Combining Ability for Sunflower Yield Contributing Characters and Oil Content over Different Water Supply Environments

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Abstract: Combining ability estimate is essential for selection of suitable parents for hybridization and identification of promising drought tolerant hybrids in breeding program. The present study aimed to select sunflower parents with good general combining ability (GCA) and crosses with best specific combining ability (SCA) effects under different levels of water supply environments. Seven sunflower inbred lines were crossed in 7x7 half diallel. The resultant 21 hybrids were evaluated along with their parents for yield contributing characters and oil content under three levels of water supply. The analysis of variance for combining ability showed that GCA variance was higher in magnitude than that of SCA for the studied characters, indicating the preponderance of additive gene action. The GCA effects of the parents revealed that the inbred lines L350, L460, L990 and L770 proved to be good combiners for seed yield, while the parents L38,L990 and L235 were found to be promising general combiners for oil % content. Inbred lines L38, L11 and L235, are good, candidates for drought tolerance. L350 is a good combiner for seed yield, while L38 proved to be good combiner for, oil content and drought tolerance. On The basis Of SCA, the cross L38 x L350 was identified as promising seed yield and oil content.

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1. Introduction

Egypt's production of edible vegetable oils has been suffering several problems due to the lower domestic production of oil crops that resulted in failing to meet the needs of domestic consumption (**Hassan and Sahfique, 2010**).

Sunflower breeders have therefore devoted effort to develop superior genotypes for seed yield and adaptation to the different stress factors. For achieving this purpose, information on the nature of combining ability of parents, their behavior and performance in hybrid combination is prerequisite. Estimate of combining ability using diallel mating design is essential for selection of suitable parents for hybridization and identification of promising hybrids in drought breeding program. The diallel method of genetic analysis proposed by **Griffing (1956)** which partition the total genetic variation into general combining ability (GCA) of the parents and specific combining ability (SCA) of the crosses have been widely used. GCA is the average performance of particular inbred in hybrid combinations while SCA refers to the performance of a combination of specific inbred in a particular cross **(Sprague and Tatum, 1942)**.The GCA and SCA variance provide an estimation for additive and non additive gene action, respectively **(Falconer, 1989).**

The importance of GCA and SCA for seed yield and other related characters have been evaluated by many investigators. **Goksoy and Turan (2005)** reported that neither GCA or SCA variances were found to be significant for head diameter and 1000-seed weight. However, **Ortis *et al.* (2005)** indicated the predominant role of additive component for plant height 1000-kernel weight and seed oil content, **Mijic *et al.* (2008)** showed that GCA variance was larger than SCA one for grain yield, oil content and oil yield. In addition GCA variance was larger than SCA variance for yield, head diameter and oil content **(Machikowa *et al.*, 2011)**. 1000-seed weight, seed number / head and oil yield were under control of both additive and dominant effects, plant height and oil content were controlled by additive effects, however over dominant effects were detected for seed yield **(Ghaffari *et al.*, 2011).**

The present study was conducted to estimate GCA and SCA for seed yield, plant height, leaf chlorophyll content, leaf water content, transpiration rate head diameter, 100- seed weight, yield / head and oil content % in 7 inbred lines and to determine perspective parental genotypes and hybrids of sunflower under drought conditions.

2. Materials and Methods

Description of the studied sunflower genotypes

Field experiments were carried out during the two successive seasons 2009 and 2010 at El-KHattra Agriculture Research Stations, Faculty of Agriculture, Zagazig University, Egypt. The experimental material comprised 7 sunflower inbred lines (L38 and L11 from Egypt and L350, L460, L990, L770 and L235 from Bulgaria). The seeds of all inbred lines were obtained from Oil Research Department, Field Crop Research Institute, Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation, Egypt.

Mating system and experimental layout

In 2009, summer growing season, the seven inbred lines were crossed in 7 x 7 half diallel to obtain sufficient seed for evaluation in next season. Each inbred line was sown in 10 rows; each row was 6 meters length, plant to plant and row to row distances were 30 and 50 cm, respectively.

In 2010, summer growing season, the resultant 21 hybrids were evaluated along with their respective parents under three levels of water regime (control supplemented with 3000 m^3, moderate drought 2000 m^2 and severe drought 1000 m^3). Quantities of water irrigation were adjusted using a water counter for all irrigation treatments under drip irrigation system.

A split plot design with four replicates was used, where the main plots assigned for water regimes and the subplots for sunflower genotypes. The subplot area was 15 m^2 and comprised two rows for each parent and F_1 hybrid.

The row length was 5m, with spacing 50 cm between rows. three seeds of sunflower genotypes were sown in hills 30 cm apart on 1^{st} June in both seasons, After 21 days from sowing, thinning to one plant / hill were done. Nitrogen fertilizer was applied as ammonium sulphate (20.6% N) at a rate of 90 kg N / fad. (Faddan=4200 m^2) in four equal doses, i.e. after thinning, then each seven days. Calcium superphosphate (15.5% P_2O_5) was added at a rate of 31 Kg P_2O_5 / fad. at seed bed preparation. Potassium sulphate was applied at a rate of 48 kg K_2O / fad, in two equal splits, the first at sowing and the second after thinning. All the other cultural practices for growing sunflower were applied.

The soil of the experimental site is sandy in texture and had an average pH of 8.1 and organic matter content of 0.26 %. The average available N, P, K contents were 15.1, 3.2 and 90.5 ppm, respectively

Collected data

Seed yield (ton/fad.), plant height (cm.) leaf chlorophyll content (%), leaf water content (%), transpiration rate, head diameter (cm), 100-seed weigh (g), head yield (g) and oil content (%) were estimated for each sunflower genotype of each replicate under the different levels of water treatments..

At flowering stage, five randomly selected plants were taken from each entry of each replication to estimate leaf chlorophyll content, transpiration rate and leaf water content. Leaf chlorophyll content (SPAD values) was assessed using chlorophyll meter (SPAD - 502, Minolta), measurements were taken from three points of each leaf (upper, middle and lower part). The average of these three readings was considered as SPAD reading of the leaf. Leaf transpiration rate (mg H_2O /cm^2/h) was estimated according to the adopted rapid weighing systems (**Migahid and Amer, 1950 and Gosev, 1960**). Leaf water content (%) was determined according to **Turner (1981).**

At harvest five guarded plants were taken from each entry of each replication and the following characters were recorded. Plant height and head diameter were measured in cm. Head yield was measured as average of seed weight from five plants. A sample of 100- filled seeds (at 8% moisture content) was drawn at random from the bulked seeds of 5 plants with an electronic balance. Seed yield was recorded by harvesting one row from each entry of each replication and weighed the harvested seeds. Seed yield / fad.. was then calculated.

Oil content was determined according to **AOAC (1984)** using soxhlet apparatus and diethyl ether as a solvent.

Statistical analysis

The obtained data were analyzed according to **Steel and Torri (1980**). There after estimates of combining ability were carried out using method 2, Model 1 of **Griffing (1956)** for the diallel formed by parental (p) and their F_1's p(p-1)/2, totaling n = p(p+1)/2 treatments considered of fixed line effects**.** The diallel was performed in a series of environments, the genotype x environment evaluation of effects in phenotypic characteristics. The statistical model is:

$$Y_{ijk} = m_k + g_{ik} + g_{jk} + s_{ijk} + \bar{e}_{ijk}$$

where,

Y_{ijk} = mean value of parental (i = j) or hybrid combination (i ≠ j) with i and j = 1, 2, . . ., p; in environment (k)

m_k = general mean;

g_{ik}, g_{jk} = GCA effects of i-th and j-th parent in environment (k);

s_{ijk} = SCA effect of the cross among the i-th and j-th parents, with sij = sji in environment (k);

$\bar{e}_{ijk}$ = mean experimental error.

The significance of GCA and SCA effects was determined at the 0.05 and 0.01 levels.of significance using A PC Microsoft Excel and SAS 9.1® Computer program for Windows (2003).

3. Results

As shown in Table (1), mean squares of sunflower seed yield (ton/fad), plant height(cm), leaf chlorophyll value (SPAD), leaf water content(%), transpiration rate(mg H2O/cm²/h), head diameter (cm), 100-achene weight(g), yield/head(g) and oil content (%) showed highly significant differences (*P* < 0.01) between the thee levels of water supply. The combined analysis of variances for combining ability showed highly significant differences (*P*< 0.01) for plant height, transpiration rate, yield / head, yield and oil content among genotypes, parents, F1 hybrids and parents Vs F1 hybrids. This confirms the presence of variability in the genetic materials. The mean squares for G x E interactions were highly significant (*P*< 0.01) for plant height, transpiration rate, yield and oil content. Further partitioning of genotype x environments indicated that the interaction of parents x environments showed highly significant differences for transpiration rate and yield /fad., suggesting the sensitivity of GCA effects of parents to water stress environments. Interaction effects of F's x E were highly significant (*P*< 0.01) for plant height, transpiration rate, yield /fad and oil content, indicating that SCA effects of hybrids interacted with the environments for these traits.

The mean squares of GCA were highly significant for seed yield (ton/fad), plant height(cm), leaf chlorophyll value (SPAD), leaf water content(%), transpiration rate**(mg H2O/cm²/h)**, head diameter (cm), 100-achene weight(g), yield/head(g) and oil content (%) (Table 2), indicating the importance of additives gene effects for these characters, the mean squares of SCA were highly significant (*P*< 0.01)) for plant height, transpiration rate, seed yield/ fad, and oil content, while only significant (P<.05) for head diameter and 100 – seed weight. The ratio of GCA to SCA variances were more than unity for all studied characters, except for plant height, indicating that the additive gene effects were more important for the control of these characters. The mean squares of GCA x E were highly significant for transpiration rate and seed yield / fed., indicating the sensitivity of GCA to environmental fluctuation for these characters, the mean square of SCA x E was significant for oil %.

Data presented in Table (3) showed the mean values of parents and GCA effects for seed yield contributing characters and seed oil content of seven sunflower genotypes. The results revealed that the parent L990 was a good combiner for seed yield and oil content. The highest GCA effect for seed yield was observed for L990 (0.103) followed by L770 (0.055) and then L350 (0.047), whereas the lowest GCA value was observed for L38 (-0.142), followed by L11 (-0.093). The inbred line L38 showed the highest GCA (3.538) for oil content followed by L235 (0.956) and L990 (0.774), whereas the lowest GCA value was observed for inbred line L350 (- 2.111), followed by L460 (- 1.784) and then L770 (1.418). L990 also exhibited the highest value of GCA for plant height followed by L770 and then L235. Highly significant and positive GCA was detected in inbred line L460 for leaf chlorophyll content, transpiration rate and head yield.

The GCA effects of the parents revealed that the L350, L460, L990 and L770 were good general combiners for seed yield, whereas the L38, L770 and L235 proved to be good combiners for seed oil content. It is likely to mention that the local inbred lines L38 and L11 as well as the imported one L235 have highly significant (P< 0.01) negative GCA effects in terms of transpiration rate, suggesting the potential of these parents to be good combiners for drought tolerance.

Specific combining ability effects (SCA) across environments is a genetic property of great interest in breeding programs aiming at hybrid cultivars. It enables assessment of the genotype combinations most promising for hybridization. The mean values of crosses and SCA effects for the studied characters are presented in Table (4). Combined analyses showed that the crosses of sunflower varied significantly from character to character and from cross to cross for all studied traits.

Mean performance for sunflower crosses across environments ranged from 0.62 (L38 x L11) to 0.97 ton/fad. (L350 x L990) for yield ; 103.42 cm (L38 x L460) to 136.62 cm (L350 x L770) for plant height ; 36.32 (L990 x L235) to 38.61 (L11 x L460) for leaf chlorophyll content ; 79.79% (L990 x L770) to 83.52 % (L38 x L350) for leaf water content ; 0.56 $mgH_2o/cm^2/h$ (L38 x L235) to 0.77 $mgH_2o/cm^2/h$ (L350 x L770) for transpiration rate ; 14.98 cm (L38 x L770) to 19.35 cm (L990 x L770) for head diameter ; 7.44 g (L990 x L235) to 9.12g (L350 x L990) for 100 seed weight ; 54.83 g (L38 x L990) to 74.98 g (L460 x L770) for yield/head and from 25.43% (L460 x L770) to 35.30% (L38 x L990) for oil content.

These results indicated that the cross (L460 x L770) gave the lowest value for seed oil content (25.43%) with the highest value for yield (0.93ton/fad) and seed yield/ head (74.98g). On the other hand, the cross (L38 x L990) had the highest mean performance for seed oil content (35.30%) with lowest value for yield (0.73ton/fad) and seed yield/ head (54.83g). So, efforts to increase seed oil content through breeding have had considerable success, but high oil lines usually have significant reduced yield. seed oil also has negative correlation with starch content. Several studies have demonstrated that the high oil trait is typically associated with an increase in embryo size and evaluated oil concentration in the embryo.

Table (1): Mean squares for sunflower yield contributing characters and oil content across three environments.

S.O.V	df	Yield (ton/fad.#)	Plant height (cm)	Leaf chlorophyll content (SPAD)	Leaf water content %	Transpiration rate (mg H2O/cm²/h)	Head diameter (cm)	100 achene weight (g)	Yield /head (g)	Oil %
Environments (E)	2	11.860**	33804.340**	61.761**	13013.729**	8.013**	853.724**	164.418**	18192.505**	137.004**
Reps (Env.)	9	0.078**	134.680	23.546**	35.461	0.004	14.151*	4.548	87.155	21.806**
Genotypes (G)	27	0.252**	2397.984**	7.375	24.750	0.066**	21.856**	4.456*	433.744**	108.619**
Parents (P)	6	0.588**	5529.937**	14.785	38.583	0.171**	16.292*	3.466	1015.474**	193.368**
F_1,s	20	0.127**	1082.105**	5.494	16.707	0.034**	18.554**	3.035	220.213**	82.994**
P *Vs.* F_1	1	0.737**	9923.850**	0.516	102.606*	0.068**	121.285**	38.814**	1213.989**	112.623**
G x E	54	0.055**	132.146**	5.100	17.100	0.026**	2.840	1.650	63.243	2.267**
Parents x E	12	0.106**	129.115	4.220	28.004	0.052**	1.607	1.425	77.375	0.453
F_1,s x E	40	0.041**	133.390**	2.814	14.261	0.019**	2.626	1.586	59.823	2.615**
P *Vs.* F_1 X E	2	0.035	125.434	56.098**	8.456	0.011**	14.518	4.279	46.849	6.178**
Error	243	0.021	72.577	8.219	19.540	0.002	5.992	2.499	72.537	0.695

***, ** Significant at 0.05 and 0.01 levels, respectively # Fad.=Faddan= 4200 m²**

Table (2): Mean squares for general (GCA) and specific (SCA) combining ability of sunflower genotypes for yield contributing characters and oil content across three environments.

S.O.V	df	Yield (ton/fad.#)	Plant height (cm)	leaf chlorophyll content (SPAD)	leaf water content %	transpiration rate(mg H2O/cm²/h)	Head diameter (cm)	100 achene weight (g)	Yield /head (g)	Oil %
GCA	6	0.852**	7642.660**	30.532**	72.6086**	0.2492**	57.543**	4.552	695.786**	426.331**
SCA	21	0.081**	899.505**	0.758	11.0758	0.0137**	11.660*	4.429*	358.875**	17.844**
GCA x E	12	0.151**	50.387	3.325	22.8999	0.0180**	1.237	0.600	31.502	0.217
SCA x E	42	0.009	39.358	1.979	4.3457	0.0016	1.307	0.750	29.194	0.940*
Error	243	0.021	72.577	8.219	19.5397	0.0023	5.992	2.499	72.537	0.695

***, ** Significant at 0.05 and 0.01 levels, respectively, Fad=4200 m²**

Table (3): Mean values of parents and general combining ability (GCA) effects of sunflower genotypes for yield contributing characters and oil content across three environments.

	Yield (ton/fad)		Plant height (cm)		leaf chlorophyll content (SPAD)		leaf water content %		transpiration rate(mg H2O/cm²/h)		Head diameter(cm)		100 achene weight (g)		Yield /head (g)		Oil %	
	$\overline{X}$	GSCA	$\overline{X}$	GCA	$\overline{X}$	GCA	$\overline{X}$	GCA	$\overline{X}$	GCA	$\overline{X}$	GCA	$\overline{X}$	GCA	$\overline{X}$	GCA	$\overline{X}$	GCA
L38	0.31	-0.142**	69.61	-15.530**	38.03	0.297	79.81	-0.229	0.43	-0.072**	13.87	-1.332**	6.58	-0.129	44.80	-5.037**	35.47	3.538**
L350	0.78	0.047**	116.23	1.200	37.30	0.163	83.51	1.559**	0.70	0.023**	14.43	-0.515*	7.55	0.245	64.24	0.627	23.17	-2.111**
L11	0.51	-0.093**	102.48	-4.822**	37.58	0.295	78.18	-0.646	0.62	-0.017**	16.15	0.022	7.46	-0.137	63.61	-0.563	28.17	0.045
L460	0.78	0.049**	111.65	-2.239**	38.97	0.771**	81.48	0.673	0.69	0.014**	16.20	0.398	7.43	-0.126	71.83	2.851**	24.90	-1.784**
L990	0.97	0.103**	130.74	7.946**	35.65	-0.783**	78.85	-0.529	0.77	0.050**	16.84	0.693**	8.28	0.266	72.19	1.380	29.60	0.774**
L770	0.86	0.055**	130.60	7.037**	36.56	-0.294	79.53	-0.246	0.76	0.052**	16.88	0.720**	8.03	0.120	67.18	1.435	26.40	-1.418**
L235	0.70	-0.021	124.76	6.408**	36.42	-0.448	79.70	-0.582	0.57	-0.050**	15.84	0.013	7.62	-0.239	64.61	-0.692	29.77	0.956**
Mean	0.70		112.30		37.21		80.15		0.65		15.74		7.56		64.07		28.21	
S.E.(gi-gj)		0.013		0.759		0.255		0.394		0.004		0.218		0.141		0.759		0.074
L.S.D 0.05	0.12		6.92		2.33		3.82		0.04		1.99		1.28		6.92		0.68	

***, ** Significant at 0.05 and 0.01 levels, respectively.** $\overline{X}$ **= Mean performance**

Table (4): Mean values of crosses and specific combining ability (SCA) effects of sunflower crosses for yield contributing characters and oil content across three environments.

Crosses	Yield (ton/fad)		Plant height (cm)		leaf chlorophyll content (SPAD)		leaf water content %		transpiration rate(mgH2O /cm²/h)		Head diameter(cm)		100 achene weight (g)		Yield /head (g)		Oil %	
	$\overline{X}$	SCA	$\overline{X}$	SCA	$\overline{X}$	SCA	$\overline{X}$	SCA	$\overline{X}$	SCA	$\overline{X}$	SCA	$\overline{X}$	SCA	$\overline{X}$	SCA	$\overline{X}$	SCA
L38xL350	0.78	0.096*	117.62	10.238**	38.33	0.582	83.52	1.078	0.65	0.026*	15.13	0.196	8.27	-0.002	70.66	7.711**	31.37	0.727**
L38xL11	0.60	0.054	107.32	5.960**	37.96	0.084	79.94	-0.292	0.59	0.007	15.90	0.426	8.05	0.163	70.16	8.401**	33.77	0.971**
L38xL460	0.91	0.218**	103.42	-0.523	37.98	-0.367	82.23	0.681	0.67	0.055**	16.83	0.975	8.29	0.393	67.29	2.121	30.24	-0.723**
L38xL990	0.73	-0.010	124.59	10.467**	36.58	-0.213	79.80	-0.551	0.70	0.052**	15.52	-0.628	8.95	0.660	54.83	-8.867**	35.30	1.775**
L38xL770	0.67	-0.022	114.28	1.068	37.18	-0.110	81.35	0.717	0.70	0.049**	14.98	-1.188	8.96	0.814	73.79	10.037**	28.97	-2.366**
L38xL235	0.66	0.040	127.46	14.872**	36.84	-0.290	80.35	0.053	0.56	0.005	16.19	0.727	8.38	0.598	67.19	5.563*	34.97	1.260**
L350xL11	0.80	0.065	119.45	1.364	38.03	0.294	81.63	-0.396	0.68	0.001	16.87	0.575	8.62	0.356	70.31	2.887	27.93	0.787**
L350xL460	0.88	0.006	116.33	-4.344	38.25	0.034	83.36	0.018	0.71	0.000	17.67	0.999	8.94	0.670	69.02	-1.819	26.03	0.716**
L350xL990	0.97	0.039	132.78	1.920	36.68	0.013	82.93	0.794	0.74	-0.003	17.39	0.429	9.12	0.453	73.83	4.468*	27.23	-0.642**
L350xL770	0.88	0.000	136.62	6.676**	37.03	-0.126	82.79	0.370	0.77	0.026*	18.34	1.352*	9.06	0.541	67.23	-2.187	26.13	0.450**
L350xL235	0.79	-0.018	129.23	-0.088	36.82	-0.181	81.66	-0.427	0.63	-0.019	15.39	-0.891	8.33	0.166	64.98	-2.318	29.67	1.610**
L11xL460	0.73	-0.007	112.78	-1.872	38.61	0.261	81.36	0.223	0.68	0.009	17.14	-0.063	8.23	0.343	68.92	-0.728	27.80	0.327
L11xL990	0.80	0.003	130.18	5.351*	36.77	-0.027	81.93	2.000	0.71	0.003	18.09	0.592	8.76	0.476	67.31	-0.866	29.83	-0.198
L11xL770	0.75	0.002	126.54	2.619	37.33	0.043	81.98	1.768	0.71	0.006	17.58	0.049	7.50	-0.636	63.48	-4.746*	28.50	0.661**
L11xL235	0.72	0.048	129.03	5.739**	37.07	-0.062	79.84	-0.038	0.62	0.014	16.61	-0.211	7.92	0.139	66.40	0.298	29.93	-0.279
L460xL990	0.92	-0.010	130.88	3.468	37.06	-0.211	81.69	0.439	0.73	-0.006	18.28	0.400	8.17	-0.126	73.08	1.495	29.40	1.197**
L460xL770	0.93	0.046	133.04	6.536**	37.73	-0.025	81.44	-0.094	0.72	-0.015	17.98	0.081	7.97	-0.180	74.98	3.340	25.43	-0.577**
L460x235	0.77	-0.042	133.78	7.898**	37.63	0.020	81.89	0.693	0.62	-0.014	17.57	0.371	7.64	-0.147	67.56	-1.958	28.93	0.549**
L990xL770	0.95	0.005	134.13	-2.566	36.51	0.304	79.79	-0.542	0.73	-0.048**	19.35	1.153	8.62	0.078	69.24	-0.931	29.77	1.198**
L990xL235	0.88	0.016	131.14	-4.921*	36.32	0.266	80.26	0.261	0.68	0.003	18.20	0.710	7.44	-0.738	68.60	0.554	29.93	-1.009**
L770xL235	0.86	0.039	131.18	-3.969	36.73	0.185	80.23	-0.055	0.70	0.022	18.75	1.233	8.13	0.100	68.69	0.591	29.33	0.584**
Mean	0.81		124.85		37.30		81.43		0.68		17.13		8.35		68.46		29.55	
S.E.(sij - sji)		0.038		2.207		0.743		1.145		0.012		0.634		0.410		2.207		0.216
L.S.D 0.05	0.12		6.92		2.33		3.82		0.04		1.99		1.28		6.92		0.68	

*, ** Significant at 0.05 and 0.01 levels, respectiv

Specific combining ability effects are indicative of heterosis and represent both dominance and epistatic gene action. The SCA effects is an important criterion for the evaluation of hybrids. The cross combination L38 x L350 showed significant positive SCA for seed yield (0.096*) along with oil content (0.727**), head yield (7.711**), transpiration rate (0.026*) and plant height (10.238*). Higher seed yield is an ultimate objective of sunflower breeding and hybrid development programs. The cross combinations L38 x L350 and L38 x L460 showed significant positive SCA effects for yield (ton/fad.). These crosses involved parents with low x high GCA effects, indicating the involvement of additive x dominance genetic interaction.

Positive and significant SCA effects for oil percentage were recorded in 13 out 21 crosses. The crosses L38 x L350, L38 x L11, L38 x L990, L38 x L235, L350 x L11, L350 x L460, L350 x L770, L350 x L235, L11 x L770, L460 x L990, L460 x L235, L990 x L770 and, L770 x L235 exhibited significant and positive SCA for oil % content, having high x low, low x low, low x high and high x high GCA parental combination, showing a genetic interaction of the additive and none additive types of gene action.

4. Discussion

General and specific combining abilities are the most important indicators for expressing the potential value of sunflower lines. The GCA and SCA variances provide an estimation for additive and non-additive gene action, respectively **(Falconer, 1989)**. It was indicated that sunflower seed yield and its contributing characters were adversely influenced under drought conditions. The mean squares of genotype x environment interactions were highly significant ($P<0.01$) for plant height, transpiration rate, yield and oil content, suggesting the differential response of sunflower genotypes to factors of water stress environments **(Gholinezhad *et al.*, 2009 and Shoric, 2009).**

The comparative estimates of GCA and SCA variances revealed the predominance of GCA variance in relation to SCA one for all studied traits, indicating the importance of additive gene effects for controlling the inheritance of these characters. This result corroborates with the findings **of Kaya and Atakisi (2004), Mijic *et al.* (2008), and Machikowa *et al.*(2011)**. The highly significance of additive genetic variance for sunflower studied characters, indicated that selecting genotype on the basis of seed yield and its contributing characters should be useful in developing genotypes with good combining ability. In this connection, **Miller *et al.* (1980)** reported significant additive genetic variance for sunflower seed yield.

The GCA effects of the parents revealed that L350, L460, L990 and L770 were good general combiners for seed yield, whereas L38, L770 and L235 proved to be good combiners for seed oil content. In this regard, **Khan *et al.* (2008)** reported that genotypes with high positive GCA estimates for seed yield are good candidates to be used as parents in a population improvement program. The local lines L38 and L11 as well as the imported one L235 have highly significant ($P< 0.01$) negative GCA effects in terms of transpiration rate, suggesting the potential of these parents to be good combiners for drought tolerance.

Out of 21 crosses, positive significant SCA were detected in two crosses for seed yield, 9 for plant height, 5 for transition rate, one for head diameter, 5 for head yield and 13 for oil content. The obtained results are in the some line with the finding of **Naik *et al*. (1999) and Khan *et al*. (2008).**

The crosses L38 x L460 and L38 x L350, having low x high GCA effects, indicated the involvement of additive dominance genetic interaction. In this connection**, Peng and Virnami (1990)** also reported the possibility of interaction between negative alleles from poor combiner and positive alleles from good sunflower combiners in low x high crosses. The involvement of both poor general combiners in some crosses or one of the parents as poor general combiner produced cross combinations with significant SCA effect in the desirable direction, which might be due to concentrations and interaction between favorable genes contributed by parents **(Chandra *et al*., 2011).**

On the basis of highly significant SCA effects, the cross L38 x L350 was identified as promising for seed yield and oil content. The performance of this cross needs to be critically evaluated over different seasons and location to confirm its superiority and stability.

Conclusion

It could be concluded that yield and oil content are the most important traits in sunflower. The results revealed that GCA effect gave greater proportion of variance than SCA effects, indicating that the additive gene effects were found to be governing the inheritance of seed yield, oil content and other studied physiological and agronomic characters. The inbred lines L350, L460, L990 and L770 were found to be good combiners for seed yield, while L38, L990 and L235 exhibited significant positive GCA effects for oil content. The local inbred lines L38 and L11 as well as the imported one L235 proved to be good combiners for drought tolerance. The cross combination L38 x L350 was found to promising for seed yield and oil content.

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Reference

1. AOAC, 1984. Official method of Analysis, of the Association of official Analytical chemist (AOAC) Washington D.C USA Pp 1250-1255.
2. Chandra B.S. Kumar S.S ; Ranganadha A.R.G. and M.Y. Dulhe, 2011. Combining ability studies for development of new hybrids over environments in sunflower (*Heianthus annuus* L). J. of Agric. Sci., 3 (2) : 230 - 237.
3. Falconer. D.S., 1989. Introduction to quantitative genetics. Oliver & Boyd. London, 3rd Ed.
4. Ghaffari M., Farokhi I and M. Mirzapour, 2011. Combining ability and gene action for agronomic traits and oil content in sunflower (*Helianthus annuns* L.) using F_1 hybrids. Crop Breeding J., 1 (1): 75- 87.
5. Gholinozhad E.; Aynaband A.; Ghorithapeh A.H.; Noormohamadi G. and J. Bernous, 2009. Study on the effect of drought stress on yield, yield components and harvest index of sunflower hybrid iroflor at different levels of nitrogen and plant population. Not. Bet. Hort. Agrobot. Cluj., 37 (2): 85-94.
6. Goksoy A. T. and Z.M. Turan, 2004. Combining abilityties of certain characters and estimation of hybrid vigour in sunflower (*Helianthus annuus* L.). Acta Agronomica Hungarica, 52 (4): 361-368.
7. Gosev, N.A., 1960. Some methods in studying plant water relations, Leningrade A cad of Sciena, USSR.
8. Griffing B., 1956. Concept of general and specific combining ability in relation to diallel crossing system. Aust. J. Biol. Sci., 9: 463.
9. Hakim Khan; Hidayat Ur-Rhhman ; Ahmad H.; Ali H.;Inamullah and M. Alam., 2008. Magnitude of combining ability of sunflower genotypes in different environments. Pak. J. Bot., 40 (1): 157 – 160.
10. Hassan Monia B.and Fatma A. Sahfiqu, 2010. Current situation of edible vegetable oils and some propositions to curb the oil gap in Egypt. Nature and Science,;8:1-12.
11. Kaya Y and I.K. Atakisi., 2004. Combining ability analysis of some yield characters of sunflower (*Hellanthus annuns* L.). Helia, 27- 84.
12. Machikowa T.; Seating C. and K. Funpeng, 2011. General and specific ability for quantitative characters in sunflower. J. of Agric Sci., 3 (1): 91-95.
13. Migahid A.M. and F.A. Amer, 1950.Three types of transpiration of snap bean. Agron. J., 44:562-568.

14. Mijic A.; Kozumplik V.; Kovacevic J.; Liovic I., Krizmanic M.; Duvnjak T.; Maric S.; Horvat D.; Simic G. and J. Gunjaca, 2008. Combining abilities and gene effects on sunflower grain yield, oil content and oil yield. Perio. Biol., 110 (3): 277 – 284.
15. Miller, J. F.; Hammond, J. J. and W.W. Roath, 1980.Comparison of inbred vs single-cross testers and estimation of genetic effects in sunflower. Crop Sci., 20:703-706.
16. Naik V. R.; Hiremath S.R. and K. Girirag. 1999. Gene action in sunflower. Karnataka J. Agric. Sci., 21 (1/4) : 43- 47.
17. Ortis L.; Nestares, G; Frutos E. and N. Machado, 2005. Combining ability Analysis for agronomic traits in sunflower (*Helianthus annuun* L.). Helia, 28 (43): 125- 134.
18. Peng, J. Y. and S. S. Virmani, 1990. Combining ability for yield and yield related traits in relation to breeding in rice. Oryza, 27: 1-10.
19. SAS Institute, Inc.,2003. SAS Proprietary Software Release 9.1. SAS Institute, Inc., Cary, NC.
20. Shoric D., 2009. Sunflower breeding for resistance to abiotic stresses. Helia, 32 (50) : 1-16.
21. Sprague. G. F. and L. A. Tatum, 1942.General *Vs* specific combining ability in single crosses of corn. J. Am. Soc. Agron., 34: 923- 932.
22. Steel, R. G. D. and J. H. Torrie, 1980. Principles and Procedures of Statistics: a Biometrical Approach. Second Edition. New York: Mc Graw-Hill Kogakusha.
23. Turner, N. C., 1981.Techniques and experimental approaches for the measurement of plant water status. Plant and Soil, 58:339-366.

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