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SELECTION OF SUPERIOR PARENTS AND CROSS COMBINATIONS FOR QUALITY TRAITS IN BREAD WHEAT (*Triticum aestivum* L.) UNDER NORMAL AND HEAT STRESSED CONDITIONS

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Heat stress causes severe loss in wheat yield at vegetative and grain filling stage in many parts of the world. To study heat stress, 50 crosses were generated by crossing 15 parents (already screened) including 10 genotypes (as female lines viz., V-13248, MISR 1, SW89.5277, Shahkar-2013, Miraj-08, AARI-11, Faisalabad-08, V-13013, V-13241 and V-12103) and 5 male testers viz.,V-12056, Millat-11, Chenab-2000, ND643 and V-12082 following Line × Tester mating design in 2014-15. Parameters like protein contents, moisture, starch, ash, gluten and test weight were investigated. These 15 parents along with their 50 F_1 hybrids were sown in a triplicate of randomized complete block design (RCBD) under normal and heat stressed conditions. Analysis of variance (ANOVA) depicted highly significant differences among genotypes for all traits. The results revealed that dominance type of gene action played a predominant role in the inheritance of all traits in this study. From parents, based on general combining ability (GCA) effects, 3 parents, MISR1, Faisalabad-08, and V-13241 proved to be good general combiners for protein, starch, gluten, test weight and ash in both normal and heat stress conditions. Genotype V-13248 showed highest negative significant value for gluten and may be useful for gluten intolerant patients. Among F_1 hybrids, AARI-11 × V-12082, V-13241 × Millat-11 and V-13013 × ND64 represented best specific combining ability (SCA) under both environments for important quality traits like protein and moisture contents. These parents and their crosses were selected for future improvement in ongoing breeding programmes of Pakistan.
Keywords: Climate change, heat stress, gene action. general combining ability, specific combining ability.

INTRODUCTION

Wheat is staple food of more than one-third world's population (including Pakistan) due to its nutritional importance, range of uses and storage qualities. Nutritional value of wheat flour has major role in human diet (Rasaei *et al*., 2017). Grain of wheat have all necessary nutrients such as carbohydrates 60-80% (mostly in the form of starch), moisture 12%, fats 1.5-2%, proteins 8-15% (Anjum *et al*., 2005). As a staple food, wheat is fulfilling the calorie demands of growing population (Kandhare, 2014). Around 4.5 billion people from 94 developing countries consume wheat as a major source of their food calories (21%) and protein (20%) as reported by Braun *et al*. (2010). The climate is changing and scarcity of water along with increasing temperature has developed a significant situation for the breeders to work accordingly. Heat stress is one of the major cause of yield loss in wheat. According to an estimate provided by You *et al*. (2009) hike of 1°C temperature causes 3-10% loss in grain yield of wheat. Approximately 40% of wheat areas in temperate environment face terminal heat stress, which is comprised of 36 million hectares (Reynolds *et al*., 2011). It is being predicted that from 2020 – 2050, 26-51% of Indo-Gangetic plain might be transferred by climate change to heat stressed, sub optimal wheat production zone (Ortiz *et al.*, 2008). Major staple food crop of Pakistan is wheat and estimated per capita consumption is about 124 kg/year, one of the highest around the globe. In current scenario, wheat can fulfill the demand of our country with an increase of at least 4% in total production to meet the pace of ever growing population (Khan *et al.*, 2015).

In Pakistan, wheat yield is severally affected by high temperature at the time of grain filling. Heat stress at grain filling stage disturbs grain maturity, reduces number of grains, reduction in grain weight and eventually causing deterioration of quality and grain yield (Khan *et al.*, 2007; Wahid *et al.*, 2007). Wheat cultivars having the ability to tolerate abiotic stresses, terminal heat tolerance in particular can be helpful in meeting the food demand in coming years (Iqbal *et al*., 2017). Protein content is very important quality parameter. Stone and Nicolas (1998), Mikhaylenko *et al*. (2000), Wardlaw *et al*. (2002) and DuPont and Altenbach

(2003) evaluated the effect of heat stress on the protein contents of wheat and their findings showed that there is significant relationship between heat and protein contents in wheat grains. Heat stress has impact on the development of wheat and grain quality (Spiertz, 1977; Wardlaw *et al*., 2002). Prakash *et al*. 2004, Bhullar, and Jenner 1985 reported reduction in starch and grain growth during high temperature. It has been previously reported that decline of test weight in wheat was due to water and temperature stress (Pierre *et al*., 2008). Impact of heat stress on development of grain and quality of wheat was studied by Spiertz (1977) and Wardlaw *et al*. (2002). Prakash *et al*. (2004) and Bhullar and Jenner (1985) reported reduction of starch and grain growth during high temperature. Pierre *et al*. (2008) furthermore noted decline of test weight in wheat due to water and temperature stress. Availability of genetic diversity in wheat offers opportunities for the breeders to develop genotypes with wider adaptability having resistance to biotic as well as abiotic stresses. Estimates of combining ability (general and specific) provide the platform to assess genetic potential of different quality characters under consideration. Combining ability describes the breeding value of parental lines to produce hybrids (Romanus *et al*., 2008).

This study was conducted to find out effective parents and their crosses having good combining ability in terms of quality traits under both normal and heat stressed conditions. The outcomes of this study could be exploited for the development of new cultivars with desirable quality attributes.

MATERIALS AND METHODS

The germplasm (120 genotypes including some commercial varieties) was collected from Wheat Research Institute, AARI, Faisalabad. In the first year, 15 parents were selected by screening parameters like cell membrane thermostability, normalized difference vegetation index, canopy temperature depression and relative water content. The selected parents were crossed in Line × Tester mating fashion which yielded 50 crosses following the procedures described by Poehlman, 1959. In next cropping season, 50 F_1 hybrids and their 15 parents were sown in a randomized complete block design with three replications at Wheat Research Institute, Ayub Agriculture Research Institute (AARI) Faisalabad under normal and heat stressed conditions. Experimental material comprised of 50 crosses was generated using 10 lines viz., V-13248, MISR 1, SW89.5277, Shahkar-2013, Miraj-08, AARI-11, Faisalabad-08, V-13013, V-13241 and V-12103 and 5 testers viz., V-12056, Millat-11, Chenab-2000, ND643 and V-12082. The wheat plants were exposed to heat stress at the time of anthesis by covering the tunnel with the plastic sheet. Temperature was recorded on daily basis both inner and outer side of the tunnel and 5°C rise in temperature was noted inside the tunnel. The gross plot size having six rows, each of six-meter length was kept at 30 cm distance between rows. Normal agronomic and cultural practices were applied to the experiment throughout the growing season.

Quality traits like protein contents, starch contents, ash percentage, moisture contents, gluten contents, and test weight were determined following the standard protocols of Approved Methods of the American Association of Cereal Chemists (AACC., 2000) by method numbers 46-12, 22-08, 08-01, 44-15A, 38-12A and 55-10 respectively.

The data collected for quality parameters was subjected to analysis of variance to determine significant differences among the genotypes under normal and heat stress conditions (Steel *et al*., 1997). Data for further analysis was subjected to Line × Tester analysis as described by Kempthorne (1957).

RESULTS

The analysis of variance revealed highly significant differences among all the genotypes for all quality characters under study, which indicated the presence of wide genetic diversity among the genotypes (Table 1). According to Griffing, (1956) the general combining ability is usually associated with additive type of gene action while specific combining ability refers to non-additive type of gene action. The estimates of general combining ability (GCA) and specific combining ability (SCA) variances are represented in Table 2 and Table 3, respectively.

Table 1. Analysis of variance for different quality traits in *Triticum aestivum* L. involving 10×5 L × T mating design under both normal and heat stressed conditions.

SOV	DF	Protein		Moisture		Starch		Ash		Gluten		Test Weight	
		Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress
Rep.	2	9.49**	8.25**	0.27*	0.91	32.56**	32.81**	0.0115*	1.92*	29.13**	23.77**	0.296	0.12
Gen.	64	4.08**	4.10**	0.31**	0.69**	2.79**	2.50**	0.1250**	0.09**	21.18**	20.33**	38.36**	30.29**
Parents	14	3.20**	3.03**	0.15*	0.12	3.52**	2.52**	0.0240**	0.02**	33.11**	22.16**	11.66**	5.91**
Crosses	49	4.39**	4.48**	0.23**	0.73**	2.61**	2.47**	0.0709**	0.062**	18.20**	20.13**	14.75**	12.84**
P. vs Cross	1	1.08**	0.42*	6.40**	6.51**	1.52*	3.57**	4.1915**	2.38**	0.03	4.36	1569.2**	1226.9**
Lines	9	5.36**	5.48**	0.23**	0.68**	4.42**	3.16**	0.0690**	0.053	15.14**	16.26**	6.28**	11.90*
Testers	4	4.74**	4.24**	0.30**	0.70*	2.89**	0.83	0.086**	0.102**	13.34**	31.63**	14.77**	21.68**
L × T	36	4.10**	4.25**	0.23**	0.74**	2.13**	2.48**	0.0629**	0.059**	19.51**	19.82**	16.86**	12.06**
Error	128	0.06	0.06	0.07	0.21	0.26	0.468	0.0029	0.028	2.33	3.63	1.31	2.39

Table 2. Estimates of GCA effects of 15 parents for quality traits under both normal and heat stressed conditions.

Parents	Protein		Moisture		Starch		Ash		Gluten		Test Weight	
	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress
V-13248	-0.47**	-0.43**	-0.04	-0.26**	0.56**	-0.03	-0.02	-0.06**	-0.97*	-1.68**	-0.22	1.00**
MISR 1	1.06**	1.07**	0.04	0.13	0.5**	0.39*	0.01	0.01	-0.62	-0.4	0.18	0.04
SW89.5277	0.73**	0.72**	-0.1	0.31**	0.38**	0.27	0.06**	0.04*	0.11	0.01	-0.04	0.83*
Shahkar-13	-0.18*	-0.22**	-0.06	-0.08	-0.87**	-0.98**	-0.13**	-0.04*	0.39	0.4	0.39	-0.69
Miraj-08	0.19**	0.11	0.14	-0.03	-0.02	-0.13	-0.07**	0.01	-0.88*	-0.9	-0.84*	-0.9*
AARI-11	0.4**	0.49**	0.18*	0.04	0.42**	0.27**	0.02	0.05*	-0.59	-0.59	0.74*	0.64
Faisalabad-08	-0.57**	-0.58**	-0.04	-0.03	0.44**	0.71	-0.06**	-0.05*	1.41**	1.46**	0.44	1.25**
V-13013	-0.82**	-0.83**	-0.07	0.12	-0.58**	-0.05	-0.03*	-0.08**	1.21**	1.11*	-1.34**	-1.17**
V-13241	0.02	0.01	-0.2**	-0.31**	-0.7**	-0.31	0.12**	0.06**	-1.26**	-0.65	0.15	-0.9*
V-12103	-0.34**	-0.35**	0.16*	0.10	-0.10	-0.14	0.11**	0.05*	1.21**	1.28*	0.52	-0.11
V-12056	-0.33**	-0.32**	0.11*	-0.1	0.49**	0.2	0.05**	-0.01	0.79*	0.93**	-0.66**	-1.15**
Millat-11	0.57**	0.56**	0.07	-0.05	-0.11	0.03	-0.06**	-0.01	0.38	0.65	0.93**	-0.3
Chenab-2000	0.26**	0.21**	-0.03	0.00	-0.32**	-0.26*	-0.05**	0.05**	-0.91**	-1.25**	-0.49*	0.82**
ND643	-0.29**	-0.27**	-0.15**	0.16**	-0.15	-0.03	0.01	-0.02	-0.4	-0.97**	-0.34	0.86**
V-12082	-0.22**	-0.18**	0.00	-0.01	0.08	0.06	0.06**	-0.02	0.14	0.65	0.55*	-0.23

For protein, out of 15 parents, eight genotypes represented negative but significant GCA values for both normal and heat stress environment while five parents showed highly positive significant GCA effects under both conditions. One parent (V-13241) showed non-significant results and one parent (Miraj-08) depicted significant under normal whereas non-significant for stress condition. Among parents, MISR1 (1.06 and 1.07) represented highest significant positive GCA variances and performed better under both normal and heat stressed conditions for protein contents (Table 2). The highest negative significant value was observed in V-13103 (-0.82 and -0.83) under both conditions. Among 50 crosses for protein, 21 showed highly significant values whereas negative significant effects observed in 19 different crosses. Non-significant effects were depicted in seven crosses and rest three crosses showed some mixed type of results under both environments. Among crosses, SCA showed maximum positive significant value for cross AARI-11 × V-12082 (2.29 and 2.16) while highest negative significant effect was showed in AARI-11 × V-12056 (-2.25 and -2.10) (Table 3). High dominance estimates from additive variance showed presence of non-additive gene action for protein in both environments.

In case of moisture, out of 15 parents AARI-11, V-12103 and V-12056 showed positive significant values while rest of all represented non-significant and negative significant values under normal conditions. Under heat stress condition, SW89.5277 and ND643 represented positive significant effects under heat stress and rest all other showed undesirable results for this trait. Genotype SW89.5277 (0.31) depicted maximum positive significant GCA value for moisture percentage among parents under high temperature stress while for normal conditions AARI-11 (0.18) had highest positive GCA effects (Table 2). Under normal climatic conditions Faisalabad-08 × ND643 (0.51) showed peak value for SCA while Shahkar-2013 × V-12082 (0.95) exhibited peak positive significant value among all crosses under heat stress as shown in Table 3. Dominance type of gene action was observed for moisture contents for normal as well as heat stress condition.

For starch, five parents showed non-significant GCA effects under both normal and stress environment. MISR1 and AARI-11 only showed only positive significant results under normal and heat stressed condition rest all have results that have no acceptance. Among 15 diverse parents, higher positive GCA estimates were identified in MISR1 (0.50 and 0.39) under both normal and heat stress environments for starch contents (Table 2). For SCA cross V-13241 × Millat-11 (1.21 and 1.26) (Table 3) showed relatively higher positive SCA estimates and three cross combinations represent negative significant effects under both conditions. Higher estimates of SCA than GCA represent Non-additive type of gene action for this trait in normal as well as heat stress conditions.

Ash represent mineral contents of flour. Three parents SW89.5277, V-13241 and V-12103 showed positive highly significant values for ash while rest of all showed undesirability of results for ash contents. Among parents, V-13241 (0.12 and 0.06) displayed that higher GCA variance (Table 2) for ash percentage among parents under both environmental conditions. Among different crosses, V-13013 × ND643 (0.23 and 0.33) represented peak positive significant values of SCA for ash contests in both environments (Table 3). For ash, only six crosses depicted positive significant effects for normal and heat stress. Analysis revealed dominance type of gene action prevailed due to greater SCA than GCA.

For making of bread, gluten is most important property that contribute towards maintenance of dough shape when baked. Among 15 parents, only four parents (Faisalabad-08, V-13013, V-12103 and V-12056) showed positive significant results under both normal and stress climatic conditions. Five parents (MISR1, SW89.5277, Shahkar-13, AARI-11 and V-12082) represent non-significant results for GCA under both

Table 3. Estimates of SCA for different quality traits in *Triticum aestivum* L. under normal and heat stressed conditions.

Crosses	Protein		Moisture		Starch		Ash		Gluten		Test Weight	
	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress	Normal	Heat Stress
V-13248 × V-12056	0.03	-0.28	-0.05	0.19	1.25**	-1.18**	0.02	0.01	0.08	0.22	-1.40	-0.90
V-13248 × Millat-11	-0.82**	-0.86**	0.02	0.56**	-1.55**	-0.41	0.06	0.01	2.47**	2.84**	1.08	-0.52
V-13248 × Chenab-2000	0.09	0.09	0.29	-0.18	0.16	0.58	-0.03	0.24**	1.22	-1.08	0.37	2.43**
V-13248 × ND643	1.14**	1.57**	-0.33**	-0.21	-0.31	0.05	-0.15**	-0.15**	0.27	1.47	-2.81**	-3.01**
V-13248 × V-12082	-0.43**	-0.52**	0.06	-0.37**	0.46	0.96**	0.10**	-0.11**	-4.04**	-3.46**	2.76**	1.98*
MISR 1 × V-12056	1.25**	1.22**	-0.2	0.12	-1.49**	-1.20**	0.15**	-0.07	-2.82**	-1.97	1.24	0.63
MISR 1 × Millat-11	0.35**	0.02	0.11	-0.09	0.81**	0.67	0.00	-0.16**	-1.37	-3.39**	-2.25**	-1.45
MISR 1 × Chenab-2000	-0.64**	-0.61**	-0.22	-0.1	0.02	-0.04	-0.16**	0.13**	0.44	0.51	2.08**	0.76
MISR 1 × ND643	0.21	0.17	0.03	0.15	0.75**	0.63	-0.16**	-0.02	0.93	1.23	2.10**	1.50
MISR 1 × V-12082	-1.16**	-0.81**	0.28	-0.08	-0.08	-0.06	0.17**	0.11**	2.82**	3.61**	-3.17**	-1.45
SW89.52277 × V-12056	0.27	0.27	-0.16	0.08	-0.17	0.12	-0.02	-0.03	-2.99**	-3.13**	-3.48**	-0.30
SW89.52277 × Millat-11	-0.12	-0.11	0.05	-0.27	-0.77**	-0.91**	-0.24	-0.13**	2.42*	2.15	1.73**	2.96**
SW89.52277 × Chenab-2000	0.98**	1.04**	0.09	0.39**	0.34	0.28	-0.02	0.09**	-1.29	-0.95	0.83	-1.26
SW89.52277 × ND643	0.34**	0.31**	-0.4**	-0.13	0.67**	0.55	0.21**	0.03	-0.8	-0.23	-0.26	1.65
SW89.52277 × V-12082	-1.47**	-1.50**	0.42**	-0.07	-0.06	-0.04	0.07**	0.03	2.66**	2.15	1.18	-3.05**
Shahkar-2013 × V-12056	-0.72**	-0.69**	0.00	-0.33	0.57	0.87**	-0.09**	0.22**	2.98**	3.26**	0.13	-0.07
Shahkar-2013 × Millat-11	-1.88**	-1.84**	0.17**	-0.32	-1.43**	-1.57**	0.11**	-0.05	-2.86**	-3.23**	0.47	-3.22**
Shahkar-2013 × Chenab-2000	0.89**	0.98**	-0.39**	-0.51**	0.28	0.23	0.04	-0.01	3.43**	3.67**	-0.83	1.26
Shahkar-2013 × ND643	1.34**	1.19**	0.32	0.21	0.72**	0.60	-0.15**	-0.13**	-0.93	-0.46	-2.38**	-1.51
Shahkar-2013 × V-12082	0.37**	0.37**	-0.09	0.95**	-0.15	-0.12	0.10**	-0.04	-2.62**	-3.23**	2.62**	3.53**
Miraj-2008 × V-12056	1.1**	1.28**	0.04	0.21	0.23	0.52	-0.09**	-0.01	-0.85	-1.07	4.53**	3.20**
Miraj-2008 × Millat-11	1.02**	1.10**	0.11	0.07	0.33	0.19	0.08**	0.14**	2.15**	2.21*	-3.16**	-1.87**
Miraj-2008 × Chenab-2000	-1.79**	-2.15**	-0.39	0.41**	0.04	-0.02	-0.01	-0.19**	-0.30	-0.04	-1.83**	-0.93
Miraj-2008 × ND643	-0.82**	-0.77**	0.33	-0.26	-0.93**	-1.05**	0.12**	-0.04	-0.66	-0.17	0.85	0.03
Miraj-2008 × V-12082	0.5**	0.54**	-0.08	-0.44**	0.34	0.36	-0.11**	0.10**	-0.35	-0.94	-0.38	-0.43
AARI-11 × V-12056	-2.25**	-2.10**	0.03	0.12	-0.81**	-0.48	0.09**	0.06	3.70**	3.48**	-1.36	-1.45
AARI-11 × Millat-11	0.71**	0.91**	-0.03	-0.24	0.79**	0.69	-0.10**	0.06	-0.88	-1.24	-2.31**	2.06**
AARI-11 × Chenab-2000	0.31**	0.27	-0.03	-0.16	-0.6**	-0.62	0.18**	-0.05	-0.22	0.48	3.71**	1.26
AARI-11 × ND643	-1.05**	-1.24**	-0.08	0.49**	0.93**	1.95**	-0.23**	-0.08	-1.11	-0.62	1.03	-0.76
AARI-11 × V-12082	2.29**	2.16**	0.11	-0.2	-0.30	-1.54**	0.06	0.02	-1.49	-2.09	-1.07	-1.12
Faisalabad-08 × V-12056	-0.73**	-0.73**	0.22	-0.26	0.17	0.26	0.04	-0.06	-2.29**	-2.57*	-2.15**	0.27
Faisalabad-08 × Millat-11	0.98**	0.99**	-0.35**	-0.02	0.17	0.16	0.01	-0.10**	1.63	1.92	3.53**	2.05*
Faisalabad-08 × Chenab-2000	-0.72**	-0.66**	0.26	0.01	0.58	0.14	0.12**	0.14**	1.41	1.61	-0.88	-1.56
Faisalabad-08 × ND643	-0.30	-0.32**	0.51**	-0.06	-0.79**	-0.08	-0.01	0.13**	2.90**	3.33**	-0.26	-0.52
Faisalabad-08 × V-12082	0.76**	0.73**	-0.64**	0.33	-0.12	-0.48	-0.16**	-0.10**	-3.64**	-4.29**	-0.23	-0.24
V-13013 × V-12056	0.03	0.02	0.04	-0.1	0.36	0.64	0.04	-0.02	-1.09	-1.22	3.69**	0.62
V-13013 × Millat-11	-0.37**	-0.36**	0.25	0.58**	0.63**	0.31	0.13**	-0.01	1.32	1.05	0.27	-2.20*
V-13013 × Chenab-2000	0.54**	0.59**	0.25	-0.22	1.09**	0.40	-0.13**	-0.31**	-1.39	-1.04	-1.41	1.41
V-13013 × ND643	0.39**	0.37**	-0.33**	0.32	-1.67**	-2.43**	0.23**	0.33**	-2.41**	-1.84	-1.72**	0.76
V-13013 × V-12082	-0.58**	-0.62**	-0.21	-0.59**	-0.41	1.08**	-0.27**	0.01	3.57**	3.06**	-0.82	-0.59
V-13241 × V-12056	1.89**	1.88**	0.04	0.17	-0.09	0.20	-0.04	-0.15**	2.38**	1.54	1.44**	0.38
V-13241 × Millat-11	0.39**	0.40**	-0.26	-0.06	1.21**	1.26**	0.12**	0.19**	-3.21**	-0.18	1.15	2.41**
V-13241 × Chenab-2000	0.8**	0.85**	0.05	-0.01	-1.38**	-0.63	-0.07**	0.06	-0.92	-0.95	-2.83**	-3.49**
V-13241 × ND643	-1.75**	-1.77**	0.26	-0.18	-0.05	-0.67	0.09**	0.05	2.72**	-2.23**	0.02	-0.14
V-13241 × V-12082	-1.32**	-1.36**	-0.08	0.09	0.32	-0.16	-0.1**	-0.15**	-0.97	1.82	0.23	0.84
V-12103 × V-12056	-0.85**	-0.86**	0.04	-0.2	0.00	0.24	-0.11**	0.05	0.91	1.46	-2.64**	-2.39**
V-12103 × Millat-11	-0.25	-0.24	-0.05	-0.22	-0.16	-0.37	-0.17**	0.05	-1.68	-2.12	-0.49	-0.23
V-12103 × Chenab-2000	-0.44**	-0.39**	0.09	0.38**	-0.51	-0.31	0.10**	-0.10**	-2.39**	-2.21**	0.80	0.12
V-12103 × ND643	0.51**	0.49**	-0.3	-0.34**	0.65**	0.46	0.04	-0.12**	-0.90	-0.49	3.45**	1.99**
V-12103 × V-12082	1.04**	1.00**	0.22	0.37**	0.01	-0.02	0.14**	0.13**	4.05**	3.37	-1.11	0.52

conditions. For gluten, Faisalabad-08 (1.41 and 1.46) among parents proved to be the best and had highest positive significant GCA effects for both normal and heat stress environments as revealed in Table 2. Some persons are gluten intolerant and they face celiac disease due to allergic interaction with gluten. In celiac disease, human body is unable to digest that form of gluten because of autoimmune reaction. For such kind of persons, lesser amount of gluten or gluten free flour is being recommended. In the present experiment negative significant effect was observed in two parents (V-13248 and Chenab-200) and highest negative significant value was revealed by V-13248 (-0.97 and -1.68) under normal and heat stress conditions. Therefore, considering allergic patients, flour of wheat genotype V-13248 could be recommended, which has lesser gluten. Among crosses, Shahkar-13 × Chenab-2000 (3.43 and 3.67)

Table 4. Estimation of genetic components of variation under normal and heat stress conditions.

Traits	Normal condition				Heat stress condition			
	∂ GCA	∂ SCA	Additive V (D)	Dominance V (H)	∂ GCA	∂ SCA	Additive V (D)	Dominance V (H)
Protein	0.0042	1.3455	0.0168	5.3818	0.0033	1.3965	0.0132	5.5861
Moisture	0.0001	0.0533	0.0003	0.2131	0.0002	0.1028	0.0009	0.4110
Starch	0.0072	0.6204	0.0286	2.4815	-0.0002	0.6594	-0.0007	2.6377
Ash	0.0001	0.0199	0.0005	0.0797	-0.0001	0.0183	-0.0004	0.0734
Gluten	-0.0193	5.5642	-0.0772	22.2569	0.0046	5.4042	0.0185	21.6168
Test Weight	-0.0313	5.1042	-0.1251	20.4166	0.0110	3.3061	0.0442	13.2244

∂ GCA = Estimate of GCA variance, ∂ SCA = Estimate of SCA variance.

Table 5. Proportional Contribution of Lines, Testers and their Interaction under normal and heat stress conditions.

Traits	Normal Condition			Heat stress condition		
	Contribution of Lines	Contribution of Tester	Contribution of L x T	Contribution of Lines	Contribution of Tester	Contribution of L x T
Protein	22.46	8.81	68.73	22.46	7.74	69.80
Moisture	17.76	10.24	71.99	23.11	6.12	70.77
Starch	31.11	9.04	59.86	23.44	2.76	73.80
Ash	24.89	9.93	65.18	14.26	3.80	81.94
Gluten	15.28	5.98	78.74	14.84	12.83	72.33
Test Weight	7.82	8.18	84.00	17.02	13.78	69.20

(Table 3) held relatively higher positive significant results while eight hybrids have negative significant and nine crosses possess positive significant results under both conditions. These results concluded that higher estimates of SCA than GCA estimates represent the presence of dominance gene action for gluten parentage in wheat for both conditions.

Test weight provide information about flexibility to survive a genotype in an environment. Positive significant GCA values of test weight normally is desired while negative and non-significant values are undesirable for this trait. Under normal conditions three parents, (AARI-11, Millat-11 and V-12082) showed positive significant results. While all other showed non-significant or negative results. For heat stress environment, five parents represented positive significant values namely V-13248, SW88.5277, Faisalabad-08, Chenab-2000 and ND643. Under heat stressed conditions, Faisalabad-08 (1.25) showed maximum positive significant results while for normal Millat-11 (0.93) had higher GCA value for test weight (Table 2). SCA was higher for cross, Miraj-2008 × V-12056 (4.53 and 3.20) both normal and heat stressed conditions (Table 3).

From 50 crosses six crosses showed positive significant SCA values while four crosses have negative significant values under both normal and stress conditions. Dominance type of gene action was observed for test weight under normal and high temperature stressed conditions.

***Estimation of genetic components of variation*:** The magnitudes of SCA variances were higher than GCA for all characters in both normal and heat stressed conditions for all the traits as shown in Table 4. The results revealed that non-additive genetic variance played a predominant role in the inheritance of all traits in this study.

***Contribution of lines, testers and their interaction towards character expression*:** Proportional contribution of lines, testers and their interaction studied for traits expression and their phenotypic differences were observed for all traits. Under both normal and heat stressed conditions lines showed more contribution for different traits viz, protein, starch and ash, while L × T interaction showed greater contribution for moisture, gluten and test weight. Tester showed minimum contribution for all the traits under study (Table 5).

DISCUSSION

Generally, for an autogamous crop like wheat, a study of segregating population for specific combining ability (SCA) would be important. In the present study, the SCA effects in both normal and heat stressed conditions (Table 3) were greater than GCA. Different stages of wheat like anthesis and grain filling stage severely affected by heat stress and have impact on nutritional quality of wheat (Rasaei *et al.*, 2017). Traits related with quality, such as, protein, starch, ash, moisture, gluten, and test weight had high magnitude of SCA effects showing predominant role of non-additive gene action. Among different parents, MISR1, Faisalabad-08 and V-13241 were outperformer (excellent performer) for protein, starch, ash and gluten so utilization of these genotypes for exploitation in hybrid breeding. Among different parents, 3 parents such as MISR1, Faisalabad-08 and V-13241 were outperformer (excellent performer) for protein contents, starch contents, ash percentage and gluten contents, so the utilization of these genotypes for exploitation in hybrid breeding is recommended. Genotype V-13248 showed highest negative effects for gluten content which showed suitability of this genotype in gluten intolerant patients. Crosses, AARI-11 × V-12082, V-13241 × Millat-11 and V-13013 × ND64 with good specific combining ability effects may further be exploited for the establishment of segregating populations.

For protein, Kraljevic-Balalic *et al.* (1982) reported non-additive type of gene action and the present study also showed similar kind of results, while Joshi *et al.* (2004), Lysa (2009) and Akram *et al.* (2011) observed additive type of gene action for protein.

In case of moisture contents, Barnard *et al.* (2002) reported non-additive type of gene action. Dominance type of gene action was observed for ash percentage, various scientists like Padhar *et al.* (2010), Adel and Ali (2013) found similar results. Gami *et al.* (2011), reported contradictory results for ash content.

For gluten contents, non-additive gene action was observed. These results are in line with previous studies (Padhar *et al*., 2010; Adel and Ali, 2013). Literature also reported over dominance type of gene action (Gami, *et al.,* 2011) which is contradictory to the present investigation for gluten contents. For test weight, non-additive genetic effect has been previously reported (Singh, 2003; Chaman *et al.,* 2005; Heidari *et al.,* 2006; Kumar *et al*., 2011; Singh *et al.,* 2012), which is in accordance to the results of this experiment. Due to heat stress, there was decrease in test weight due to compressed growth period and Kumar *et al.* (2013) observed similar results of grains shrinking in wheat. Gooding *et al.* (2002) found indirect relation between wheat quality traits and grain yield under high temperature stress. High temperature stress causes alteration of grain quality due to reduction in grain weight at grain filling stage that disturb photosynthesis of plant for grain development, accumulation and synthesis of starch in grain (Bhullar and Jenner 1985). Short exposure of heat stress has no drastic affects but prolonged stress to wheat cause severe yield and quality loss in genotypes.

Conclusions**:** There is a dire need for the development of heat tolerant wheat genotypes with improved quality that can perform well under both stress as well as non-stress conditions. The results of this study depicted that among parents based on their GCA effects under both normal and heat stress conditions, three genotypes, MISR1, Faisalabad-08 and V-13241 depicted good general combiners for most of the traits under consideration. From 15 genetically diverse parents, V-13248 appeared as best genotype for the patients having gluten intolerance problem. The estimated value of SCA effects from all crosses for some desirable quality trait in both normal and heat stressed environments involving combination of hybrids AARI-11 × V-12082, V-13241 × Millat-11 and V-13013 × ND64 were favorable for most of quality traits. Hence, these selected parents and crosses can be utilized in future breeding programmes for overall improvement of quality parameters.

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