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Ranjana Tiwari
Department of Genetics and Plant Breeding, Sam Higgin Bottom Institute of Agriculture, Technology and Sciences, Deemed University, Allahabad, Uttar Pradesh, India, India

Shailesh Marker
Department of Genetics and Plant Breeding, Sam Higgin Bottom Institute of Agriculture, Technology and Sciences, Deemed University, Allahabad, Uttar Pradesh, India, India

DR Meghawal
Department of Genetics and Plant Breeding, Sam Higgin Bottom Institute of Agriculture, Technology and Sciences, Deemed University, Allahabad, Uttar Pradesh, India, India

Correspondence
Ranjana Tiwari
Department of Genetics and Plant Breeding, Sam Higgin Bottom Institute of Agriculture, Technology and Sciences, Deemed University, Allahabad, Uttar Pradesh, India, India

Combining ability estimates for spike characters in f_1 hybrids developed through diallel crosses among macaroni wheat (*Triticum durum* Desf.) genotypes

Ranjana Tiwari, Shailesh Marker and DR Meghawal

Abstract
The present study was conducted to obtained information of combining ability effects for spike related traits in durum wheat and to select suitable parents and population for designing an effective wheat breeding programme. The experimental material designed in an 8×8 diallel set to synthesized 28 hybrids excluding reciprocals. Analysis of variance (ANOVA) revealed the presence of significant variance due to General Combining Ability (GCA) and Specific Combining Ability (SCA) among the parents and F_1 hybrids for all the traits studied. Combining ability analysis revealed the involvement of both additive and non additive gene action in the inheritance of most of the traits. On the basis of GCA/SCA effects and *per se* performance, parents PDW 300 followed by RAJ 1555 and HI 8653 were found good general combiners for spike characters. Similarly, F_1's crosses PDW 300×HI 8653 and PDW 300×RAJ 1555 were found good specific combiners for spike related traits. Therefore, these parents can be considered as best combiners and their crosses are expected to be worthful for subsequent utilization in genetic enhancement of macaroni wheat.

Keywords: Durum wheat, F_1, GCA, SCA, spike characters

1. Introduction

Global demand for wheat is growing at approximately 2% year^{-1}, twice the current rate of gain in genetic yield potential (Skovmand and Reynolds, 2000) [21]. Durum wheat is the second most important wheat species, plays an important role in Indian economy being the staple food of the population. It is a naturally bi-fortified food and used for making large numbers of products including 'nutritive chapatti' and semolina, (Prasad *et al* 2014) [15]. Historically durum has received insufficient attention from plant breeders. Therefore, efforts to increase yield in durum wheat will not only support to the overall wheat production of this country but it will also help to meet the food requirements of the bourgeoning population of country like India. The yield levels of durum wheat are low compared to bread wheat under both irrigated and rain fed conditions (Sharma *et al.*, 2004) [12,18]. Therefore, it is necessary to improve durum wheat with high yielding capacity. This could be only realized via intensive and effective breeding programmes. Thus, careful selection of the parents is the first important step in the process for the development of superior high yielding cultivars.

The wheat inflorescence spike has a direct bearing on grain yield. It makes an important contribution to the final grain yield through photosynthesis (Araus *et al.*, 1993) [3]. Thus any improvement of spike characteristics through selection and breeding would help improve plant^{-1} productivity (Iqbal and Khan, 2006) [9]. For breaking the yield barrier level and make durum wheat cultivation more attractive it is now necessary to explore alternative approaches to increasing wheat production.

Combining ability analysis provides information on additive and non additive variances, which are important to decide the proper parents for hybridization and to produce superior hybrids. The present investigation was therefore an attempt to obtain information on the extent of combining ability for the spike related traits and to select suitable parents and hybrids for designing an effective wheat breeding programme.

2. Materials and Methods

The experimental material comprising of a set of 28 hybrids, developed from eight diverse parents (PDW 300, NIDW 295, AKDW-2997-16, RAJ 6560, DBP-01-11, DBP-01-12, RAJ 1555, HI 8653) of durum wheat using direct straight diallel mating system excluding reciprocals during *Rabi* 2011-12 (45 to 55 seeds). 8 parents and their 28 F_1s hybrids were laid out in Randomized Block Design with three replications evaluated during *Rabi* 2012–13, at the

Field Experimentation Centre of Department of Genetics and Plant Breeding Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad, Uttar Pradesh, with Recommended doses of fertilizers at @ 120 kg N+60 kg P_2O_5+40 kg K_2O ha^{-1} were applied in the experimental field along with five irrigations at all critical stage to raised a healthy crop.

The observations were recorded on five randomly selected competitive plants from parents as well as in F_1 hybrids for spike length, spikelet's $spike^{-1}$, spike weight productive $tiller^{-1}$, grain weight $spike^{-1}$, grains $spike^{-1}$, grains $spikelet^{-1}$, spike density, spike harvest index in every plot. Data on these quantitative traits in each replication were subjected to appropriate biometrical approaches. The combining ability analysis was worked out by the procedure suggested by Griffing's (1956) Method II, Model I. The mathematical model for the combining ability analysis is assumed to be:

Yijkl=μ+gi+ gj+sij+1/bc Σi Σeijkl

(ij=1, 2, 3,……….n;

k=1, 2, 3...…b;

l=1, 2, 3 ….c)

Where, Yijkl, Mean of i×jth genotype in kth replication; μ, the population mean; gi, the GCA effect of ith parent; gj, the GCA effect of jth parent; sij, the specific combining ability (SCA) effect for the cross between ith, j^{th} parent such that $s_{ij}=s_{ji}$; Σi Σeijkl, the environmental effect associated with the $ijkl^{th}$ individual observation on ith individual in the kth block with ith as female parent and jth as male parent. The usual restrictions such as Σgi=0 and $\Sigma s_{ij}=s_{ii}=0$ (for each i) were imposed. The analysis of variance (ANOVA) table for combining ability with expectation of mean sum of squares (M.S.) is shown in Table 1.

[Σ (Yi+Yii) ^{2}–(4/n) Y^2] Ss=Sum of squares due to SCA,

Ss=Σ < ΣY^2ij–1/ (n+2) [Σ (Yi+Yii) ^{2}+2/ (n+1) (n+2) Y^2], me'=Me1/r

Where Y_i, Total of the array involving ith as a female parent; Y_{ii}, the value of the i^{th} of the array; Y.., the grand total; Y_{ij}, the value of i x j^{th} cross; Mel, the error M.S. obtained from main ANOVA by Fone SCA and Patterson., 1968.

The components of variances were estimated as suggested by (Singh *et al.*, 1990) in the following ways:

GCA expected M.S. =σ^2 *e*+ (n+2)/ (n–2) $\sigma^2 gi$

SCA expected M.S. =σ^2 *e*+2/ $(n–1)^2$sij

2.1. Estimates of various effects

The various effects were estimated as follows:

GCA effect of i^{th} parent=gi=1/ (n+2) [(Yi.+Yii)–2/nY..]

SCA effect of ij^{th} cross=Sij=Y_{ij}–1/ (n+2) [$Y_{i.}$+$Y_{.j}$+Y_{ij})+2Y/ (n+1) (n+2) Y.]

Where, gi and s_{ij}, the estimates of the GCA and SCA effects, respectively; n, Yi, Y_{ii}, Y. and Y_{ij}, the same as explained earlier; $Y_{.j}$, total of the arrays involving j^{th} parent as a male; Y_{jj}, the value of the j^{th} parent in the array.

3. Results and Discussion

Analysis of variance for combining ability revealed that the variance due to GCA and SCA were significant for all the traits (Table 1). The extent of mean square due to GCA was higher than SCA for all the characters except spike length, which indicates existence of considerable genetic variability in the parental lines included in the present study and involvement of both additive and non-additive gene effects in the inheritance of these traits (Jaiswal *et al*., 2013; [11] Joshi *et al*., 2004) [12]. The ratio of GCA and SCA variances as less than one and degree of dominance more than one for all traits indicated greater role of non additive components in the inheritance of these characters.

3.1. General combining ability effects

The information regarding general combining ability (GCA) effects of the parents is of prime importance because it helps in successful prediction of genetic potentiality, which would give desirable individuals in subsequent segregating populations. Estimates of GCA effects (Table 2) showed that it was not possible to pick up a good general combiner for all the spike characters because the combining ability of the parents was not consistent for all yield attributing components (Kashif *et al*., 2008 [13]; Dhadhal and Dobariya, 2006) [6]. The GCA effects of the parents along with parental means (Table 2) indicated that there was a close and desirable relationship between parents and their GCA effects almost all of the studied characters. On the basis of overall performance, two parent PDW-300 followed by RAJ 1555 was found to be the desirable combiner for spike length, spikelets $spike^{-1}$, spike weight productive $tiller^{-1}$, grain weight $spike^{-1}$, grains $spike^{-1}$, spike density and spike harvest index. Similarly parent DBP-01-11 found to be the best combiner for more numbers of grains $spikelets^{-1}$. Thus, the perfect relationship could be established between *per se* performance and GCA effects of the parents. It is therefore suggested that these parental lines may be used in hybridization programme to have the superior recombinants for respective traits. Similar findings in durum wheat have been reported by Barot *et al*. (2014) [4].

3.2. Specific combining ability effects

The magnitude of specific combining ability (SCA) effects is of vital importance in selecting cross combination with higher probability of generating transgressive segregates. Significant yield performance in the specific crosses was due to the involvement of best general combiners in our study. The desirable SCA effects are presented in Table 3. The significant SCA effects with the mean performance of the genotypes indicated that among overall 28 crosses, hybrid PDW 300×HI 8653 had maximum spike length with a perfect correlation of SCA performance also. Grain weight is an essential component contributing for yield production with grains $spike^{-1}$ which directly determines the yield potential of a genotype. Cross PDW 300×HI 8653 performed well in all the three yield attributing traits viz., spike length, grain weight $spike^{-1}$ and grains $spike^{-1}$ with higher *per se* performance and SCA effects. Similar finding in wheat has been reported by Ismail *et al*. (2006) [10], Khan and Ali (1998) [2, 17] and Shahzad *et al.* (1998) [17]. Spike Harvest Index (SHI) is the dry weight (at anthesis) to total dry weight ratio at physiological maturity. It shows the proportion of mobilized dry matter to spike in a genotype (Donalson, 1996) [7]. A marked variation is evident for average spike harvest index among the parents and hybrids. In the present study cross RAJ 1555×HI 8653 represent the highest significant positive SCA effects for spike harvest index. Cross AKDW-2997-16×DBP-01-12 found to be common good and significant cross combination for spike density and spike harvest index. Grains $spikelets^{-1}$ is the most important yield determinant of wheat (Sinclair and Jamieson, 2006). The individual comparison of mean performance and SCA effects represented the significant and correlated value by the cross combination PDW 300×RAJ 1555. Spikelets $spike^{-1}$ and spike weight productive $tiller^{-1}$ is an important and effective yield component and greater number could results in more grains spike^{-1}. The hybrid RAJ 6560×DBP-01-12 found to be best for spikelets spike^{-1} followed by PDW 300×HI 8653 for both spike characters having significant and desirable SCA effects indicative of best yielding cross combination. Similar finding has also reported by Adel *et al.* (2013) [1], Mishra *et al*. (1996) [14] and Chowdhry *et al*. (1999) [5] in wheat.

3.3. Per se performance and SCA common superior cross combinations

The ranking of specific cross combination on the basis of their *per se* performance and SCA effects computed in Table 4. In the present study, the common good crosses on the basis of *per se* performance and SCA effects were PDW 300×HI 8653, PDW 300×RAJ 1555 and PDW 300×DBP-01-12 for spike length, RAJ 6560× DBP-01-12 and PDW 300×HI 8653 for spikelets spike^{-1}, RAJ 6560×HI 8653 AND RAJ 6560×DBP-01-12 for spike weight productive tiller^{-1}; PDW 300×HI 8653 for grain weight spike^{-1}; PDW 300×HI 8653 and RAJ 6560×DBP-01-12 for grains spike^{-1}; PDW 300×RAJ 1555 for grains spikelet^{-1}; DBP-01-11×HI 8653 for spike density and RAJ 1555×HI 8653 for spike harvest index. However some crosses showed desirable SCA effects for more than one characters. Cross combination PDW 300×HI 8653 exhibited significant and desirable SCA effects for 4 traits viz.; spikelets spike^{-1}, spike length, grain weight spike^{-1} and grains spikelet^{-1}. Similarly cross combination RAJ 6560×DBP-01-12 recorded desirable SCA effects for 3 spike characters, spikelets spike^{-1}, spike weight productive tiller^{-1} and grains spike^{-1}. It is thus evident that high yielding varieties involved in the crosses were predominately responsible for enhancing the yield. Similar findings in wheat have been reported by Raiyani *et al* (2015), Adel *et al.* (2013) [1], and Ismail *et al*. (2006) [10].

Table 1: ANOVA for combining ability (GCA and SCA) for 8 characters in 8×8 diallel crosses of durum wheat

Sources of variance	Degree of freedom	Spike length	Spikelets spike^{-1}	Spike weight productive Tillers^{-1}	Grain weight spike^{-1}	Grains spike^{-1}	Grains spikelets^{-1}	Spike density	Spike harvest index
Parents	7	0.09**	5.17**	0.34**	0.31**	71.71**	0.09**	0.03**	23.90**
Crosses	28	0.28**	1.96**	0.09**	0.10**	42.04**	0.06**	0.01**	22.10**
Error	70	0.00	0.04	0.00	0.33	0.45	0.00	0.00	2.14
GCA variance		17.79	123.06	102.35	95.62	156.54	19.05	33.3	11.14
SCA variance		55.62	46.74	29.53	31.8	91.78	13.1	18.08	10.3
GCA/SCA variance		0.03	0.26	0.3	0.3	0.17	0.14	0.18	0.1

*Significant at (p=0.05) level of significance; **, significant at (p=0.01) level of significance; GCA, general combining ability; SCA, specific combining ability

Table 2: Estimation of GCA effects of 8 parents along with their mean performance for 8 characters in F_1 hybrids of wheat

Characters	Spike length		Spikelets spike^{-1}		Spike weight productive tillers^{-1}		Grain weight spike^{-1}		Grains spike^{-1}		Grains spikelets^{-1}		Spike density		Spike harvest index	
Parents	GCA effect	Parent Mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean	GCA effect	Parent mean
PDW-300	0.15**	8.27	1.23**	22.73	0.29**	3.46	0.31**	2.54	3.10**	63.13	-0.07**	2.77	0.10**	2.74	3.36**	73.31
NIDW-295	-0.10**	8.07	-0.98**	19.90	-0.33**	2.29	-0.28**	1.64	-3.96**	53.47	-0.07**	2.68	-0.09**	2.44	-0.73	71.78
AKDW-2997-16	-0.11**	8.20	-0.19**	21.60	-0.06**	3.45	-0.05**	2.55	-1.51**	60.93	-0.03	2.82	0.01	2.63	-0.29	73.98
RAJ-6560	0.06**	7.73	-0.19**	19.20	0.04*	2.94	0.00	1.95	-3.41**	54.33	-0.13**	2.83	-0.04**	2.48	-0.38	66.44
DBP-01-11	-0.10**	8.10	-0.55**	20.13	-0.12**	3.19	-0.14**	2.41	0.60**	59.97	0.13**	2.98	-0.02*	2.56	-1.72**	75.55
DBP-01-12	0.00	8.07	-0.31**	20.57	-0.02	3.19	-0.04*	2.29	0.70**	58.53	0.09**	2.84	-0.04**	2.55	-1.14*	71.71
RAJ-1555	0.07**	8.37	0.80**	23.47	0.17**	3.64	0.15**	2.85	2.03**	65.00	-0.03	2.60	0.06**	2.74	0.58	75.68
HI-8653	0.04	8.17	0.19**	22.03	0.04*	3.39	0.04*	2.52	2.45**	62.07	0.11**	2.81	0.01	2.69	0.33	74.70

*, Significant at (p=0.05) level of significance; **, Significant at (p=0.01) level of significance

Table 3: Estimation of SCA effects and corresponding mean performance of 8 characters in 8×8 diallel cross of wheat

Characters	Spike length		Spikelets spike^{-1}		Spike weight productive tillers^{-1}		Grain weight spike^{-1}		Grains spike^{-1}		Grains spikelets^{-1}		Spike density		Spike harvest index	
Crosses	SCA effect	Parent mean	SCA effect	Parent mean	SCA effect	Parent Mean	SCA effect	Parent Mean	SCA effect	Parent mean	SCA effect	Parent mean	SCA effect	Parent mean	SCA effect	Parent mean
PDW 300×NIDW-295	-0.46**	8.07	-0.32	20.87	0.22**	3.41	0.02	2.35	0.2	63.20	-0.22**	2.68	0.10**	2.58	-2.69	70.67
PDW 300×AKDW 2997-16	-0.72**	7.80	-1.38**	20.60	-0.26**	3.20	-0.30**	2.25	-3.41**	62.03	0.05	2.99	0.06	2.64	-3.55*	70.25
PDW 300×RAJ 6560	-0.42**	8.27	-2.24**	19.73	-0.39**	3.17	-0.17**	2.44	-14.68**	48.87	-0.37**	2.47	-0.15**	2.38	3.25*	76.97
PDW 300×DBP-01-11	0.03	8.57	0.28	21.90	0.02	3.42	0.11*	2.58	0.6	68.17	0.01	3.11	0.01	2.55	3.38*	75.75
PDW 300×DBP-01-12	0.77**	9.40	1.71**	23.57	0.42**	3.92	0.40**	2.97	8.94**	76.60	0.18**	3.24	-0.03	2.50	2.67	75.61
PDW 300×RAJ 1555	0.83**	9.53	1.16**	24.13	0.25**	3.94	0.28**	3.04	11.01**	80.00	0.38**	3.31	-0.10**	2.52	2.46	77.13
PDW 300×HI 8653	1.00**	9.67	2.11**	24.47	0.42**	3.99	0.43**	3.08	11.19**	80.60	0.21**	3.29	-0.05	2.53	2.75*	77.17
NIDW 295×AKDW-2997-16	0.43**	8.70	1.10**	20.87	0.35**	3.19	0.38**	2.35	1.85**	60.23	-0.05	2.88	0	2.40	3.92**	73.64
NIDW 295×RAJ 6560	0.46**	8.90	0.1	19.87	0.18**	3.12	0.29**	2.31	-0.55	55.93	-0.02	2.81	-0.07*	2.28	4.41**	74.03
NIDW 295×DBP-01-11	0.48**	8.77	0.46*	19.87	0.01	2.80	0.08	1.96	2.30**	62.80	0.07	3.16	-0.10**	2.26	2.27	70.55

NIDW 295×DBP-01-12	0.29**	8.67	-0.55**	19.10	0.06	2.94	-0.07	1.91	-1.50*	59.10	0.03	3.09	-0.14**	2.20	-3.56*	65.30
NIDW 295×RAJ 1555	-0.42**	8.03	-1.60**	19.17	-0.16**	2.91	-0.30**	1.87	1.21	63.13	0.36**	3.29	-0.06	2.38	-4.31**	66.27
NIDW 295×HI 8653	-0.35**	8.07	-1.05**	19.10	-0.09	2.86	-0.20**	1.87	1.45*	63.80	0.26**	3.33	-0.04	2.35	-5.07**	65.26
AKDW 2997-16×RAJ 6560	0.44**	8.87	1.54**	22.10	0.25**	3.46	0.31**	2.55	9.84**	68.77	0.24**	3.11	0.05	2.49	3.62*	73.69
AKDW 2997-16×DBP-01-11	-0.14*	8.13	-0.67**	19.53	-0.09	2.97	-0.22**	1.88	-0.48	62.47	0.07	3.19	-0.06*	2.40	-5.36**	63.36
AKDW 2997-16×DBP-01-12	-0.23**	8.13	0.55**	21.00	-0.1	3.05	0.05	2.25	-3.14**	59.90	-0.24**	2.85	0.13**	2.58	3.99**	73.29
AKDW 2997-16×RAJ 1555	-0.1	8.33	-1.19**	20.37	-0.42**	2.92	-0.45**	1.94	0.6	64.97	0.22**	3.19	-0.10**	2.44	-4.40**	66.63
AKDW 2997-16×HI 8653	0.43**	8.84	-2.01**	18.93	-0.41**	2.81	-0.46**	1.82	-5.46**	59.33	0.02	3.13	-0.35**	2.14	-5.88**	64.89
RAJ 6560×DBP-01-11	-0.08	8.37	-1.20**	19.00	-0.26**	2.89	-0.44**	1.72	-0.98	60.07	0.13*	3.16	-0.14**	2.27	-9.31**	59.33
RAJ 6560×DBP-01-12	0.56**	9.10	2.22**	22.67	0.42**	3.67	0.41**	2.67	11.03**	72.17	0.18**	3.18	0.09**	2.49	3.57*	72.78
RAJ 6560×RAJ 1555	0.12	8.73	0.38	21.93	-0.01	3.43	-0.03	2.42	-7.27**	55.20	-0.36**	2.51	0.02	2.51	-0.48	70.45
RAJ 6560×HI 8653	0.65**	9.23	1.92**	22.87	0.55**	3.87	0.34**	2.68	8.00**	70.90	0.09	3.10	0.03	2.47	2.01	72.69
DBP-01-11×DBP-01-12	0.15	8.53	-0.89**	19.20	-0.27**	2.83	-0.32**	1.79	3.48**	68.63	0.32**	3.57	-0.16**	2.25	-4.51**	63.37
DBP-01-11×RAJ 1555	0.61**	9.07	1.43**	22.63	0.21**	3.50	0.07	2.38	4.18**	70.67	-0.01	3.12	-0.01	2.49	-1.62	67.97
DBP-01-11×HI 8653	-0.66**	7.77	0.01	20.60	-0.02	3.14	-0.07	2.13	1.09	68.00	0.03	3.29	0.19**	2.65	-1.34	68.00
DBP-01-12×RAJ 1555	-0.48**	8.07	-1.57**	19.87	0.02	3.40	-0.17**	2.24	-3.21**	63.37	0.08	3.17	-0.03	2.46	-4.42**	65.75
DBP-01-12×HI 8653	-0.22**	8.30	-1.96**	18.87	-0.56**	2.70	-0.45**	1.85	-2.17**	64.83	0.20**	3.43	-0.17**	2.27	-4.28**	65.64
RAJ 1555×HI 8653	-0.06	8.53	-0.44*	21.50	-0.04	3.41	0.13*	2.62	-0.7	67.63	0.06	3.16	-0.02	2.51	5.19**	76.83

*, Significant at (p=0.05) level of significance; **, Significant at (p=0.01) level of significance

Table 4: Ranking of good cross combination on the basis of *per se* performance and their SCA effect in a 8×8 diallel cross of wheat

Characters	Parents with higher *Per se* Performance	Good cross combination	Superior Common Cross Combinations
Spike length	[1] PDW 300×HI 8653 [2] PDW 300×RAJ 1555 [3] PDW 300×DBP-01-12 [4] RAJ 6560×DBP-01-12 [5] RAJ 6560×HI 8653	PDW 300×HI 8653 PDW 300×RAJ 1555 PDW 300×DBP-01-12	PDW 300×HI 8653 PDW 300×RAJ 1555
Spikelets spike-1	[1] PDW 300×HI 8653 [2] PDW 300×RAJ 1555 [3] PDW 300×DBP-01-12 [4] RAJ 6560×HI 8653 [5] RAJ 6560×DBP-01-12	RAJ 6560×DBP-01-12 PDW 300×HI 8653 RAJ 6560×HI 8653 AKDW 2997-16×NIDW 295	RAJ 6560×DBP-01-12 PDW 300×HI 8653 RAJ 6560×HI 8653
Spike weight productive tillers-1	[1] PDW 300×HI 8653 [2] PDW 300×RAJ 1555 [3] PDW 300×DBP-01-12 [4] RAJ 6560×HI 8653 [5] RAJ 6560×DBP-01-12	RAJ 6560×HI 8653 RAJ 6560×DBP-01-12	RAJ 6560×HI 8653 RAJ 6560×DBP-01-12
Grain weight spike-1	[1] PDW 300×HI 8653 [2] PDW 300×RAJ 1555 [3] PDW 300×DBP-01-12 [4] RAJ 6560×HI 8653 [5] RAJ 6560×DBP-01-12	PDW 300 x HI 8653 RAJ 6560×DBP-01-12	PDW 300 x HI 8653
Grains spike-1	[1] PDW 300×HI 8653 [2] PDW 300×RAJ 1555 [3] PDW 300×DBP-01-12 [4] RAJ 6560×DBP-01-12 [5] RAJ 6560×HI 8653	PDW 300×HI 8653 RAJ 6560×DBP-01-12	PDW 300×HI 8653 RAJ 6560×DBP-01-12
Grains spikelets-1	[1] DBP-01-11×DBP-01-12 [2] DBP-01-12×HI 8653 [3] PDW 300×HI 8653 [4] PDW 300×RAJ 1555	PDW 300×RAJ 1555 NIDW 295×RAJ 1555	PDW 300×RAJ 1555
Spike density	[1] DBP-01-11×HI 8653 [2] PDW 300×AKDW 2995-16 [3] PDW 300×DBP-01-11 [4] PDW 300×HI 8653	DBP-01-11×HI 8653 AKDW 2997-16×DBP-01-12	DBP-01-11×HI 8653
Spike harvest index	[1] PDW 300×HI 8653 [2] PDW 300×RAJ 1555 [3] PDW 300× RAJ 6560 [4] RAJ 1555×HI 8653	RAJ 1555×HI 8653 NIDW 295×RAJ 6560	RAJ 1555×HI 8653

4. Conclusion

The GCA and SCA variances were significant for almost all the characters, indicating the importance of both additive and non additive gene effects. On the basis of GCA effects it was observed that PDW 300 was best general combiner for almost all the spike characters, followed by RAJ 1555 and HI 8653. The best specific combiners PDW 300×HI 8653 was considerable for spike length, spikelets spike^{-1}, grain weight spike^{-1}, grains spike^{-1}, the cross PDW 300×RAJ 1555 was found desirable for grains spikelet^{-1} and spike length, and cross DBP-01-11×HI 8653 for spike density and cross RAJ 1555×HI 8653 for spike harvest index. The presence of parents having significant GCA effects, indicating additive×additive gene action played an important role for the expression of all the spike traits.

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References

1. Adel MM, Ali EA. Gene action and combining ability in six parent diallel cross of wheat. Asian Journal of Crop Science 2013; 5(1):14-23.
2. Ali Z, Khan AS. Combining ability studies of some morpho-physiological traits in bread wheat (*Triticum aestivum* L.). Pakistan Journal Agriculture Science 1998; 35:1–3.
3. Araus JL, Brown HR, Febrero A, Bort J, Serret MD. Ear photosynthesis, carbon isotope discrimination and the contribution of respiratory CO2 to differences in grain mass in durum wheat. Plant Cell Environment 1993; 16:383-392.
4. Barot HG, Patel MS, Sheikh WA, Patel LP, Allam CR. Heterosis and combining ability analysis for yield and its component traits in wheat [*Triticum aestivum* (L.)]. Electronic Journal of Plant Breeding 2014; 5(3):350-359.
5. Chowdhry MA, Rabbani GM, Khaliq SI. Combining ability studies for some polygenic traits in aestivum spp. Pakistan Journal of Biological Science 1999; 2:434-437.
6. Dhadhal BA, Dobariya KL. Combining ability analysis over environment for grain yield and its components in bread wheat (*T. aestivum* L.). National Journal of Plant Improvement 2006; 8(2):172–174.
7. Donalson E. Crop traits for water stress tolerance. American Journal of Alternative Agriculture 1996; 11:89-94.
8. Griffing B. A generalized treatment of the use of diallel crosses in quantitative inheritance. Heredity 1956; 10:31-50.
9. Iqbal M, Khan AA. Analysis of combining ability for spike characteristics in wheat (*Triticum aestivum* L.). International Journal of Agriculture and Biology 2006; 8(5):684–687.
10. Ismail AA, Ahmed TA, Tawfils MB, Khalifa EMA. Gene action and combining ability analysis of diallel crosses of bread wheat under moisture stress and non stress condition. Assiut Journal of Agriculture Science 2006; 37:17-33.
11. Jaiswal KK, Marker S, Kumar B. Combining ability analysis in diallel crosses of wheat (*Triticum aestivum* L.). The Bioscan 2013; 8(4):1557-1560.
12. Joshi SK, Sharma SN, Sain RS. Nonallelic interactions for yield and its components in hexaploid wheat (*T. aestivum* L. Em. Thell.). Indian Journal Genetics 2004; 64:63-64.
13. Kashif M, Khan AS. Combining ability studies for some yield contributing traits of bread wheat under normal and lat sowing condition. Pakistan journal of Agriculture science 2008; 4: 44-49.
14. Mishra PC, Singh TB, Kurmvanshi SM, Soni SN. Gene action in diallel cross of wheat under late sown condition. Journal of Soils and Crops 1996; 6:128-131.
15. Prasad SV, Dubey VG, Ambati D, Prakash TL, Mishra AN. Poshan A Healthy Alternative. Agriculture Today 2014; 38-39.
16. Raiyani AM, Patel DA, Kapadia VN, Boghara MC, Sisara HC. Combining ability and gene action for different characters in bread wheat (*Triticum aestivum* L), The Bioscane, 2015; 10(4):2159-2162.
17. Shahzad K, Chowdhry M, Hussain AD, Mohy-ud-Din Z, Haidar S, Alam K, Khan SH. Combining ability studies of grain yield and related characters in spring wheat (*Triticum aestivum* L.). Pakistan Journal of Biological Sciences 1998; 1: 134-136.
18. Sharma SN, Mann MS, Sain RS. Heterosis in durum wheat (*Triticum turgidum* var. durum). SABRAO Journal of Breeding and Genetics 2004; 36(2):127-130.
19. Sinclair TR, Jamieson PD. Grain number, wheat yield and bottling beer: An analysis. Field Crops Research 2006; 98: 60-67.
20. Singh SP, Singh RK, Singh J, Agarwal RK. Combining ability for yield and some of its important components in Induced mutants of bread wheat. Indian journal of Genetics 1990; 50:167-170.
21. Skovmand B, Reynolds MP. Increasing yield potential for marginal areas by exploring genetic resources collections. The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia 2000; 18(22):67-77.