Research Article

Genetic Characterization in 5 × 5 Diallel Crosses for Yield Traits in Bread Wheat

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Abstract | The seed of five parental cultivars alongwith their 10 F_1 hybrids of wheat were sown in a randomized complete block design with four replications during 2010 at Sindh Agriculture University, Tandojam, Pakistan. Genetic analysis of yield traits from half diallel crosses was carried-out. Mean squares due to GCA and SCA were significant for days to 75% maturity, tillers plant^{-1}, spike length, spike density, grains spike^{-1}, grain yield plant^{-1}, seed index and harvest index. Significance of GCA and SCA variances suggested that both additive and non-additive genes were controlling these characters. The magnitude of SCA variances were higher than GCA indicating pre-dominance of non-additive gene effects for spike length, spike density, seeds spike^{-1}, grain yield plant^{-} and harvest index, while GCA variances were greater for days to 75% maturity, tillers per plant. Parental cultivar TD-1 expressed maximum GCA effects for tillers plant^{-1}, spike length, grain yield plant^{-1}, seed index and harvest index; while negative and desirable GCA for days to 75% maturity. The SCA estimates revealed that F_1 hybrid TD-1 × TJ-83 manifested maximum SCA effects for tillers plant^{-1}, spike length, grains spike^{-1} and negative yet desirable for days to 75% maturity. The cross TJ-83 × Sarsabz recorded with higher estimates for grains spike^{-1}, grain yield plant^{-1}, seed index and harvest index. Thus both the F_1 hybrids may be choice breeding material for hybrid crop development to improve the yield traits.

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Introduction

Wheat production can be increased either by bringing more area under cultivation or vertically by increasing per unit yield. It is not possible horizontally to increase area under wheat due to other competing crops and shortage of irrigation water. Therefore, the only alternative left is to increase yield ha^{-1}, which is possible by introducing genetically superior new high yielding cultivars that are adapted to a wider range of environments.

Due to greater diversification, wheat provides many opportunities for the development of new and improved genotypes through crossing and recombination of favourable genes. Wheat breeders, all over the world, have been utilizing the existing genetic resources to modify the wheat varieties in order to meet the requirement of an ever increasing population. Strains that possess a wide range of variability in economically important yield contributing traits have been utilized by the breeders to develop new varieties. In this context, a diallel mating design is being used to estimate GCA and SCA of parents in hybrid combinations. This involves utilizing the same set of parents as males and females, and thus provides estimates of GCA and SCA. GCA is defined as an average performance of a parent in a series of crosses while SCA denotes those instances where certain hybrids are either better or poorer than would be expected as based on average performance of parents in hybrid combinations (Sprague and Tatum, 1942). Despite the fact that a lot of research on combining ability has been carried-out by wheat breeders, the results obtained still remain controversial either due to the material used or the environment in which material was evaluated or the breeding methodology adopted. Combining genetic information from multiple crosses as in diallel design has proved to be a powerful approach (Xu, 1998). The diallel method thus provides an experimental framework for a straightforward analysis of variance, in order to identify crosses likely to produce desirable segregates as a result of transgressive segregation of alleles in a relatively short time (Reynolds et al., 2007). Rajara and Maheshwari (1996) and Dhadhal and Dobariya (2006) reported the importance of both additive and non-additive genes, yet found a preponderance of non-additive gene effects for seed yield plant^{-1}, plant height and spikelets spike^{-1}. On the contrary, Singh et al. (2003) studied 80 F_1s developed from four lines crossed with 20 testers evaluated via line x tester analysis. The estimates of variance components due to GCA and SCA indicated the predominance of non-additive genes for plant height, spike length, spikelets spike^{-1}; grains weight spike^{-1}, 100-seed weight and yield plant^{-1} as reported by Ribadia et al. (2007). Baloch et al. (2013) and Brahim and Mohamed (2014) also noted significant GCA and SCA and found also a high proportion of non-additive genes for main spike length and spikelets spike^{-1} in wheat.

Heritability plays a predictive role in breeding programmes and expresses the reliability of phenotype as a guide to its breeding value. It is understood that the breeding values of individuals are derived from appropriate analyses. It is the breeding value, which determines how much of the phenotype would pass onto the next generation. There is a direct relationship between heritability and response to selection, which is referred to as genetic progress. The present study is therefore designed to determine GCA and SCA of parental cultivars and their F_1 hybrids, respectively and heritability assessments of seed yield characters in wheat.

Materials and Methods

The seeds of five wheat cultivars viz. Khirman, Mehran, TD-1, TJ-83 and Moomal alongwith their F_1 hybrids were planted in a randomized complete block design with four repeats at Sindh Agriculture University, Tandojam, during the 2010 crop season. The sowing was done in mid December, 2010 with a drill method and the distance between plant to plant and row to row was kept at 6 and 9 cm, respectively. Inorganic fertilizer (50 kg) of DAP per hectare was applied at the time of sowing whereas 100 kg of nitrogen ha^{-1}, first dose with 3rd irrigation and second dose was applied at the time of grain formation. The crop was harvested in April, 2010. To reduce the intensity of harmful weeds, Buctrol Supper herbicide at the rate of 1000cc was applied after first irrigation. Analysis of variance was carried out according to Gomez and Gomez (1984) with Statistix 8.1 version, whereas, the heritability was estimated according to Hallauer and Miranda (1986). A diallel is a mating system that involves all possible crosses among a group of parents. This genetic design is used to study polygenic traits. Diallel mating designs have been used primarily to estimate genetic variances when parents are either random individuals or inbred lines from a random mating population in linkage equilibrium. They have also been used to estimate combining ability and heterotic potential of fixed lines or varieties in crosses or for basic studies on the genetic structure of populations. Several methodologies for the analysis and interpretation of diallel crosses have been suggested (Sprague and Tatum, 1942). The GCA and SCA variances and their effects were calculated according to Griffing's Method-2 Model-1 = n (n-1)/2 = parents + F_1 hybrids. Diallel analysis was carried-out according to Griffing (1956) numerical approach as adopted by Singh and Choudhary (1979). The analysis determined additive and non-additive variances and effects for various traits.

Ten plants per replication from each F_1 hybrid and parental cultivars were randomly selected and treated as index plants to record the data for days to 75% maturity, tillers plant^{-1}, spike length (cm), spike density (%), seeds plant^{-1}, grain yield plant^{-1} (g), 1000-grain weight (g) and harvest index (%).

Results and Discussion

Mean squares due to GCA and SCA were significant for all the traits except for parents and parents vs. hybrids were non-significant for spike length and harvest index, respectively (Table 1). The significance of mean squares due to GCA and SCA employed that additive as well as non-additive genes were important for majority of the traits (Baloch et al., 2013). Importance of GCA variance for grain yield plant^{-1} was also observed by Akram et al. (2011) and Baloch et al. (2011) who suggested that additive genes were responsible for grain yield plant^{-1}, while Shabbir et al. (2011) believed that non-additive genetic effects were high for grain yield, revealing the prevalence of SCA effects. Additive type gene action with high values of GCA for tillers per plant and spike density was reported by Mahpara et al. (2008), for spike length by Yucel et al. (2009), for grains per spike by Shabbir et al. (2011) and for 1000-grains by Dhadhal et al. (2008). Contrary to these findings, a substantial number of SCA rather than GCA effects were recorded for spike length and seed index (Cifci and Yagdi, 2010; Akram et al., 2011; Shabbir et al., 2011) and for spike density and grains per spike (Iqbal and Khan, 2006).

With respect to mean performance of 15 genotypes including parental lines and their F_1 crosses, revealed that the parent, TD-1 took minimum days to 75% maturity (104.25 days), produced more tillers plant^{-1} (7.00), highly dense spikes (68.00%), minimum grains spike^{-1} (52.65) with higher seed yield plant^{-1} (15.14g)

Table 1: *Mean squares from diallel analysis for different characters in wheat*

Source of variation	D. F.	Days to 75% maturity	Tillers^{-1} plant	Spike length	Spike density	Grains spike^{-1}	Grain yield plant^{-1}	Seed index	Harvest index
Replication	3	2.93	1.61	0.41	1.11	1.00	0.63	0.73	1.59
Genotypes	14	56.91**	6.10*	10.53*	75.56**	111.13**	30.98**	32.80**	8.122**
Parents (P)	4	63.80**	2.25 *	0.54	61.50*	44.67**	18.83**	35.58**	10.49**
Hybrids (H)	9	59.82**	6.01*	10.85**	69.24*	76.92**	27.43**	22.00**	7.90*
P vs. H	1	3.11*	22.34	47.61**	188.71**	684.87**	111.54**	118.88**	0.63
GCA	4	121.38**	9.70**	9.14**	30.42**	28.01**	10.79**	42.84**	7.75*
SCA	10	31.12**	4.66**	11.09**	93.61**	144.38**	39.06**	28.78**	8.27**
Error	42	0.71	0.56	0.36	2.27	1.38	1.05	1.19	0.91

**,*: *Significant at P< 0.01 and P< 0.05 Probability levels, respectively*

Table 2: *Mean performance of parental cultivars and F_1 hybrids for various traits in wheat*

	Mean performance							
Parents/Hybrids	Days to 75% maturity	Tillers plant^{-1}	Spike length (cm)	Spike density (%)	Grains spike^{-1}	Grain yield plant^{-1} (g)	Seed index (g)	Harvest index (%)
TD-1	104.25	7.00	10.98	68.00	52.65	15.14	44.48	53.22
TJ-83	110.00	5.50	11.08	63.55	56.55	11.56	38.47	49.73
Kiran-95	111.00	5.00	11.57	63.36	59.00	10.93	37.93	49.53
Moomal	112.50	5.50	10.54	58.69	60.00	10.17	36.93	50.34
Sarsabz	115.00	5.75	10.90	58.65	60.70	9.62	39.89	49.25
F_1 Hybrids								
TD-1 × TJ-83	101.25	9.75	15.90	64.14	72.75	16.22	46.33	50.79
TD-1 × Kiran-95	109.50	8.00	15.22	61.30	69.40	15.46	42.02	49.97
TD-1 × Moomal	112.25	8.00	13.95	61.42	65.55	13.23	40.33	49.91
TD-1 × Sarsabz	114.75	7.25	12.25	69.82	61.75	10.61	41.63	51.65
TJ-83 × Kiran -95	107.25	6.00	12.65	68.28	64.05	10.35	40.62	50.55
TJ-83 × Moomal	109.00	6.00	10.95	72.39	66.10	15.17	42.89	49.29
TJ-83 × Sarsabz	112.75	6.00	12.80	67.03	60.60	19.11	47.04	53.83
Kiran-95 × Moomal	110.25	6.75	11.22	60.19	69.10	13.53	40.61	50.58
Kiran-95 × Sarsabz	110.50	6.50	11.85	69.11	59.35	13.98	42.22	50.51
Moomal × Sarsabz	113.75	6.25	11.77	68.42	61.55	15.69	41.39	48.69
L.S.D (5%)	1.21	1.08	0.87	2.15	1.69	1.47	1.57	1.37

seed index (44.48g) and harvest (53.22) (Table 2).

Table 3: *General combining ability estimates of parental genotypes for various characters in wheat*

Parents	Days to 75% maturity	Tillers^{-1} plant	Spike length	Spike density
TD-1	-2.19	1.04	0.83	0.43
TJ-83	-1.62	-0.13	0.14	1.30
Kiran-95	-0.30	-0.35	0.09	-0.58
Moomal	1.23	-0.24	-0.63	-1.43
Sarsabz	2.87	-0.31	-0.42	0.27
S. E. (gi.)	**0.02**	**0.01**	**0.01**	**0.6**
Parents	**Grains spike^{-1}**	**Grain yield plant^{-1}**	**Seed index**	**Harvest index**
TD-1	-0.14	0.80	1.46	0.80
TJ-83	0.11	0.47	0.68	0.10
Kiran-95	0.58	-0.71	-1.10	-0.35
Moomal	1.04	-0.33	-1.46	-0.56
Sarsabz	-1.59	-0.23	0.42	0.008
S. E. (gi.)	**0.03**	**0.03**	**0.03**	**0.02**

The parents Moomal and Sarsabz were late maturing and took maximum time (66.25 days) to 75% maturity, yet formed more grains spike^{-1} (60.70). Among the hybrids, the cross TD-1 × TJ-83 required minimum days to 75% maturity (101.25) and produced maximum tillers plant^{-1} (9.75), and simultaneously produced longer spikes (15.90 cm) and more grains spike^{-1} (72.75). The F_1 hybrid TJ-83 × Sarsabz took maximum days to 75% maturity (69.25) being late maturing, but nonetheless recorded the highest grain yield plant^{-1}, seed index as well as well as harvest index with 19.11 g, 47.04 g and 53.83%, respectively.

It was generally observed that parental and hybrid performances were not reflected in GCA and SCA except TD-1 among the parents and TD-1 × TJ-83 from hybrids which showed that *per se* parental or hybrid performance may not be set as general criteria for identification of best general combiners for various traits (Baloch and Bhutto, 2003). Therefore, both parents can reliably be used in hybridization and selection programmes to improve majority of the yield contributing traits. Regarding GCA effects of parents, TD-1 displayed maximum positive GCA effects of 1.04, 0.83, 0.80, 1.46 and 0.80 for tillers plant^{-1}, spike length, grain yield plant^{-1}, seed index and harvest index, respectively. Similarly parents, TJ-83 (1.30), Moomal (1.93) and and Sarsabz (2.87) manifested maximum positive GCA effects for spike density, grains spike^{-1}, and days to 75% maturity, respectively. Results suggested that TD-1, TJ-83, Moomal and Sarsabz may be chosen for crossing and selection programmes so as to improve these traits (Table 3). Similar results were obtained by Kalhoro et al. (2015) who reported that among the parents, Imdad and TD-1 were the best general combiners for plant height, tillers plant^{-1}, spike length, spikelets spike^{-1}, seeds spike^{-1}, seed index and grain yield plant^{-1} and F_1 hybrids like Imdad × TD-1 and Imdad × SKD-1 expressed higher SCA effects for most of the studied traits. In agreement with the present findings, Esmail (2007) found that three wheat varieties, Jup/Biy, Giza-164 and Sids-4 exhibited large estimates of GCA effects for spikes per plant.

Ribadia et al. (2007) noted that the variety Flamingo's was a good general combiner for as many as six

Table 4: *Specific combining ability estimates of F_1 hybrids for various characters in wheat*

F_1 hybrids	Days to 75% Maturity	Tillers plant^{-1}	Spike length	Spike density	Grains spike^{-1}	Grain yield plant^{-1}	Seed Index	Harvest index
TD-1 × TJ-83	-4.09	2.30	2.81	-1.87	10.78	1.67	3.13	-0.12
TD-1 × Kiran-95	2.85	0.76	2.19	-2.82	6.96	2.16	0.59	-0.48
TD-1 × Moomal	4.07	0.66	1.64	-1.87	2.77	-0.46	-0.78	-0.33
TD-1 × Sarsabz	4.94	-0.02	-0.27	4.84	1.47	-3.18	-1.32	0.84
TJ-83 × Kiran -95	0.03	-0.07	0.30	3.27	1.35	-2.69	-0.04	0.79
TJ-83 × Moomal	0.25	-0.17	-0.67	8.21	3.06	1.74	2.55	-0.26
TJ-83 × Sarsabz	2.37	-0.10	0.96	1.16	0.06	5.58	4.86	3.71
Kiran-95 × Moomal	0.19	0.79	-0.35	-2.10	5.59	1.34	2.05	1.49
Kiran-95 × Sarsabz	-1.20	0.61	0.07	5.13	-1.66	1.70	1.81	0.85
Moomal × Sarsabz	0.53	0.26	0.71	5.27	0.20	3.01	1.30	-0.75
S. E. (si.)	**0.08**	**0.06**	**0.04**	**0.27**	**0.16**	**0.12**	**0.14**	**0.10**

yield characters while CPAN-6153 was good general combiner for main spike length, while H-6178 exerted significant positive GCA effects for spike length, spikelets spike^{-1} and grain yield plant^{-1}.

The SCA effects revealed that the maximum positive SCA effect was displayed by the F_1 hybrid TD-1 × Sarsabz for days to 75% maturity (4.94), TD-1 × TJ-83 for tillers plant^{-1} (2.30), spike length (2.81) and number of grains spike^{-1} (10.78); TJ-83 × Moomal for spike density (8.21) and TJ-83 × Sarsabz for the seed yield plant^{-1} (5.58), seed index (4.86) and harvest index (3.71) (Table 4). The higher SCA effects of these hybrids indicated their suitability for selection in later generations or they may be considered for hybrid crop development. The higher SCA effects have been reported for tillers plant^{-1}, plant height, spike length, grains spike^{-1}, 1000-grain weight and yield plant^{-1} by Inamullah et al. (2006). Compareable to our results, Kandil et al. (2016) reported that cultivar Sids-12 proved to be the best general combiner for number of spikes/plant, spike length, number of grains/spike, 1000-grain weight and grain yield/plant and variety Gemmiza-11 was also the best general combiner for all the characters except 1000–grain weight; Miser-1 for spike length and 1000- grain weight in wheat. They also found three crosses to be best specific cross combinations Sides 12 × Miser 1 for spike length, Sides-12 ×Miser-2 for number of spikes/plant and 1000-Kernel weight and Miser 2 × Shandaweel 1 for number of spikes/spike, 1000-kernel weight and Kernel yield/plant. Our and their results are of great interest to bread wheat breeders to improve grain yield through higher GCA and SCA of parents.

With respect to broad sense heritability estimates, the results indicated that days to 75% maturity (98.75%), tillers plant^{-1} (90.81%), spike length (96.58%), grains spike^{-1} (98.75%), grain yield plant^{-1} (96.61%), 1000-grain weight (96.37%) and harvest index (88.79%) were highly heritable and most likely controlled by additive genes (Table 5). The spike density (59.17%) was moderately heritable indicating that this character was more influenced by environment factors. The high heritability of characters is attributable to a predicted par amount of genetic variance ($ð^2p$=14.05) and phenotypic variance ($ð^2p$=14.22) which indicated low environmental influence and the characters were under the control of additive gene effects. Characters with high heritability estimates are expected to be more amenable to selection of superior genotypes.

The narrow sense heritability estimates were, 79.57% for days to 75% maturity, 67.38% for tillers plant^{-1}, 45.13% for spike length, 24.50% for spike density, 16.24% for grains spike^{-1}, 21.62 for grain yield plant^{-1}, 59.75% for seed index and 48.21% for harvest index (Table 4). Our results agreed with those of Ahmed et al. (2007) and Chandra et al. (2010) who reported high heritability for days to 75% maturity; while other researchers like Chandra et al. (2010), Kumar et al. (2010), Laghari et al. (2010), Khan et al. (2010), Khattab et al. (2010), Majumder et al. (2008) and Ajmal et al. (2009) who also observed high heritabilty for tillers plant^{-1},spike length, spike density, grains spike^{-1} and seed yield plant^{-1}.

Table 5: *Phenotypic ($ð^2p$) and genotypic variances ($ð^2g$) and heritability estimates in broad sense ($h^2_{(b.s.)}$) as well as in narrow sense ($h_{(n.s.)}$) for various characters in wheat*

Characters	$ð^2p$	$ð^2g$	$h^2_{(b.s.)}$	$h_{(n.s.)}$
Days to 1st heading	8.5925	8.4625	98.48	54.83
Days to 75% maturity	14.2275	14.05	98.75	79.57
Plant height (cm)	56.0025	50.6075	90.36	32.12
No. of tillers plant^{-1}.	1.525	1.385	90.81	67.38
Spike length	2.6325	2.5425	96.58	45.13
Spike density	1.39	0.8225	59.17	24.50
No. of grains spike^{-1}	27.7825	27.4375	98.75	16.24
Grain yield plant^{-1}	7.745	7.4825	96.61	21.62
Seed index 1000-grain weight in g)	8.2	7.9025	96.37	59.75
Harvest index	2.03	1.8025	88.79	48.21

h^2bs: *heritability in broad sense;* **h^2ns:** *heritability in narrow sense*

Conclusions

Magnitudes of variances due to SCA indicated the predominance of dominant genes in the expression of majority of the traits. Among the parents, TD-1 was the best general combiner for the majority of the traits, and thus can reliably be used in a hybridization programme so as to select the desirable plants from segregating populations. The crosses TD-1 x TJ-83 and TJ-83 x Sarsabz expressed higher SCA effects and hence can be the chosen as breeding material for hybrid crop development. High heritability estimates generally suggested that the characters were encoded by additive genes. The potential parents and F_1 hybrids could be utilized in breeding programmes for development of new for early maturing and high yielding wheat varieties.

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Author's Contribution

Muhammad Jurial Baloch designed and conducted the research with Ghulam Murtaza Channa, Wajid Ali Jatoi, Abdul Wahid Baloch, Imdad Hussain Rind, Muhammad Ahmed Arain and Ayaz Ali Keerio. They helped in conducting the experiment, taking the observations, data analysis and write-up of this manuscript in the form of team work.

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