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Combining Ability Analysis of Various Yield Components for Drought Tolerance in *Zea mays* L.

[1]Hafiz Mahboob Ahamed, [1]Muhammad Ahsan, [1]Saif-ul-Malook,
[3]Saeed Ahmad Qasrani, [1]Muhammad Umer Ali, [2]Zubair Aslam,
[1,5]Babar Farid, [1]Muhammad Naeem Yousaf and [4]Muhammad Sohail

[1]Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan
[2]Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.
[3]Department of Environmental Sciences,
COMSATS Institute of Information Technology, Vehari, Punjab, Pakistan
[4]Department of Agronomy, University of Agriculture Faisalabad, Pakistan
[5]Department of Plant Breeding and Genetics,
Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan

Abstract: Drought is a major issue for low yield in Pakistan as well as in the world. The yield of maize hybrid is higher than the open pollinated varieties. Eight maize genotypes (M14, A50-2, A509, A545, A638, A239, A521-1, A556) were assessed under normal and drought conditions. Results indicated that the female parent M14 and A50-2 and male parent A521-1 were best general combiners under normal condition. The female A509 and male parent A521-1 proved to be best general combiner under water stress conditions. Among crosses M14 x A521-1 was the best specific combiner under normal conditions and under water stress conditions M14 x A556 proved to best as a specific combiner. It was concluded that the parental genotypes M14, A509, A50-2 and A521-1 and crosses M14 x A521-1, A509 x A556 and M14 x A556 can be used for further breeding programs.

Key words: *Zea mays* · Breeding · Drought · Genotypes · GCA · SCA

INTRODUCTION

Maize (*Zea mays* L.) is world's leading cereal crop with added importance for countries like Pakistan where population is rapidly increasing. Maize is third important cereal in Pakistan after wheat and rice. Maize is a tropical plant but it is also adapted to subtropical and temperate regions of the world. It becomes the significant crop of the world due to multi-locational adaptability. Maize accounts for 2.20 % of value of agriculture and 0.5% to GDP. Its area of production in Pakistan is 1085 thousand hectares with annuals production of 4631 thousand tons and yield per hectare is 4268 tons. Production increased 6.8 % over last year due to use of hybrid varieties at large area [1]. Maize is dual purpose crop such as food for human and feed for livestock and poultry and also used as industrial raw material for manufacture of different products in different food industries. It has highest crude protein (6.0-10%) from early stages to maturity, starch 72 %, protein 10 %, oil 4.80 %, sugar 3.0 % and endosperm 82 % [2].

Maize is grown twice in a year i.e. spring and autumn. The production per hectare is low in spring season because of high temperature that effects the pollination and seed setting in maize. Its main contribution to fulfill the dietary needs of country especially the summer season due to short duration crop and large production of grains per unit area. It contains oil 1.4% and ashes 1.7% [3].

Crop productivity is limited due to abiotic stresses [4]. Among different abiotic stresses drought is one of the most undesirable factor effecting the growth and yield of crop plant. The crop production with improved tolerance under stresses especially drought is one of the

Corresponding Author: Saif-ul-Malook, Department of Plant Breeding and Genetics, University of Agriculture Faisalabad Pakistan.

vital force for world food security [5]. Extra maize production from water scarce "marginal" areas of Pakistan is the need of time, which require proliferation of drought tolerant maize varieties producing comparatively better yield in drought conditions [6].

Production of maize in Pakistan is low as compared to other countries due to biotic and abiotic stresses. Drought is major problem for low production in Pakistan as well as in the world. The yield of maize hybrid is more than the open pollinated varieties. But the farmers in most countries do not use hybrid seed due to high cost of hybrid seed. It is needed to increase the production by producing local low cost hybrids that perform better in water deficit conditions. To produce hybrids it is needed to collect information about germplasm diversity, combining ability and heterotic pattern that is essential in maximizing the effectiveness of the breeding programs.

Combining abilities and heritability analysis are useful tools to select better inbred lines for the development of desirable hybrids. General combining ability indicated average performance of parental lines as reflected in its hybrid combinations and specific combining ability indicates average performance of specific cross. Higher GCA indicates additive gene effects and higher SCA indicates the dominance gene effects. If both GCA and SCA are non-significant then it indicates that epistatic gene effects play role for studying traits [7].

There are highly significant differences among yield and yield related traits like ear length, kernel rows per ear, 100 grain weight and grain yield observed by parents and their crosses. General and specific combining ability were also observed by using Line x tester analysis [8]. The present study was conducted for evaluation of maize inbred lines for various yield component traits under both normal and water stress condition.

MATERIALS AND METHODS

The experiment was conducted in the research area of Department of Plant Breeding and Genetics research area, University of Agriculture, Faisalabad, during the spring season 2013 for estimation of combining ability. Five inbred lines of maize viz. M14, A50-2, A509, A545, A638 used as female parents and three testers A239, A521-1 and A556 used as male parents had crossed in spring season 2013. Necessary precautions had taken to avoid the contamination of genetic material at the time of crossing. These crosses were grown in the autumn season 2013.

The F_1 seeds had sown at 50 % irrigation as compared to normal irrigation to create water stress environment and also sown in normal conditions. A randomized complete block design with two replications had adopted for its sowing plan. Each genotype had grown keeping plant-plant and rows-rows distances as 25 cm and 75 cm, respectively. Two seeds had sown in each hole and after germination one healthy seedling had retained by thinning the germinated seedlings. Non experimental plants had sown at the border to avoid the edge and border effects. All standard agronomic practices like hoeing, weeding, irrigation, fertilizer etc. had been adopted uniformly to reduce the experimental error. Each male parent was crossed with each female parent according to line ×tester mating system. The hybrids seeds (F_o) obtained from crosses along with their parents were sown under normal conditions and 50% water stress conditions in the field of experimental area during crop season July 2013 according to randomized complete block design involving two replications. Total number of irrigation were given to the field were eight and four irrigations were given to the drought area. Each replication comprised of 15 crosses and 8 parental genotypes. After the crop attained maturity, five guarded plants from each row were selected and data were recorded at an appropriate time for yield related morphological traits. Data for following traits were recorded such as plant plant height (cm), leaves per plant, fifth leaf area (cm^2), flag leaf area (cm^2), Internodal length (cm), cob girth (mm).,cob length, rows per cob, 100 grains weight, kernals per row, kernals per cob.

Statistical Analysis: The data thus recorded were subjected to analysis of variance (Steel *et al*., 1997) [9] in order to determine the genotypic differences for studied traits. Data were further subjected to line × tester analysis according to Kempthorne (1957) [10]. Genetic components, heritability and GA of each trait were also computed in Tables (7) and (8).

Estimation of Genetic Components:

- Environmental Variance

Ve= MSE

- Genotypic Variance

Vg = MSG

- Phenotypic Variance

$Vp = Vg + Ve$

- Genotypic Co-efficient of Variation

$GCV = (Vg/Gm) \times 100$

- Phenotypic Co-efficient of Variance

$PCV = (Vp/Gm) \times 100$

- Heritability

$H = Vg/Vp$

- Genetic Advance %age

$GA\%age = (GA/Gm) \times 100$

RESULTS AND DISCUSSION

Analysis of Variance: The analysis of variance for all traits under normal conditions presented in Table 1 and under drought conditions presented in Table 2. Plant height showed highly significant differences among parents vs crosses, genotypes, crosses, parents, lines and testers under normal as well as drought conditions. Highly significant differences among the parent vs crosses, genotypes, crosses and lines but there are non-significant differences among the parents, testers and interaction between lines and testers for number of leaves per plant under normal conditions and under drought conditions Number of leaves per plant showed highly significant differences among the parent vs crosses, genotypes, crosses and parents but there are non-significant differences among the lines and testers. Flag leaf area and 5th leaf area also exhibit highly significant differences among the parent vs crosses, genotypes, crosses, parents, lines and testers under normal as well as drought conditions. Internodal length, ear girth and ear length highly significant differences among the parent vs crosses, genotypes, crosses, parents and lines under normal as well as drought conditions. Under normal conditions internodal length, ear girth and ear length showed highly significant differences among the testers but under drought conditions only intermodal length shows significant differences occur among the testers. Number of ear rows also showed high significant differences among the parent vs crosses, genotypes, crosses lines and interaction between the lines and testers but there are non-significant differences among the parents and testers under normal condition and drought conditions. However, there are non-significant differences among the crosses, lines, testers and interaction between the lines and testers. 100-grain weight, number of grains per ear row and grain yield per plant exhibit highly significant differences among the parent vs crosses, genotypes, crosses, lines and testers and interaction between lines and testers under normal as well as drought conditions.

General Combining Ability (GCA): General combining ability effects for all traits are showed in Tables 3 and 4. General combining ability was partitioned into both male and female parents for different characters to search out the potential parents for further breeding programs to assess variation among parents.

Plant Height: In case of plant height, highly positive GCA effects were recorded for the parent M14 (12.65) followed by genotype A50-2. Under normal irrigation these two lines M14 and A50-2 showed positive general combining ability effects but other three lines A509, A545 and A638 have GCA -5.55, -5.84 and -9.23, respectively. The tester A521-1 showed highest positive GCA (7.05) but other two testers A239 and A556 showed negative GCA values of -1.26 and -5.78, respectively. In case of plant height under water stress conditions highly positive GCA was recorded for parent A521-1 (12.86) followed by A638 (9.71). The lines A638, A50-2 and A509 showed positive GCA values of 9.71. 4.81 and 0.99, respectively and the lines M14 and A545 showed negative GCA values of -10.37 and -5.14, respectively. The tester A521-1 showed positive GCA of 12.86 and A239 and A556 showed negative GCA -10.91 and -1.95, respectively. On the basis of higher GCA we can prove that line A638 and tester A521-1 are best combiners under drought conditions [11-19].

Number of Leaves per Plant (cm): According to the number of leaves per plant (Table 4) highly positive GCA effects were recorded for the parent A509 (0.67) followed by genotype A239 (0.33). Under normal irrigation, the lines M14, A50-2, A509 and A545 showed positive general combining ability effects of 0.17, 0.17, 0.67 and 0.17 but line A638 have GCA -1.17, respectively.

The tester A239 showed highest positive GCA (0.33) but other two testers A521-1 and A556 showed negative GCA effects of -0.27 and -0.07, respectively. When studying GCA effects for number of leaves per plant under water stress conditions, highly positive GCA was

Table 1: Mean square values from ANOVA of yield and its components in maize under normal conditions

S.O.V	df	PH	LPP	5th LA	100-GW	EG	EL	FLA	ER	IL	GPER	GYPP
Replications	1	2.80	0.09	0.23	0.04	1.49	0.14	0.54	0.35	0.06	0.54	153.39
Genotypes	22	582.82	1.07	11209.99	28.30	18.75	7.74	2771.57	3.66	4.03	66.11	14947.96
Parents	7	896.73	0.57	16601.09	22.62	14.33	7.23	3018.49	1.57	3.23	43.71	8475.78
Crosses	14	341.31	1.19	7741.01	21.96	12.96	5.37	2833.02	3.61	4.17	67.90	13111.77
P. vs Crosses	1	1766.58	2.81	22038.10	156.66	130.68	44.54	182.89	19.14	7.63	197.83	85959.98
Lines	4	560.08	2.83	13910.60	43.51	24.41	12.94	4533.98	4.45	4.44	133.08	22658.45
Testers	2	423.48	0.93	18093.77	11.90	20.19	4.56	962.60	2.54	5.64	93.03	19772.40
L x T	8	211.39	0.43	2068.02	13.70	5.43	1.78	2450.14	3.45	3.67	29.03	6673.28
Error	22	4.42	0.36	10.96	0.05	0.41	0.30	7.62	0.98	0.08	14.04	580.85
Total	45	287.16	0.70	5485.81	13.86	9.40	3.93	1358.73	2.28	2.01	39.20	7595.27

PH = plant height, LPP= Number of leaves per plant, 5th LA= 5th leaf area, 100-GW= 100-grain weight, EG= ear girth, EL= ear length, FLA= flag leaf area, ER= Number of ear rows, IL= Internodal length, GPER= grains per ear row, GYPP= grain yield per plant.

Table 2: Mean square values from ANOVA of yield and its components in maize under50% drought conditions

S.O.V	df	PH	LPP	5th LA	100-GW	EG	EL	FLA	ER	IL	GPER	GYPP
Replications	1	15.71	2.28	1.17	0.16	1.39	3.11	0.37	0.09	0.02	3.13	350.63
Genotypes	22	663.62	1.58	4634.21	23.09	23.56	6.91	3157.00	4.78	3.42	121.63	25758.45
Parents	7	412.62	1.71	7475.33	16.54	24.46	13.40	3706.07	6.54	1.07	117.96	34615.78
Crosses	14	580.52	1.25	2816.55	27.72	13.21	2.60	2317.80	3.28	3.74	114.92	18368.13
P. vs Crosses	1	3583.94	5.42	10193.63	4.14	162.23	21.73	11062.39	13.60	15.22	241.25	67221.59
Lines	4	378.39	1.11	4382.91	18.52	15.32	2.36	3319.68	0.47	6.69	100.97	16139.12
Testers	2	1441.57	0.89	5466.37	22.95	0.96	2.43	1343.79	1.73	10.66	168.13	36571.60
L x T	8	466.33	1.41	1370.91	33.52	15.21	2.76	2060.36	5.07	0.54	108.59	14931.77
Error	22	3.13	0.47	8.36	0.49	0.26	0.66	2.75	1.91	0.04	6.90	500.95
Total	45	326.31	1.05	2269.73	11.53	11.68	3.77	1544.78	3.27	1.69	62.91	12845.72

PH = plant height, LPP= Number of leaves per plant, 5th LA= 5th leaf area, 100-GW= 100-grain weight, EG= ear girth, EL= ear length, FLA= flag leaf area, ER= Number of ear rows, IL= Internodal length, GPER= grains per ear row, GYPP= grain yield per plant

Table 3: Estimation of general combining abilityeffects for some morphological traits in Zea mays under Normal conditions

SOV	PH	LPP	5th LA	FLA	IL	EG	EL	ER	100-GW	GPER	GYPP
Lines											
M14	12.65	0	78.01	47.11	0.84	2.5	2.18	1.13	3.94	-3	-5.03
A-50-2	7.96	0	-35.07	-11.02	-0.48	-1.49	-0.59	0.13	0.94	5.17	82.47
A-509	-5.55	1	-20.65	-13.47	-1.11	-0.14	-0.12	-0.2	-0.36	1.33	15.8
A-545	-5.84	0	14.18	-22.37	-0.12	1.49	0.36	0.13	-3.33	-6.5	-89.53
A-638	-9.23	-1	-36.47	-0.25	0.88	-2.36	-1.84	-1.2	-1.19	3	-3.7
Testers											
A239	-1.26	0	47.07	-3.61	-0.84	1.64	-0.19	-0.13	0.27	0.03	-2.8
A521-1	7.05	0	-35.69	-7.5	0.22	-0.75	-0.56	0.27	0.93	3.03	45.8
A-556	-5.78	0	-11.37	11.1	0.61	-0.88	0.75	-0.13	-1.2	-3.07	-43

Table 4: Estimation of general combining ability for some morphological traits in Zea mays under 50% water stress conditions

SOV	PH	LPP	5th LA	FLA	IL	EG	EL	ER	100-GW	GPER	GYPP
Lines											
M14	12.65	0	78.01	47.11	0.84	2.5	2.18	1.13	3.94	-3	-5.03
A-50-2	7.96	0	-35.07	-11.02	-0.48	-1.49	-0.59	0.13	0.94	5.17	82.47
A-509	-5.55	1	-20.65	-13.47	-1.11	-0.14	-0.12	-0.2	-0.36	1.33	15.8
A-545	-5.84	0	14.18	-22.37	-0.12	1.49	0.36	0.13	-3.33	-6.5	-89.53
A-638	-9.23	-1	-36.47	-0.25	0.88	-2.36	-1.84	-1.2	-1.19	3	-3.7
Testers											
A239	-1.26	0	47.07	-3.61	-0.84	1.64	-0.19	-0.13	0.27	0.03	-2.8
A521-1	7.05	0	-35.69	-7.5	0.22	-0.75	-0.56	0.27	0.93	3.03	45.8
A-556	-5.78	0	-11.37	11.1	0.61	-0.88	0.75	-0.13	-1.2	-3.07	-43

PH= Plant Height, EL= Ear Length, LPP= Number of leaves per plant, FLA = Flag Leaf Area, 5thLA= 5th Leaf Area, ER= Number of Ear Rows, 100-GW= 100- grain weight, IL= Internodal Length, EG=Ear Girth, GPER=Grains per Ear Row, GYPP=Grain Yield Per Plant recorded for parents M14 (0.30), A50-2 (0.30) and A638 (0.30). The lines A638, A50-2 and M14 showed positive GCA effects of 0.30, 0.30 and 0.30 respectively and the lines A509 and A545 showed negative GCA effects of - 0.37 and -0.53, respectively, The tester A521-1 showed positive GCA effects of 0.27 and A239 and A556 showed negative GCA -0.13 and -0.13 respectively [20-24].

Fifth Leaf Area (cm^2): The GCA values for 5th leaf area under normal conditions are given in Table 3. Highly positive GCA effects was recorded for the parent M14 (78.01) followed by genotype A239. Under normal irrigation the lines M14 and A545 showed positive general combining ability effects of 78.01 and 14.18 but lines A50-2, A509 and A638 have GCA effects of -35.07, -20.65 and -36.47, respectively.

The tester A239 showed highest positive GCA (47.07) but other two testers A521-1 and A556 showed negative GCA effects of –35.69 and -11.37, respectively. The study under water stress conditions highly positive GCA effects was recorded for parents A509 (25.09), A545 (21.59) and A50-2 (9.30). The lines A509, A545 and A50-2 showed positive GCA values of 25.09, 21.59 and 9.30, respectively and the lines M14 and A638 showed negative GCA effects of -37.27 and -18.72, respectively. The tester A239 and A521-1 showed positive GCA effects of 18.72 and 7.48, respectively. A556 showed negative GCA -26.21. On the basis of higher GCA we can prove that line A509, A545 and tester A239 and A521-1 are best positive combiners under drought conditions [23].

Flag Leaf Area (cm^2): Highly positive GCA effects for flag leaf area was recorded for the parent M14 (47.11) followed by genotype A556. Under normal irrigation the line M14 showed positive general combining ability effects of 47.11 but lines A50-2, A509, A545 and A638 have negative GCA effects of -11.02, -13.47, -22.37 and -0.25, respectively. The tester A556 showed highest positive GCA (11.10) but other two testers A239m and A521-1 showed negative GCA effects of –3.61 and -7.50, respectively.

The parents that showed high GCA under water stress are A50-2 (25.27), A638 (18.49) and A509 (3.70). The lines A50-2, A545 and A638 showed positive GCA effects of 25.27, 18.49 and 3.70, respectively and the lines M14 and A545 showed negative GCA effects of -16.92 and -30.54, respectively. The tester A239 and A521-1 showed positive GCA effects of 9.18 and 3.85, respectively. A556 showed negative GCA -13.03. On the basis of higher GCA we can prove that line A50-2, A638 and tester A239 and A521-1 are best positive combiners under drought conditions [22, 11, 12, 25, 24].

Internodal Length (cm): The GCA effects for all traits under normal conditions are given in Table 4.23. Highly positive GCA effects for intermodal length were recorded for the parent A638 (0.88) followed by genotype M14 (0.84). Under normal irrigation the lines M14 and A638 showed positive general combining ability effects of 0.88 and 0.84 but lines A50-2, A509 and A545 have negative GCA effects of -0.48, -1.11 and -0.12, respectively. The testers A556 and A521-1 showed highest positive GCA values of (0.61) and 0.22 but the tester A239 showed negative GCA effects of –0.84, respectively.

According to recorded data the highly positive GCA was recorded for parents A509 (1.03), A521-1 (1.08) and A50-2 (0.83). The lines A50-2, A509 and A638 showed positive GCA effects of 0.83, 1.03 and 0.13, respectively and the lines M14 and A545 showed negative GCA effects of -1.60 and -0.39, respectively The tester A521-1 showed positive GCA effects of 1.08, respectively. A239 and A556 showed negative GCA effects of -0.98 and -0.10. On the basis of higher GCA we can prove that line A509, A50-2 and tester A521-1 are the best positive combiners under drought conditions. The trait that show higher GCA are used as selection criteria so we can say that Intermodal length can be used as selection criterion to develop a drought tolerant synthetic variety. These results are in accordance to various researchers [14, 26, 27].

Ear Girth (mm): GCA effects for cob girth was recorded for the parent M14 (2.50) followed by genotype A239 (1.64). Under normal irrigation the lines M14 and A545 showed positive general combining ability effects of 2.50 and 1.49 but lines A50-2, A509 and A638 have negative GCA effects of -1.49, -0.14 and -2.36, respectively. The tester A239 showed highest positive GCA effects of (1.64) but the tester A521-1 and A556 showed negative GCA values of –0.75 and -0.88, respectively.

The study under water stress conditions revealed that the highly positive GCA effects for cob girth was recorded for parents A545 (1.50), A50-2 (0.80) and A239 (0.24). The lines A50-2, A545 and A638 showed positive GCA effects of 0.80, 1.50 and 0.39, respectively and the lines M14 and A509 showed negative GCA effects of -2.68 and -0.01, respectively. The tester A239 and A556 showed positive GCA value of 0.24 and 0.11 respectively. A521-1 showed negative GCA effects of -0.35. On the basis of higher GCA we can prove that line A545 and tester A239 are the best positive combiners under drought conditions. On the basis of higher GCA under drought conditions we can say that cob girth may be used as selection criterion to develop a drought tolerant synthetic variety [14, 15].

Ear Length (cm): For cob length, highly positive GCA effects were recorded for the parent M14 (2.18) followed by genotype A556 (0.75). Under normal irrigation, the lines M14 and A545 showed positive general combining ability effects of 2.18 and 0.36 but lines A50-2, A509 and A638 have negative GCA effects of -0.59, -0.12 and -1.84, respectively. The tester A556 showed highest positive GCA effects of (0.75) but the tester A239 and A521-1 showed negative GCA effects of –0.19 and -0.56, respectively. According to recorded data under water stress conditions highly positive GCA effects were recorded for parents A638 (0.98), A239 (0.56) and A509 (0.10). The lines A638 and A509 showed positive GCA effects of 0.98 and 0.10, respectively and the lines M14, A50-2 and A545 showed negative GCA effects of -0.10, -0.72 and -0.27 respectively The tester A239 showed positive GCA value of 0.56. A521-1 and A556 showed negative GCA effects of -0.35 and -0.21. On the basis of higher GCA we can prove that line A638 and tester A239 are the best positive combiner under drought conditions [28, 24, 15, 17].

Number of Ear Rows: Highly positive GCA effects for number of ear rows was recorded for the parent M14 (1.13) followed by genotype A521-1 (0.27). Under normal irrigation, the lines M14, A50-2 and A545 showed positive general combining ability effects of 1.13, 0.13 and 0.13 but lines A509 and A638 have negative GCA values of -0.12 and -1.20, respectively. The tester A521-1 showed highest positive GCA effects of (0.27) but the tester A239 and A556 showed negative GCA values of –0.13 and -0.13 respectively. Number of ear rows under water stress conditions showed highly positive GCA effects for parents M14 (0.40), A521-1 (0.33). The lines M14, A50-2 and A638 showed positive GCA effects of 0.40, 0.07 and 0.07, respectively and the lines A509 and A545 showed negative GCA effects of -0.27 and -0.27, respectively. The tester A521-1 and A556 showed positive GCA value of 0.33 and 0.13. A239 showed negative GCA effects of -0.47. We can suppose that line M14 and tester A521-1 are the best positive combiners under drought conditions. These results show that this trait may be used as selection criterion to develop a drought tolerant variety [29, 30, 16, 17, 26, 27].

100-Grains Weight: In case of 100- grain weight, highly positive GCA effects were recorded for the parent M14 (3.94) followed by genotype A50-2 (0.94). Under normal irrigation the lines M14 and A50-2 showed positive general combining ability effects of 3.94 and 0.94 but lines A509, A545 and A638 have negative GCA effects of -0.36, -3.33 and -1.19, respectively. The tester A239 and A521-1 showed highest positive GCA effects of (0.27) and (0.93) but the tester A556 showed negative GCA values of -1.20 respectively. Under water stress conditions highly positive GCA effects for 100-grain weight were recorded for parents A509 (2.17), A521-1 (1.73). The lines A509 and A545 showed positive GCA effects of 2.17 and 1.20, respectively and the lines M14, A50-2 and A638 showed negative GCA effects of -2.30, -0.13 and -0.95, respectively. The tester A521-1 showed positive GCA effects of 1.73. A239 and A556 showed negative GCA effects of -1.09 and -2.30. The line A509 and tester A521-1 are the best positive combiner under drought conditions [30, 31, 19, 16, 17].

Number of Grains per Ear Row: The GCA effects was recorded for number of grains per ear row. Highly positive GCA effects was recorded for the parent A50-2 (5.17) followed by genotype A521-1 (3.03). Under normal irrigation the lines A50-2, A509 and A638 showed positive general combining ability effects of 5.17, 1.33 and 3.00 but lines M14 and A545 have negative GCA effects of -3.00 and -6.50, respectively. The tester A239 and A521-1 showed positive GCA effects of (0.03) and (3.03) but the tester A556 showed negative GCA values of -3.07, respectively. According to GCA recorded data under water stress conditions the highly positive GCA effects for number of grains per ear row was recorded for parents A638 (5.57), A509 (3.23) and A521-1 (4.07). The lines A509 and A638 showed positive GCA effects of 3.23 and 5.57, respectively and the lines M14, A50-2 and A545 showed negative GCA effects of -2.93, -2.77 and -3.10, respectively. The tester A521-1 and A239 showed positive GCA effects of 4.07 and 0.07. A556 showed negative GCA value of -4.13. The line A638 is the best positive combiners under drought conditions. Higher GCA for this trait indicated that it may be used as selection criterion to develop a drought tolerant synthetic variety. These results are in accordance to Hamid et al. 1995 [32].

Table 5: Estimation of Specific combining ability for some morphological traits in *Zea mays* under normal conditions

CROSSES	PH	LPP	5th LA	FLA	IL	EG	EL	ER	100GW	GPER	GYPP
M14 × A239	2.27	-0.17	-9.14	-0.69	0.34	-1	-0.75	-0.53	1.58	-3.2	-64.37
A50-2 × A239	-10.93	-0.07	0.22	2.8	-1.25	2	1.22	1.07	0.87	-1.7	17.53
A-509 ×A-239	8.66	0.23	8.92	-2.11	0.91	-1.01	-0.47	-0.53	-2.45	4.9	46.83
A-545×A4239	-15.44	-0.17	-21.07	-16.88	-0.66	-0.33	-0.55	-0.53	-1.57	-3.37	-66.37
A-638 ×A239	10.71	0.43	50.59	-32.16	0.63	0.05	-0.39	0.07	-2.78	0.13	10.03
M14 ×A521-1	4.73	-0.27	-29.52	49.05	0.02	0.28	0.94	0.47	4.35	3.23	56.33
A502×A521-1	-0.68	0.33	-11.29	24.16	-0.76	-0.65	0.22	0.8	-1.67	0.97	37.8
A509×A521-1	1.51	-0.57	-31.1	19.36	1.66	-1.26	-0.63	0.4	2.47	0.47	22.7
A545×A521-1	-0.82	0.23	42.39	-43.52	-0.9	1.92	0.41	-1.2	-0.8	-1.43	-60.5
A638×A521-1	9.41	-0.17	17.11	28.99	1.51	1.6	0.65	0.47	-0.05	1.8	45.63
M14×A-556	-6.15	-0.07	-9.61	-9.89	-0.1	0.39	-0.83	0.07	-0.61	-0.7	-16.47
A50-2×A-556	-3.26	0.23	-7.5	-19.1	-1.4	-1.99	0.19	-0.53	0.67	-1.1	-29.17
A-509×A556	4.45	0.17	24.39	-35.57	-0.44	0.38	0.44	-0.2	1.71	3.8	47.3
A-545×A-556	4.86	0.27	-10.1	19.89	-0.93	-1.18	0.63	-1.6	0.06	1.8	-33.8
A-638×A-556	-9.31	-0.43	-14.3	15.68	1.37	0.79	-1.07	1.8	-1.77	-5.6	-13.5

Table 6: Estimation of Specific combining ability for some morphological traits in Zea mays under 50% water stress conditions

CROSSES	PH	LPP	5th LA	FLA	IL	EG	EL	ER	100GW	GPER	GYPP
M14 × A239	23.56	0.8	19.49	5.18	0.55	-2.18	0.8	0.8	-6.79	1.93	47.57
A50-2 × A239	-18.95	0.4	-11.83	-24.81	-0.31	0.77	-1.1	-1	4.06	-0.57	-30.83
A-509 ×A-239	-4.6	-1.2	-7.66	19.63	-0.24	1.41	0.3	0.2	2.74	-1.37	-16.73
A545×A4239	5.47	0.3	35.96	42.69	0.19	3.76	1.3	1.13	-0.21	0.77	42.07
A-638 ×A239	-6.15	-0.1	-7.93	1.61	-0.3	-3.24	-0.5	-0.67	-2.41	-6.23	-107.83
M14 ×A5211	0.68	-0.2	-28.03	-44.3	0.11	-0.52	-0.8	-0.47	2.62	5.47	65.77
A502×A5211	1.04	-0.53	-8.56	-11.74	0.24	2.77	-0.36	-1.53	5.24	1.27	-32.1
A509×A5211	4.71	0.07	-1.5	-2.18	0.36	-1.28	0.73	2.67	-1.36	-8.73	-41.5
A545×A5211	-5.74	0.47	10.06	13.93	-0.6	-1.49	-0.37	-1.13	-3.88	7.47	73.6
A638×A5211	-10.43	-0.37	-11.1	-44.24	-0.76	-2.14	0.19	-0.53	-0.14	1.1	-0.27
M14×A-556	10.87	-0.77	-6.43	26.51	0.34	1.83	0.07	0.67	-0.14	5.6	100.83
A50-2×A-556	-0.44	1.13	17.54	17.73	0.42	0.31	-0.26	-0.13	0.29	-6.7	-100.57
A-509×A556	-19.63	-0.2	-35.79	8.11	-0.22	-2.21	-1.92	0.13	1.91	-5.07	-57.27
A-545×A-556	9.52	0.4	27.7	-1.13	-0.09	1.92	0.8	-1.67	-0.14	9.93	79.33
A-638×A-556	10.11	-0.2	8.09	-6.99	0.31	0.29	1.12	1.53	-1.76	-4.87	-22.07

PH = plant height, LPP= Number of leaves per plant, 5th LA= 5th leaf area, 100-GW= 100-grain weight, EG= ear girth, EL= ear length, FLA= flag leaf area, ER= Number of ear rows, IL= Internodal length, GPER= grains per ear row, GYPP= grain yield per plant

In water stress conditions the positive SCA effects were found in cross combination A50-2 × A556 (1.13), M14 × A239 (0.80), A545 × A521-1 (0.47). A50-2 × A239 (0.40), A545 × A556 (0.40), A545 × A239 (0.30) and A509 × A521-1 (0.07). All other crosses exhibited negative SCA effects ranging from -1.20 (A509 × A239) to -0.10 (A638 × A239). These findings are according to Abdelmula and Sabiel. 2007 [37].

Grain Yield per Plant: The GCA effects for grain yield per plant under normal conditions are given in Table 4 Highly positive GCA effects was recorded for the parent A50-2 (82.47) followed by genotype A521-1 (45.80). Under normal irrigation the lines A50-2 and A509 showed positive general combining ability effects of 82.47 and 15.80 but lines M14, A545 and A638 have negative GCA effects of -5.03, -89.53 and -3.70, respectively. The tester A521-1 showed positive GCA value of (45.80) but the testers A556 and AA239 showed negative GCA effects of -43.00 and -2.80, respectively. Under water stress conditions highly positive GCA was recorded for parents A638 (73.47), A509 (35.80) and A521-1 (65.00). The lines A509 and A638 showed positive GCA effects of 35.80 and 73.47, respectively and the lines M14, A50-2 and A545 showed negative GCA effects of -31.37, -33.37 and -44.53, respectively. The tester A521-1 showed positive GCA value of 65.00. A239 and A556 showed negative GCA effects of -10.40 and -54.60. The line A638 and tester A521-1 show higher GCA results under drought conditions. This trait may be useful in next breeding program. These results are in accordance to Hussain and Aziz (1998) [28].

Specific Combining Ability (SCA): Specific combining ability effects provide information about potential hybrids. Specific combining ability effects of various yield component traits under normal conditions as well as 50% water stress conditions is presented in Table 5-6.

Plant Height: The positive SCA effects for plant height under normal conditions were shown by eight out of fifteen crosses. The cross A638 × A239 (10.71) and A638 × A521-1 (9.41) showed highest SCA effects and A545 × A239 showed lowest SCA (-15.44) under normal conditions. Under water stress conditions the highest SCA were shown by M14 × A239 (23.56) and M14 × A556 (10.87) and negative SCA effects were shown by A509 × A556 (-19.63) and A50-2 × A239. On the basis of these results that in the development of drought tolerant hybrid, the selection of high yield maize genotypes may be useful that had high SCA value for plant height under water stress condition [33, 34, 35, 31, 36, 15].

Number of Leaves per Plant: For number of leaves per plant the positive SCA effects under normal condition were found in cross combination A638 × A239 (0.43), A50-2 × A521-1 (0.33), A509 × A239 (0.23), A545 × A521-1 (0.23), A50-2 × A556 (0.23), A545 × A556 and A509 × A556 (0.17). All other crosses exhibited negative SCA effects ranged from -0.57 (A509 × A521-1) to -0.07.

Fifth Leaf Area (cm^2): There are six crosses that showed positive SCA effects for 5th leaf area under normal conditions out of fifteen crosses. The crosses that showed positive SCA effects were namely as A50-2 × A239 (0.22), A509 × A239 (8.92), A638 × A239 (50.59), A545 × A521-1 (42.39), A638 × A521-1 (17.11) and A509 × A556 (24.39). All the other crosses exhibited negative SCA effects ranging from -31.10 (A509 × A521-1) to -7.50 (A50-2 × A556). In water stress conditions the cross A545 × A239 (35.96) and A545 × A556 (27.70) exhibited highly positive SCA effects for 5th leaf area. The crosses that showed negative SCA effects were A50-2 × A239, A509 × A239, A638 × A239, M14 × A521-1, A50-2 × A521-1, A509 × A521-1, A638 × A521-1, M14 × A556 and A509 × A556 with values -11.83, -7.66, -7.93, -28.03, -8.56, -1.50, -11.10, -6.43 and -35.79 [29, 38, 39, 40].

Flag Leaf Area: In case of flag leaf area the highly positive SCA effects under normal conditions were shown by cross combinations M14 × A521-1 (49.05) and A638 × A521-1 (28.99) and the lowest positive effects was found by cross combination A50-2 × A239 (2.80). The cross combinations that had negative SCA effects under normal conditions ranged from -43.52 (A545 × A521-1) to -0.69 (M14 × A239). Under water stress conditions the highly positive SCA effects for flag leaf area were found by cross combination A545 × A239 (42.69), M14 × A556 (26.51) and A509 × A239 (19.63). Similarly the negative SCA effects under water stress conditions ranged from -44.30 (M14 × A521-1) to -1.13 (A545 × A556). On the basis of these results that in the development of drought tolerant hybrid, the selection of high yield maize genotypes may be useful who's had high SCA value for flag area under water stress condition. Higher SCA values under drought condition indicated that flag leaf area may be useful for selection of drought tolerant hybrids [31].

Internodal Length (cm): The highly positive SCA effects for intermodal length were shown by cross combinations A509 × A521-1 (1.66), A638 × A521-1 (1.51), A638 × A556 (1.37) and A509 × A239 (0.91). The negative SCA effects ranged from -1.40 (A50-2 × A556) to -0.10 (M14 × A556). Under water stress conditions the cross combinations that showed positive GCA effects were M14 × A239 (0.55), A545 × A239 (0.19), M14 × A521-1 (0.11), A50-2 × A521-1 (0.24), A509 × A521-1 (0.36), M14 A556 (0.34), A50-2 × A556 (0.42) and A638 × A556 (0.31). The cross combination that showed negative SCA effects ranged from -0.76 (A638 × A521-1) to -0.09 (A545 × A556).

Ear Girth: There are eight crosses were found positive SCA effects for ear girth under normal conditions out of fifteen crosses. The crosses that showed positive SCA effects were A50-2 × A239 (2.00), A638 × A239 (0.05), M14 × A521-1 (0.28), A545 × A521-1 (1.92), A638 × A521-1 (1.60), M14 × A556 (0.39), A509 × A556 (0.38) and A638 × A556 (0.79). All the other crosses exhibited negative SCA effects ranging from -1.99 (A50-2 × A556) to -0.33 (A545 × A239). In water stress conditions, the cross A545 × A239 (3.76) and A50-2 × A521-1 (2.77) exhibited highly positive SCA effects for 5th leaf area. The crosses that showed negative SCA effects were A50-2 × A239, A509 × A239, A638 × A239, M14 × A521-1, A50-2 × A521-1, A509 × A521-1, A638 × A521-1, M14 × A556 and A509 × A556 with values of -11.83, -7.66, -7.93, -28.03, -8.56, -1.50, -11.10, -6.43 and -35.79 [41-44].

Ear Length: For ear length highly positive SCA effect under normal conditions were found by cross combinations, A50-2 × A239, M14 × A521-1, A50-2 × A521-1, A545 × A21-1, A638 × A521-1, M14 × A556 and A638 × A556. The negative SCA effects ranged from -1.07 (A638 × A556) to -0.39 (A638 × A239). In water stress condition the highly positive SCA effects were shown by cross combinations, A545 × A239 (1.30), A638 × A556 (1.12), M14 × A239 (0.80) and A545 × A556. Some cross combinations showed negative SCA effects like A509 × A556 (-1.92), A50-2 × A239 (-1.10), M14 × A521-1 [45, 44].

Number of Ear Rows: For number of ear rows the positive SCA effects under normal condition were shown in cross combinations A638 × A239 (0.07), A50-2 × A521-1 (0.80), A50-2 × A239(1.07, M14 × A521-1 (0.47), A509 × A521-1 (0.40), A638 × A521-1 (0.47) and M14 × A556 (0.07). All other crosses exhibited negative SCA effects ranged from -1.60 (A545 × A556) to -0.20 (A509 × A556). In water stress conditions, the positive SCA effects were found in cross combinations M14 × A239 (0.80), A509 × A239 (0.20), A545 × A239 (1.13), A509 × A521-1 (2.67), M14 × A556 (0.67), A509 × A556 (0.13) and A638 × A556 (1.53). All other crosses exhibited negative SCA effects ranging from -1.67 (A545 × A556) to -0.13 (A50-2 × A556). Results were similar with Kanagarasu et al. 2010 and Masekha S and J. Ishaaq. 2012 [41, 18].

100-Grain Weight: In case of 100 grain weight, the highly positive SCA effects under normal condition were shown by cross combinations M14 × A521-1 (4.35) and A509 × A521-1 (2.47) and the lowest positive effects was shown by cross combination A545 × A556 (0.06). The cross combination that have negative SCA effects under normal conditions ranged from -2.78 (A638 × A239) to -0.05 (A638 × A521-1). Under water stress conditions the highly positive SCA effects for 100-grain weight were found by cross combinations A50-2 × A521-1 (5.24), A50-2 × A239 (4.06) and A509 × A239 (2.74). Similarly the negative SCA effects under water stress conditions ranged from -6.79 (M14 × A239) to -0.14 (A545 × A556). For the development of drought tolerant hybrid, the selection of high yield maize genotypes may be useful that had high SCA value for 100-grain weight under water stress condition [41, 46, 12, 44].

Grains per Ear Row: Different cross combinations have highly positive SCA effects under normal conditions like A509 × A239 (4.90), A509 × A556 (3.80) and M14 × A521-1 (3.23) etc. Some crosses have negative SCA effects like A638 A556 (-5.60) and A545 × A239 (-3.23) etc. Under water stress conditions the highly positive combiner cross combinations are A545 ×A556 (9.93), A545 × A521-1 (7.47), M14 × A556 (5.60) and M14 A521-1 (5.47) etc. Some negative combiners were also presented in Table 4.26 like A509 × A521-1 (-8.73). [30, 12, 47].

Grain Yield per Plant: Grain yield per plant is a important parameter for selection of best hybrids. For the selection of drought tolerant hybrids we use hybrids that have high SCA effects for grain yield under water stress. The highly positive SCA effects under normal conditions were exhibited by cross combinations M14 × A521-1 (56.33), A509 × A556 (47.30), A509 × A239 (46.83) and A638 × A521-1 (45.63). The negative SCA effects ranged from -64.37 (M14 × A239) to M14 × A556 (-0.70). Under water stress conditions the highly positive combiner cross combinations are M14 × A556 (100.83), A545 × A521-1 (73.60), M14 × A521-1 (65.77) and A545 × A556 (79.33). The negative SCA effects ranged from -100.57 (A50-2 × A556) to -0.27 (A638 × A521-1). On the basis of these results that in the development of drought tolerant hybrid, the selection of high yield maize genotypes may be useful that had high SCA value for grain yield per plant under water stress conditions. These results are in accordance to Mhike *et al*. 2011 [45].

Genetic Components: The results depicted that higher heritability (98.5%) and genetic advance (265.878%) for plant height was reported and which showed that there may be additive or dominance effects was present so genotypes may be used for synthetic as well as hybrid breeding program. Phenotypic coefficient of variance and genotypic coefficient of variance had little difference which depicted that an environmental effect was very low under normal conditions. It was suggested that selection for plant height may be fruitful for breeding program. The results showed that low heritability (50%) was observed for number of leaves per plant while very low genetic advance (4.08%) was calculated under normal conditions. Due to low heritability and genetic advance there are narrow dominance and additive gene effects which showed that selection for this traits is useless for breeding program. Under drought conditions, high heritability (65%) and lowest genetic advance (6.45%) was reported that depicted the dominance effect of genes. It was suggested that inbred lines can be used for development of synthetic varieties under drought conditions. In case of 5^{th} leaf area phenotypic variance has minute difference from genotypic variance. It indicated that role of environment is very low. The high heritability (99.7%) and genetic advance (1059.820%) for 5^{th} leaf area were reported which showed that there may be additive or dominance effects so genotypes for 5^{th} leaf area may be used for synthetic as well as hybrid breeding program. It was shown from results that higher heritability (99.4%) and genetic advance (2290.181%) for flag leaf area was reported and which showed that there may be additive or dominance effects was present so genotypes for flag leaf area may be used for synthetic as well as

Table 7: Estimation of genetic components for some morphological traits in Zea mays under normal conditions

Genetic components	PH	LPP	5th LA	FLA	IL	EG	CL	ER	100GW	GPER	GYPP
Environmental variance	4.418	0.36	10.963	7.65	0.083	0.4	0.299	0.98	0.047	14.044	580.864
Genotypic variance	289.2	0.35	5599.518	1381.334	1.974	9.17	3.72	1.34	14.124	26.033	7183.545
Phenotypic variance	293.618	0.71	5610.482	1388.984	2.057	9.58	4.019	2.32	14.171	40.077	7764.409
Genotypic coefficient of variance	149.79	2.3	1194.335	1290.243	15.291	59.54	23.885	8.7	46.982	80.97	1585.317
Phenotypic coefficient of variance	152.079	4.63	1196.673	1297.388	15.933	62.16	25.805	15.09	47.137	124.649	1713.506
Heritability %	98.5	50	99.8	99.4	96	96	92.6	58	99.7	65	92.5
Genetic advance %	265.878	4.08	2119.944	2290.181	27.142	105.68	42.396	15.44	83.393	143.721	2813.937

Table 8: Estimation of genetic components for some morphological traits in Zea mays under 50% water stress conditions

Genetic components	PH	LPP	5th LA	FLA	IL	EG	EL	ER	100GW	GPER	GYPP
Environmental variance	3.13	0.46	7.896	2.75	0.038	0.26	0.664	1.905	0.494	6.903	500.955
Genotypic variance	330.25	0.56	2313.393	1577.036	1.689	11.65	3.121	1.439	11.299	57.363	12628.75
Phenotypic variance	333.37	1.02	2321.289	1579.786	1.727	11.91	3.785	3.344	11.793	64.266	13129.71
Genotypic coefficient of variance	2144.05	3.63	597.082	1515.07	14.205	75.65	21.012	10.373	73.358	218.433	3457.279
Phenotypic coefficient of variance	2164.33	6.65	599.12	1517.712	14.523	77.32	25.482	24.109	76.566	244.72	3594.422
Heritability %	99	55	99.7	99.8	97.8	98	82.5	43	95.8	89.3	96.2
Genetic advance %	329.057	6.45	105.982	268.9249	25.215	134.28	37.297	18.412	130.21	387.719	613.6671

PH = plant height, LPP= Number of leaves per plant, 5th LA= 5th leaf area, 100-GW= 100-grain weight, EG= ear girth, EL= ear length, FLA= flag leaf area, ER= Number of ear rows, IL= Internodal length, GPER= grains per ear row, GYPP= grain yield per plant

hybrid breeding program. The results showed the higher value of heritability (99.7%) and genetic advance (268.9249%) for flag leaf area. Higher flag leaf area may be used to select higher yielding maize genotypes under drought conditions. The results showed that high heritability (96%) and low genetic advance (27.142%) for fresh root intermodal length was reported. It was depicted that traits were controlled by dominance type of gene action. Phenotypic coefficient of variance and genotypic coefficient of variance had little difference which depicted that an environmental effect was very low under normal condition. It was suggested that selection for 100-grain weight may be fruitful for breeding program. The higher value of heritability (97.90%) and genetic advance (131.634%) for 100-grain weight under drought showed that higher 100-grain weight may be used to select higher yielding maize genotypes under drought conditions. The results showed that higher heritability (92.5%) and genetic advance (281.3937%) for grain yield per plant was reported which showed that there may be additive or dominance effects were present so genotypes for grain yield per plant may be used for synthetic as well as hybrid breeding program. The results showed the higher value of heritability (97.90%) and genetic advance (131.634%) for grain yield per plant under drought conditions showed that higher grain yield per plant may be used to select higher yielding maize genotypes under drought conditions [48, 22, 49, 37, 41, 45].

CONCLUSIONS

It was persuaded that the female inbred parent M14 and A50-2 and male inbred parent A521-1 were best general combiner under normal conditions. The female parent A509 and male parent A521-1 proved to be best general combiners under water stress conditions. It was observed that among crosses M14 x A521-1 was the best specific combiners under normal condition and under water stress conditions M14 x A556 proved to best the best specific combiners. It is concluded that the parental inbred lines M14, A509, A50-2 and A521-1 and crosses M14 x A521-1, A509 x A556 and M14 x A556 can be used to develop drought tolerant varieties.

REFERENCES

1. Anonymous, 2012-2013. Economic Survey of Pakistan. Govt. of Pakistan, Finance and Economic Affairs Division, Islamabad.
2. Chaudary, A.R., 1983. Maize in Pakistan. Punjab Agriculture Research Coordination Board, University of Agriculture Faisalabad.
3. Tahir, M., M.R. Javed, A. Tanveer, M.A. Nadeem, A. Wasaya, S.A.H. Bukhari and J.U. Rehman, 2008. Effect of different herbicides on weeds, growth and yield of spring planted maize (*Zea mays* L.). Pakistan Journal Life Sciences, 7: 168-174.

4. Araus, J., G.A. Slafer, M.P. Reynolds and C. Toyo, 2002. Plant Breeding and drought ic C_3 cereals, What should be breed for? Annals of Botany. 89:925-940. Doi: 10.1093/aob/mcf049.
5. Denby, K. and C. Gehring, 2005. Engineering drought and salinity tolerance in plants: lessons from genome wide expression profiling in Arabidopsis. Trends in Biotechnology, 23: 547-552.
6. Qayyum, A., S. Ahmad, S. Liaqat, W. Malikm, E. Noor, H. M. Saeed and M. Hanif. 2012. Screening for drought tolerance in maize (*Zea mays* L.) hybrids at any early seedling stage. African Journal of Agriculture Research, 24: 3594-3604. DOI: 10.5897/AJAR11.1475.
7. Fehr, W.R., 1993. Principles of Cultivar Development. 1. MacMillan Publ. Co. New York, USA.
8. Rahman, H., A. Ali, Z. Shah, M. Iqbal, M. Noor and M. Amanullah, 2013. Line X Tester Analysis for grain yield and yield related traits in maize variety Sarhad White. Pakistan Journal of Botany, 45: 383-387.
9. Steel, R.G.D., J.H. Torrie and D.A. Dickey, 1997. Principles and Procedures of statistics: A Biometrical Approach. 3rd ed. McGraw Hill Book Co., New York.
10. Kempthorne, O., 1957. An introduction to Genetic Statistics. John Wiley and Sons, New York.
11. Malik, S.I., H.N. Malik, N.M. Minhas and M. Munir, 2004. General and specific combining ability studies in maize diallel crosses. International Journal of Agriculture and Biology, 6: 856-859.
12. Pavan, R., V. Prakash, N. M. Mallikarjuna, 2011. General and specific combining ability studies in single cross of hybrids of maize. Current Biotechnology, 5: 196-208.
13. Haddadi, H.M, M. Eesmaeilof, R. Choukan and V. Rameeh, 2012. Combining ability analysis of days to silking, plant height, yield components and kernel yield in maize breeding lines. African Journal of Agriculture Research, 7: 5153-5159.
14. Saif-ul-Malook, Q. Ali, M. Ahsan, A. Mumtaz, 2014a. Genetic variability of maize genotypes under water stress and normal conditions. Researcher, 6: 31-37.
15. Saif-ul-Malook, Q. Ali, M. Ahsan and A. Mumtaz, 2014b. Inheritance of yield related traits in maize under normal and drought condition. Nature and Science, 12: 36-49.
16. Saif-ul-Malook, Q. Ali, M. Ahsan and A. Mumtaz, 2014d. An overview of conventional breeding for drought tolerance in Zea mays. Nature and Science, 12: 7-22.
17. Saif-ul-Malook, Q. Ali, A. Shakeel, M. Sajjad and I. Bashir, 2014c. Genetic variability and correlation among various morphological traits in students of UAF, Punjab Pakistan. 2014. International Journal of Advances in Case Reports, 1: 1-4.
18. Masekha, S. and J. Ishaaq, 2012. Combining ability analysis among Sudanese and IITA maize germplasm and Geizra research station. Journal of Applied Biosciences, 57: 4198-4207.
19. Mumtaz, A., H.A. Sadaqat, Saif-ul-Malook, A.S. Nazik and H.M. Ahamad, 2014. Genetic behavior of quality traits in Brassica rapa. Vegetose, 27: 139-145. 10.5958/2229-4473.2014.00081.0.
20. Ahamed, H.M., Saif-ul-malook, I. Ali, M.U. Ali, Z. Aslam, B. Farid, A. Mumtaz and M. Ahsan, 2015. Assessment of gene action to develop drought tolerance maize inbred lines. American-Eurasian J. Agric. And Environ. Sci., 15: 454-461.
21. Ali, F., 2012. Genetic studies based on conventional and molecular approach in *Zea mays* L. M. Sc. Thesis Department of Plant Breeding of Genetics, University of Agriculture Faisalabad.
22. Aliu, S., S. Fetahu, L. Rozman and A. Sallillari, 2008. General and specific combining ability studies for leaf area in some maize inbreds in agroecological conditions of Kosovo. Acta Agriculture Slovenica 91, 67-73.http://dx.doi.org/10.2478/v10014-008-0007-4.
23. Nouman, M., 2012. Combining ability estimates for grain yield and its components in maize (*Zea mays* L.) single crosses. M.Sc. Thesis Department of Plant Breeding and Genetics, University of Agriculture Faisalabad.
24. Zare, M., R. Choukanb, M.R. Bihamtac, E.M. Heravand and M.M. Kamelmaneshe, 2010. Gene actions for some agronomic traits in maize (*Zea mays* L.). Crop Breeding, 1: 133-141.
25. Saif-u-Malook, S.A. Qaisarani, M.K. Shabaz, H.G.M. Ahmed, M.A. Nawaz, M. Sarfaraz, G. Mustafa and A. Qurban. 2015. Mutation breeding approach to breed drought tolerant maize hybrids. International Journal of Biosciences, 6: 427-436. http://dx.doi.org/10.12692/ijb/6.2.427-436.
26. Sarfaraz M., Wasi-Ud-Din, M. Sajjad, M. Wajid, Saif-ul-Malook, M.K. Shabaz, H.M. Ahamed and H.S. Saeed, 2014a. Effect of Planting Time and Nitrogen Levels on various yield Components of Sunflower (*Helianthus annuus* L.). Nature and Science, 12: 19-28.

27. Sarfaraz, M., Wasi-Ud-Din, Saif-ul-Malook, M. Sajjad, A. Ali, A. Iram, G. Mustafa, M.K. Shabaz, H. Ahmed, T. Rahman, Samiullah, J. Ali, Junaid, S. Azam, S.A. Qasrani and Q. Ali, 2014b. Role of nitrogen and sowing date to improve yield of (*Helianthus annus* L.) to improve yield and oil contents. An overview. Int. J. Adv. Lif. Sci. (IJALS), 7(4): 691-698.
28. Hussain, M.R. and K. Aziz, 1998. Study of combining ability in maize through line × tester hybridization. Pakistan Journal of Biological Sciences, 1: 196-198.
29. Iqbal, M.A., F.A. Nahvi, S.A. Wani, R. Qadir and A.D. Zahoor, 2007. Combining ability analysis for yield and yield related traits in maize (*Zea mays* L.). International Journal of Plant Breeding and Genetics, 1, 101: 105.
29. Ahsan, M.A., M.Z. Hader, M. Saleem and M. Aslam, 2008. Contribution of various leaf morphological parameters towards grain yield in maize. International Journal of Agriculture and Biology, 10: 546-550.
30. Farooq, A., 2008. Analysis of some phsio-genetic parameters related to drought tolerance in maize. Msc. Thesis Department of Plant Breeding & Genetics. University of Agriculture Faisalabad.
31. Khan, M.B., N. Hussain and M. Iqbal, 2001. Effects of water stress on growth and yield components of maize variety YHS 202. Journal of Research, 12: 15-18.
32. Hamid, F., M. Saleem, A. Ahmad and A. Naveed, 1995. Combining ability for grain yield and its components in maize (*Zea mays* L.). Pak. J. Agric. Sci., 32: 168-171.
33. Cakir, R., 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field crop Research, 89: 1-16.
34. Camacho, G.R. and D.F. Caraballo, 1994. Evaluation of morphological characteristics in Venezuelan maize (*Zea mays* L.) genotypes under drought stress. Scientific Agriculture Piracicaba, 51: 453-458.
35. Jabeen, S., 2010. Estimation of combining ability and heterosis for the some economic parameters in maize. M. Sc. Thesis Dept. Plant Breed. Genet. Univ. Agri. Faisalabad.
37. Abdelmula and Sabiel, 2007. Genotypic and differential responses of growth and yield of some Maize (*Zea mays* L.) genotypes to drought stress. Conference on International ARS for Developing. University of Gottingen, Germany.
38. Amin, W. Saif-ul-Malook, A. Mumtaz, S. Ashraf, H.M. Ahmad, K. Hafeez, M. Sajjad and A. Bibi, 2014a. Combining ability analysis and effect of seed priming on seedling traits in Sunflower (Helianthus annuus). Report and Opinion, 6: 19-30.
39. Amin, W. Saif-ul-malook, S. Ashraf and A. Bibi, 2014b. A review of screening and conventional breeding under different seed priming conditions in sunflower (*Helianthus annuus* L.) Nature and Science, 12: 23-37.
40. Hussain I.M. Ahsan, M. Saleem and A. Ahmad, 2009. Gene action studies for agronomic traits in maize under normal and water stress conditions. Pak. J. Agric. Sci., pp: 46.
41. Kanagarasu, S., G. Nallatthambi and K.N. Ganesan, 2010. Combining ability analysis for yield and its component traitsin maize (*Zea mays* L.). Electronic Journal of Plant Breeding, 1: 915-920.
42. Mustafa G., Ehsanullah, Saif-ul-Malook, M. Sarfaraz, M.K. Shahbaz, U. Chopra and Q. Ali, 2014a. A review of production for various Bt and non Bt cotton varieties in Pakistan. Nature and Science, 12: 81-91.
43. Mustafa G., Ehsanullah, Saif-ul-Malook, E. Ahmad, M. Sarfaraz, S.A. Qaisarani and M.K. Shahbaz, 2014b. Yield attributes and productivity of various Bt and non Bt cotton varieties in Faisalabad environment. Nature and Science, 12: 92-103.
44. Wasif, A.H.M., 2008. Estimation of combining ability for various quantitative traits in Maize (*Zea mays* L.). M. Sc. Thesis Department of Plant Breeding and Genetics, University of Agriculture Faisalabad.
45. Mhike, X., D.M. Lungu and B. Vivek, 2011. Combining ability analysis amongst AREX and CIMMYT maize (*Zea mays* L.) inbred lines under stress and non-stress conditions. African Journal of Agriculture Research, 6: 1952-1957.
46. Mehmood, Z., S.R. Malik, R. Akhtar and T. Rafique, 2004. Heritibilities and genetic advance estimates from maize genotypes in shishi lusht a valley of karkurm. International Journal of Agricultural Biology, 5: 790-791.
47. Wali, C.M., R.M. Kachapur, C.P. Chadrashekar, V.R. Kulkarni and S.B. Devaaranavadagi, 2010. Gene action and Combining ability studies in single cross hybrids of maize (*Zea mays* L.). Karnataka Journal of Agricultural Science, 23: 557-562.

48. Alam, A.K.M.M., S. Ahmed, M. Begum and M.K. Sultan, 2008. Hetrosis and combining ability for grain yield and its contributing characters in maize. Bangladesh J. Agric. Res., 33: 375-379.
49. Amiruzzaman, M., M.A. Islam, L. Hasan, M. Kadir and M.M. Rohman, 2013. Hetrosis and combining ability in a diallel among elite inbred lines of maize (*Zea mays* L.). Plant Sci., 25: 132-137.