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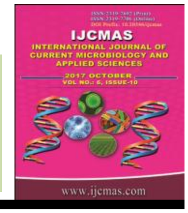

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Combining Ability in Relation to Wheat (*Triticum aestivum* L.) Breeding Programme under Heat Stress Environment

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A B S T R A C T

A set of 45 crosses were generated by crossing 10 lines *viz*., K9533, K9162, K9465, K8962, HUW234, NW2036, K9423, K9351, KRL210 and K906 following half diallel design of wheat under late sown condition. Ten parents, 45F_1 hybrids and 45 F_2 populations using Randomized Block Design with three replications were evaluated for yield and other important morpho-physiological characters at Kanpur (UP, India). General combining ability (GCA) and specific combining ability (SCA) for maturity and yield components traits were determined. The main objective of the research was the identification and proper selection of best performing wheat parental genotypes and best F_1 crosses, based on GCA and SCA estimates under heat stress environment. Significant differences were observed among the wheat genotypes for all the studied traits. The estimates of σ2GCA and σ2SCA and its ratio (σ2GCA/σ2SCA) indicated that non-additive genetic expression was a pre-dominant for most of traits studied. K9533, K906, K9351 and K9423 were good general combiners for most of the traits under consideration, while F_1 hybrids and F_2 populations K9465 x K9351, K9162 x K906, NW2036 x K9351, K9162 x K8962 and HUW234 x KRL210 were best specific combiners observed for several important traits including grain yield plant-1 which can be subsequently utilized in future wheat breeding to develop high yielding new wheat cultivars from transgressive segregants recovered in latter generations.

Keywords

Wheat, General combining ability, Specific combining ability.

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Introduction

Wheat (*Triticum aestivum* L.) cultivation reaches far back into history. It is one of the oldest domesticated grain crops and since then it has been the basic staple food of different civilizations of Europe, West Asia, and North Africa. The total cultivated area of wheat in India for the cropping year 2016-17 was 9.75 m hectares, with the total wheat produce of 96.64 million tonnes and average grain yield of 2989 Kg ha^{-1} (Anonymous 2016-17). As a staple food crop, wheat is fulfilling the calorie demands of growing population. It is only behind the pulses for the protein content (Kandhare, 2014). The main focus is on to increase wheat production and to break the yield stagnancy from last decades. This has been in response to the pressure for an adequate food supply caused by constantly increasing population in India and the world in general. Wheat cultivars that can withstand abiotic stresses particularly terminal heat tolerance will be able to fulfill the food demand in coming years Iqbal *et al.*, (2017). Therefore, development of new improved wheat cultivars with high genetic potential for yield under stress environment has become a major objective in the wheat breeding.

For improvement in wheat yield, the study of the genetic structure and trend of combining ability and plant behavior under heat stress is of great importance for the wheat scientist, knowledge of general and specific combining ability along with the mode of gene action in the available breeding material is very important to start the effective wheat breeding programme. Half diallel mating is an effective strategy to evaluate genotypes used as parents for combining ability effects in order to select suitable parents for developing new cultivars Hayman (1954a, b) and Jinks (1954). Many researchers have studied the combining ability and genetic structure of bread wheat hybrid populations using half diallel mating method related to yield and yield components. Several researchers like Sprague and Tatum (1942); Griffing (1956 a), have reported that majority of genetic variances of grain yield as well as yield components are under control of non-additive nature of genes. However, Zahid *et al.*, (2008) have reported that numbers of tillers plant-1 are controlled by additive gene action.

This study was undertaken to find out good combining ability for important yield contributing traits for a heat stress condition, so that superior cross combination are selected for development of new cultivars with desirable attributes.

Materials and Methods

An experiment was conducted at Crop Research Farm, Nawabganj, C. S. Azad University of Agriculture and Technology, Kanpur- 208 002. (U.P.) during *Rabi*, 2012-13. Experimental material for present investigation comprised of 45 F'_1s developed by crossing 10 lines *viz*., K-9533, K9162, K9465, K8962, HUW234, NW2036, K9423, K9351, KRL210 and K906 following half diallel design. A total of 100 treatments and 10 parents (45 F_1's and 45 F_2's) were used for the study of combining ability for eighteen quantitative characters in wheat. The F_1 hybrids and F_2 generation along with their parents were evaluated during the cropping year 2012-13 using Randomized Block Design with three replications in late sown (LS) condition.

The entries were sown in a single row plot of 3 m length with inter and intra-row spacing of 23 cm and 18 cm, respectively. Data were taken on maturity, morphological and yield parameters namely, leaf angle, chlorophyll fluorescences, canopy temperature depression, chlorophyll intensity and grain yield plant -1. Analysis of variance was performed by the formula of Fisher (1918) to determine the significant differences among wheat genotypes. Combining ability analysis was carried out by the method of Kempthorne (1957).

Results and Discussion

Analysis of variance (Table 1) for combining ability, revealed highly significant variance for both general and specific combining ability in both the generations for all the characters, indicating the importance of both additive and non-additive gene action in the expression of these traits. However, the additive variance was predominant for all the characters in both generations having higher values.

The GCA and SCA effects as per perusal of results (Table 1) were highly significant for all the characters in both the generations. The magnitudes of SCA variances were higher than GCA for all characters in both the generation except leaf angle. However, in few cases, the reliability has a question due to the expression of hybrid vigor among the progenies of parental crosses and could not be treated as best general combiners.

Thus, under such situations when the character is controlled unidirectionally by a set of allele and additive effects were important then parents might be more effective. The genetic variance of F_1 generation was more than F_2 for all the traits except in few cases under this study. Similar performance was observed due to GCA/ SCA ratio as indicated for that F_1 values were higher than the F_2 values in respect of all the attributing traits except canopy temperature depression and days to physiological maturity a predominant role of additive gene action and non-additive gene action in F_1 and F_2 generations respectively (Siddique *et al.*, 2004).

The estimates of GCA effects and corresponding mean performance of the parents along with succeeding generations for days to anthesis were most effective due to the parent K8962, HUW234 and K9351; for specific leaf weight due to K9533, K9351 and K906; leaf angle due to K9533, K9162, K8962, and K9423 having maintaining metabolic activities in system a sustainable manner; NW2036 and K9423, for chlorophyll florescences; K906, K9423, K9351 and HUW234 for canopy temperature depression; K9423, K9351 and KRL210 for chlorophyll intensity; NW2036, K9351 and K906 for increased flag leaf area of main shoot; K9533, K8962 and HUW234 for decrease in days to physiological maturity; The grain yield per plant, K9423, K9351 and K906 were most considerable due to their highly productive nature. It indicated that these parents in a future breeding programme might be most effective in improvement of quality traits.

In most of the cases, if the character is unidirectionally controlled by a set of alleles with predominant additive effects, the section of parents on the basis of *per se* performance may be adequate (Tables 4 and 5). Other researchers were also in agreement of this conclusion that some phenotypically superior line may yield poor recombinants in segregating populations (Yadav and Murty, 1976 and Singh *et al.*, 1990). It is, therefore, essential that the parents should be selected on the basis of their combining ability estimates.

The diversity of origin of parents combined with additive x additive interaction effects is likely to give better recombinants in their cross combinations with high yield on the advancement of generation. Genetic diversity within a population can be an appropriate compromise between the demands for uniformity and advantage of diversity (Allard and Hansche, 1964). Generally for an autogamous crop like wheat, a study of segregating population for specific combining ability (SCA) would be important. In the present study, the SCA effects in both the generations (Table 3) were most outstanding. The estimated value of SCA effects for a desirable trait like days to anthesis in both the generations involving combination, K 9351 x KRL 210 was favorable for earliness. The estimated value of SCA effects for chlorophyll fluorescences in K 9162 x NW 2036, K 8962 x K 906, K 9465 x KRL 210, K 9533 x K 9351 and K 9533 x K 9162 in F_1 and K 9162 x NW 2036, K 9465 x KRL 210, K 8962 x K 906 and KRL 210 x K 906 and K 9533 x K 9162 crosses of F_2 generation were most considerable higher value of chlorophyll fluorescence indicated that good health of PS-II thereby generation of more ATP which later utilize in CO_2 reduction via process of photosynthesis. A similar finding was reported by Balouhi (2010) and Shahbazi *et al.*, (2012). For canopy temperature depression in 9465 x KRL 210, K 9162 x K 906, K 9423 x KRL 210. HUW 234 x NW 2036 and HUW 234 x K 9351 in F_1 and K 9465 x K 9351, K 9423 x KRL 210, K 9162 x K 906, HUW 234 x KRL 210 and HUW 234 x NW 2036 crosses of F_2 generation were most considerable at higher canopy temperature depression proved to be more heat tolerant. Similar findings were observed by (Mohammadi *et al.*, 2012).

Table.1 Weather data recorded at Nawabganj during the crop season 2012-13

Met. weeks	Standard weeks	Temperature (^{0}C)		Average relative humidity (%)		Total Rainfall (mm)	Sunshine (hrs)
		Min.	Max.	Min.	Max.		
49	3-9 Dec	8.5	26.5	36	76	00.0	7.7
50	10-16	9.7	25.9	55	93	00.0	5.5
51	17-23	8.0	20.2	61	87	00.0	5.7
52	24-31	4.4	15.6	71	96	00.0	0.8
1	1-7Jan	3.0	14.3	67	95	00.0	2.1
2	8-14	3.7	21.1	52	90	00.0	4.4
3	15-21	9.4	21.9	90	93	00.0	2.9
4	22-28	5.4	19.9	61	92	00.0	5.9
5	29-4 Feb	6.8	23.0	56	89	00.0	4.9
6	5-11	10.0	22.3	65	92	00.0	5.9
7	12-18	10.5	21.7	69	93	00.0	5.7
8	19-25	10.9	24.7	69	92	00.0	7.4
9	26-4 Mar	11.7	26.3	57	89	00.0	9.4
10	5-11	12.5	30.0	44	87	00.0	9.8
11	12-18	14.5	30.4	41	80	00.0	8.6
12	19-25	15.9	33.1	45	79	00.0	8.2
13	26-1April	15.5	31.9	42	82	00.0	8.3
14	2-8	17.3	36.2	26	56	00.0	9.7
15	9-15	18.7	38.4	26	54	00.0	7.9
16	16-22	18.5	35.1	36	60	00.0	6.5

Source: Department of Agro-meteorology C. S. Azad University of Agriculture and Technology, Kanpur

Table.2 Feature of genotype used in a 10 parental diallel mating design in wheat (*Triticum aestivum* L. em. Thell)

S. No.	Genotype	Species	Pedigree	Production Condition	Place of origin
1	K9533	*T. aestivum*	HI1077/HUW234	Irrigated, late sown	CSA, Kanpur
2	K9162	*T. aestivum*	K7827/HD2204	Irrigated, late sown	CSA, Kanpur
3	K9465	*T. aestivum*	B1153/CB85	Late sown, rainfed	CSA, Kanpur
4	K8962	*T. aestivum*	K7401/HD2160	Rained, timely sown	CSA, Kanpur
5	HUW234	*T. aestivum*	HUW-21*2/CPAN1666	Irrigated, late sown	BHU, Varanasi
6	NW2036	*T. aestivum*	BOW/CROW//BUC/PVN	Irrigated, late sown	NDUAT Faizabad
7	K9423	*T. aestivum*	HP1633/KSONA/UP262	High fertility, irrigated and very late sown	CSA, Kanpur
8	K9351	*T. aestivum*	K72/K8077//K72	Rained, timely sown	CSA, Kanpur
9	KRL210	*T. aestivum*	PBW65/2*PASTOR	Irrigated, timely sown	CSSRI, Karnal
10	K906©	*T. aestivum*	UP2338/PBW373	Irrigated, late sown	CSA, Kanpur

© check variety

Table.4 Ranking of the desirable parents on the basis of *per se* performance and GCA effects for five characters in bread wheat

Character	Desirable parent on the basis of *per se* performance	Good general combiner		Common parent in F_1 and F_2	Common parent on the basis of *per se* and gca effect in F_1 and F_2
		F_1	F_2		
Leaf Angle	K9162 K9533 K8962 HUW234 K9351	K8962** K9533** K9423** K9162** K903**	K8962** K9533** K9423** K9162** K9351**	K8962 K9533 K9423 K9162	K8962 K9533 K9162
Chlorophyll florescence	K8962 K9351 K9423 K9162 K9533	NW203** K9423** K9351** K8964** K9162**	K9533** K906** K9423** HUW234** NW2036**	K9423 NW2036	K9423
Canopy temperature depression	K9533 K9162 K9465 NW2036 K906	K906** K9423** K9351** HUW234**	K906** K9423** K9351** HUW234**	K906 K9423 K9351 HUW234	K906
Chlorophyll intensity	K9162 KRL210 K906 NW2036 K9533	K9423** K906** KRL21** K9351**	K9423** K9351** HUW234** K9162** KRL210**	K9423 KRL210 K9351	KRL210
No. of grain yield plant-1	K9162 K9423 K9533 K906 KRL2140	K9351** K906** K9423**	K906** K9351** K9423**	K906 K9351 K9423	K906 K9423

* Significance at 5% probability level, ** Significance at 1% probability level

Table.5 Ranking of the cross in respect to their superiority for specific combining ability, *per se* performance and general combining ability effect of the parent for five charters in bread wheat

Charters	Good specific combiner		Superior cross on the basis of *per se* performance
	F_1	F_2	
Leaf angle	**K9533 x KRL210**, HUW234 x NW2036, **K9533 x NW2036**, K9162 x k8962 and **HUW324 x K9423**	**K9162 x KRL210**, **K9533 x NW2036**, **HUW324 x K9423**, HUW234 x NW2036 and K8962 x KRL210	**K9533 x KRL210**, **K9533 x NW2036**, K9533 x K9423, K9162 x K8962 and K8962 x KRL210
Chlorophyll fluorescences	**K 9162 x NW 2036**, **K 8962 x K 906, K 9465 x KRL 210**, K 9533 x K 9351 and **K 9533 x K 9162**	**K 9162 x NW 2036**, **K 9465 x KRL 210**, **K 8962 x K 906** and KRL 210 x K 906 and **K 9533 x K 9162**	**K9162 x NW2036**, **K8962 x K906, K8962 x K906**, K9533 x K9351, **K9533 x K9162** and **K9465 x KRL210**
Canopy temperature depression	9465 x KRL 210, **K 9162 x K 906**, K **9423 x KRL 210**. HUW 234 x NW 2036 and HUW 234 x K 9351	K 9465 x K 9351, **K 9423 x KRL 210, K 9162 x K 906**, HUW 234 x KRL 210 and HUW 234 x NW 2036	K9465 x K9351, **K9162 x K906**, K9423 x K906, **K9423 x KRL210** and HUW234 x K906
Chlorophyll intensity	**HUW 234 x K 9423**, **NW 2036 x K 9351, K 9465 x K 9351**, K 9465 x KRL 210 and **K 9162 x K 902**	**NW 2036 x K 9351, HVW 234 x K 9423, K 9485 x K 9351**, K 9423 x K9351 and K **9162 x K 906**	**HUW234 x K9423**, NW2036 x K9351, **K9465 x K9351, K9162 x K906,** K9423 x KRL210
No. of grain yield plant-1	**K 9465 x K 9351, K 9162 x K 906, K 9465 x KRL 210**, HUW 234 x KRL 210,NW 2036 x K 9351	**K 9465 x K 9351, K 9162 x K 906, K 9465 x KRL 210**, K 9162 x K 8962, K 8962 x KRL 210	**K9465 x K9351, K9162 x K906**, NW2036 x K9351, K9162 x K8962, HUW234 x KRL210

Table.3 Analysis of variance for combining ability for five attributes in a 10 parent diallel cross in F1 and F2 generation of wheat (*Triticum aestivum* L.): Mean sum of squares (Griffings Method 2 Model I)

Characters / Source of variation		D. F.	Leaf angle	Chlorophyll fluorescence's	Canopy temperature depression	Chlorophyll intensity	Grain yield plant-1
GCA	F_1	9	303.96**	0.00**	1.53**	18.34**	0.93**
	F_2	9	252.34**	0.00**	2.51**	12.83**	1.69**
SCA	F_1	45	179.48**	0.00**	1.98**	33.79**	1.61**
	F_2	45	167.51**	0.00**	2.69**	28.46**	3.54**
Error	F_1	**108**	0.38	0.00	0.01	0.06	0.00
	F_2	**108**	0.13	0.00	0.01	0.07	0.01
Estimated variance components							
$\sigma^2 g$	F_1		**25.30**	**0.00**	**0.13**	**1.52**	**0.08**
	F_2		21.02	0.00	0.21	1.06	0.14
$\sigma^2 s$	F_1		**179.10**	**0.00**	**1.96**	**33.73**	**1.60**
	F_2		167.38	0.00	2.68	28.38	3.53
$\sigma^2 g/\sigma^2 s$	F_1		**0.141**	**0.00**	**0.066**	**0.045**	**0.05**
	F_2		0.125	0.00	0.078	0.037	0.039
$(\sigma^2 s/\sigma^2 g)^{0.5}$	F_1		2.65	0.00	3.88	4.71	4.47
	F_2		2.82	0.00	3.57	5.17	5.02

* Significance at 5% probability level, ** Significance at 1% probability level.
GCA = General combining ability; SCA = Specific combining ability

The estimated value of SCA effects for a desirable trait like chlorophyll intensity in both the generations involving combination, HUW234 x K9423, K9465 x K9351 and K9162 x K906 was favorable which a higher value of chlorophyll intensity showed a persistent green color under stress thereby, proved to be more tolerant to heat stress.

Out of 45 combinations, 25 F_1s and 22 F_2s resulted in significant SCA effects. The positive and significant SCA effect for flag leaf area of a main shoot was much effective.

In this study, the estimated values of three combinations were considerable which showed a best performance in both the generations and noted as best specific combiners i.e. K9351 x K906, K9162 x K906 and HUW234 x NW2036 over the part of increased leaf area.

The estimated value of SCA effects for specific leaf weight in K 8962 x HUW 234, K 9162 x K 906, K 9533 x K 9162, K 9465 x K 9351 and NW 2036 x K 9551 in F_1 and K 8962 x HUW 234, NW 2036 x K 9351, K 9465 x K 9351, K 9162 x K 906 and K 9423 x K 906 crosses of F_2 generation were most considerable; for leaf angle in K9533 x KRL210, HUW234 x NW2036, K9533 x NW2036, K9162 x K8962 and HUW324 x K9423 in F_1 and K9162 x KRL210, K9533 x NW2036, HUW324 x K9423, HUW234 x NW2036 and K8962 x KRL210 crosses of F_2 generation were most considerable which showed their superiority for producing more dry weight per unit area and per unit time proved to be more tolerant to heat stress as reported by Ashok Kumar (1995) in various crops. The performance in most of the cases of F_1 and F_2 generations indicated that the crosses K9465 x K9351, K9162 x K906, NW2036 x K9351, K9162 x K8962 and HUR234 x KRL210 base population due to high grain yield will be reliable for consideration in this study Similar approaches were also reported by Ahmad *et al.,* (1978) in case of wheat.

Breeders normally vested to obtain transgressive segregants followed hybridization in order to develop a homozygous line in the self-pollinated crop. Therefore, crosses involving general combiners in respect of some characters in the present investigation may be utilized for obtaining transgressive segregants in the segregating generation or to undertake intense crossing in the early generation for getting desirable recombinants.

The possible combination for multiple parents comes under central gene pool, which supplements in the faster speed of recombination and also breaking the genetic barriers if present in such situation mass selection with concurrent random mating could be the useful breeding procedure in wheat. Based on current findings K9533, K906, K9351 and K9423 were good general combiners and K9465 x K9351, K9162 x K906, NW2036 x K9351, K9162 x K8962 and HUW234 x KRL210 were best specific combiners have better morpho-physiological traits to withstand heat stress and can be used a further breeding programme. Moreover, modified mass selection or modified pedigree method in an early generation could be most useful for developing plant ideotypes for different stress conditions.

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