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Combining Ability Analysis for Yield and Its Component Traits in Wheat (*Triticum aestivum* L.).

S.G. DESHMUKH[1], N.R. POTDUKHE[2], H.S. DESHMUKH[3] AND R.S. NANDANWAR[4]

[1]*Department of Agril. Botany, Dr.PDKV, Akola.*
[2]*Wheat Research Unit, Dr.PDKV, Akola.*
[3]*Department of Agril. Botany, MPKV Rahuri.*
[4]*Department of Agril. Botany, Dr.PDKV, Akola.*
email : sgd.2015@gmail.com

ABSTRACT

The present investigation was undertaken for analysis of gene action involved in grain yield and yield contributing traits in 16 parental genotypes (9 lines and 7 testers) and 63 F_1 hybrids in a line x tester design. The F_{1S} along parents and one check variety viz. GW-322, were evaluated using Randomized Block Design during Rabi 14-15. The Analysis of Variance for combining ability showed that mean square due to general (GCA) and specific (SCA) combining ability, were significant for all the traits studied, reflecting the importance of both additive and non-additive gene effects in the inheritance of these characters. The ratio of GCA to SCA variance were found high for days to 50% earhead emergence, days to 50 per cent flowering, plant height, length of earhead (cm) and number of spikelets earhead^{-1}. The characters, days to maturity, number of effective tillers, number of grains earhead^{-1}, grain weight earhead^{-1} (g), grain weight plant^{-1}(g), straw weight plant^{-1} (g), 1000 grain weight (g) and harvest index, in which the ratio of GCA to SCA variances was found lower than unity. Among female parents, FLW-25 and WH-595 were the best general combiner for grain yield and yield related traits. Two crosses viz., FLW-25×ISD-215 and DWR-4101× FLW-27 have been identified which were exhibited high mean performance, high standard heterosis, significant sca effects and both the parents involved in these crosses had good (high × high) combining ability effect for yield.

Key words *Combining ability, Line × Tester, Gene action, Wheat.*

Among the major crops, wheat is one of the most critical for warranting human nourishment, it is the most widely crop grown globally and is the primary source of protein for the world population. India is considered to be the second largest producer of wheat (Sharma 2013) and occupies second position after China. The geometrical increase in India's population has been a challenge for agricultural scientists. To fulfill the projected demand of the world population for food grains, it is essential that production and productivity of wheat must be increased. However, this may not be easily achieved as there is mounting evidence that genetic gains in yield have recently been much lower than what it would be required (Reynolds *et a*l.2012). Future wheat breeding needs to be extremely efficient as the land allocated to wheat is unlikely to increase significantly, and the use of inputs cannot increase at similar rates as they have in the last half-century (Hall and Richards, 2013).The selection of genetically superior parents is an important step in the development of high yielding varieties which is possible only by the study of combining ability. In systematic breeding program, selection of parents with desirable characteristics having good general combining ability effects for grain yield and its components, high heterosis and high estimates of specific combining ability effects are essential. These parameters will help in formulating an efficient and effective breeding procedure to bring about rapid and suitable improvement in this crop. The general and specific combining ability effects are very effective genetic parameters in deciding, the next phase of breeding program (Kumar *et al*, 2015). The main objective of the present study was to obtain the information on the extent of combining ability for grain yield and its related traits in the selection process.

MATERIALS AND METHODS

The experimental material were consists of 9 lines, 7 testers, 63 crosses and 1 Zonal check variety (GW- 322). The experiment was carried out in two phases, during *Rabi*, 2013-14 selected genotypes were crossed in line x tester design to generate 63 crosses and these crosses along with parents and check were evaluated for combining ability analysis at Wheat Research Unit, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth,Akola during Rabi 14-15. All these genotypes were grown in randomized block design with three replications. The data were recorded for characters (*viz.* days to 50% earhead emergence, days to 50 per cent flowering, days to maturity, plant height, number of effective tillers, length of earhead (cm), number of spikelets earhead^{-1}, number of grains earhead^{-1}, grain weight earhead^{-1} (g), grain weight plant^{-1}(g), straw weight plant^{-1} (g), 1000 grain weight (g), harvest index.). Analysis of Variance was carried out as per the standard method (Panse and Sukhatme, 1967) for all the characters under study. The variation among hybrids was partitioned further into general (gca) and specific (sca) combining ability components in accordance with the procedure of Kempthorne (1957). The criticism and suggestions of Arunachalam (1974) are kept in view. The actual combining ability variances, their effects and

Table 1. Analysis of variance for combining ability.

Sources of variation	d.f.	Mean Sum of Squares						
		Days to 50% emergence	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers/plant	Length of earhead (cm)	Number of spikelet/ earhead
Replications	2	7.762	0.862	3.815	51.610	0.749	0.127	1.941
Crosses	62	24.295**	25.032**	24.160**	70.534**	3.327**	4.165**	13.097**
Females (Lines)	8	126.488**	134.259**	117.228**	238.896**	13.702**	23.375**	69.596**
Males (Testers)	6	17.924	15.626	3.480	133.912**	0.309	1.001	3.542
Females Vs Males (Lines Vs Testers)	48	8.059**	8.003**	11.234**	34.552	1.975**	1.359**	4.875**
Error	124	4.649	3.228	2.041	25.641	0.434	0.609	1.436

Sources of variation	d.f.	Mean Sum of Squares					
		Number of grains/ earhead	Grain weight/ Earhead (g)	Grain weight/ plant (g)	Straw weight/ plant (g)	1000 Grain weight (g)	Harvest index
Replications	2	2.025	0.068	1.786	2.847*	5.950	0.001
Crosses	62	190.629**	0.345**	19.697**	9.339**	45.588**	0.013**
Females (Lines)	8	858.397**	1.517**	63.106**	24.165**	195.573**	0.042**
Males (Testers)	6	77.199	0.173	15.636	3.513	28.341	0.012
Females Vs Males (Lines Vs Testers)	48	93.513**	0.171**	12.969**	7.597**	22.746**	0.009**
Error	124	4.587	0.027	0.589	0.712	7.475	0.001

Table 2. Analysis of Variance of combining ability for different characters

Sources of variation	Mean Sum of Squares						
	Days to 50% emergence	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers/plant	Length of earhead (cm)	Number of spikelet/ earhead
GCA	2.672**	2.789**	2.046**	6.327**	0.209**	0.451**	1.320**
SCA	1.366**	1.734**	3.095**	3.767*	0.510**	0.259**	1.190**
GCA/SCA	1.955	1.608	0.661	1.679	0.410	1.740	1.109

Sources of variation	Mean Sum of Squares					
	Number of grains/ earhead	Grain weight/ Earhead (g)	Grain weight/ plant (g)	Straw weight/ plant (g)	1000 Grain weight (g)	Harvest index
GCA	15.595**	0.028**	1.100**	0.260**	3.717**	0.0008**
SCA	29.441**	0.044**	4.129**	2.278**	5.079**	0.0027**
GCA/SCA	0.529	0.629	0.266	0.114	0.731	0.281

Table 3. General combining ability effects of the parents for different characters.

SN	Genotype	GCA						
		Days to 50% emergence	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers/plant	Length of earhead (cm)	Number of spikelet/ earhead
	Females							
01	WH - 595	-4.952**	-5.323**	-1.074**	3.003**	0.466**	-1.018**	-2.388**
02	RL-83	2.619**	2.439**	4.402**	0.479	1.508**	0.587**	0.374
03	PAU HD-2329 KLM-3B	-0.905*	-1.132**	-0.598	-2.817**	-0.049	0.192	-1.531**
04	FLW – 8	-1.143**	-0.608	-4.122**	2.764**	-0.111	0.120	-1.450**
05	HW- 2015	-0.333	-0.466	-1.026**	-0.861	-0.639**	0.330*	0.603*
06	DWR-4099	1.667**	1.582**	0.974**	-3.374**	-0.468**	-2.242**	-0.778**
07	DWR -4101	2.952**	3.011**	1.735**	-4.634**	-0.434**	-0.037	3.650**
08	FLW - 25	1.286**	1.534**	-1.074**	5.703**	0.828**	0.720**	1.384**
09	GIENT-3	-1.190**	-1.037**	0.783*	-0.262	-1.101**	1.349**	0.136
	SE (gi)±	0.307	0.258	0.215	0.004	0.103	0.118	0.176
	SE (Gi – Gj)±	0.434	0.365	0.305	1.052	0.145	0.166	0.249
	C.D.5%	1.215	1.022	0.853	2.945	0.407	0.466	0.698
	C.D.1%	1.606	1.351	1.127	3.893	0.538	0.616	0.922
	Males							
01	SG-15	0.725	0.640*	0.577*	0.244	0.139	0.231	0.346
02	ISD-215	1.021**	0.862**	0.243	-2.286*	-0.183	0.097	0.657**
03	WH-712	-0.460	-0.138	-0.497	1.733	-0.061	-0.017	-0.158
04	RL -22	0.725	0.714*	0.169	-1.567	0.024	-0.084	-0.310
05	VL -798	-0.534	-0.471	-0.275	2.578**	0.095	-0.284	-0.099
06	PUSA-2099	-0.349	-0.434	-0.053	-2.813**	0.028	-0.158	-0.292
07	FLW - 27	-1.127**	-1.175**	-0.164	2.111*	-0.042	0.216	-0.143
	SE (gi)+	0.271	0.228	0.190	0.004	0.091	0.104	0.155
	SE (Gi – Gj)±	0.383	0.322	0.269	0.928	0.128	0.147	0.220
	C.D.5%	1.072	0.902	0.752	2.598	0.359	0.411	0.615
	C.D.1%	1.417	1.192	0.994	3.433	0.474	0.543	0.813

SN	Genotype	GCA					
		Number of grains/ earhead	Grain weight/ Earhead (g)	Grain weight/ plant (g)	Straw weight/ plant (g)	1000 Grain weight (g)	Harvest index
	Females						
01	WH - 595	-0.621	0.030	1.167**	-0.324	1.442*	0.042**
02	RL-83	-6.521**	-0.459**	-1.012**	0.112	-4.828**	-0.025**
03	PAU HD-2329 KLM-3B	-7.802**	-0.309**	-2.751**	-1.507**	-2.922**	-0.053**
04	FLW – 8	-1.731**	-0.069	-0.400*	-0.780**	-1.148	0.009
05	HW- 2015	6.517**	0.094*	0.172	-1.245**	-1.468*	0.031**
06	DWR-4099	0.031	0.205**	0.588**	0.053	3.730**	0.020**
07	DWR -4101	4.288**	0.224**	0.581**	1.501**	1.391*	-0.018**
08	FLW - 25	11.355**	0.392**	3.261**	1.033**	-0.747	0.063**

SN	Genotype	GCA					
		Number of grains/ earhead	Grain weight/ Earhead (g)	Grain weight/ plant (g)	Straw weight/ plant (g)	1000 Grain weight (g)	Harvest index
09	GIENT-3	-5.516**	-0.108*	-1.606**	1.156**	4.550**	-0.070**
	SE (gi)±	0.351	0.030	0.118	0.135	0.423	0.004
	SE (Gi – Gj)±	0.497	0.042	0.167	0.190	0.598	0.006
	C.D.5%	1.391	0.118	0.466	0.533	1.674	0.016
	C.D.1%	1.839	0.155	0.616	0.704	2.212	0.021
	Males						
01	SG-15	0.675	0.133**	1.255**	-0.120	1.594**	0.032**
02	ISD-215	-0.877*	-0.066	-0.537**	0.244	-1.306*	-0.022**
03	WH-712	2.279**	0.050	0.132	0.417*	0.603	-0.004
04	RL -22	-3.151**	-0.094*	-1.014**	0.250	0.236	-0.030**
05	VL -798	-0.173	-0.056	-0.409**	-0.534**	-1.084*	0.003
06	PUSA-2099	0.664	-0.008	-0.057	-0.404*	-0.500	0.006
07	FLW - 27	0.583	0.041	0.629**	0.148	0.457	0.014**
	SE (gi)+	0.310	0.026	0.104	0.119	0.373	0.004
	SE (Gi – Gj)±	0.438	0.037	0.147	0.168	0.527	0.005
	C.D.5%	1.227	0.104	0.411	0.470	1.476	0.014
	C.D.1%	1.622	0.137	0.543	0.621	1.951	0.019

the test of significance, were carried out by following the methods given by Singh (1973 a, b).

RESULTS AND DISCUSSION

The analysis of variance for combining ability (Table 1) showed that the variance due to crosses and females was found significant for all the characters indicating considerable amount of interaction. The males showed significant difference for plant height. The variance due to female vs. male was found significant for all the characters except plant height, suggesting that significant contribution of sca effects towards the variation among the crosses. Results are in agreement with Desale and Mehta (2013), Ankita Singh and Anil Kumar (2014)

The Analysis of Variance for combining ability (Table 2) showed that mean square due to general (GCA) and specific (SCA) combining ability, were significant for all the traits studied, reflecting the importance of both additive and non-additive gene effects in the inheritance of these characters. The results corroborates with the findings of Dholariya *et al* (2014), Yadav *et al* (2014) and Ranjana Tiwari *et al* (2015).The ratio of GCA to SCA variance were found high for days to 50% earhead emergence, days to 50 per cent flowering, plant height, length of earhead (cm) and number of spikelets earhead^{-1}, which indicated that importance of additive gene actions in the expression of these characters. Similar findings were also reported by Singh *et al* (2007), Preeti Raj and Kandalar (2013) and Barot *et al* (2014). The characters, days to maturity, number of effective tillers, number of grains earhead^{-1}, grain weight earhead^{-1} (g), grain weight plant^{-1}(g), straw weight plant^{-1} (g), 1000 grain weight (g) and harvest index, in which the ratio of GCA to SCA variances was found lower than unity which indicated the preponderance of non additive gene actions for these characters. Similar findings were also reported by Ankita Singh and Anil Kumar (2014) and Patel (2015).

Among female parents, FLW-25 was the best general combiner for grain yield and yield related traits, i.e. number of effective tillers, length of earhead (cm), number of spikelets earhead^{-1}, number of grains earhead^{-1}, grain weight earhead^{-1} (g), grain weight plant^{-1}(g), straw weight plant^{-1} (g), harvest index and also showed negative significant GCA effects for the trait days to maturity, followed by WH-595 for grain yield and yield related traits, i.e. number of effective tillers, 1000 grain weight (g) and harvest index, by exhibiting significant positive gca effects (Table 3) and also for negative significant gca effects for the traits like days to 50% earhead emergence, days to 50 per cent flowering, days to maturity indicating usefulness in breeding for early maturing hybrids (Table 3). Among male parents, SG-15

Table 4. SCA effects of promising crosses in desirable direction for yield and other traits.

SN	Crosses	SCA						
		Days to 50% emergence	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of effective tillers/plant	Length of earhead (cm)	Number of spikelet/ earhead
01	HW-2015 × SG-15	-	-	-	-	1.247**	1.141*	-
02	DWR-4101 × PUSA-2099	-	-	-1.995*	-	-	1.163**	-
03	GIENT-3 × PUSA-2099	-	-	-	-	0.786*	-	1.901**
04	DWR-4101 × FLW-27	-	-	-	-	0.923*	-	-
05	GIENT-3 × WH-712	-	-2.481*	-	-	0.875*	-	-

SN	Crosses	SCA					
		Number of grains/ earhead	Grain weight/ Earhead (g)	Grain weight/ plant (g)	Straw weight/ plant (g)	1000 Grain weight (g)	Harvest index
01	HW-2015 × SG-15		0.375**	4.986**	2.763**	4.316**	0.054**
02	DWR-4101 × PUSA-2099	3.860**	0.229*	4.662**	1.468**	3.618*	0.085**
03	GIENT-3 × PUSA-2099	15.198**	0.570**	3.880	-	-	0.108**
04	DWR-4101 × FLW-27	7.941**	0.390**	3.446	1.916**	-	0.048**
05	GIENT-3 × WH-712	6.850**	0.383**	3.403**	-	4.736**	0.084**

Note: * Significant at 5% level of significance. ** Significant at 1% level of significance.

was the best general combiner for grain yield and yield related traits, i.e. grain weight earhead^{-1}(g), 1000 grain weight (g) and harvest index, followed by FLW-27 for grain yield and harvest index. The male parent FLW-27 possessed favorable genes for days to 50% earhead emergence, days to 50 per cent flowering by recording significant negative gca effects. The parents which are good general combiners for yield, possessed GCA effects in the desired direction for yield components was also reported earlier by Patel (2015), Kumar *et al* (2015), Raiyani *et al* (2015).

Based on significant high sca effects (Table 4), five crosses viz., HW-2015 X SG-15, DWR-4101 X PUSA-2099, GIENT-3 X PUSA-2099, DWR-4101 X FLW-27, GIENT-3 X WH-712 were identified as promising for seed yield and other yield contributing characters. Out of these five crosses, cross HW-2015 X SG-15 exhibited highest significant sca effects for grain yield per plant and other traits viz., number of effective tillers, length of earhead, grain weight earhead^{-1}, straw weight plant^{-1}, 1000 grain weight and harvest index, followed by cross DWR-4101 X PUSA-2099 for the traits grain yield per plant, length of earhead, number of grains earhead^{-1}, grain weight earhead^{-1}, 1000 grain weight and harvest index. Kumar and Kerkhi (2015) reported that significant positive or negative sca effects in F1 generation for yield and various yields attributing traits. But, none of the crosses expressed good specific combining ability effect for all the traits. Similar results also recorded by Kalhoro *et al* 2015, Saeed *et al* (2016), Uzair *et al.* (2016).

In systematic breeding program, selection of parents with desirable characteristics having good general combining ability effects for grain yield and its components, high heterosis and high estimates of specific combining ability effects are essential. These parameters will help in formulating an efficient and effective breeding procedure to bring about rapid and suitable improvement in this crop. General and specific combining ability effects are very effective genetic parameters in deciding, the next phase of breeding program (kumar *et al* 2015).

On the basis of *per se* performance, standard heterosis, gca and sca effects (Table 5), two crosses viz., FLW-25×ISD-215 and DWR-4101× FLW-27 have been identified which were exhibited high mean performance, high standard heterosis, significant sca effects and both the parents involved in these crosses had good (high × high) combining ability effect for yield. This indicated important

Table 5. Mean yield performance, standard heterosis and SCA effects of the promising crosses.

SN	Crosses	Grain yield per plant (g)		Heterosis (%)		Significant Standard Heterosis for other characters (%)	SCA effects for Grain yield per plant (g)	GCA effects of parents for grain yield per plant (g)		Significant SCA effects for other characters in desirable direction	
		Mean	Range	H_2	H_3			P1	P2		
1	HW-2015×SG-15	15.11	3.04 - 15.11	88.46	109.50	5,6,7,9,11,12,13.	4.986**	0.172	1.255**	5,6,7,9,11,12,13.	L×H
2	FLW-25×ISD-215	13.99		70.63	93.96	5,6,7,8,9,11,13.	2.568**	3.261**	0.537**	1,2,5,6,8,11,13.	H×H
3	DWR-4101×PUSA-2099	13.88		87.19	92.47	4,7,9,11,12,13.	4.662**	0.581**	-0.057	3,6,8,9,11,12,13.	H×L
4	DWR-4101× FLW-27	13.35		127.05	85.14	5,7,8,9,11,12,13.	3.446**	0.581**	0.629**	5,8,9,11,13.	H×H
5	FLW-25× SG-15	12.74		55.33	76.57	5,7,8,9,11,13,16.	-0.478	3.261**	1.255**		H×H

*, **- significant at 5% and 1% level, respectively H_1: Heterobeltiosis H_2: Standard heterosis

1. Days to 50% emergence 2. Days to 50% flowering 3. Days to maturity 4. Plant height 5. No. of effective tillers/plant 6 Length of earhead 7.No. of spikelet/ earhead 8.No. of grains/earhead 9.Grain weight/earhead 10.Grain weight/plant 11 Straw weight/plant 12.1000 Grain weight 13.Harvestindex

role of additive x additive gene interaction in high ranking per se performance of these hybrids. However, if a cross combination exhibiting high SCA as well as high per se performance having at least one parent as good general combiner for a specific trait, viz. HW-2015×SG-15 and DWR-4101×PUSA-2099, it is expected to throw desirable transgressive segregants in later generations (Singh *et al.,* 2013, Awasthi *et al.,* 2011).

The cross FLW-25× SG-15 recorded high mean performance, high standard heterosis, non significant sca effects and one parent involved in these crosses had good (high × low) and (low × high) combining ability effects. This indicated the important role of additive x dominance gene interaction in high ranking per se performance of these hybrids. So, these crosses can be further be utilized to exploit additive component by isolating superior genotypes to develop the varieties with high yield potential (Awasthi *et al.,* 2011)

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