBN- 3375, MACS-2496, HI-977
Lower			
B. Developmental characters :			
Days to 50% flowering	PBN-3375, PBN-3963, PBN-3324, PBN-1607-2	PBN-3375, PBN-1607-2, PBN-3963	PBN-3375, PBN-3963, PBN-1607-2
Plant height	PBN-3375	PBN-51, MACS-2496	PBN-3375, PBN-51, MACS-2496
No. of tillers/plant	Non-significant	PBN-3963, PBN-51	PBN-3963, PBN-51
C. Grain and spike characters :			
Ear length	HI-977	HI-977, PBN-1607-2	HI-977, Sonalika, PBN-1607-2
No. of grains/plant	HI-977, PBN-3235	Non-significant	PBN-3235, HI-977
1000 grain weight	PBN-3375, HI-977, Kalyansona, PBN-3235	PBN-51, PBN-3375	PBN-3375, PBN-51, PBN-3963
Grain yield/plant	HI-977, Kalyansona	HI-977, PBN-51	HI-977, Kalyansona

on upper surface was observed for parents MACS 2496 and PBN 51 and on lower surface for the parent HI 977. Deshpande and Nayeem [8] observed that parents Hindi 62 and C 306, were good general combiners for heat tolerance while NI 5439 and CC 464 were good general combiners for chlorophyll content and stomatal frequency.

Developmental characters

Among the developmental traits for heat tolerance, earliness (perhaps favoured the plant to escape the losses due to rise in temperature), and profuse tillering (contributor to grain yield) are desirable [9]. On the basis of pooled analysis (Table 2) the cultivars PBN 3375. PBN 3963 and PBN 1607-2 are the best general combiners, exhibiting negative significant gca for flowering and are high tillering suited for warmer regions. Parbhani- 51 is notified for warmer region of peninsular region, and exhibited high tillers [10]. These parents could be utilized for transfer of genes responsible for profuse tillering under high temperature conditions.

Grain and spike characters

The maximum gca recorded by various cultivars under study for grain and spike characters are presented in Table 2. The maximum highly positive and significant gca effects for ear length and number of grain per plant were observed by HI 977. This is a recommended variety under late sown conditions [10], and as such better combiner for these two traits.

Kernel weight or 1000 grain weight is also an important yield contributor under high temperature conditions [9]. It is interesting that the parents PBN-3375, Parbhani-51 and PBN- 3963 are the best general combiner for kernel weight (Table 2).

Grain yield per plant particularly under high temperature of late sown conditions, indicate presence of genes for heat tolerance. HI 977 and Kalyansona are the best combiners for grain yield under normal sown conditions. However, Parbhani-51 is the best combiner under late sown conditions for grain yield. This indicated the tolerance to the damage due to high temperature. These genetic resources are useful for improvement of thermo tolerance in wheat.

Specific combining ability

The specific combining ability effects represent non-fixable components of gene action. The estimates of sca effects were not consistant over two environments viz., normal and late sown situations.

Physico-chemical characters

The crosses exhibiting maximum sca effects for different physico-chemical characters are presented in Table 3.

It is interesting to note that none of the cross combinations showed desirable significant sca for normal, late and pooled analysis for all the physico-chemical parameters. However, one cross combination PBN 3963 × Kalyansona has displayed maximum sca effect for proline content under both situations. PBN 3939 is a mutant derived from recurrent irradiation of local land race 'Sharbati'. Hence both the parents of the combination had adaptability to the changing environments.

In respect of chlorophyll stability index, PBN 3375 × Sonalika and PBN 3963 × PBN 3235 were the best. The combinations of MACS 2496 × PBN 3235, MACS 2496 × PBN 3324 and Sonalika × PBN 1607-2 possessed high sca effect for heat injury. These crosses had combinations of high × low, and medium × low gca for heat injury. The crosses involving high × low gca parents with positive sca effects may be expected to produce desirable segregants in F_2. However crosses between medium × low indicated importance of non-additive genetic variation for heat injury per cent. As regards nitrate reductase activity at 60, 90 and 120 days it was observed that the hybrids Parbhani 51 × PBN 1607-2, Sonalika × PBN 3235 and PBN 3963 × PBN 3324 possessed high sca effects. From the sca effects and *per se* performance of these crosses, nitrate reductase activity decreased from 60 to 120 days, but it had significant role at respective stages. The low stomatal frequency was one of the desirable parameter while breeding for heat tolerant varieties. In the present studies, the crosses showing high sca effects for stomatal frequency on upper and lower surfaces were also sensitive to heat injury. Deshpande and Nayeem [8] observed significant sca effects for chlorophyll content, stomatal frequency and heat injury in 21 cross combinations. High sca effects for chlorophyll content was observed in the cross NI 5439 × CC 464. They also observed negative significant sca effects for the cross NI 5439 × CC 464. Three crosses viz., Hindi 62 × Ajantha (–12.25), Hindi 62 × CC 464 (–7.25) and Kalyansona × NI 5439 (–5.25) were found to be heat tolerant.

Spike and grain characters

In respect of spike length the parental lines parbhani 51, PBN 3375, PBN 3963, Kalyansona and PBN 1607-2, produced superior crosses. However, crosses viz., HI 977 × PBN 1607-2, Sonalika × PBN 3235 were best specific combinations for number of grains, and involved high × low gca parents with positive sca effects. The crosses MACS 2496 × PBN 1607, PBN-51 × MACS 2496 displayed high positive sca for 1000 grain weight, involving low × low and low × high gca parents, thereby suggesting to resort to multiple crosses followed by intermating. [11-13].

The sca estimates indicated that out of 45, seven crosses expressed positive significant effects, whereas only two crosses showed negative sca effects for grain

Table 3. Best crosses selected on the basis of sca effect for different characters in wheat

Characters	Normal sown crop	Late sown crop	Pooled
A. Physio-chemical parameters :			
Chlorophyll content	PBN-3375×Kalyansona PBN-3375× MACS-2496 PBN-3375×PBN-51	PBN-3235× PBN-1607-2 MACS-2496×Sonalika MACS-2496×PBN-3235	PBN-3375×PBN-1607-2 PBN-3235×PBN-1607-2 PBN-3375×MACS-2496
Chlorophyll stability index	PBN-3375×Sonalika PBN-3963×MACS-2496	Kalyansona×PBN-3235 Sonalika×PBN-3235	PBN-3375×Sonalika PBN-3963×PBN-3235 MACS-2496×PBN-1607-2
Heat injury	MACS-2496×PBN-3324 MACS-2496×PBN-3235 PBN-51×PBN-3235 Kalyansona×PBN-3235	MACS-2496× Kalyansona Sonalika×PBN-1607-2 PBN-3375×PBN-3235 MACS-2496×PBN-1607-2	MACS-2496×PBN-3324 Sonalika×PBN-1607-2 MACS-2496×PBN-3235 MACS-2496×PBN3235
Proline content	Kalyansona×PBN-3235 PBN-3963× Kalyansona PBN-3963×Sonalika	HI-997×PBN-3235 PBN-3375×PBN-51 Sonalika×PBN-3235 PBN-3963×Kalyansona	PBN-51×HI-977 HI-977×PBN-3235 PBN-51×HI-977 PBN-3963×Sonalika
Nitrate reductase activity at 60 days at 90 days at 120 days	Non-significant	PBN-51×PBN-1607-2 Sonalika×PBN-3235 PBN-3963×PBN-3324 PBN-3375×PBN-3235	-
	Non-significant	PBN-51×PBN-1607-2 Sonalika×PBN-3324 PBN-3375×PBN-3235 PBN-3963×PBN-3324	
	Non-significant	PBN-51×PBN-1607-2 Sonalika×PBN-3235 PBN-3963×PBN-3324	
Stomatal frequency Upper	Sonalika×HI-977 Kalyansona×PBN-1607-2P BN-3963×PBN-3324	PBN-51×MACS-2496 PBN-3324×PBN-1607-2 PBN-3963×MACS-2496	Kalyansona×PBN-3235 Kalyansona×PBN-1607-2PB N-3963×Sonalika
Lower	Sonalika×Kalyansona Kalyansona×PBN-3963	PBN-3375×PBN-1607-2 PBN-3324×PBN-1607-2	Kalyansona×PBN-1607-2Ka lyansona×PBN-3235

(*Table 3 Contd.*)

Characters	Normal sown crop	Late sown crop	Pooled
B. Development characters :			
Days to 50% flowering	PBN-3963×MACS-2496 PBN-3375×MACS-2496 PBN-3235×PBN-1607-2	PBN-3963×PBN-51 PBN-3375×MACS-2496 MACS-2496×PBN-3324	PBN-3375×MACS-2496 PBN-3963×PBN-51 HI-977×PBN-3324
Plant height	PBN-3963×MACS-2496 MACS-2496×Sonalika HI-977×PBN-3235	PBN-3375×PBN-3324 Kalyansona×PBN-1607-2 Sonalika×PBN-3235	HI-977×PBN-3235 Kalyansona×PBN-1607-2PBN -3375×PBN-3324
No. of tillers/plant	Non-significnat	MACS-2496×Sonalika PBN-3375×PBN-51 PBN-3963×PBN-51	MACS-2496×Sonalika PBN-3963×PBN-51 MACS-2496×HI-977
C. Grain and spike characters :			
Ear length	PBN-51×PBN-3324 PBN-3375×MACS-2496 PBN-3963×Kalyansona	PBN-51×HI-977 Sonalika×Kalyansona Sonalika×PBN-1607-2	PBN-3375×PBN-1607-2 PBN-3963×Kalyansona PBN-3375×Kalyansona
Number of grains/plant	HI-977×PBN-1607-2 PBN-3375×PBN-3324 Sonalika×PBN-3235	Non-significant	Sonalika×PBN-3235 MACS-2496×HI-977 HI-977×PBN-1607-2 PBN-3863×PBN-1607-2
1000 grain weight	PBN-51×MACS-2496 MACS-2496×PBN-1607-2 PBN-3324×PBN-3235	PBN-3963×Sonalika Sonalika×PBN-3235 MACS-2496×PBN-3324	PBN-3963×MACS-2496PBN- 3963×PBN-1607-2 MACS-2496×PBN-1607-2
Grain yield/plant	PBN-3963×PBN-3324 MACS-2496×Kalyansona HI-977×PBN-1607-2 PBN-3375×Sonalika	Sonalika×PBN-3235 Sonalika×Kalyansona HI-977×PBN-3324 Sonalika×PBN-3324	PBN-3963×PBN-3324 MACS-2496×HI-977 PBN-3375×Sonalika MACS-2496×PBN-3324

yield. The crosses viz., PBN 3963 × PBN 3324 and PBN 3375 × Sonalika under normal planting and pooled analysis, while Sonalika × PBN 3235 for late sown situations, produced superior hybrids for economic yield. These crosses were derived from low × low gca parents, indicated the importance of non-additive genetic variation which can be exploited by multiple crosses followed by intermating among desirable segregants. On the contrary Chovatia and Jordan [14] and anonymous [10] reported high sca crosses for grain yield involving one good and one average or poor combiner parents.

The present study has identified desirable parents PBN 1607-2, Parbhani 51, MACS 2496, PBN 3235, PBN 3375, HI 977 for most of the heat tolerant parameters and yield attributes. The importance of additive but mainly non-additive gene action is highlighted. Improvement in heat injury and other heat tolerant parameters combined with high yield should be possible by resorting to biparental mating followed by recurrent selection or by selective diallel mating system.

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