Journal of Research in Agricultural Science
Vol. 6 (2010), pages:19-28

Estimation of Combining Ability and Gene Action in Maize Using Line × Tester Method under Three Irrigation Regimes

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Received:23 April 2009 Accepted:25 February 2010

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ABSTRACT
This study was conducted to estimate combining ability, gene action and proportional contribution of cross components in some maize genotypes under different irrigation conditions. In 2007 in Research Farm of Islamic Azad University, fifteen maize inbred lines as parents, consist of twelve females (No:4-15) and three males (NO:1-3) were crossed to produce 36 F_1 hybrids. Parents and their 36 F_1 hybrids were evaluated in a RCB design with three replications under irrigation after 70, 90 and 110 mm evaporation from a class A pan in 2008. Results showed both additive and dominance variances were important under drought stress conditions. Gene expression increased with intensify of drought stress. Proportional contribution of lines ,testers and their interactions revealed that female line contributed higher compared to male line under drought stress conditions in all studied traits and maternal parents play the most important role under drought stress conditions. The ratio of GCA to SCA variances was less than unity for all studied traits and showed the predominant role of non additive action in the inheritance. In conclusion, it can be suggested that female parents should be considered more for a successful plant breeding programs under drought stress conditions .

Keywords: Maize, Drought stress, Line × tester, Combining ability, Proportional contribution, Gene action

INTRODUCTION

Estimation of combining ability and genetic variance components are important in the breeding programs for hybridization (Fehr, 1993). In any breeding program, the choice of the correct parents is the secret of the success. One of the most important criteria in breeding programs for identifying the hybrids with high yield is knowledge of parents genetic structure and information regarding their combining ability (Ceyhan, 2003). Information regarding general and specific combining ability and gene action in a breeding material is a prerequisite to lunch effective corn-breeding. The success of a hybridization program primarily depends upon the judicious choice of parents for producing the hybrids with high yield (Hallauer and Miranda, 1988). Studies showed that crossing between inbred lines with high combining ability can improve tolerance to different stresses and superior hybrids with high yield produce under stress conditions (Beck et al., 1997; Vassal *et al*., 1997; Betran *et al*., 1997) and may obtain high correlation between parental lines traits with hybrid yield (Russell and Mchado, 1978; Prior and Russell, 1975; El-Lakany and Russell, 1971).Combining ability analysis is an important tool in the choice of suitable parents together with the information regarding nature and magnitude of gens effects controlling quantitative traits (Basbag *et al.,* 2007). Genetic information was obtained by different quantitative genetic methods that line × tester analysis is a suitable and efficient method with eligible speed (Singh and Chaudhary, 1985). The line × tester analysis method has been widely used by plant breeders. This method was suggested by kempthorne in 1957 and is used to breed both self and cross-pollination plants, as well as estimating favorable parents, crosses, and their general and specific combining ability effects (Kempthorn, 1957) of line × tester analysis method can use to recognize suitable parents and crosses among parents without necessary to many crosses (Prasad and Sastery, 1987). Gene expressions and genetic variances of some traits such as yield and secondary traits in maize are influenced by level of stress (Banziger and Lafitte, 1997; Bolanos and Edmeades, 1996; Ludlow and Muchow, 1990). Mean squares for grain yield, kernel row number per ear, number grain per ear, ear length was reported significantly (Singh and Asnani, 1979). Gene dominance effects had important role in inheritance of kernel number per row, 100-grains weight, grain yield and ear length and additive effects had the most important role in inheritance kernel row number per ear (Petrovic, 1998, Konak *et al*., 1999). The present investigation was accomplished to get **i**nformation regarding general and specific combining ability and gen action in the heritance of ear characters under drought stress and non-drought stress for improving drought tolerance in maize.

MATERIALS AND METHODS

This study was conducted in Research Field of Islamic Azad University (32.40 N: 51.48 E 1555 m,a.s.l) during 2007- 2008. The parental materials consisted of three maize inbred lines (1,2,3) as males (tester) and twelve maize inbred lines (4-15) as females (lines) which were crossed to develop 36 F_1 crosses using line × tester mating design in the 2007. The experimental population was kept under normal agronomic care from sowing to maturity. Necessary precautions were taken to avoid the contamination of genetic material at the time of crossing. The progenies along with their parents were evaluated in a randomized complete block design (RCBD) with three replications under three irrigation regimes after 70, 90 and 110 mm evaporation from a Class A pan (Epan) in 2008. In each replication, 36 hybrids and 15 parents were raised each in single row of 9 m length with a spacing of 75x20 cm. Recommended agronomic practices were followed. Observation were recorded on five competitive randomly selected plants of each genotype of each replication for ear length, ear weight, kernel row number per ear, kernel number per row, 100 – grains weight and grain yield. The combining ability analysis were made by line × tester analysis as described by Kempthorne (1957). Statistical analysis were processed by Excel and SAS soft-wares.

RESULTS AND DISCUSSION

The results of analysis of variance for genotypes under each irrigation condition are presented in Table 1. The results showed significant differences among genotypes for all the traits studied except kernel number per row under irrigation after 70 mm Epan. Genotye differences for this trait was significant in irrigation conditions after 90 and 110 mm Epan. This result indicated that significant probability of some traits increased under drought stress conditions. Studies have also shown that significant probability of some traits would increase under stress conditions (Betran *et al.,* 2003;Troyer *et al.,* 1996).

Sum of squares of genotypes were further portioned into parents, crosses and parents *vs.* crosses (Table 1), which revealed significant differences among each source of variation for all traits. The significant of parent's mean squares in the line × tester analysis showed that diverse variability occurred among the parents. Therefore, male and female parents were used in the present study provided broad range of expression for various characters. The significance of parents' *vs.* crosses contrast generally indicated the presence of desired average mid- and high parent heterosis.

Partitioning of crosses variability into lines, testers and lines x tester components (Table 1) showed that the studied traits were influenced by different irrigation regimes and different effects demonstrate. Significant differences among lines and testers or both for studied traits reveal the presence of additive effects,but significant among line × tester shows the presence non additive and dominance effects in controlling traits (Dabhokar, 1992).

Mean squares of crosses for some traits were not significant under irrigation conditions after 70 and 90 mm Epan, but they were significant under intensify drought conditions (Table 1). These results showed that gene expression increased with intensify of drought. Genetic variance components are in Table 1. Dominance variance was calculated for traits that their mean squares of line × tester were significant. Results showed that additive variance was presente for some traits under irrigation conditions after 70 and 90 mm Epan. While additive variances were for all studied traits under irrigation condition after 110 mm Epan.

These results showed that additive variance also increased with drought stress. Dominance variance for ear weight and grain yield would exist under irrigation conditions after 70 Epan wholes values were more than additive variance. With increasing drought level stress under irrigation conditions after 110 mm Epan, values' additive variance of these traits were more than their dominance variance and also more traits showed dominance variance under this conditions. In conclusion, both additive and dominance variance are important under drought stress. Therefore both selection and hybridization would be effective for improving drought tolerance under drought stress conditions.

Studies have shown both additive and dominance variance are important in the maize traits such as kernel number per row (Choukan , 2000; Singh and Singh 1998), kernel row number per ear (Kumar *et al.,* 1999),100-grains weight (Nestarze *et al.,* 1999. Konak *et al.,* 1999) and grain yield (Choukan, 2000; Nestarse *et al.,* 1999).

Estimates of variances due to specific combining ability (σ^2sca)and general combining ability (σ^2gca) and their ratio (σ^2gca / σ^2 sca) are revealed for traits in which their line × tester mean squares were significant inTable 1. The ratio of GCA to SCA variances was less than unity for all traits studied and ranged 0.01 for kernels number per row to 0.66, for ear weight which indicates this ratio vary for different traits and the predominant role of non-additive gene action play in the inheritance of all the characters studied in maize. By increasing drought stress, this ratio increased and role additive effects intensified. But also non additive effects were important.

The use of hybridization program for improvement of these characters was suggested.

The proportional contributions of lines (female), testers (male) and their interactions (crosses) to total variance for different traits (Table 2) under different irrigation conditions revealed that females lines (maternal) contributed higher compared to male lines (paternal) under drought stress conditions in all studied traits. Results showed that maternal parents play the most important role under drought stress conditions. Maternal parents should be used in further programs to improve drought stress tolerance. Perhaps these results are due to expression of cytoplasmic genes. Studies have shown that proportional contributions of line, tester and line × tester change for different traits (Sarker *et al.,* 2002; Rashid *et al.,* 2007).

Variation in general combining ability (GCA) effects was estimated for lines and testers for 6 ear characters to identify the best parents for subsequent hybrid development programs. The results of the general combining ability effects of lines and testers are presented in Table 3. In this study the presence of significant and positive GCA effects were desirable of yield. Among females parents, lines (4, 6), (6) and (11) had significant and positive GCA effects under irrigation condition after 70 mm Epan and were the best general combiner for ear length, ear weight and kernel number per row, respectively.

Testers (1), (3), (3), (1), and (3) were recorded as a good general combiner for ear length, ear weight, kernel row number per ear, 100- grain weight and yield grain ,respectively. Lines 6 and 11 and tester 3 seemed to be as better general combiners in grain yield improvement.

Under irrigation condition after 90 mm Epan, lines (12), (6, 11), (11)and (11) had significant positive GCA effects for ear length, ear weight, 100-grains weight and grain yield respectively. Testers (1), (3) had significant positive GCA effects for ear length, and kernel row number per ear, respectively. Line 11 was the best general combiner Under irrigation condition after 110mm Epan, lines (6), (6, 11, 12 , 13), (13), (7), (11) and (12,13) had significant positive GCA effects for ear length, ear weight kernel row number per ear and kernel number per row ,100-grains weight and grain yield respectively. Testers (3)and(1) had significant positive GCA effects for kernel row number per ear and kernel number per row respectively. The GCA considered as the intrinsic genetic value of the parent for a trait act which is due to additive genetic effects and is fixable (Simmondes, 1979). The presence of positive GCA effects indicates that continued progress should be possible the thought breeding for yield. Lines 4 and tester 3 could be considered as good combiners for yield and most of the yield attributing traits. Lines 6 and 11 were good general combiners in different irrigation conditions. Griffing (1956) suggested that the high GCA effects might be due to additive gene action as well as additive x additive types of epitasis gen action.

The estimate of specific combining ability effects from 36 hybrids are presented in Table 4. Under irrigation condition after 70mm Epan crosses (4x3, 6x2, 8x3, 9x2), (11x2) and (4x3, 8x3, 9x2) were observed as good specific combiners and had significant positive SCA effects for ear weight ,kernel number per row and grain yield, respectively. Better specific combining crosses might involve two good general combining parents such as 4x3 but this is not a rule for all crosses, sometimes two poor combiners such as 9x2 may

Table1. Analysis of variance for line × tester design and estimates of genetic components for ear characters under irrigation conditions after 70, 90 and 110 Epan[1]

Source of variation		Ear length (cm)			Ear weight (g)			Kernel Row number ear^{-1}			Kernel number row^{-1}			100-grain weight (g)			Grain yield (t/ha)		
	df	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm
Replication	2	2.77	6.94	0.05	1651.24	1590.12	2619.92	7.25	28.67**	21.92	1346.50	606.15	396.40	47.72	52.73	13.70	5.68	6.67	6.85
Genotype	50	20.45**	15.20**	29.46**	11726.53* *	7667.99**	5890.78**	21.14**	44.22**	38.05**	3888.24	570.28**	556.55**	60.14**	110.60**	179.78**	42.19**	26.47**	19.47**
Parents(P)	14	19.50**	13.63**	10.99	3287.59**	2836.29**	2033.49**	18.34**	12.92	46.88**	98.57	147.31	79.06**	82.41*	61.95**	169.95**	10.53**	9.59**	5.94**
Crosses(C)	35	6.74**	7.08**	25.30**	3221.96**	1857.57	3036.65**	17.09**	18.72**	19.15**	4854.52	458.56	573.75**	21.54**	62.41	78.18*	11.27**	5.79	9.87**
P.*VS*.C	1	513.6**	321.38**	4333.64**	42753.64* *	278676.4* *9	159787.3* *0	202.09**	374.92**	575.93**	23123.82* *	10506.06* *	6639.41**	1099.36**	2475.35**	3873.4**	1567.63**	986.59**	544.89**
Lines(L)	11	6.15*	9.16*	27.74*	1570.74	2204.24	5083.83**	6.75	8.34	24.46**	4551.39	389.65	853.06**	18.43	58.23	59.48	5.93	5.21	16.15**
Testers(T)	2	47.08**	16.93*	22.74	11829.67* *	2217.60	212.31	215.74**	204.02**	103.35**	6624.05	1163.59	507.12**	108.00**	48.57	96.76**	35.47**	4.26	1.44
L X T	22	3.36	5.15	24.31*	3265.04**	1651.50	2269.82**	4.20	7.06	8.85	4845.22	428.93	581.67**	15.54	65.76	85.84*	11.74**	6.21	7.50*
Error	100	2.47	3.89	10.70	897.54	1313.78	848.34	4.73	8.34	87.84	3659.10	353.01	259.43	20.17	36.09	44.95	3.09	4.42	2.96
σ^2A		0.10	0.06	0.76	475.82	----	625.34	11.76	10.94	.32	---	---	2.56	5.14	---	0.6	1.32	---	1.92
σ^2D		---	---	4.54	879.17	---	473.83	---	---	---	---	---	107.41	---	---	13.63	2.88	---	1.51
$SE_{\sigma^2_A}$		0.91	1.14	1.89	17.30	20.93	282.78	1.26	1.67	1.67	34.92	10.85	9.30	2.59	3.47	3.88	1.01	1.47	0.99
$SE_{\sigma^2_D}$		0.26	0.11	0.30	24.93	36.49	23.565	0.36	0.48	0.47	10.08	3.13	2.68	0.75	1.00	1.12	0.29	0.35	0.29
σ^2gca		0.05	0.03	0.38	237.91	---	292.67	5.88	5.47	0.16	---	---	1.28	2.57	---	0.30	0.66	---	0.96
σ^2sca		---	---	4.54	789.17	---	473.83	---	---	---	---	---	107.41	---	---	13.63	2.88	---	1.51
$\sigma^2gca / \sigma^2sca$		---	---	0.08	0.3	---	0.66	---	---	---	---	---	0.01	---	---	0.02	0.23	---	0.64

*significant at 5%level of significance **highly significant at 1% level of significance, 1: evaporation from a class A pan= Epan

Table 2. Proportional contribution of lines, testers and their interactions to total variance under irrigation after 70, 90 and110 mm from Epan

source	Ear length (cm)			Ear weight (g)			Kernel Row number ear^{-1}			Kernel number row^{-1}			100-grain weight (g)			Grain yield (t/ha)		
	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm
Due to lines	0.29	0.40	0.34	0.15	0.37	0.53	0.12	0.14	0.40	0.29	0.27	0.47	0.27	0.29	0.24	0.17	0.28	0.51
Due to testers	0.40	0.14	0.0∘	0.21	0.07	0.004	0.72	0.62	0.30	0.08	0.14	0.05	0.29	0.04	0.07	0.18	0.04	0.01
Due to line × testers	0.31	0.46	0.61	0.64	0.56	0.47	0.16	0.24	0.30	0.63	0.59	0.64	0.45	0.66	0.69	0.65	0.68	0.47

Table 3. General combining ability (GCA) effects of parents for ear characters under irrigation conditions after 70,90 and110 Epan

	Ear length (cm)			Ear weight (g)			Kernel Row number ear^{-1}			Kernel number row^{-1}			100-grain weight (g)					
line	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm
4	1.52**	-0.24	-1.40	2.67	-2.11	-28.61*	-1.73*	-0.81	-2.24*	-3.10	1.39	-4.78	2.05	0.57	-1.19	0.44	0.15	-1.45*
5	-1.09*	-1.36*	0.17	-10.73	-13.34	-2.00	0.39	0.50	-0.76	-13.47	-6.21	-0.04	-0.60	0.56	-1.93	-0.78	-0.79	-0.20
6	1.11*	0.91	4.53**	20.69*	25.28*	20.80*	1.35	1.16	2.65	-8.82	7.28	-1.05	-1.02	-3.54	-0.72	0.98	0.89	0.89
7	-0.47	-0.62	-1.34	-15.74	-12.48	-15.50	0.73	-0.47	-0.23	-15.00	-1.08	21.77**	-0.22	-1.69	-2.74	-1.19*	-0.61	-0.67
8	-0.14	-1.22	-0.05	6.23	-8.61	14.22	0.12	0.44	0.90	2.13	-4.00	-2.22	2.93	-0.18	-0.01	0.49	-0.33	0.93
9	-1.10*	-0.41	-1.54	-23.38*	-2.39	-22.31*	-1.08	-0.59	-0.58	-14.77	-3.56	-4.84	-0.70	1.20	-3.21	-1.32*	-0.16	-1.47*
10	-0.40	0.45	-0.30	2.71	-7.34	9.20	0.22	1.00	0.03	-10.75	-4.32	-0.01	0.71	1.02	2.29	0.32	-0.27	0.64
11	0.39	1.25	1.01	6.33	26.88*	20.72*	-0.28	-1.25	0.37	59.27*	4.28	0.02	0.26	6.50**	6.11**	0.27	1.42*	1.01
12	0.76	1.37*	0.83	13.36	16.23	28.37**	0.75	0.29	1.75	-9.56	10.97	0.44	0.81	-2.25	1.36	0.85	0.88	1.66**
13	0.22	0.84	0.89	5.45	8.93	31.37**	0.58	0.35	2.15*	-9.45	1.62	3.10	-1.21	0.44	1.15	0.25	0.43	1.90**
14	-0.61	-1.38*	-2.00	7.42	-19.70	-36.26**	-0.50	1.14	-1.92*	-4.72	-5.90	-8.07	-1.01	-2.23	-1.76	0.58	-1.01	-2.05**
15	-0.20	0.42	-0.80	-15.02	-11.36	-20.00*	-0.56	-1.76	-2.12*	31.86	-0.46	-4.32	-2.02	-0.43	0.65	-0.90	-0.61	-1.16*
SE	0.52	0.66	1.09	9.99	12.08	9.71	0.72	0.96	0.93	20.16	6.26	5.37	1.50	2.00	2.23	0.59	0.70	0.57
Tester																		
1	1.29**	0.75*	0.28	-0.97	-5.48	-0.64	-2.31**	-2.23**	-1.62**	-7.02	1.21	5.53*	1.99**	0.83	0.83	0.09	-0.17	0.11
2	-0.89**	-0.16	0.62	-17.63**	-3.51	2.68	-0.26	-0.28	-0.13	15.64	2.48	-1.90	-0.79	0.49	1.06	-1.03**	-0.23	0.12
3	-0.40	-0.59	-0.90	18.59**	8.99	-2.04	2.57**	2.51**	1.76**	-8.61	-3.68	-3.63	-1.19	-1.33	-1.89	0.95**	0.40	-0.23
SE	0.26	0.33	0.55	4.99	6.04	4.85	0.36	0.48	0.47	10.08	3.13	2.68	0.75	1.00	1.12	0.29	0.35	0.29

*Significant at 5% Probability level,**highly significant at 1% Probability level

Table 4. Specific combining ability (SCA) effects for ear characters in maize under irrigation conditions after 70, 90 and110 Epan[1]

	Ear length (cm)			Ear weight (g)			Kernel Row number ear⁻			Kernel number row^{-1}			100-grain weight (g)			Grain yield (t/ha		
Linextester	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm	70mm	90mm	110mm
4×1	-1.03	-2.06	0.79	-42.31*	-48.53*	-18.69	0.28	-0.14	-2.09	-2.74	-1.82	-9.12	-0.39	-1.32	5.88	-2.64*	-2.89*	-1.18
4×2	0.36	0.65	0.38	-13.66	4.50	33.95*	-0.85	0.07	0.99	-7.58	-5.26	9.74	0.66	1.17	1.53	-0.79	0.10	2.17*
4×3	0.67	1.41	-1.17	55.97**	44.03*	-15.26	0.57	0.06	1.10	9.41	7.09	-0.61	-0.27	0.14	-7.41	3.43**	2.79*	-0.99
5×1	0.75	-0.52	0.02	17.77	7.78	5.80	0.69	0.48	-0.58	8.50	0.55	-1.79	1.79	0.47	-1.38	1.08	0.45	0.29
5×2	-0.01	0.50	-0.62	-2.08	11.12	-12.29	-0.48	-0.46	-0.27	-15.00	-1.61	0.76	-1.49	1.10	-0.03	0.03	0.53	-0.57
5×3	-0.74	0.02	0.59	-15.69	-18.90	6.49	-0.21	-0.02	0.85	5.59	1.06	1.03	-0.30	-1.57	1.41	-1.11	-0.98	0.28
6×1	0.90	2.57	-2.60	16.29	27.71	14.21	-0.40	1.23	2.02	10.05	-1.11	-2.64	2.15	3.37	-1.18	0.93	1.99	0.97
6×2	1.26	-0.73	8.20**	42.35*	-13.08	9.39	-0.52	1.12	0.42	-10.04	8.55	2.05	-0.24	-5.35	-0.29	2.40*	-0.15	0.21
6×3	-2.16*	-1.84	-5.60**	-58.64**	-14.63	-23.60	0.92	-2.34	-2.44	-0.92	-7.44	0.60	-1.91	1.98	1.47	-3.34**	-1.84	-1.18
7×1	0.73	2.57*	-0.67	11.33	27.71	-17.34	-0.66	1.23	0.36	12.37	-1.11	48.05**	-0.93	3.37	-8.25*	0.40	1.99	-1.05
7×2	-1.18	-1.16	-0.95	-5.44	-12.44	6.10	1.57	0.66	-0.69	-21.63	-5.21	-25.61	0.26	-1.23	2.31	-0.40	-0.62	0.35
7×3	0.46	0.45	1.62	-5.89	11.02	11.24	-0.91	-0.99	0.33	8.35	5.51	-22.44*	0.67	0.17	5.95	0.00	0.75	0.70
8×1	-1.19	0.88	-1.14	-26.32	2.93	-23.69	-0.15	-2.08	-0.46	-4.98	2.71	-7.73	-0.68	2.67	-1.39	-1.58	0.02	-1.30
8×2	-0.01	-0.76	-2.01	-8.80	-11.34	-23.35	0.48	-0.05	-0.83	-36.40	-3.57	2.19	2.40	-2.84	-2.97	-0.54	-0.64	-1.13
8×3	1.21	-0.12	3.15	35.12*	8.40	47.04**	-0.33	2.13	1.30	40.48	0.86	5.54	-1.72	0.17	4.36	2.12*	0.61	2.43*
9×1	-0.20	-0.69	-2.47	-10.77	-18.03	-26.95	0.65	-0.33	-0.58	7.01	-0.34	-11.70	-2.75	-2.92	4.92	-0.81	-1.12	-1.53
9×2	1.70	1.85	2.83	53.37**	28.27	43.14*	1.24	0.22	1.59	-14.57	0.79	10.42	4.62	4.91	-1.45	3.30**	1.64	2.34*
9×3	-1.49	-1.16	-0.36	-42.60*	-10.25	-16.19	-1.88	0.11	-1.01	6.65	-0.45	1.28	-1.87	-2.00	-3.47	-2.49*	-0.52	-0.81
10×1	0.00	0.40	0.23	0.61	11.16	3.04	-0.93	-1.73	-0.32	11.20	2.96	1.77	-0.61	1.83	-2.86	0.19	0.67	0.11
10×2	-0.20	0.62	-1.64	-19.63	17.14	-22.12	-0.97	-1.56	1.05	-19.25	0.48	-3.15	-0.74	-0.88	-3.26	-1.07	0.75	-1.33
10×3	0.20	-1.02	1.41	19.01	-28.30	19.08	1.90	3.29*	-0.73	7.14	-3.44	1.39	1.35	-0.95	6.12	0.89	-1.43	1.22
11×1	0.16	-0.62	-0.28	8.57	6.89	-10.07	0.98	0.47	-0.63	-62.70	3.59	-6.30	2.29	-6.46	-3.86	0.32	0.31	-0.67
11×2	-0.13	-0.62	-0.14	19.20	-6.26	0.09	0.82	-0.37	0.42	125.40**	-4.11	0.81	-0.81	13.42**	10.83**	1.24	-0.54	-0.14
11×3	-0.03	1.24	0.42	-27.77	-0.63	9.98	-1.80	-0.10	0.21	-63.61	0.52	5.50	-1.48	-6.96*	-6.97	-1.56	0.23	0.81
12×1	0.09	0.24	3.51	13.08	12.63	76.09**	0.22	1.04	1.73	10.98	-10.52	3.83	-0.89	3.29	7.20	0.94	0.86	4.65**
12×2	-1.31	-0.66	-1.59	-39.10*	-18.24	-4.24	-0.95	0.76	-0.64	-22.81	15.76	1.33	0.31	-5.62	-0.17	-2.30*	-1.24	-0.32
12×3	1.22	0.42	0.02	26.02	5.61	-15.74	0.73	-1.79	0.78	10.92	-5.24	1.25	0.58	2.33	-3.48	1.36	0.38	-0.91
13×1	0.12	-1.08	2.89	4.45	18.65	37.65*	-1.52	1.87	2.56	12.19	9.05	-4.39	2.11	-3.94	4.18	0.42	1.19	2.25*
13×2	-0.61	-0.24	-1.63	-21.76	-9.38	-9.88	0.82	-0.33	-0.07	-20.34	-5.89	-1.35	-3.98	-0.43	-0.70	-1.52	-0.59	-0.61
13×3	0.49	1.32	-1.26	17.30	-9.27	-27.77	0.70	-1.54	-2.49	7.24	-3.16	5.74	1.87	4.38	-3.49	1.10	-0.60	-1.64
14×1	0.24	0.95	1.82	16.73	12.05	35.71*	-0.18	-0.64	1.25	16.49	2.45	4.01	-1.52	0.82	0.20	1.27	0.60	2.18*
14×2	-0.36	16.32**	-3.04	-14.05	140.06**	-35.80*	-0.64	17.81**	-3.53*	-16.62	25.96*	-1.27	-1.86	24.70	-5.60	-1.00	7.71**	-1.89
14×3	0.11	-1.34	1.22	-2.69	-3.41	0.09	0.82	-0.33	2.28	-0.78	0.85	-2.74	3.38	2.32	5.40	-0.27	-0.10	-0.29
15×1	0.21	-0.77	-0.16	15.54	-34.66	-19.64	0.54	-0.50	-1.38	-32.07	-7.24	-7.57	2.07	1.13	0.09	0.93	-1.97	-1.29
15×2	0.49	0.17	0.21	9.58	18.35	15.00	-0.53	-1.02	1.57	55.19	3.39	4.09	0.88	-1.12	-0.20	0.66	1.26	0.92
15×3	0.07	0.60	-0.04	-0.14	16.31	4.64	-0.51	1.52	-0.18	-34.11	3.85	3.48	-0.32	-0.01	0.11	-0.13	0.71	0.37
$S.E_{(SCA)}$	0.91	1.14	1.89	17.30	20.93	16.82	1.26	1.67	1.62	34.92	10.85	9.30	2.59	3.47	3.87	1.01	1.21	0.99

*Significant at 5% Probability level,**highly significant at 1% Probability level ensue to good specific combination due to epistatic gen action. Such type of gen action may be exploited in cross–pollinated crops like maize or vegetative propagating crops. Specific combining ability is a suitable index to determine the usefulness of a cross. Under irrigation conditions after 90 mm Epan crosses (7x1, 14x2),(4x3, 14x2), (10x3, 14x2), (14x2) , (11x2) and (4x3, 14x2) had significant positive SCA effects for ear length, ear weight, row number per ear, kernel number per row, 100- grains weight and grain yield, respectively. Cross 14 x 2 seemed to be the best specific combiners under these conditions. Under irrigation conditions after 110 mm Epan crosses (6x2), (4x2 , 8x3 , 9x2 , 12x1 , 13x1, 14x1), (7x1), (11x2) and (4x2, 8x3, 9x2, 12x1, 13x1, 14x1) had significant positive SCA effects for ear length, ear weight, kernel number per row, 100-grains weight and grain yield, respectively. Crosse 12x1 showed the highest value of SCA effects (4.65**) for grain yield that seemed to be the best specific combiners. Better specific combining crosses might involved two good general combining parents under same conditions such as 12x1.

In conclusion, with increasing drought stress more GCA and SCA effects would be significant. Therefore effects of GCA and SCA are important under different drought stress conditions because under each conditions specific combiners were significant. In selection followed by hybridization , GCA and SCA are important; because GCA effects are attributed to pre ponderance of genes with additive effects and SCA indicates predominance of genes with no additive effects (Kenga *et al.,* 2004. Mutengwa *et al.,* 1999; Sharma, 1994). However, both GCA and SCA effects are dependent on germplasm set evaluation and the specific environments sampling hence it cannot be generally applied (Falconer and Mackay, 1996). Therefore it would be better evaluated in target environment.

Studies have also shown that genotypes must be evaluated in target environments in order to their best selection for that conditions (Matzinger *et al*., 1959; Blum., 1988; Vasal *et al.,* 1992; Jagadeshwar *et al.,* 1992; Edmeads *et al.,* 1997).

The results of this investigation suggested that parents and crosses should be evaluated under different drought stress conditions in order to obtain precise required genetic information. This information helps in optimizing the breeding strategy under drought stress conditions.

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