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Research Article

Combining ability analysis of some yield and quality traits in durum wheat (*Triticum durum* Desf.)

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Abstract
A study was conducted for the analysis of combining ability of some yield and quality taits in a set of 10 durum wheat genotypesfollowing a diallel mating design excluding reciprocals. The analysis of variance for combining ability revealed that mean square values due to parents and hybrids were significant for the traits days to 50% heading, days to maturity, plant height, number of effective tillers per plant, length of main spike, peduncle length, number of spikelets per main spike, grain yield per main spike, grain yield per plant, test weight, biological yield per plant, harvest index, specific sedimentation volume, protein content, sedimentation value and β carotene which revealed that existence of differences among the parents and hybrids. Significance of both σ^2_{GCA} and σ^2_{SCA} for the characters days to 50% heading, days to maturity, length of main spike and number of spikelets per main spike suggested that importance of both additive and non-additive gene effects for the inheritance of these characters. The value of average degree of dominance was close to one for days to maturity and length of main spike which revealed complete dominance behaviour of interacting alleles for these characters. The parents GDW 1255, GW 2007-112 and GW 1 were good combiners for multiple traits *viz.*, days to 50% heading, days to maturity, length of main spike, number of spikelets per main spike, number of grains per main spike and spike density in F_1 generation. The crosses (give best crosses for grain yield) GW 2002-51 x GW 1 and GW 2007-77 x GW 1277 was good specific combiners for multiple traits along with grain yield in F_1 generation and these crosses may be utilized in the development of high yielding progenies in durum wheat.

Key words
Half-Diallel, GCA, SCA, and Durum Wheat

Introduction

Durum or macaroni wheat, *Triticum durum*, (2n=4x=28, genomes AABB), is one of the ancient staple food grain crop consumed by human beings. It is commonly grown in central and peninsular India. In the world, durum wheat are mainly cultivated in Central India, Southern USSR, Mediterranean countries, East Africa, Argentina, Chille, United States of America and Canada(Anonymous, 2013). Presently, India ranked in durum wheat poduction.Globally durum or macaroni wheat is grown in about 30 million hectares and accounts for almost 8 per cent of total world wheat production (Anonymous, 2013). In India, the major durum wheat growing states are..Uttar Pradesh, Haryana, Punjab, Gujarat, Karnataka and Rajasthan. In Gujarat, Durum wheat is mostly grown in the districts of Ahmedabad, Anand, Bhavnagar, Surendranagar, Bharuch, Patan and Dahod. Wheat contains gluten protein which enables leavened dough to rise by forming minute gas cells and this property enables bakers to produce light breads. Bread wheat is mostly preferred for making chapatti's/breads because of its binding properties of gluten; whereas, durum wheat is highly valued for preparation of macaroni, spaghetti, vermicelli and noodles. Macaroni wheat till recently were confined to only rainfed areas of Central and Peninsular India. However, being responsive to higher fertilizer application and development of rust resistant high yielding varieties encouraged cultivation of durum wheat under irrigated conditions. Combining ability study in self-pollinated crops is regarded useful to select parents with better nicking ability, which on crossing would produce more desirable recombinants. Such studies also elucidate the nature and magnitude of gene effects for an inheritance of grain yield and its component characters.

Material and Methods

The experimental materials consisted of ten genetically diverse parental lines including GW 2002-51, GDW 1255, GW 2007-77, GW 2007-112, GW 1276, GW 1277, GW 2007-54, HI 8725, GW 1 and Arnej 206 were crossed in a diallel mating design excluding reciprocals during the year *rabi* 2011-12. The resulting 55 genotypes (45 hybrids and 10 parents) were grown in Randomized Complete Block Design with three replications. The investigation was carried out at Regional Research Station, Anand Agricultural University,

Anand during *Rabi* 2012-13. Observation for different quantitative characters under study excluding phenological trait like days to 50% heading and days to maturity were recorded on five randomly selected competitive plants in each experimental unit; however, phenological traits were recorded on plot bases. Whereas, quality traits like, sedimentation value, specific sedimentation volume, protein content and β carotene were estimated as a random sample of seeds were taken from bulk seeds harvested from five selected plants of each replication of the experiment and analysed using Fourier Transform-Near Infrared Reflectance Spectroscopy (FT-NIRS). The mean values of analysis of variance and the estimation of combining ability variances and its effects for all the characters of parents and their hybrids were analysed as per Model-1, Method-2 of Griffing, B. (1956); while, the magnitude of GCA and SCA variances were estimated by Potence ratio (Romero G.E. and Frey K.J. (1973)) and Predictability ratio (Baker R.J.H. (1978))

Result and discussion

The analysis of variance (ANOVA) for combining ability (Table 1) revealed that mean square values due to parents were significant for all the characters like days to 50% heading, days to maturity, plant height. Number of effective tillers per plant, length of main spike, peduncle length, number of spikelets per main spike, number of grains per main spike, grain yield per main spike, grain yield per plant, test weight, biological yield per plant, harvest index, spike density, hectoliter weight, specific sedimentation volume, protein content, sedimentation value and β carotene. Likewise, mean square values due to hybrids were significant for all the characters viz., days to 50% heading, days to maturity, plant height. Number of effective tillers per plant, length of main spike, peduncle length, number of spikelets per main spike, grain yield per main spike, grain yield per plant, test weight, biological yield per plant, harvest index, specific sedimentation volume, protein content, sedimentation value and β carotene. which revealed that existence of appreciable variability among the parents and hybrids for these traits.

The estimates of revealed that both additive and non-additive gene effects were involved for inheritance of days to 50% heading, days to maturity, length of main spike and number of spikelets per main spike. The result was in conformity with reports of Singh *et al.* (1983), Chovatia and Jadon (1989), Budak (2001), Ajmal *et al.* (2004), Sanjeev *et al.* (2005), Singh *et al.* (2007),Mahpara *et al.* (2008) and Singh *et al.* (2013)

The estimates of σ^2sca were significant for the characters *viz.,* plant height, number of effective tillers per plant, peduncle length, grain yield per main spike, grain yield per plant, test weight, biological yield per plant, harvest index, kernel length, specific sedimentation volume, protein content, sedimentation value and β carotene revealing importance of non additive gene effect and the finding confirmed the reports of Gorjanovic and Kraljevic-Balalic (2004) . While, for the character hectolitre weight none of the components of genetic variance had significant estimate, which could be because of absence of sufficient genic variability among the parental genotypes and/or possibility for more complicated bahaviour of genes for inheritance of this character.

However, the magnitude of either of component of genetic variance could be judged from their potence ratio and predictability ratio; when, both the components σ^2gca and σ^2sca had significant estimates, the said parameters/ratio were worked out. The estimates of potence ratio was more than one (>1) and value of predictability ratio was more than 0.5 for two characters viz., days to 50% heading and number of spikelets per main spike revealed preponderance of additive genetic variance. The result was in conformity with report of Singh *et al.* (1983), Borghi and Perenzin (1994), Kakar *et al.* (1999), Sanjeev *et al.* (2005), Akinci (2009) and Kumar (2012).

The characters plant height, number of effective tillers per plant, grain yield per main spike, test weight, specific sedimentation volume, protein content, sedimentation value and β carotene had more than one value of average degree of dominance, which revealed over dominance behaviour of interacting alleles was evidenced. The value of average degree of dominance was close to one for the characters days to maturity and length of main spike which revealed complete dominance behaviour of interacting alleles for these characters. Whereas, for the character kernel length the value of average degree of dominance was zero, it revealed absence of dominance for the character and the finding confirmed the report of Kumar (2012).

The general combining ability effect of the parents and specific combining ability effect of the crosses were estimated for those characters, which had significant value of respective variance of the combining ability analysis. The parents having significant GCA effect in desirable direction, non-significant GCA effect and significant GCA effect in undesirable direction were classified as good, average and poor general combiner, respectively.

Accordingly, crosses were also classified as good, average and poor specific combiner. The GCA effect of the parents varied from -4.24 (GW 1276) to 3.18 (GW 2002-51) for days to 50% heading,-5.93 (GW 2007-54) to 3.15 (GW 2007-112) for days to maturity, -0.40(HI 8725) to 0.41 (GW 2002-51) for length of main spike, -0.56 (GW 2007-54) to 0.67 (GW 2007-112) for number of spikelets per main spike, -2.62 (GW 2007-54) to 2.34 (GDW 1255) for number of grains per main spike and -0.08 (GW 2002-51) to 0.09 (GW 2007-112) for spike density. The parents GDW 1276, GW 2007-54 and GW 1 were good general combiners for the characters days to 50% heading and days to maturity. While for the characters number of length of main spike, spikelet's per main spike and number of grains per main spike GDW 1255 was good general combiner. GW 2007-112 was good general combiner for spikelets per main spike, number of grains per main spike and spike density (Table 2). Most of the parents had relatively high degree of correspondence between *per se* performance and their GCA effects for majority of the characters, which could be because of existence of genes showing additivity and *pseudo* additive gene effects. Therefore, in selection of parents for hybridization work, equal importance should be given to their *per se* performance along with GCA effects.

The information pertaining to different aspects of SCA effect was presented in Table 3. The SCA effect of the crosses varied from -4.78 (GW 2007-77 x GW 1276) to 4.56 (GW 1276 x GW 2007-54) for days to 50% heading, -9.39 (GW 2007-77 x GW 1276) to 9.44 (GW 2002-51 x GW 2007-77) for days to maturity, -10.12 (GW 1 x Arnej 206) to 8.46 (GW 2007-77 x GW 1) for plant height, -2.62 (GDW 1255 x Arnej 206) to 4.16 (GW 2007-77 x GW 1277) for number of effective tillers per plant, -0.73 (GW 1 x Arnej 206) to 0.85 (GW 1276 x HI 8725) for length of main spike, -3.27 (GDW 1255 x GW 2007-54) to 5.33 (GW 1 x Arnej 206) for peduncle length, -1.50 (GW 1 x Arnej 206) to 1.98 (GDW 1255 x GW 1) for number of spikelets per main spike, -0.60 (GW 1 x Arnej 206) to 0.78 (GW 2007-77 x Arnej 206) for grain yield per main spike, -2.97 (GW 2007-77 x HI 8725) to 6.17 (GW 2007-77 x GW 1277) for grain yield per plant, -13.97 (GW 2002-51 x GW 1276) to 12.93 (GW 2007-54 x Arnej 206) for test weight, -4.13 (GDW 1255 x Arnej 206) to 7.64 (GW 2007-77 x GW 1277) for biological yield per plant, -4.67(GW 1277 x Arnej 206) to 6.75 (GW 2007-54 x Arnej 206) for harvest index, -0.49 (GW 2002-51 x GW 1277) to 0.58 (GW 2002-51 x GW 2007-77) for kernel length, -1.40 (GW 2007-77 x GW 1277) to 0.43 (GDW 1255 x GW 1277) for specific sedimentation volume, -2.03 (GW 2002-51 x GW 2007-54) to 1.91 (GW 2007-77 x GW 1277) for protein content, -16.12 (GW 2007-77 x GW 1277) to 5.28 (GW 2002-51 x GW 1276) for sedimentation value and -0.60 (GW 1 x Arnej 206) to 0.79 (GW 2007-77 x Arnej 206) for β carotene.

The cross GW 2002-51 x GW 1 was good specific combiners for number of effective tillers per plant, length of main spike, peduncle length, grain yield per main spike, grain yield per plant, test weight, biological yield per plant, harvest index, kernel length and B carotene followed by the cross GW 2007-77 x GW 1277. For grain yield per plant, crosses GW 2007-77 x GW 1277 (6.17**), GW 2007-54 x Arnej 206 (5.90**) and GW 1277 x HI 8725 (3.45**) had higher SCA estimates, and all these crosses were good/average specific combiners for rest of the characters like hectolitre weight and specific sedimentation volume. Therefore, these crosses may be given due weightage in crop improvement work. the involvement of either one or both the parents with significant GCA effect, contributed to significant SCA effect for the crosses, indicating the occurrence of additive gene action in such crosses. The crosses involving at least one good general combiner parent may produce transgressive segregants. However, for full exploitation, intermating of elite plants in the early segregating generations may be profitable to build up the population having early and dwarf plants with high grain yield.

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Table 1. Analysis of variance of combining ability for the different yield and quality characters in durrum wheat

Source of variation	Days to 50% heading	Days to maturity	Plant height	Number of effective tillers per plant	Length of main spike	Peduncle length	Number of spikelets per main spike	Number of grains per main spike	Grain yield per main spike	Grain yield per plant
Parents	74.16**	112.79**	59.48**	3.54**	0.69**	5.00*	2.24**	32.98**	0.25**	3.54*
Hybrids	4.90**	20.81**	27.05**	3.24**	0.19**	7.38**	0.58*	8.34	0.16**	5.65**
Error	1.22	2.78	9.11	0.88	0.11	2.05	0.38	6.44	0.003	1.40
σ^2_{GCA} ($\sum g_i^2$)	5.77*	7.67*	2.70	0.02	0.04*	-0.20	0.14*	2.05*	0.007	-0.18
σ^2_{SCA} ($\sum\sum s_{ij}^2$)	3.68*	18.04*	17.94*	2.36*	0.09*	5.33*	0.20*	1.90	0.16*	4.24*
Potence ratio	7.83	2.13	-	-	2.40	-	3.40	-	-	-
Predictability ratio	0.76	0.46	-	-	0.49	-	0.58	-	-	-
σ^2A	11.54	15.33	5.40	0.05	0.08	-0.40	0.28	4.11	0.01	-0.35
σ^2D	3.68	18.04	17.94	2.36	0.09	5.33	0.20	1.90	0.16	4.24
$(\sigma^2D/\sigma^2A)^{0.5}$	0.56	1.08	1.82	7.02	1.02	-2.22	0.86	0.68	3.37	-1.97

(Conti…)

Table 1. Analysis of variance of combining ability for the different characters

Source of variation	Test weight	Biological yield per plant	Harvest index	Spike density	Kernel length	Hectoliter weight	Specific sedimentation volume	Protein content	Sedimentation value	β carotene
Parents	54.49**	5.64*	6.96*	0.05**	0.07ns	2.38*	0.27**	1.05**	45.57**	0.25**
Hybrids	53.82**	8.42**	10.25**	0.01	0.07ns	1.3ns	0.14**	0.93**	24.56**	0.17**
Pooled error	3.96	2.19	2.72	0.014	0.050	1.20	0.03	0.31	0.99	0.002
σ^2_{GCA} ($\sum g_i^2$)	0.06	-0.23	-0.28	0.004*	0.000	0.091	0.011	0.010	1.752	0.007
σ^2_{SCA} ($\sum\sum s_{ij}^2$)	49.86*	6.23*	7.54*	-0.005	0.022*	0.091	0.111*	0.615*	23.557*	0.165*
Potence ratio	-	-	-	-	-	-	-	-	-	-
Predictability ratio	-	-	-	-	-	-	-	-	-	-
σ^2A	0.11	-0.46	-0.55	0.008	0.000	0.18	0.02	0.02	3.50	0.01
σ^2D	49.86	6.23	7.54	-0.005	0.022	0.091	0.111	0.615	23.557	0.165
$(\sigma^2D/\sigma^2A)^{0.5}$	21.10	-2.40	-2.64	-0.79	0.00	0.71	2.25	5.55	2.59	3.43

Table 2. Estimates of general combining ability effect of parents for the different yield and quality traits in durum wheat.

Sr. No.	Parents	Days to 50% heading	Days to maturity	Length of main spike	Number of spikelets per main spike	Number of grains per main spike	Spike density
1	GW 2002-51	**3.18**** P (69.33)	**3.04**** P (110.33)	**0.41**** G (7.97)	0.22 A (15.20)	0.83 A (44.87)	***-0.08**** P (1.93)
2	GDW 1255	**2.26**** P (66.67)	**3.07**** P (112.33)	**0.19*** G (8.31)	**0.56**** G (15.93)	**2.34**** G (46.87)	0.02 A (1.93)
3	GW 2007-77	0.82* P (68.33)	2.32** P (111.33)	***-0.25**** P (7.25)	0.07 A (16.80)	0.47 A (49.27)	**0.08*** G (2.32)
4	GW 2007-112	**1.29**** P (64.67)	**3.15**** P (105.33)	-0.01 A (7.31)	**0.67**** G (16.53)	**1.89*** G (48.07)	**0.09**** G (2.27)
5	GW 1276	***-4.24**** G (58.33)	***-3.13**** G (99.33)	0.02 A (7.19)	***-0.38**** P (14.73)	-0.90 A (42.53)	-0.05 A (2.05)
6	GW 1277	0.62 A (67.33)	-0.68 A (104.00)	-0.06 A (7.53)	**0.25** A (16.27)	**0.90** A (47.93)	**0.05** A (2.17)
7	GW 2007-54	***-4.21**** G (54.33)	***-5.93**** G (91.33)	0.01 A (7.23)	***-0.56**** P (14.47)	***-2.62**** P (41.93)	***-0.08**** P (2.01)
8	HI 8725	0.96** P (68.00)	1.04* P (100.67)	***-0.40**** P (7.01)	***-0.45**** P (14.87)	***-1.98**** P (42.53)	0.05 A (2.13)
9	GW 1	***-0.99**** G (63.00)	***-1.54**** G (94.67)	**0.24*** G (6.98)	-0.01 A (14.33)	0.51 A (42.20)	***-0.07*** A (2.06)
10	Arnej 206	0.32 A (65.33)	-1.32** G (97.00)	***-0.15*** A (6.63)	-0.36* P (14.53)	***-1.45**** P (41.07)	-0.01 A (2.19)
Range	Min.	-4.24	-5.93	-0.40	-0.56	-2.62	-0.08
	Max.	3.18	3.15	0.41	0.67	2.34	0.09
SE (g_i)±		0.314	0.474	0.092	0.175	0.721	0.034
C. D. 5%		0.615	0.929	0.180	0.343	1.413	0.067
SE (g_i-g_j)±		0.471	0.711	0.138	0.262	1.082	0.051
C.D. 5 % (g_i-g_j)		0.934	1.408	0.274	0.520	2.144	0.101
Positive		07	05	05	05	06	05
Positive significant		05	05	03	02	02	02
Negative		03	05	05	05	04	05
Negative significant		03	04	02	04	03	02

A = Average combiner G = Good combiner P = Poor combiner
Value in bracket indicted the *per se* performance of the parent for its respective character

Table 3. Estimation of specific combining ability effect of hybrids for the different characters

Characters	Top ranking three crosses in desire direction	SCA effect of the crosses	Number of crosses with significant +ve and –ve SCA effect	
			+ve	-ve
Days to 50% heading	GW 2007-77 x GW 1276	-4.78**	06	08
	GW 2002-51 x GW 1277	-4.67**		
	GW 2007-77 x GW 1277	-3.31**		
Days to maturity	GW 2007-77 x GW 1276	-9.39**	10	07
	GW 2002-51 x GW 1277	-7.56**		
	GDW 1255 x GW 2007-54	-7.33**		
Length of main spike	GW 1276 x HI 8725	0.85**	03	02
	GW 2002-51 x GW 1	0.70*		
	GW 1276 x Arnej 206	0.69*		
Peduncle length	GDW 1255 x GW 2007-54	-3.27*	11	03
	GW 1277 x Arnej 206	-2.87*		
	GW 2002-51 X GDW 1255	-2.80*		
Number of spikelets per main spike	GDW 1255 x GW 1	1.98**	01	01
	GW 1276 x GW 2007-54	1.00		
	GW 2002-51 x GW 2007-54	0.87		
Grain yield per main spike	GW 2007-77 x Arnej 206	0.78**	24	17
	GW 2002-51 x GW 1	0.69**		
	GW 2002-51 x GDW 1255	0.59**		
Grain yield per plant	GW 2007-77 X GW 1277	6.17**	09	04
	GW 2007-54 x Arnej 206	5.90**		
	GW 1277 x HI 8725	3.45**		
Test weight	GW 2007-54 x Arnej 206	12.93**	18	09
	GW 2002-51 x GW 1	12.39**		
	GDW 1255 x GW 1277	11.70**		
Biological yield per plant	GW 2007-77 x GW 1277	7.64**	09	03
	GW 2007-54 x Arnej 206	6.82**		
	GDW 1255 x GW 2007-77	4.12**		
Harvest index	GW 2007-54 x Arnej 206	6.75**	09	04
	GW 2007-77 x GW 2007-54	6.06**		
	GW 2007-77 x GW 1277	6.04**		
Kernel length	GW 2002-51 x GW 2007-77	0.58**	04	01
	GW 2007-112 x GW 1277	0.50*		
	GDW 1255 x Arnej 206	0.48*		
Specific sedimentation volume	GDW 1255 x GW 1277	0.43**	09	06
	GDW 1255 x GW 2007-77	0.42**		
	GW 1276 x GW 1	0.39*		
Protein content	GW 2007-77 x GW 1277	1.91**	03	08
	GW 2002-51 x GW 1276	1.76**		
	GDW 1255 x GW 2007-54	1.49**		
Sedimentation value	GW 2002-51 x GW 1276	5.28**	14	10
	GDW 1255 x GW 2007-77	4.30**		
	GW 2007-77 x GW 2007-112	4.29**		
β carotene	GW 2007-77 x Arnej 206	0.79**	26	17
	GW 2002-51 x GW 1	0.69**		
	GW 2002-51 x GDW 1255	0.59**		