RESEARCH PAPER *International Journal of Agricultural Sciences,* **January to June, 2010, Vol. 6 Issue 1 : 267-272**

Combining ability analysis of grain yield and its contributing characters in bread wheat (*Triticum aestivum* L. em. Thell) under late sown condition

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ABSTRACT

Combining ability analysis was under taken in a 12 x 12 half diallel progenies (F_1 and F_2) for grain yield and its component characters under late sown condition (5th December). The mean squares due to gca and sca showed highly significant differences for all the characters in F_1 and F_2 generations, suggesting the importance of both additive and non-additive gene action. However, variances due to sca were higher in magnitude than gca variances for most of the traits except plant height and length of main spike in both the generations indicating the predominance of non-additive gene actions. The low predictability ratios for most of the traits in both generations also confirm the results. However, the predictability ratios for plant height and length of main spike were near to unity suggesting the importance of additive gene action in the inheritance of these characters. The estimates of gca effects of the parents revealed that HUW 234 (in both the generations), J 24 and GW 496 (in F_1) and GW 273, HD 2189 and Lok 1 (in F_2) were observed to be the good general combiners for grain yield and some its contributing traits. The perusal of sca effects for crosses in F_1 and F_2 generations revealed that the cross MACS 2496 x GW 173 was found to be good specific combiners with considerable *per se* performance in both the generations. The crosses GW 496 x HD 2189 in F_1 and GW 273 x GW 173 in F_2 gave the highest sca effects as well as *per se* performance in respective generation. These crosses also showed desirable sca effects for the important yield contributing traits like number of tillers per plant, number of grains per plant, flag leaf area and biological yield per plant. The crosses showing high sca effects for grain yield per plant involved high x high, high x low or low x low general combiners indicating the involvement of additive x additive, additive x dominance and dominance x dominance type of gene actions in the inheritance of these characters. The simple pedigree selection in succeeding generations and non-conventional breeding methods in form of biparental mating coupled with few cycles of recurrent selection could be utilized for the exploitation of additive and non-additive gene actions, respectively.

Key words : Diallel analysis, gca, sca, Bread wheat

INTRODUCTION

Wheat (*Triticum aestivum* L. em. Thell) is a thermo-sensitive crop and adapted best to the temperate climate. However, it is predominantly produced and consumed in tropical and subtropical regions of the world, where it is exposed to high temperature stress during certain growth stages, resulting in tremendous yield losses. Wheat crop sown under late conditions is exposed to high temperature during grain filling period that enable grain development under high temperature conditions leading to poor grain yield. For improvement with respect to heat tolerance, information on the genetic control of grain yield and associated characters under heat stress and identification of good combiner parents/crosses are the primary requirements. In cereal crops such as wheat, providing of sufficient quantity of F_1 seeds is always a difficult task particularly when large number of parents is to be included in a crossing programme. This eventually imposes restrictions upon the screening of a large number of genotypes for their general combining ability. Bhullar *et al*. (1979) and Patil and Chopde (1982) suggested that F_2 generation can also be effectively utilized for the estimation of combining ability and gene action governing yield and its components. Therefore, the present study was carried out to estimate the combining ability of the 12 bread wheat varieties and their 66 crosses for 12 quantitative characters in F_1 and F_2 generations using diallel mating approach under late sown and irrigation conditions.

MATERIALS AND METHODS

The experimental material comprised 12 diverse varieties of wheat *viz*., J 24, GW 273, GW 496, GW 322, HD 2189, MACS 2496, PBW 373, UP 2425, HUW 234, DL 788-2, Lok 1 and GW 173, exhibiting the geographical and genetic diversities in respect of the various quantitative characters. These genotypes were crossed in a diallel mating design to produce 66 F_1's excluding reciprocals during *Rabi* 2001-02. The few seeds of F_1 were sown during *Rabi* 2002-03 to generate F_2 progenies. The experimental material, consisting of 144 entries comprising 12 parents, 66 F_1s and 66 F_2s, was sown late (5th December) under irrigation condition in a Randomized Block Design (RBD) with three replications during *Rabi* 2003-04 at the Wheat Research Station, Junagadh Agricultural University, Junagadh. The parents and F_1 were sown in a single row plot and F_2 progenies in a plot of four rows of 2.50 m length. The row-to-row and plant-to-plant distance were kept at 22.5 cm and 10.0 cm, respectively. All the recommended agronomic practices

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were followed for raising good crop. The five competitive plants from parental lines and F_1s and 20 plants from each F_2s from each replication were selected randomly, excluding border plants, for recording the single plant observations on 12 characters *viz.*, days to flowering, days to maturity, plant height (cm), number of tillers per plant, length of main spike (cm), number of grains per spike, flag leaf area (cm^2), 1000-grain weight (g), protein content (%), biological yield per plant (g), harvest index (%) and grain yield per plant (g). The flag leaf area was measured in cm^2 by using leaf area meter (AM-100, ADC Bio-Scientifics Ltd., England). The mean values of the data recorded in respect of the various characters were subjected to the combining ability analysis according to the method 2 model I proposed by Griffing (1956). The predictability ratio (2ó^{2}gca / 2ó^{2}gca + ó^{2}sca) was computed by following the method of Baker (1978).

RESULTS AND DISCUSSION

The mean squares due to gca and sca showed highly significant differences (Table 1) for all the characters in both the generations reflecting the existence of sufficient variability both in parents and crosses and hence warranted further analysis and exploitation of material. This signifies that the variances due to gca and sca had played an important role in build up of the differences among the parents and crosses for the general and specific combining ability effects, respectively. Similar findings have also been reported by several workers for different traits in wheat (Sharma *et al.*, 2003 and Singh *et al.*, 2008). However, the magnitudes of sca variance were higher than gca variance indicating the predominance of non-additive gene action for all the traits except plant height and length of main spike in both the generations. Further, the low predictability ratios for most of the traits in both generations also confirm the results. However, the predictability ratios for plant height and length of main spike were near to unity suggesting the importance of additive gene action in the inheritance of these characters. Similar results have also been reported by Kant *et al.* (2001), Dhayal and Sastry (2003), Sinha (2003), Sharma and Garg (2005) and Ashok Kumar and Sharma (2008) for most of the above mentioned traits. Thus, in general, the results indicated that both the additive and non-additive gene actions played an important role for the control of different traits in both the generations.

The results of gca effects of F_1 and F_2 generation are presented in Table 2. The results revealed that HUW 234 was found to be good general combiner for grain yield per plant, days to flowering, plant height, number of tillers per plant and biological yield per plant in both the generations. This parent also showed significant gca effects for number of grains per spike in F_1 and days to maturity and harvest index in F_2 generation. Like wise, J 24 and GW 496 (in F_1) and GW 273, HD 2189 and Lok 1 (in F_2) were also observed to be the good general combiners for grain yield per plant and some of its contributing traits such as J 24 for length of main spike, flag leaf area, 1000-grain weight and biological yield per plant; GW 496 for plant height, flag leaf area and protein content; GW 273 for days to maturity, length of main spike, number of grains per spike, flag leaf area and 1000-grain weight; HD 2189 for length of main spike and number of grains per spike and Lok 1 for days to flowering, days to maturity, 1000-grain weight and harvest index in both the generations. Remaining parents such as MACS 2496 was found as good general combiner for length of main spike, number of grains per spike and protein content; PBW 373 for length of main spike and number of grains per spike; UP 2425 for days to flowering, 1000-grain weight and protein content; DL 788-2 for days to flowering, days to maturity, 1000-grain weight, protein content and harvest index and GW 173 for days to flowering, days to maturity, plant height, protein content and harvest index in both the generations. The results thus, indicated that these parents possess high concentration of desirable genes for yield and important yield contributing characters and could be used effectively in multiple crossing programme in order to combine desirable characters and to isolate high yielding types for late sown condition in bread wheat. The importance of these characters has also been emphasized by Patil *et al*. (1995), Kathiria and Sharma (1996), Singh and Chatrath (1997), Sheikh and Singh (2000), Sharma *et al*. (2003) and Joshi and Sharma (2006).

A perusal of significant cross combinations on the basis of sca effect for grain yield per plant, its *per se* performance alongwith gca status of the parents used in these crosses are presented in Table 3. The magnitude of sca effect revealed that 11 and 17 cross combinations exhibited significant and positive sca effects for grain yield per plant in F_1 and F_2, respectively. The best specific cross combination was GW 496 x HD 2189 with the highest *per se* performance in F_1 generation. It was followed by GW 496 x MACS 2496, PBW 373 x DL 788-2, J 24 x GW 173, DL 788-2 x GW 173, MACS 2496 x DL 788-2 and J 24 x HUW 234. In case of F_2 generation, the highest sca effect for grain yield per plant with the second highest *per se* performance was observed in GW 273 x GW 173 followed by UP 2425 x Lok 1, MACS 2496 x DL 788-2 and J 24 x GW 496. These crosses also showed desirable

Table 1: Analysis of variance for combining ability in F_1 and F_2 for different characters under late sown condition in bread wheat

Sources	d. f.	Days to flowering		Days to maturity		Plant height (cm)		No. of tillers per plant		Length of main spike (cm)		No. of grains per spike	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Gca	11	115.21**	91.65**	38.06**	51.81**	167.63**	186.18**	2.13**	0.99**	5.60**	4.58**	177.28**	120.79**
Sca	66	8.86**	9.66**	5.95**	5.74**	7.26**	13.86**	0.74**	0.65**	0.20**	0.25**	14.18**	12.81**
Error	154	0.20	0.61	0.04	0.61	2.58	2.10	0.35	0.23	0.04	0.03	0.10	0.32
σ^2gca		7.60	5.86	2.29	3.29	11.46	12.31	0.10	0.02	0.39	0.31	11.65	7.71
σ^2sca		8.66	9.05	5.91	5.13	4.68	11.76	0.39	0.42	0.16	0.22	14.08	12.49
$2\sigma^2$gca / $(2\sigma^2$gca + σ^2sca)		0.64	0.56	0.44	0.56	0.83	0.68	0.32	0.09	0.83	0.74	0.62	0.55

Sources	d. f.	Flag leaf area (cm^2)		1000-grain weight (g)		Protein content (%)		Biological yield per plant (g)		Harvest index (%)		Grain yield per plant (g)	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Gca	11	35.49**	48.00**	70.17**	67.91**	2.16**	3.45**	68.91**	21.46**	52.48**	48.80**	4.62**	2.78**
Sca	66	14.29**	6.29**	5.53**	5.56**	0.31**	0.49**	14.10**	17.71**	6.50**	5.44**	2.00**	2.33**
Error	154	0.36	0.32	0.21	0.26	0.03	0.03	4.73	3.20	1.86	0.73	0.70	0.50
σ^2gca		1.51	2.98	4.62	4.45	0.13	0.21	3.92	0.27	3.28	3.10	0.19	0.03
σ^2sca		13.93	5.97	5.32	5.30	0.28	0.46	9.37	14.51	4.64	4.71	1.30	1.83
$2\sigma^2$gca / $(2\sigma^2$gca + σ^2sca)		0.18	0.50	0.63	0.63	0.48	0.48	0.46	0.04	0.59	0.59	0.23	0.03

** indicate of significance of value at P = 0.01

sca effects for as many as 5 to 6 yield contributing characters. Among the 11 crosses in F_1 and 17 crosses in F_2, only one cross *viz*., MACS 2496 x GW 173 was observed to be good specific combiners in both F_1 and F_2 generations with considerable *per se* performance. Most of the crosses which have significant sca effects for grain yield were the crosses involved parents with high x high, high x low and low x low gca effects, indicating the presence of additive x additive, additive x dominance of dominance x dominance type of non-allelic interaction. Intermating between crosses followed by selection may be a useful strategy for obtaining desirable segregants in crosses from high x low and low x low general combining ability parents. It also appears that high sca effects of any cross do not necessarily depend upon the high gca effects of the parents involved in this cross. The superiority of these crosses may be due to complementary type of gene interaction, which can be exploited in subsequent generations.

The results signify the importance of exploitation of both additive and non-additive genetic effects for attaining maximum improvement in the crop. Most of the characters except plant height and length of main spike are governed by non-additive genetic variance. Hence, non-conventional breeding methods could be beneficiary for achieving an appropriate progress for these characters. Plant height and length of main spike could be improved by utilizing simple selection methods as they inherited by additive component of genetic variance. It is also suggested that high gca parents *viz*., HUW 234 followed by GW 496, GW 273, HD 2189, Lok 1 and J 24 for grain yield and its component characters (length of main spike, number of tillers per plant, number of grains per spike, flag leaf area and 1000-grain weight) may be used as donor parent for the development of the varieties suitable for late sown condition. The cross combinations like GW 496 x HD 2189, GW 496 x MACS 2496, GW 273 x GW 173, MACS 2496 x GW 173 and UP 2425 x Lok 1 may be used directly as they have high sca effects with good *per se* performance for grain yield per plant and its important yield contributing characters.

Table 2: Estimates of gca effects in F_1 and F_2 generations under late sown condition in bread wheat

Parents	Days to flowering		Days to maturity		Plant height (cm)		No. of tillers per plant		Length of main spike (cm)		No. of grains per spike	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
J 24	-0.06	0.29	0.91**	0.72**	5.38**	3.40**	0.61**	-0.11	1.13**	0.82**	0.65**	-2.52**
GW 273	0.16	-0.33	-0.43**	-1.20**	1.91**	5.79**	-0.38*	-0.16	0.49**	0.37**	2.39**	2.00**
GW 496	1.41**	1.13**	0.35**	-1.32**	-1.72**	-0.90**	0.60**	0.00	0.17**	0.03	-0.84**	0.39**
GW 322	3.42**	3.20**	1.34**	0.75**	1.00**	1.26**	-0.17	-0.14	0.00	-0.12**	2.37**	1.44**
HD 2189	0.70**	0.19	1.25**	1.10**	4.45**	4.81**	-0.13	0.12	0.40**	0.41**	3.18**	4.35**
MACS 2496	4.50**	4.03**	2.35**	3.21**	1.97**	0.36	-0.28	-0.40**	0.59**	0.55**	6.01**	3.17**
PBW 373	3.51**	3.38**	1.38**	3.50**	0.64	1.31**	-0.39*	-0.25*	0.14**	0.47**	1.63**	3.57**
UP 2425	-2.56**	-2.16**	-1.92**	-0.19	-0.38	-1.35**	-0.54**	-0.12	0.04	0.19**	-1.45**	-1.31**
HUW 234	-1.00**	-1.02**	0.18**	-1.12**	-0.99*	-1.30**	0.45**	0.62**	-0.69**	-0.36**	0.78**	-0.49**
DL 788-2	-3.63**	-3.40**	-0.38**	-1.37**	-5.59**	-5.08**	0.14	0.07	-0.92**	-0.82**	-3.52**	-4.44**
Lok 1	-2.18**	-1.87**	-1.65**	-1.27**	-0.46	-1.91**	0.10	0.11	-0.49**	-0.60**	-5.82**	-3.20**
GW 173	-4.27**	-3.45**	-3.38**	-2.82**	-6.21**	-6.40**	-0.02	0.27*	-0.88**	-0.94**	-5.38**	-2.94**
S.E. (g_i) ±	0.11	0.20	0.05	0.20	0.41	0.37	0.15	0.12	0.05	0.04	0.08	0.15
S.E. ($g_i - g_j$) ±	0.17	0.30	0.08	0.29	0.61	0.55	0.22	0.18	0.08	0.07	0.12	0.21

Parents	Flag leaf area (cm^2)		1000-grain weight (g)		Protein content (%)		Biological yield per plant (g)		Harvest index (%)		Grain yield per plant (g)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
J 24	1.40**	2.15**	0.65**	0.67**	-0.16**	-0.19**	5.32**	1.52**	-3.96**	-4.06**	1.09**	-0.43*
GW 273	1.14**	3.60**	0.68**	1.08**	0.14**	-0.38**	-0.13	0.62	0.64	0.36	0.12	0.40*
GW 496	0.68**	1.03**	-0.02	-0.50**	0.15**	0.18**	1.58**	0.04	-0.76*	0.00	0.65**	0.03
GW 322	-1.32**	-2.43**	-2.33**	-2.46**	-0.77**	-0.90**	-0.53	-1.09*	-1.14**	-0.85**	-0.68**	-0.80**
HD 2189	-0.17	0.31*	-2.61**	-2.30**	-0.11*	-0.06	0.31	0.93*	-0.59	0.32	-0.04	0.52**
MACS 2496	-0.18	-0.02	-3.13**	-3.69**	0.36**	0.47**	0.79	-0.66	-0.66	-0.93**	0.17	-0.47**
PBW 373	1.65**	-1.58**	-0.56**	-1.05**	0.02	0.08	-1.15*	0.77	-0.82*	-1.56**	-0.61**	-0.10
UP 2425	2.69**	1.16**	1.94**	2.02**	0.66**	0.64**	-1.66**	-0.31	0.41	0.76**	-0.52**	0.12
HUW 234	-0.77**	-0.26	-1.05**	-0.12	-0.65**	-0.84**	1.48**	1.11*	0.32	0.63**	0.66**	0.61**
DL 788-2	-0.35*	-0.15	1.94**	2.30**	0.12*	0.37**	-1.57**	-1.12*	1.30**	0.63**	-0.32	-0.20
Lok 1	-2.78**	-0.94**	4.81**	4.01**	0.10	0.34**	-0.85	0.95*	0.89*	0.72**	0.05	0.50**
GW 173	-2.00**	-2.88**	-0.32**	0.04	0.14**	0.28**	-3.58**	-2.75**	4.37**	3.97**	-0.58**	-0.18
S.E. (g_i) ±	0.15	0.14	0.12	0.13	0.05	0.04	0.56	0.46	0.35	0.22	0.21	0.18
S.E. ($g_i - g_j$) ±	0.23	0.21	0.17	0.19	0.07	0.07	0.82	0.68	0.51	0.32	0.32	0.27

* and ** indicates significance values at P=0.05 and 0.01, respectively

Table 3 : Crosses showing significant sca effect for grain yield per plant, their *per se* performance and gca status of parents involved in the crosses under late sown condition in bread wheat

Desirable crosses	Sca effect	*Per se*	Gca effect		Desirable sca effects for other traits
			P_1	P_2	
F_1					
GW 496 x HD 2189	3.58**	13.57	L (0.12)	L(-0.04)	4,6,8,10
GW 496 x MACS 2496	2.57**	12.77	L (0.12)	L (0.17)	1,3,8,10
PBW 373 x DL 788-2	2.41**	10.87	L (-0.61**)	L (0.32)	1,4,8,9,10
J 24 x GW173	2.25**	12.13	H (1.09**)	L (-0.58**)	1,6,9
DL 788-2 x GW 173	2.11**	10.37	L (-0.32)	L (-0.58**)	7
MACS 2496 x DL 788-2	2.10**	11.33	L (0.17)	L (-0.32)	1,2,4,6,10
J 24 x HUW 234	2.07**	13.20	H (1.09**)	H (0.66**)	1,2,5,6,8,10
Lok 1 x GW 173	1.88*	10.73	L (0.05)	L (-0.58**)	6,8,9,10
MACS 2496 x GW 173	1.67*	10.63	L (0.17)	L (-0.58**)	1,2,6,8
GW 273 x HD 2189	1.62*	7.83	L (0.12)	L (-0.04)	2,3,7
HUW 234 x GW 173	1.60*	11.07	H (0.66**)	L (-0.58**)	1,2,4,6
F_2					
GW 273 x GW 173	2.83**	13.00	H (0.40*)	L (-0.18)	4,5,6,7,10
UP 2425 x Lok 1	2.49**	13.07	L (0.12)	H (0.50**)	2,3,4,8,10,11
MACS 2496 x DL 788-2	2.45**	11.73	L (-0.47**)	H (-0.20)	1,4,5,6,10
J 24 x GW 496	2.44**	12.00	L (-0.43*)	L (0.03)	3,4,6,10
MACS 2496 x GW 173	2.36**	11.67	L (-0.47**)	L (-0.18)	1,8,10
UP 2425 x DL 788-2	2.29**	12.17	L (0.12)	L (-0.20)	3,4,6,10
GW 273 x DL 788-2	2.28**	12.43	H (0.40*)	L (-0.20)	4,5,6,7,10
UP 2425 x HUW 234	2.14**	12.83	L (0.12)	H (0.61**)	6,7,8,9,10
PBW 373 x Lok 1	2.05**	12.40	L(-0.10)	H (0.50**)	4,5,10
GW 322 x HD 2189	1.92**	11.60	L (-0.80**)	H (0.52**)	5,6,7,9,10
HD 2189 x GW 173	1.71**	12.00	H (0.52**)	L (-0.18)	4,7,11
HD 2189 x MACS 2496	1.59*	11.60	H (0.52**)	L (-0.47**)	1,2,3,7,8,10
GW 496 x GW 322	1.55*	10.73	L (0.03)	L (-0.80**)	1,5,6,11
GW 496 x Lok 1	1.51*	8.97	L (0.03)	H (0.50**)	6,7
HD 2189 x DL 788-2	1.46*	11.73	H (0.52**)	H (-0.20)	6,8,11
HUW 234 x Lok 1	1.37*	12.40	H (0.61**)	H (0.50**)	3,4,9,10
PBW 373 x UP 2425	1.32*	11.30	L (-0.10)	L (0.12)	8,9,10

* and ** indicates significance values at P=0.05 and 0.01, respectively

1 = Days to flowering; 2 = Days to maturity; 3 = Plant height; 4 = Number of tillers per plant; 5 = Length of main spike; 6 = Number of grains per spike; 7 = Flag leaf area; 8 = 1000- grain weight; 9 = Protein content; 10 = Biological yield per plant; 11 = Harvest index; 12 = Grain yield per plant

H = High, L= Low

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Received : September, 2009; Accepted : November, 2009