Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(5): 649-654
Received: 18-07-2018
Accepted: 22-08-2018

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Study of combining ability and gene action in f_1 generation of winter x spring wheat derivatives

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Abstract
Introgression of winter wheat gene pool in spring wheat is one of the potential approaches to break the yield barrier. To assess the combining ability of yield and yield contributing traits, ten diverse winter wheat or their derivatives were crossed with three spring wheat testers in line x tester fashion to generate 30 cross combinations. The thirty F_1 hybrids along with the 13 parents (10 lines and 3 testers) were evaluated in randomized block design during rabi 2016-17 at university Research Farm of Sher-e-Kashmir university of Agricultural Sciences and Technology, Jammu (SKUAST,J) Main campus, Chatha. The gca effects was greater than sca effects for most of the yield and yield attributing traits. The compassion of relative magnitude of gca and sca variances indicated greater magnitude of gca variance than sca variance for yield traits, indicating the presence of additive gene action for the inheritance of these traits. On the basis overall ranking of the parents for gca, the lines Arkaan, Blue boy, Nordresprez, Diana and WW25 and in testers WH1080, PBW 175 revealed desirable significant effect for many traits. Crosses China x PBW 175 for tillers per plant; WW25x WH 1080 for spike length; Arkaan x WH 1080 for biological yield per plant, harvest index and grains per plant Arkaan x PBW 644; for grain yield WW21 x WH 1080 were possessing desirable significant sca for yield contributing traits in the F_1 generation. The allelic resources of these lines and testers could be utilized in a multiline crossing approach to generate substantial genetic variability.

Keywords: Combining ability, gene action, line x tester, winter wheat, spring wheat

1. Introduction

Wheat (*Triticum aestivum* L.), self-pollinated crop of the Poaceae family and of the genus *Triticum*, is the world's largest cereal crop. It is popularly known as 'Stuff of life or King of the cereals' because of the acreage occupied, high productivity and the prominent position it holds in the international food grain trade. Wheat (*Triticum* spp.), is the most important cereal crop and occupies prominent position in Indian agriculture after rice. India is now the second largest producer of wheat in the world with the production hovering around 75 million tonnes during the last decade.). The area and production of wheat in India during year 2016-17 was recorded 30.97 million ha with 97.44 million tonnes production and with an average productivity of 3172 kg ha-1 (Director's Report, IIWBR, Karnal, 2016- 17). The problem of drought is in the soil with low water holding capacity especially in the rain fed areas of mountainous and sub-mountainous regions. Therefore, there is an urgent need for genetic improvement of wheat in such environments. One of the ways by which this can be achieved is by the incorporation of genes from winter wheat. The importance of winter wheat for the improvement of spring wheat under rainfed conditions was highlighted as early as in 1949 by Ackerman and Mackey. The success of winter x spring hybridization depends upon the ability of these two physiologically different ecotypes to combine well with each other. In order to formulate a sound breeding strategy, information on the relative magnitude of genetic variance, combining ability for grain yield and its related traits is essential. Such information is useful for the selection of parental lines having superior performance and isolation of potential combination for their further use in the breeding programmes. The technique of line x tester analysis tends itself to the detailed genetic analysis and identifies superior parents and cross combinations on the basis of the combining ability. Such information is useful for the selection of parental lines having superior performance and isolation of potential combinations for their use in breeding programmes.

2. Materials and Methods

The breeding material, represented ten winter wheat and their derivatives that were used as females (lines) and three of spring wheat, used as males (Testers). The above selected ten winter wheat lines used as females were crossed with three spring wheat lines used as males (Testers) in Line x Tester fashion during 2015-2016 at university Research Farm of Sher-e-

Kashmir university of Agricultural Sciences and Technology, Jammu (SKUAST,J) Main campus, Chatha, Jammu to generate 30 F_1s. Thirty F_1 crosses and 13 Parents (10 lines + 3 testers) were evaluated in RBD replicated thrice at the Research Farm of Sher-e- Kashmir university of Agricultural Sciences and Technology, Jammu (SKUAST, J)Main campus, Chatha, Jammu during the rabi season of 2016. Experimental Plot in each replication consisted of a single row of 1.5 m length spaced 25 cm apart for number of such rows. For proper growth the seedling – seedling spacing was maintained at 5 cm. The observation were recorded on five competent for different traits namely : tillers per plant, spike length, grains per plant, 1000 grain weight, Biological yield per plant, grain yield per plant and harvest index.

3. Results and Discussion

Treatment revealed highly significant variance (table I) for all the trait viz, tillers per plant, spike length, grains per plant, 1000 grain weight, Biological yield per plant, grain yield per plant and harvest index. Variance for parents (lines and testers) and crosses was also significant in both F_1 generation. Exception among lines was observed for harvest index (F_1). Comparison of crosses vs parents revealed significant variances for all the traits except grain yield per plant and harvest index (F_1 generation) while as comparison of lines vs Tester also revealed significant variance except spike length (F_1) and harvest index.

Table 1: Analysis of variance for yield traits on the basis of F_1 generation of crosses in spring x Winter wheat derivatives (Line x Tester).

Sources of variation	**D.F**	**Tillers Per Plant (no.)**	**Spike Length (cm)**	**Grains Per Plant (no)**	**Grain Yield (g)**	**1000 Grain Weight (g)**	**Biological Yield Per Plant (g)**	**Harvest Index (%)**
Replicates	2	2.39	0.05	8.43	10.53	0.57	46.08	6.53**
Treatments	42	82.97 **	5.43 **	77.96 **	325.84 **	219.55 **	574.63 **	142.47 *
Parents	12	38.94 **	1.38 **	27.99**	141.65 **	49.29 **	274.64**	23.91 **
Parents (Line)	9	28.45 **	1.05 **	25.39 **	138.93 **	48.14 **	197.37 **	25.51
Parents (Testers)	2	67.44 **	3.09 **	2.21	195.46 **	1.53	726.88 **	9.75
Parents (L vs T)	1	76.41 **	0.94	102.91 **	58.49 *	155.18 **	65.56	37.83 *
Parents vs Crosses		265.24 **	20.05 **	210.83 **	30.60	4620.17*	184.66 *	1523.67
Crosses	29	94.91 **	6.59 **	94.06 **	412.23 **	138.25 **	712.22***	143.89*
Error	84	4.92	0.30	7.47	14.32	2.04	32.22	5.41

*, **significant at 5% and 1% level, respectively.

Table 2: Analysis of variance for combining ability for yield traits on the basis of F_1 generation of cross in spring x Winter wheat derivatives (line x tester)

Sources of variation	**D.F**	**Tillers Per Plant (no.)**	**Spike Length (cm)**	**Grains Per Plant (no)**	**Grain Yield (g)**	**1000 Grain Weight (g)**	**Biological Yield Per Plant (g)**	**Harvest Index (%)**
Line Effect	9	41.89 *	1.97	66.84*	118.96	84.54 *	484.01	47.14
Tester Effect	2	1068.31**	76.55 **	834.76 **	4952.13**	1356.94 **	5875.13 **	1585.87 **
Line * Tester Eff.	18	13.26 **	1.14**	25.37 **	54.43**	29.70**	252.67 *	32.05 **
σ^2GCA Tester		4.11	0.19	6.60	11.63	4.64	9.17	50.20
σ^2GCA (Average)		28.21	2.00	22.73	129.29	36.86	161.40	41.59
σ^2L X T (SCA)		2.78	0.28	5.97	13.37	9.22	73.48	8.88
σ GCA / SCA		10.14	7.14	3.80	9.67	3.99	2.19	4.68
$\sigma^2{}_A$		35.45	2.54	27.58	164.59	52.68	45.16	194.76
$\sigma^2{}_D$		28.21	2.00	22.73	129.29	36.86	161.40	41.59
$\sigma^2{}_{D} / s^2{}_A$		2.78	0.28	5.97	13.37	9.22	73.48	8.88

*, **significant at 5% and 1% level, respectively.

Significant variance was observed for the treatment combinations in F_1 generation. The variance for the parents (lines + tester) was also significant for all the traits viz tillers per plant, spike length, grains per plant,1000 grain weight, Biological yield per plant, grain yield per plant and harvest index, it was observed that for lines this variance was significant for all the traits except harvest index in F_1 whereas for the tester this variance was significant for all the traits except grains per plant,1000 grain weight and harvest index in generations. The crosses arising from spring x winter wheats revealed significant variance for all the traits. Comparison of parents with crosses revealed significant variance for all the traits, confirming that significant variability was created in the crosses from the parental allelic resources. However, comparing lines with tester revealed that the significant contrast existed in magnitude of variability in two groups of wheat (winter and spring) except spike length and harvest index in F_1 generation.

Component analysis of variance arising from line, tester and line x tester for different yield and yield component traits into combining ability variances (general and specific) revealed that variance, due to lines was significant only for tillers per plant, grains per plant and 1000 grain weight in F_1 generation, whereas the contribution form tester was significant for all the traits.. The crosses revealed significant variance arising from line x tester variance component for all the traits, variance due to gca was significant and much higher than variance due to sca that was non –significant.

Translating the variance due to gca and sca into component of gene action, it was found that (additive genetic variance) was much and several times more than the variance due to dominance deviation. Average degree of dominance ($\sigma^2{}_D$ / $\sigma^2{}_A$) was mostly incomplete for all the traits except biological yield per plant that revealed this partial dominance ratio in F_1 generation. On the whole, almost all the yield component traits exhibited significant contribution of additive gene action. General combining effects (g_i) (table III, IV) for tillers per plant in F_1 generation significantly higher (g_i) values for this traits were revealed by WW21 and Diana NS 720 (among lines) and PBW175 and WH1080 (among testers). These were rates as good combiners. Significant negative (g_i) values (Poor combiners) were recorded in WW23 and Arkaan (among lines) PBW644 (among testers), rest of the genotypes were average combiners. For Spike length, significant positive (g_i) values (Good combiners) was recorded in Blue boy and Arkaan (among lines). PBW 175 in the testers. The poor combiners (significant negative g_i values) were WW21, Diana and Diana NS720 (among lines) and PBW 644 and WH1080 (testers), the rest were average combiners.

Table 3: Estimates of gca and per se performance on the basis of F_1 generation of crosses in Spring x winter wheat derivatives (Line x Tester)

Parents	Tillers per plant		Spike length		Gain per plant		Grain yield	
	g_i	Per se performance	g_i	Per se performance	g_i	Per se performance	g_i	Per se performance
Lines								
Arkaan	-1.99^{**}	26.66	0.44^{*}	9.88	-.12	40.0	-1.81	54.10
Blue Boy	-0..32	25.33	0.57^{**}	10.16	-1.67	48.66	2.59^{**}	52.00.
China	-0.88	30.66	-0.36	10.65	0.71	49.33	1.73	44.0344
WW 23	-2.88^{**}	30.67	-0.28	9.96	1.74	46.667	-8.46^{**}	58.5
Diana NS 720	2.46^{**}	26.66	-0.37	10.00	3.63^{**}	43.00	3.12^{*}	46.066
WW 21	4.34^{**}	26.33	-0.81^{**}	9.86	-5.05^{**}	46.00	2.41	51.00
WW25	0.46	24.00	0.27	9.27	1.86^{**}	44.00	-1.09	45.9
WW 12	-1.43	30.00	-0.31	11.04	-2.42	46.00	3.22^{*}	63.20
Nordresprez	-0.77	26.07	0.25	10.40	3.07	43.00	-2.57^{**}	60.33
Diana	1.01	34.00	-0.47^{**}	11.22	-1.76	46.66	0.86	59.74
Testers								
PBW 175	6.89^{**}	28.00	1.84^{**}	11.05	6.02^{**}	44.00	14.82^{**}	65.66
PBW 644	-3.31^{**}	27.00	0.99^{**}	9.27	-3.83^{**}	42.33	-6.80^{**}	50.90
WH1080	3.58^{**}	19.33	-0.85^{**}	9.30	-2.19^{**}	46.66	-8.02	52.63
C.D (0.05) line	1.48		0.37		-1.8		2.52	
C. D (0.05) Tester	0.81		0.20		1.00		1.38	

*, **significant at 5% and 1% level, respectively.

For grain yield, In F_1 generation lines showing significant positive (g_i) values (Good combiners) were Diana NS 720, WW25 and Nordresprez while PBW175 (among testers) was good combiners. Poor combiners (significant negative g_i values) were WW21 and WW12 (among lines) and PBW644 and WH1080 (among testers). For 1000 grain weight, in F_1 generation highly significant values of (g_i) contributing to good performance of parents (lines and testers) in generating high performance cross combinations were revealed by WW23,Arkaan and WW12 (Lines) and PBW175 (testers). Poor significant Performers were Blue boy, China, Diana NS 720 and Nordersprez (among lines), and PBW 644 and WH1080 (among testers). For biological yield per plant, in F1 generation, among lines the genotypes WW12, WW25 and Diana NS720 revealed significant (gi) values (good performers), while in the testers PBW175 as significantly good performer. For harvest Index, in F1 generation Positive significant (g_i) values (good performance) among lines was revealed by Diana and Nordresprez while as among the testers the genotype were PBW 175 and PBW 644. For grains per plant, lines showing significant positive (g_i) values (Good combiners) were Diana NS 720, WW25 and Nordresprez while PBW175 (among testers) was good combiners. Poor combiners (significant negative g_i values) were WW21 and WW12 (among lines) and PBW644 and WH1080 (among testers). Rest of the lines were average combiners.

Table 4: Estimates of gca and per se performance on the basis of F_1 generation of crosses in Spring x winter wheat derivatives (Line x Tester)

Parents	1000 grain weight		Biological Yield per Plant		Harvest index	
	g_i	Per se performance	g_i	Per se performance	g_i	Per se performance
Lines						
Arkaan	3.49^{**}	60.46	-1.74	113.10	1.10	47.86
Blue Boy	-3.59^{**}	55.50	-3.18	102.86	1.58^{**}	45.67
China	-3.90^{**}	52.66	1.32	123.67	-0.20	50.06
WW 23	5.08^{**}	51.00	2.76	127.81	0.14	44.14
Diana NS 720	-2.97^{**}	50.13	3.92^{*}	124.33	-0.75	48.26
WW 21	0.02	50.00	-13.8^{**}	125.33	1.31^{**}	49.13
WW25	0.30	48.63	5.98^{**}	127.47	-4.75	44.90
WW 12	2.90^{**}	48.63	11.65^{**}	129.27	0.14	43.33
Nordresprez	-1.06	47.50	-8.91^{**}	125.00	2.24^{**}	41.70
Diana	-0.28	47.73	2.03	129.37	3.67	48.70
Testers						
PBW 175	7.76^{**}	47.03	16.14^{**}	113.10	8.34^{**}	48.70
PBW 644	-4.05^{**}	46.90	-7.45^{**}	108.13	3.37^{**}	50.66
WH1080	-3.71^{**}	45.73	-8.69^{*}	138.47	-4.97	47.06.
C.D (0.05) Line	0.95		3.79		1.55	
C.D (0.05) Testers	0.52		2.07		0.85	

*, ** significant at 5% and 1% level, respectively.

Specific combining ability effects (**s_{ij}**) Table (V,VI) for tillers per plant crosses showing good specific combining ability in F_1 generation were WW21 x PBW 644 and WW25 x WH 1080 and Diana x WH 1080.

Table 5: Estimates of sca and per se performance on the basis of F_1 generation of crosses in Spring x Winter wheat derivatives (Line x Tester)

Crosses	Tillers Per Plant		Spike length		Grains per Plant	
	S_{ij}	Per se performance	S_{ij}	Per se performance	S_{ij}	Per se performance
Arkaan x PBW175	-0.78	28.33	-1.11**	10.47	-0.16	47.33
Arkaan x PBW 644	0.09	19.00	-0.37	8.37	3.35*	41.00
Arkaan x WH1080	0.69	19.33	1.48**	10.36	-3.19*	36.10
B.BOY x PBW175	0.56	31.33	-0.16	11.56	1.16	47.10
B.BOY x PBW 644	1.09	21.66	0.19	9.08	-1.43	34.67
B.BOY x WH1080	-1.64	18.66	-0.02	8.98	0.26	38.00
China x PBW175	1.44	31.66	0.18	10.62	2.80	50.40
China x PBW 644	-2.36	17.66	0.19	7.93	0.03	38.50
China x WH1080	0.91	20.66	0.04	8.27	-2.11	38.00
WW23 x PBW175	-2.22	26.00	0.16	11.05	0.68	48.67
WW23 x PBW 644	1.98	20.00	0.02	8.43	-1.17	38.33
WW23 x WH1080	0.24	18.00	0.18	7.56	1.58	48.67
Diana NS720 X PBW175	0.78	34.3	0.19	10.60	0.76	38.33
Diana NS720 X PBW 644	-1.69	21.66	0.41	8.15	2.61	43.00
Diana NS720 X WH1080	0.91	24.00	0.60	8.04	-3.37	52.00
WW21 X PBW175	-3.11*	32.33	0.17	12.29	-1.23	47.7000
WW21 X PBW 644	3.42**	28.66	0.63	8.65	0.85	44.00
WW21 X WH1080	-0.31	24.66	-0.68*	9.38	0.38	39.66
WW25 x PBW175	-1.56	30.00	0.06	11.50	0.53	41.33
WW25 x PBW 644	-1.69	19.66	-0.12	7.36	1.51	33.73
WW25 x WH1080	3.24*	24.33	0.06	8.23	-2.04	39.23
WW12 x PBW175	1.00	30.66	-0.68	10.71	-4.59**	40.60
WW12 x PBW 644	0.53	20.00	-0.06*	8.43	-1.08	34.27
WW12 x WH1080	1.53	17.66	-0.12	7.82	5.68**	42.67
Nordresprez x PBW175	2.00	32.33	0.43	11.31	0.32	51.00
Nordresprez x PBW 644	-0.80	19.33	-0.32	8.88	0.17	42.33
Nordresprez x WH1080	1.90	18.66	0.08	8.46	-0.17	47.67
Diana x PBW175	1.89	34.00	0..32	11.32	-0.15	47.67
Diana x PBW 644	-0.58	21.33	0.08	7.83	1.82	42.33
Diana x WH1080	-1.31	20.33	0.32	7.35	-4.50**	40.33

*, ** significant at 5% and 1% level, respectively.

For spike length crosses showing good specific combining ability in F_1 generation were WW21 x PBW 644 and WW25 x WH 1080 and Diana x WH 1080. For grains per plant crosses showing good specific combining ability in F_1 generation were Arkaan x PBW 644, and WW12 x WH 1080. For grains yield per plant crosses showing good specific combining ability in F_1 were WW21 x WH1080; WW25 x WH 1080 and WW12 x PBW 644. For 1000 grain weight crosses showing good specific combining ability in F_1 generation were cross Arkaan x PBW 644, China x WH1080, Diana NS 720 x WH 1080, WW21 X PBW 175, WW25 x PBW 175, WW12 x WH 1080, Diana x PBW 644. For biological yield per plant crosses showing good specific combining ability in F_1 generation were Arkaan x PBW 644, WW23 x WH 1080, WW21 x WH 1080; Blue boy x PBW 175. For harvest index crosses showing good specific combining ability in F_1 Arkaan x WH 1080; China x PBW 175; WW23 x PBW 175 and WW25 X WH 1080.

Table 6: Estimates of sca and per se performance on the basis of F_1 generation of crosses in Spring x Winter wheat derivatives (Line x Tester)

Crosses	Grain Yield		1000 Grain weight		Biological yield / Plant		Harvest Index	
	Sij	Per se performance	Sij	Per se performance	Sij	Per se performance	Sij	Per se performance
Arkaan x PBW175	0.56	67.66	-2.49**	45.93	0.58	135.33	-1.64	49.9
Arkaan x PBW 644	-2.08	44.53	2.80**	39.40	12.18**	123.33	-3.36*	36.1
Arkaan x WH1080	-2.64	48.33	-0.31	36.63	-12.75**	97.1667	5.01**	49.7
B.BOY x PBW175	-1.53	71.10	-0.94	40.40	7.36	140.66	-1.12	50.5
B.BOY x PBW 644	4.23	55.33	1.28	30.80	-1.21	108.50	1.26	50.9
B.BOY x WH1080	-2.79	47.00	-0.33	29.53	-6.14	102.33	-0.14	45.9
China x PBW175	1.22	73.00	-3.56	37.46	-4.14	133.66	3.32*	54.46
China x PBW 644	2.87	53.03	1.29	30.50	-4.21	110.00	-1.63	48.2
China x WH1080	-4.10	44.87	2.28**	31.83	8.36	121.33	-1.69	36.9
WW23 x PBW175	3.41	65.00	-0.57	49.43	2.08	141.33	3.32*	45.99
WW23 x PBW 644	-0.14	39.83	0.04	38.23	-9.32**	106.33	-1.63	37.45
WW23 x WH1080	-3.28	35.46	0.53	39.06	7.25*	121.66	-1.69	33.00
Diana NS720 X PBW175	1.84	75.00	-6.03**	35.93	-4.41	136.00	0.68	55.14
Diana NS720 X PBW 644	-3.51	48.03	0.35	30.50	1.32	118.13	1.59	40.65
Diana NS720 X WH1080	1.68	52.00	5.68**	36.16	3.09	118.66	-2.27	43.8
WW21 X PBW175	-0.12	72.33	2.75**	47.70	0.00	122.66	1.81	51.00
WW21 X PBW 644	-5.14*	45.70	-2.97**	30.16	-11.00**	88.06	-0.14	58.9
WW21 X WH1080	5.25*	54.86	0.22	33.70	11.00**	108.83	-1.67	1.62
WW25 x PBW175		66.23	3.87**	49.10	-0.81	141.66	-5.79**	46.7

WW25 x PBW 644	-4.90*	42.43	-1.41	32.00	1.45	120.33	-0.07	35
WW25 x WH1080	7.62**	53.73	1.17	31.30	-0.64	117.00	5.86**	45.92
WW12 x PBW175	-1.16	72.10	0.52	49.00	12.19**	160.33	2.66	44.9
WW12 x PBW 644	5.85	57.50	-1.69	36.53	1.52	126.06	1.37	45.61
WW12 x WH1080	-4.69*	45.73	2.46**	34.66	-13.71**	109.60	-4.03**	41.72
Nordresprez x PBW175	0.86	68.33	3.35	46.33	-12.59	115.00	-1.36	59.4
Nordresprez x PBW 644	-0.56	45.30	1.84	32.00	7.01*	111.00	1.69	40.8
Nordresprez x WH1080	-0.30	44.33	-1.51	30.00	5.58	108.33	-0.32	40.9
Diana x PBW175	-1.24	69.66	-2.40**	48.00	-0.25	138.26	-1.86	50.38
Diana x PBW 644	3.28	52.57	3.35	31.00	2.28	117.20	0.92	44.8
Diana x WH1080	-2.03	46.03	-1.84	31.66	-2.02	111.66	0.96	41.2

*, ** significant at 5% and 1% level, respectively.

Assessing the overall situation it was observed that none amongst the lines was a good (high) general combiner for all the traits, whereas PBW175 (tester) possessed high gca for almost all the traits. Thus, for incorporating alleles for the improvement of a set of economic traits, a multi-line crossing approach would be needed. The knowledge of combining ability of parents (general) and crosses (specific) together with the per se performance of the parents and crosses is of permanent importance in crop improvement programme for isolating desirable lines in the segregating population and selection of an appropriate breeding methodology for handling such populations. Specific combining ability of 30 line x tester crosses revealing that none of the cross combinations exhibited significant and desirable sca effect for all the traits. Cowan (1943) [4] concluded that low x low general combiners always yielded distinctly less than high x high, high x average or average x average general combiners. In the present study also the crosses showing higher per se performance and desirable significant sca were the outcome of high x high, high x average or average x average general combiners.

Lebana *et al.* (1978) [12] suggested that manifestations of gca effects in some cross combinations results due to concentration of more favourable alleles and their interaction. Some of the desirable cross combination for grain yield and its major components on the basis of sca effects could be used to generate desirable segregants by adopting biparental mating to increase the chances of recombination (Peer Arif, 2004) [15], advocated inter –mating among desirable early generation segregants in bi parental fashion and the bulking of the best families to produce phenotypically more uniform but genetically buffered populations in autogamous crop species. Desirable segregants could be obtained if additive gene effects exhibited by good combiners and the complementary epistasis in crosses act complementarily. The inter se crossing, involving multiple parents would result in creation of broad based gene pools that would help to generate tremendous genetic variability after few generations of intermating.

Singh *et al.* (2012) [18] studied combining ability in wheat and found that best cross combination involved high x low or low x low general combiners for most of the yield component traits.

4. Conclusion

Based on the findings in the present study, the material selected (winter and spring wheat) possessed good magnitude of variability for all the traits. Greater magnitude of gca variance than sca variance revealed that the traits had predominant role of additive gene action as compared to non-additive gene action. The results were also confirmed from the average degree of dominance that was incomplete to partial for all the traits. Multiline crossing programme is needed to introgress allelic resources from elite genotypes and the progenies showing better early generation performance are further crossed through bi- parental procedure to increase chances of generation of hidden latent variability in heterozygous polygenic blocks. Use of recurrent selection procedure for the identification of superior transgressive segregants before fixation of alleles in homozygous condition.

5. References

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