

# COMBINING ABILITY ESTIMATES IN SOME SALT TOLERANT AND SENSITIVE SUNFLOWER (*Helianthus annuus* L.) GENOTYPES

## I. MORPHOLOGICAL PARAMETERS

---

Obaid U. Rehman<sup>1</sup> and Medhet K. Hussain<sup>2</sup>

---

<sup>1</sup>Maize Research Station, Ayub Agricultural Research Institute, Faisalabad, Pakistan

<sup>2</sup>Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan

Received: March 10, 1998

Accepted: April 15, 1999

### SUMMARY

A complete set of diallel cross experiments was conducted involving six sunflower (*Helianthus annuus* L.) inbred lines under non-saline and saline soil conditions during 1992-1994. The inbreds were selected on the basis of their salt tolerance and included two salt tolerant, two moderately tolerant and two salt sensitive lines. The experiments, which included the parents and their F<sub>1</sub> and F<sub>2</sub> generations under non-saline and saline soil conditions, were repeated in subsequent years. It was observed that additive and non-additive gene effects were frequent over the environments. Cytoplasmic inheritance was more pronounced under saline than under non-saline conditions. The performance of inbreds and their combinations was variable under the different environments. GIMSUN-856 invariably exhibited high general combining ability in both, non-saline and saline soils. Similarly, the reciprocal combination GIMSUN-790 x GIMSUN-630 remained immutable under different soil conditions. Direct crosses between moderately tolerant and sensitive lines were promising under saline conditions and so were reciprocal crosses between moderately tolerant and tolerant lines. Direct and reciprocal crosses showed more promise under non-saline and saline soils, respectively. It appeared that salt tolerance potential was contributed more by the male than by the female parent.

**Key words:** sunflower, *Helianthus annuus* L., combining ability, yield and yield components, non-saline and saline soils

### INTRODUCTION

Sunflower is generally considered moderately tolerant to soil salinity (Hardwick and Ferguson, 1978; Heikal *et al.*, 1980; Blamey *et al.*, 1986). Increasing levels of salinity reduced achene mass and head diameter (Farah *et al.*, 1980; Gharsalli *et*

*al.*, 1982; Hussain and Rehman, 1992). Evidences are also available on stimulatory effects of low and to some extent moderate salinity levels on growth and yield of plants (Abel and Mackenzic, 1964) and sunflower (Ahmed *et al.*, 1979; Hussain and Rehman, 1992). Higher salinity decreased plant height (Gharsalli *et al.*, 1982; Girdhar, 1989; Rehman and Hussain, 1992), achene mass and achene yield (Cheng, 1984; Girdhar, 1989; Hussain and Rehman, 1992) by accelerating achene formation which decreased their growth period (Asaliev, 1976). Genetic variability in sunflower is reported for plant growth and development (Rehman and Hussain, 1992), achene yield and yield components (Hussain and Rehman, 1992).

Putt (1966) indicated that specific combining ability was more important than general combining ability for plant height. It was suggested that non-additive gene effects were more important (Putt, 1966; Dua and Yadava, 1982; Rao *et al.*, 1992). Head diameter in sunflower is greatly influenced by environmental factors, especially by plant population, soil moisture and soil fertility. Thus, the portion of total variation in head size attributable to genetic effects is often less than it is for certain other agronomic traits (Fick, 1978). Significant heterosis was obtained for head diameter in crosses between inbred lines with relative contribution of both additive and non-additive genetic effects (Putt, 1966; Khair *et al.*, 1992).

The components of general and specific combining ability for 1000-seed mass were approximately equal, suggesting that both additive and non-additive gene effects were important in the control of seed mass (Putt, 1966). Many researchers involved in hybrid sunflower development have encountered marked differences among inbred lines in combining ability for seed yield (Unrau, 1947; Putt, 1966; Marinković, 1993). The heritability of good general combiner lines is high, ranging from 60 to 86% when the relative combining ability of inbreds was comparable to the combining ability of the source populations (Voskoboinik and Soldatov, 1974). Putt (1966) studied combining ability in a diallel cross of 10 inbred lines and reported that specific combining ability was more important than general combining ability for seed yield, suggesting that non-additive genetic variance was relatively more important than additive in affecting seed yield. Similar results were reported by Rao *et al.* (1992). In cases when the yield is determined primarily by additive genetic variance, selection procedures that utilize  $S_1$  or  $S_2$  progeny evaluation might prove most effective. Conversely, if a relatively large non-additive genetic component is involved, breeding procedures following some type of testcross evaluation might be more effective in the selection for seed yield (Fick, 1978).

The genotypes previously marked for their ability of salt tolerance (Rehman and Hussain, 1992; Hussain and Rehman, 1992) are now included in this study to evaluate their performance in hybrid combinations. The diallel analysis is an efficient and appropriate systematic method of evaluating populations or selecting groups of inbreds for combining ability in hybrid combinations (Griffing, 1956). The concept of general and specific combining ability has become increasingly important to plant breeders because of the widespread use of hybrid cultivars in many crops.

General combining ability provides information for each parental inbred while specific combining ability provides information for hybrids; thus, performance of specific genotypes can be evaluated.

## MATERIALS AND METHODS

The genetic material included in the study consisted of six inbreds, GIMSUN-157, GIMSUN-232, GIMSUN-603, GIMSUN-764, GIMSUN-790 and GIMSUN-856. These lines were developed from segregating populations of commercial hybrids from the United States, through six successive years of self-pollination. These were maintained by selfing and sibmating, alternatively. The genetic material was assessed for the response to salinity and categorized as tolerant (GIMSUN-856, GIMSUN-603), moderately tolerant (GIMSUN-764, GIMSUN-790) and sensitive (GIMSUN-157, GIMSUN-232) before the start of these studies (Hussain and Rehman, 1992, 1993, 1994; Rehman and Hussain, 1992, 1993, 1994, 1995).

The inbreds were crossed in all possible combinations in a diallel fashion, including direct and reciprocal crosses. In the sunflower, anthesis begins in the outermost whorl of florets in a head and proceeds inwards. Flowers in each capitulum were hand emasculated early in the morning and all necessary precautions taken to avoid contamination by foreign pollen. To produce sufficient  $F_0$  seed, the maximum possible number of florets in each head was emasculated and the rest from the middle of the head removed with a scalpel. Each head was covered with a kraft paper bag (35 x 45 cm) one day before the start of anthesis and kept covered until seed setting. Pollen from the male parent, which had also been previously bagged, was collected in the bag by giving a gentle shake to the head. The pollen was then transferred to a sterilized petri dish. Pollen was dusted onto the stigma of the emasculated florets by using soft camelhair brush and covered again with its respective kraft paper bag. Before moving to the next pollination, hands and the entire equipment in use were sterilized with absolute alcohol.  $F_0$  seed was harvested separately for each cross, at maturity. Fresh  $F_0$  seeds were developed for second year experiments. During February 1993, the experiments were laid out at two separate locations, on non-saline and saline soils. The experiment on non-saline soil was planted in the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. The other experiment was planted in a salt-affected field at a private farm about 3 km (north-west) from the site of the first experiment. The salt-affected field having clay loam soil with an  $EC_e$  12.10 to 15.75  $dSm^{-1}$ , SAR 17.25 to 18.85 and pH 8.32 to 8.79 was selected. The clayey soil due to its compact texture minimized the rapid leaching of salts to lower soil profiles and helped to maintain an almost uniform salt level throughout the experiment. The replications were so designed that there should be minimum variation within each replication.

Hybrid seed of thirty crosses and six parental lines were planted in a randomized complete block design with three replications on non-saline soil and with six replications on salt-affected soil. The number of replications was increased keeping in view the soil heterogeneity of the salt-affected soil. In all the experiments sowing was done by dibbling four seeds per hill to ensure uniform stand which was thinned to one plant per hill at four-leaves stage. Each row was 5 m long while plant-to-plant and row-to-row distances were kept 23 and 60 cm, respectively. Normal cultural practices were repeated next year, in spring 1994.

The data on the following plant characters were recorded on 50 plants per replication for each parent and cross in  $F_1$ :

1. plant height (cm),
2. head diameter (cm),
3. 100-achene mass (g),
4. achene yield per plant (g),
5. oil yield (g/plant).

#### **Statistical analyses**

The data recorded for five parameters in each of the 36 entries were averaged for replications and subjected to analysis of variance technique (Steel and Torrie, 1980) in order to determine genotypic differences for each parameter. Further analysis was performed only in the case of significant genotypic differences. The data on  $F_1$  hybrids and parental lines thus collected were subjected to combining ability analysis using procedures outlined by Griffing (1956) Method I, Model II. The variance due to crosses was partitioned into the variance due to general combining ability effects, specific combining ability effects and reciprocal effects.

## **RESULTS AND DISCUSSION**

Combining ability analysis is of special importance in cross-pollinated crops like sunflower as it helps in identifying potential inbreds that can be used for producing hybrids and synthetics; thus, it helps in isolating basic material on which the success of any breeding program primarily depends. Some lines produce outstanding progenies on crossing, while others prove to be poor parents although they appeared equally promising. The inbreds included in the present study were previously assessed for their ability of salt tolerance thus information on their combining ability estimates are very important.

The data on different agronomic parameters were subjected to analysis of variance technique to confirm the presence of genetic variability for different plant traits in the  $F_1$  generation under non-saline and saline conditions. Genotypic differences were found significant ( $p < 0.01$ ) for all plant characters under non-saline and saline conditions in both years, 1993 and 1994 (Table 1), which confirmed the presence of variability in the genetic material. The significant differences among genotypes allowed the data to proceed further to the combining ability analysis.

Table 1: Mean squares for different plant traits in sunflower (*Helianthus annuus* L.) under non-saline and saline conditions

Plant trait	Non - saline				Saline			
	Year 1993		Year 1994		Year 1993		Year 1994	
	Source of variation							
	Genotype	Error	Genotype	Error	Genotype	Error	Genotype	Error
Plant height (cm)	432.40**	6.53	425.53**	10.13	758.09**	10.56	468.71**	2.43
Head diameter (cm)	6.84**	0.08	5.66**	0.33	9.57**	0.11	10.48**	0.06
100-achene mass (g)	0.99**	0.014	1.06**	0.11	1.49**	0.003	1.37**	0.002
Achene yield per plant (g)	200.17**	1.12	127.34**	0.22	72.42**	0.85	71.97**	0.35
Oil yield per plant (g)	33.59**	1.14	24.15**	0.06	11.46**	0.19	14.39**	0.06

\*\* , \* - Significant at 0.01 and 0.05 probability level, respectively  
 NS - Non-significant

The ability of an inbred to transmit desirable performance to its hybrid progenies is referred to as combining ability. Those parental lines / genotypes which prove as good donors and good combiners for desirable plant traits are considered to be superior from breeding point of view. Breeding for salinity tolerance needs the best combiners and desirable donors which could be helpful in developing hybrids and synthetics that would successfully grow in salt-affected areas. The total genetic variability observed in the analysis of each character was partitioned into its components, i.e., general and specific combining ability as defined by Sprague and Tatum (1942) and reciprocal effects as outlined by Griffing (1956).

Table 2: Mean squares due to general combining ability (GCA), specific combining ability (SCA) and reciprocal effects for different plant traits in sunflower (*Helianthus annuus* L.) under non-saline soil conditions

Trait	Year 1993				Year 1994			
	GCA (5)!	SCA (15)	Recipr. (15)	Error (70)	GCA (5)!	SCA (15)	Recipr. (15)	Error (70)
Plant height (cm)	90.74 <sup>NS</sup>	165.99**	140.07**	2.18	69.70 <sup>NS</sup>	125.63**	136.66**	3.35
Head diameter (cm)	4.59*	1.60**	2.19**	0.03	3.47 <sup>NS</sup>	1.27**	1.98**	0.11
100-achene mass (g)	0.75 <sup>NS</sup>	0.44**	0.08**	0.0001	0.81 <sup>NS</sup>	0.47**	0.09**	0.04
Achene yield per plant (g)	177.66 <sup>NS</sup>	96.04**	0.42**	0.37	138.20 <sup>NS</sup>	50.57**	2.41**	0.07
Oil yield per plant (g)	28.80 <sup>NS</sup>	15.72**	1.10**	0.08	24.32 <sup>NS</sup>	9.06**	1.60**	0.02

\* , \*\* - Significant at 0.05 and 0.01 probability level, respectively  
 NS - Non-significant, ! - Degree's of freedom

Table 3: Estimates of components of variance for the F<sub>1</sub> generation for different plant traits in sunflower (*Helianthus annuus* L.) under non-saline soil conditions

Trait	GCA				SCA				Recipr.				Error				Additive				Non-additive				GCA/SCA ratio			
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
Plant height (cm)	-5.83	-4.33	95.12	70.99	68.95	66.65	0.18	3.35	-11.66	-8.66	95.12	70.99	-0.06	-0.06	-0.06	-0.06	-11.66	-8.66	95.12	70.99	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Head diameter (cm)	0.25	0.19	0.91	0.67	1.08	0.94	0.03	0.11	0.51	0.37	0.91	0.67	0.28	0.28	0.28	0.28	0.51	0.37	0.91	0.67	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
100-achene mass (g)	0.03	0.03	0.03	0.25	0.04	0.03	0.01	0.04	0.05	0.06	0.03	0.25	0.04	0.12	0.04	0.12	0.05	0.06	0.03	0.25	0.04	0.12	0.04	0.12	0.04	0.12	0.04	0.12
Achene yield/plant (g)	7.06	7.44	55.55	29.32	0.03	1.17	0.37	0.07	14.12	14.88	55.55	29.32	0.13	-0.25	0.13	-0.25	14.12	14.88	55.55	29.32	0.13	-0.25	0.13	-0.25	0.13	-0.25	0.13	-0.25
Oil yield/plant (g)	1.13	1.29	9.08	5.25	0.51	0.79	0.08	0.02	2.26	2.59	9.08	5.25	0.12	0.25	0.12	0.25	2.26	2.59	9.08	5.25	0.12	0.25	0.12	0.25	0.12	0.25	0.12	0.25

Table 4: Estimates of general combining ability (GCA) effects for different plant traits in sunflower (*Helianthus annuus* L.) under non-saline conditions

Inbred line	Plant height (cm)		Head diameter (cm)		100-achene mass (g)		Achene yield/plant (g)		Oil yield/plant (g)	
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
GIMSUN-856	1.55**	3.22**	0.61**	0.51**	0.29**	0.32**	1.20**	1.08**	0.39**	0.42**
GIMSUN-603	0.16	-0.11	-0.27**	-0.25**	-0.07**	-0.04	-4.19**	-3.82**	-1.65**	-1.54**
GIMSUN-764	-2.59**	-2.44**	-0.75**	-0.73**	0.29**	0.30**	0.71**	3.26**	0.33**	1.62**
GIMSUN-790	0.15	1.76**	-0.51**	-0.36**	-0.19**	-0.23**	-0.31**	-2.48**	-1.33**	-1.29**
GIMSUN-232	-3.41**	3.05**	0.12**	0.16	0.001	-0.07	-1.32**	-2.42**	-0.39**	-0.84**
GIMSUN-157	4.13**	0.62	0.79**	0.66**	-0.32**	-0.29**	6.61**	4.37**	2.66**	1.62**
SE (g) <sup>a</sup>	0.39	0.48	0.04	0.09	0.02	0.05	0.16	0.07	0.07	0.04
SE (g - g) <sup>b</sup>	0.60	0.75	0.07	0.14	0.03	0.08	0.25	0.11	0.11	0.06

<sup>a</sup> Standard error for individual GCA effect of any parent, and<sup>b</sup> for difference between any two parents

\*\*, \* - Significant at 0.01 and 0.05 probability level

Table 5: Estimates of specific combining ability (SCA) effects for different plant traits in sunflower (*Helianthus annuus* L.) under non-saline soil conditions

Cross	Plant height (cm)		Head diameter (cm)		100-achene mass (g)		Achene yield/plant (g)		Oil yield/plant (g)	
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
GIMSUN-856 x GIMSUN-603	-5.36**	-5.56**	0.51**	0.66**	0.88**	0.83**	5.11**	5.27**	1.98**	1.85**
GIMSUN-856 x GIMSUN-764	13.57**	12.58**	0.33**	0.51**	-0.23**	-0.21	8.15**	5.51**	2.52**	2.49**
GIMSUN-856 x GIMSUN-790	-0.44	1.85	0.38**	0.33	0.15**	0.12	-3.50**	-3.29**	-0.93**	-0.76**
GIMSUN-856 x GIMSUN-232	-4.37**	-5.62**	-0.67**	-0.43**	-0.56**	-0.05**	-4.84**	-2.06**	-1.99**	-1.07**
GIMSUN-856 x GIMSUN-157	6.58**	9.66**	0.39**	0.18	-0.07	-0.09	3.28**	2.17**	1.89**	1.28**
GIMSUN-603 x GIMSUN-764	-3.57**	-2.46**	-1.21**	-1.09**	-0.57**	-0.60**	-1.54**	-4.25**	-0.82**	-1.38**
GIMSUN-603 x GIMSUN-790	-1.19	-1.44	-0.79**	-0.79**	0.40**	0.42**	-1.27**	-1.25**	-0.77**	-0.79**
GIMSUN-603 x GIMSUN-232	-1.26	-1.79	0.53**	0.53**	-0.11**	-0.06	-1.76**	-0.80**	0.13	0.26**
GIMSUN-603 x GIMSUN-157	-6.07**	-1.92	-0.04	0.15	-0.72**	-0.72**	-11.58**	-9.06**	-5.08**	-4.33**
GIMSUN-764 x GIMSUN-790	9.98**	8.63**	1.88**	1.66**	-0.09*	0.06	6.05**	3.06**	2.86**	-0.94**
GIMSUN-764 x GIMSUN-232	-4.19**	-5.31**	-0.80**	-0.75**	0.74**	0.72**	-0.83*	-1.84**	-0.68**	-1.20**
GIMSUN-764 x GIMSUN-157	-11.42**	-7.82**	-0.97**	-0.61**	0.47**	0.39**	0.30	0.07	0.94**	0.65**
GIMSUN-790 x GIMSUN-232	-4.05**	-5.09**	-0.23*	-0.37	-0.33**	-0.64**	-2.61**	-1.81**	-1.56**	-1.20**
GIMSUN-790 x GIMSUN-157	-1.76	0.17	0.42**	0.47*	0.08*	0.27	7.05**	7.44**	1.94**	2.34**
GIMSUN-232 x GIMSUN-157	-6.53**	-2.85**	0.16	0.12	0.39**	0.43**	10.68**	4.53**	4.26**	1.95**
SE (S <sub>ij</sub> ) <sup>a</sup>	0.89	1.10	0.10	0.20	0.04	0.12	0.37	0.16	0.17	0.08
SE (S <sub>ij</sub> - S <sub>ik</sub> ) <sup>b</sup>	1.35	1.67	0.15	0.30	0.06	0.18	0.56	0.25	0.25	0.12
SE (S <sub>ij</sub> - S <sub>kl</sub> ) <sup>c</sup>	1.20	1.49	0.13	0.27	0.05	0.16	0.50	0.22	0.23	0.11

<sup>a</sup> - Standard error for individual SCA effects (i≠j), <sup>b</sup> for mean difference between two cross combinations, having one parent common (i≠j, k; j≠k) and c having no parent in common (i≠j, k, l; j≠k, l; k≠l)  
 \*\*, \* - Significant at 0.01 and 0.05 probability level

### Combining ability analysis under non-saline soil conditions

The analysis of variance for combining ability showed that mean squares (Table 2) due to general combining ability effects were significant ( $p < 0.05$ ) only for head diameter for the year 1993. SCA were significant at 0.01 probability level for all the characters for the years 1993 and 1994. The mean squares for reciprocals were also significant ( $p < 0.01$ ) for all the characters and both years. These results indicated that non-additive gene effects were important for the control of these characters along with a significant role of cytoplasmic inheritance. The variance components (Table 3) were estimated to determine precisely the relative importance of additive and dominance components in the control of characters under study. High SCA effects were observed for almost all characters and both years, 1993 and 1994, except for 100-achene mass where GCA effects were higher for the year 1993. These results showed higher non-additive effects for all the characters. 100-achene mass seemed to be under additive control in the year 1993, whereas high non-additive effects were present in the year 1994. These results were supported by GCA/SCA ratio which was almost one for 100-achene mass for the year 1993 and very low for the other characters.

High reciprocal effects were found for head diameter and 100-achene mass for both years, 1993 and 1994, however, reciprocal effects were low for 100-achene mass for the year 1994. Low reciprocal effects were observed in the cases of achene and oil yield per plant for both years, 1993 and 1994. However, a high proportion of reciprocal effects, but lower than SCA effects, was present for plant height for both years, 1993 and 1994. The contribution of reciprocal effects exhibited the involvement of cytoplasmic inheritance, along with the non-additive gene effects, in the control of different parameters in sunflower under non-saline soil conditions. However, the relative contribution of additive effects was very small.

The estimates of general combining ability effects (GCA) under non-saline soils (Table 4) demonstrated that variable number of inbreds showed significant GCA effects for different plant traits. The inbred GIMSUN-157 exhibited high positive general combining abilities for plant height, head diameter, achene yield per plant and oil yield per plant for the year 1993. The same inbred demonstrated high negative general combining ability effects for 100-achene mass. GIMSUN-157 proved to be a good general combiner for achene yield, oil yield and the other related parameters. This inbred line demonstrated almost similar results in both years (Table 4), except it did not show high general combining ability for plant height in the year 1994. Otherwise, it was consistently superior to the other inbreds over the years. The inbred other than GIMSUN-157 which displayed high general combining ability was GIMSUN-856. It was the best general combiner for 100-achene mass and second in plant height, head diameter, achene yield and oil per plant. It demonstrated similar performance for the year 1994, when it was a good general combiner for plant height and 100-achene mass. It was found second in head diameter and oil yield per plant. Therefore, it is suggested on the basis of results presented in Table

4 that GIMSUN-157 and GIMSUN-856 were good general combiners. Hence, these lines could be used as donor parents for specific characters in hybridization programs.

Table 5 shows that variable number of crosses expressed positive specific combining ability effects for different parameters. A comparison of crosses involving high specific combining ability effects for achene yield along with other traits, for both years, showed that the crosses GIMSUN-856 x GIMSUN-764 and GIMSUN-856 x GIMSUN-157 exhibited positive specific combining ability effects for plant height, head diameter, achene yield and oil yield. Two cross combinations, GIMSUN-790 x GIMSUN-157 and GIMSUN-232 x GIMSUN-157, exhibited high positive SCA effects for head diameter, achene mass, achene yield and oil yield. There were two other crosses, GIMSUN-764 x GIMSUN-790 and GIMSUN-764 x GIMSUN-157, which had high positive specific combining ability effects for oil yield and its related parameters. Therefore, it was concluded that six cross combinations, GIMSUN-856 x GIMSUN-764, GIMSUN-856 x GIMSUN-157, GIMSUN-790 x GIMSUN-157, GIMSUN-232 x GIMSUN-157, GIMSUN-764 x GIMSUN-790 and GIMSUN-764 x GIMSUN-157, showed potential for non-saline soil conditions over years with little difference between each other. The inbreds GIMSUN-157, GIMSUN-764 and GIMSUN-856 demonstrated good combining ability and proved valuable.

Specific combining ability effect (Table 5) and reciprocal effects (Table 6) were compared with each other and maximum positive effects for plant height were observed in reciprocal crosses over the years. All other plant traits produced maximum positive or negative effects in direct crosses. The cross GIMSUN-764 x GIMSUN-603 had maximum positive reciprocal effects for plant height while the combination GIMSUN-790 x GIMSUN-603 had maximum negative reciprocal effects for plant height for both years, 1993 and 1994. The combination GIMSUN-157 x GIMSUN-232 was the best reciprocal cross as it exhibited positive reciprocal effects for oil yield. Similarly, the combination GIMSUN-790 x GIMSUN-603 expressed positive reciprocal effects for 100-achene mass and oil yield and showed more potential than its direct cross.

Combining ability analysis revealed that cytoplasmic inheritance is very important, in addition to additive and non-additive gene effects, for different plant parameters in sunflower under non-saline soils. The inbred lines GIMSUN-157 and GIMSUN-856 displayed high general combining ability. There were six cross combinations, GIMSUN-856 x GIMSUN-764, GIMSUN-856 x GIMSUN-157, GIMSUN-764 x GIMSUN-790, GIMSUN-232 x GIMSUN-157, GIMSUN-790 x GIMSUN-157, and GIMSUN-764 x GIMSUN-157, which demonstrated capability for production under non-saline soils, with small differences between each other. Reciprocal crosses expressed maximum positive effects for plant height while direct crosses expressed superior results for achene yield and oil yield. However, only GIMSUN-790 x GIMSUN-603 was better than its direct cross.

Table 6: Estimates of reciprocal effects for different plant traits in sunflower (*Helianthus annuus* L.) under non-saline soil conditions

Cross	Plant height (cm)		Head diameter (cm)		100-achene mass (g)		Achene yield/plant (g)		Oil yield/plant (g)	
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
GIMSUN-603 x GIMSUN-856	1.71	1.67	1.72**	1.77**	0.06	0.04	-0.49	0.05	-0.40*	-0.30**
GIMSUN-764 x GIMSUN-856	1.60	1.46	-0.03	-0.01	0.50**	0.54**	0.10	-0.35	0.62**	-1.20**
GIMSUN-790 x GIMSUN-856	0.26	4.79**	-0.94**	-0.78**	0.12*	0.16	0.04	0.30	0.15	0.16
GIMSUN-232 x GIMSUN-856	-7.10**	-7.70**	-0.54**	-0.52*	0.03	0.05	0.29	0.45*	-0.02	-0.13
GIMSUN-157 x GIMSUN-856	-5.56**	-6.83**	-1.69**	-1.25**	-0.33**	-0.33*	0.01	3.63**	-0.67**	1.03**
GIMSUN-764 x GIMSUN-603	13.91**	13.03**	0.71**	0.68**	0.04	0.04	-0.04	-0.04	0.71**	-0.17
GIMSUN-790 x GIMSUN-603	-18.78**	-18.61**	-0.95**	-0.99**	0.21**	0.19	0.24	-0.25	1.07**	0.90**
GIMSUN-232 x GIMSUN-603	-1.98	-2.76*	-0.18	-0.19	0.01	-0.01	-0.20	-0.12	-0.05	-0.24*
GIMSUN-157 x GIMSUN-603	-2.62*	-3.07*	-0.04	-0.03	-0.22**	-0.20	-0.49	-1.11**	-0.90**	-1.31**
GIMSUN-790 x GIMSUN-764	9.85**	9.17**	-0.28*	0.05	0.06	0.07	-0.51	-0.53**	-1.44**	-1.05**
GIMSUN-232 x GIMSUN-764	3.70**	2.52	0.54**	0.58*	-0.19**	0.28**	1.29**	1.21**	0.35	0.46**
GIMSUN-157 x GIMSUN-764	12.83**	12.34**	0.62**	0.67**	-0.04	-0.06	0.49	0.64**	-0.17	0.15
GIMSUN-232 x GIMSUN-790	3.75**	4.13**	0.80**	0.83**	-0.26**	0.25	-0.28	-0.09	0.62**	-0.18
GIMSUN-157 x GIMSUN-790	-10.65**	-9.76**	-2.28**	-2.23**	-0.07	0.08	-0.53	0.74**	1.39**	2.32**
GIMSUN-157 x GIMSUN-232	1.99	1.66	1.18**	1.18**	0.10*	0.10	0.01	-0.66**	-0.34	-0.08
SE ( $r_{ij}$ ) <sup>a</sup>	1.04	1.29	0.12	0.24	0.05	0.14	0.43	0.19	0.20	0.10
SE ( $r_{ij} - r_{kj}$ ) <sup>b</sup>	1.48	1.83	0.16	0.33	0.07	0.19	0.61	0.27	0.28	0.14

<sup>a</sup> - Standard error for individual reciprocal effects ( $r_{ij}$ ), <sup>b</sup> for difference between two cross combinations ( $r_{ij}$ ;  $k \neq i$ ),

\*\* , \* - Significant at 0.01 and 0.05 probability level

Table 7: Mean squares due to general combining ability (GCA), specific combining ability (SCA) and reciprocal effects for different plant traits in sunflower (*Helianthus annuus* L.) under saline soil conditions

Trait	Year 1993					Year 1994						
	GCA (5)!	SCA (15)	Recipr. (15)	Error (175)	GCA (5)!	SCA (15)	Recipr. (15)	Error (175)	GCA (5)!	SCA (15)	Recipr. (15)	Error (175)
Plant height (cm)	167.34 <sup>NS</sup>	136.41 <sup>**</sup>	102.63 <sup>**</sup>	1.76	112.84 <sup>NS</sup>	70.59 <sup>**</sup>	74.08 <sup>**</sup>	0.41				
Head diameter (cm)	2.69 <sup>NS</sup>	1.30 <sup>**</sup>	1.53 <sup>**</sup>	0.02	3.00 <sup>NS</sup>	1.52 <sup>**</sup>	1.56 <sup>**</sup>	0.01				
100-achene mass (g)	0.61 <sup>*</sup>	0.16 <sup>**</sup>	0.22 <sup>**</sup>	0.0001	0.47 <sup>NS</sup>	0.23 <sup>**</sup>	0.15 <sup>**</sup>	0.0001				
Achene yield/plant (g)	30.18 <sup>NS</sup>	12.87 <sup>**</sup>	5.24 <sup>**</sup>	0.14	53.01 <sup>**</sup>	8.37 <sup>**</sup>	1.94 <sup>**</sup>	0.06				
Oil yield/plant (g)/	5.65 <sup>NS</sup>	2.37 <sup>**</sup>	0.76 <sup>**</sup>	0.05	10.49 <sup>**</sup>	1.73 <sup>**</sup>	0.37 <sup>**</sup>	0.01				

\*, \*\* - Significant at 0.05 and 0.01 probability level, respectively

NS - Non-significant

! - Degrees of freedom

Table 8: Estimates of components of variance for different plant traits in sunflower (*Helianthus annuus* L.) under saline soil conditions

Trait	GCA		SCA		Recipr.		Error		Additive		Non-additive		GCA/SCA ratio	
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
Plant height (cm)	2.94	3.71	78.19	40.75	50.44	36.84	1.76	0.41	5.88	7.42	78.18	40.75	0.04	0.09
Head diameter (cm)	0.12	0.13	0.74	0.87	0.75	0.77	0.02	0.01	0.24	0.25	0.74	0.87	0.16	0.14
100-achene mass (g)	0.04	0.02	0.09	0.13	0.11	0.07	0.001	0.0003	0.08	0.04	0.09	0.13	0.42	0.16
Achene yield/plant (g)	1.48	3.74	7.39	4.83	2.55	0.94	0.14	0.06	2.95	7.48	7.39	4.83	0.20	0.77
Oil yield/plant (g)	0.28	0.73	1.35	0.99	0.36	0.18	0.05	0.01	0.56	1.47	1.35	0.99	0.21	0.39

### Combining ability analysis under saline soil conditions

The analysis of variance for combining ability showed that mean squares (Table 7) due to GCA effects were significant for achene mass for the year 1993, and for achene yield and oil yield for the year 1994. Specific combining ability effects and reciprocal effects were significant for all the traits over the years of 1993 and 1994. The preliminary results demonstrated the contribution of both additive and non-additive gene effects to the control of various plant parameters in sunflower under saline soil conditions. In addition, cytoplasmic inheritance appeared to play a significant role in the control of all traits in both years.

The components of variance (Table 8) were estimated to distinguish accurately the relative importance of additive and dominance components in the control of different plant traits in sunflower under saline soil conditions. High SCA effects were found for almost all plant parameters in both years, 1993 and 1994. Virtually balanced contributions of GCA and SCA effects were observed in the cases of achene yield and oil yield for the year 1994. The situation was even clearer when additive and non-additive variances were compared. Additive variance was higher than non-additive variance for achene yield per plant and oil yield per plant for the year 1994, whereas these were roughly equivalent for 100-achene mass for the year 1993. The GCA:SCA ratio was close to one for achene yield and oil yield for the year 1994 and approximately 0.5 for 100-achene mass for the year 1993. The conclusion that may be drawn from the results presented in Table 8 is that non-additive control of various plant parameters was present in the above lines. However, both types of gene effects were important for 100-achene mass, achene yield and oil yield under saline soil conditions. The contribution of reciprocal effects was higher for 100-achene mass for the year 1993, showing that the maternal or cytoplasmic effects were more important for 100-achene mass under saline soil conditions.

The estimates for general combining ability effects (Table 9) give a good illustration of the situation found under saline soil conditions. There were only two inbreds (GIMSUN-856 and GIMSUN-603) which demonstrated high general combining ability effects for all the parameters under study consistently over the years of 1993 and 1994. GIMSUN-856 manifested positive GCA effects for achene yield, oil yield, head diameter, 100-achene mass and plant height. The second inbred, GIMSUN-603, had high positive GCA effects for all traits except head diameter.

Specific combining ability estimates for the years of 1993 and 1994 (Table 10) showed that variable number of crosses displayed positive and negative SCA effects for different plant traits under saline soil conditions. There were only three crosses which had positive SCA effects for achene yield in both years, 1993 and 1994. When the same crosses were compared for positive SCA effects for the other plant parameters over the years, it was found that two cross combinations were consistently the best performers over the years. The combination GIMSUN-790 x GIMSUN-232 expressed positive SCA effects for head diameter, 100-achene mass, achene yield and oil yield. The other combination, GIMSUN-764 x GIMSUN-232, demonstrated

Table 9. Estimates of general combining ability (GCA) effects for different plant traits in sunflower (*Helianthus annuus* L.) under saline soil conditions

Inbred line	Plant height (cm)		Head diameter (cm)		100-achene mass (g)		Achene yield/plant		Oil yield/plant (g)	
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
GIMSUN-856	3.47**	2.53**	0.68**	0.61**	0.22**	0.17**	1.98**	2.35**	0.72**	0.91**
GIMSUN-603	5.00**	4.72**	0.40**	0.56**	0.25**	0.22**	2.09**	2.94**	1.03**	1.41**
GIMSUN-764	-3.57**	-1.84**	-0.34**	0.05	0.07**	0.03**	-0.95**	-0.60**	-0.36**	-0.23**
GIMSUN-790	1.45**	0.04	-0.57**	-0.56**	-0.24**	-0.18**	-1.03**	-1.20**	-0.45**	-0.53**
GIMSUN-232	-2.64**	-2.79**	-0.23**	-0.46**	-0.01	0.04**	-1.29**	-1.69**	-0.53**	-0.74**
GIMSUN-157	-3.41**	-2.67**	0.06	-0.20**	-0.28**	-0.28**	-0.79**	-1.80**	-0.40**	-0.82**
SE (g) <sup>a</sup>	0.35	0.17	0.04	0.03	0.01	0.007	0.10	0.06	0.06	0.03
SE (gr-g) <sup>b</sup>	0.54	0.26	0.05	0.04	0.01	0.01	0.15	0.10	0.09	0.04

<sup>a</sup> Standard error for individual GCA effect of any parent and <sup>b</sup> for difference between any two parents  
 \*\*, \* - Significant at 0.01 and 0.05 probability level

Table 10: Estimates of specific combining ability (SCA) effects for different plant traits in sunflower (*Helianthus annuus* L.) under saline soil conditions

Cross	Plant height (cm)		Head diameter (cm)		100-achene mass (g)		Achene yield/plant (g)		Oil yield/plant (g)	
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
GIMSUN-856 x GIMSUN-603	-4.68**	-3.50**	-0.12	-0.02	-0.12**	-0.30**	-1.53**	-0.36**	-0.67**	-0.23**
GIMSUN-856 x GIMSUN-764	-0.66	-0.79**	0.02	-0.10*	-0.04**	-0.07**	-2.56**	-2.45**	-1.14	-1.11**
GIMSUN-856 x GIMSUN-790	0.05	2.05**	0.36**	0.44**	0.11**	-0.07**	-0.42	-0.37**	-0.10	-0.06
GIMSUN-856 x GIMSUN-232	8.79**	6.88**	0.27**	0.35**	-0.22**	-0.30**	-0.75**	-0.51**	-0.13	-0.06
GIMSUN-856 x GIMSUN-157	9.90**	5.98**	0.04	-0.28**	0.32**	0.29**	2.63**	0.01	0.81**	-0.11
GIMSUN-603 x GIMSUN-764	0.81	-1.96**	-1.11**	-1.39**	0.02*	0.003	-2.41**	-1.92**	-1.09**	-0.81**
GIMSUN-603 x GIMSUN-790	2.82**	-0.50	0.12	0.26**	-0.15**	-0.25**	0.30	-0.40**	-0.08	-0.25**
GIMSUN-603 x GIMSUN-232	1.87**	-0.29	1.00**	1.38**	0.45**	0.30**	-1.12**	-0.51**	-0.52**	-0.36**
GIMSUN-603 x GIMSUN-157	2.68**	2.77**	0.15	0.04	-0.22**	-0.26**	3.27**	-2.96**	-1.37**	-1.38**
GIMSUN-764 x GIMSUN-790	6.92**	7.59**	1.06**	1.00**	-0.32**	-0.43**	-0.71**	-0.59**	-0.21	-0.26**
GIMSUN-764 x GIMSUN-232	11.70**	9.10**	0.31**	0.48**	-0.06**	-0.17**	1.17**	0.96**	0.51**	0.47**
GIMSUN-764 x GIMSUN-157	-13.82**	-5.32**	-0.95**	0.16**	0.38**	0.32**	-0.90**	-0.45**	-0.25	-0.06
GIMSUN-790 x GIMSUN-232	-5.33**	-2.80**	0.47**	0.58**	0.28**	0.59**	1.80**	0.74**	0.71**	0.35**
GIMSUN-790 x GIMSUN-157	5.10**	3.91**	0.15	-0.23**	0.34**	0.20**	-1.22**	0.15	-0.36**	0.13*
GIMSUN-232 x GIMSUN-157	-13.10**	-7.76**	-0.07	-0.047**	-0.31**	-0.46**	-0.03	-0.11	0.04	0.04
SE ( $S_{ij}$ ) <sup>a</sup>	0.80	0.38	0.08	0.06	0.01	0.02	0.23	0.14	0.13	0.06
SE ( $S_{ij} \cdot S_{ik}$ ) <sup>b</sup>	1.21	0.58	0.23	0.09	0.04	0.03	0.67	0.22	0.19	0.09
SE ( $S_{ij} \cdot S_{kl}$ ) <sup>c</sup>	1.08	0.52	0.22	0.08	0.04	0.02	0.61	0.20	0.17	0.08

<sup>a</sup> Standard error for individual SCA effects ( $i \neq j$ ), <sup>b</sup> for mean difference between two cross combinations, having one parent common ( $i \neq j$ ,  $k$ ,  $j \neq k$ ) and <sup>c</sup> having no parent in common ( $i \neq j$ ,  $k$ ,  $l$ ,  $j \neq k$ ,  $l$ ,  $k \neq l$ )  
 \*\*, \* - Significant at 0.01 and 0.05 probability level

positive SCA effects for plant height, head diameter, achene yield and oil yield. Therefore, it was concluded that the combinations involving the inbred lines GIMSUN-790, GIMSUN-764 and GIMSUN-232 are valuable for future breeding programs.

Specific combining ability effects (Table 10) and reciprocal effects (Table 11) were compared and highest positive effects for plant height, head diameter, 100-achene mass, achene yield and oil yield were identified in reciprocal crosses over the years. There were many cross combinations which indicated change in direction and magnitude of combining ability effects while shifting from specific to reciprocal effects. It was found that the combinations GIMSUN-790 x GIMSUN-603 and GIMSUN-232 x GIMSUN-603 exhibited positive reciprocal effects for head diameter, 100-achene mass, achene yield and oil yield over the years of 1993 and 1994. The combination GIMSUN-764 x GIMSUN-603 displayed positive reciprocal effects for plant height, head diameter, achene yield and oil yield. GIMSUN-157 x GIMSUN-764 exhibited positive reciprocal effects for plant height, head diameter, 100-achene mass and oil yield. There were two other combinations, GIMSUN-232 x GIMSUN-764 and GIMSUN-232 x GIMSUN-790, which showed some promise under saline soils but their performance was not stable over the years. However, the direct cross GIMSUN-790 x GIMSUN-232 was much better than its reciprocal. Three reciprocal combinations, GIMSUN-790 x GIMSUN-603, GIMSUN-764 x GIMSUN-603 and GIMSUN-232 x GIMSUN-603, showed more potential under saline soils. Reciprocal crosses demonstrated higher potential than direct crosses under saline soils, as confirmed by the fact that eleven out of fifteen reciprocal crosses had positive effects for achene yield, whereas only three direct crosses expressed positive SCA effects for this trait.

Combining ability analysis under saline soils indicated the presence of non-additive control of different plant traits. However, both additive and non-additive gene effects were decisive for achene mass, achene yield and oil yield. The exceptional role of reciprocal effects for all the traits bestowed the promise of using cytoplasmic inheritance for monitoring various plant traits in addition to additive and non-additive genetic effects.

The inbreds GIMSUN-856 and GIMSUN-603 exhibited an explicit behavior under saline soils and displayed high general combining abilities for most of the parameters. There were only two direct crosses which demonstrated a combination of positive SCA effects for achene yield and other plant traits. GIMSUN-790 x GIMSUN-232 and GIMSUN-764 x GIMSUN-232 appeared promising under saline soil conditions. However, the reciprocal crosses exhibited higher potentials than the direct crosses. Three reciprocal crosses, GIMSUN-790 x GIMSUN-603, GIMSUN-764 x GIMSUN-603 and GIMSUN-232 x GIMSUN-603, exhibited high potentials under saline soil conditions.

It was generally concluded that additive and non-additive gene effects were frequent over the environments. Cytoplasmic inheritance was more pronounced under

Table 1.1: Estimates of reciprocal effects for different plant traits in sunflower (*Helianthus annuus* L.) under saline soil conditions

Cross	Plant height (cm)		Head diameter (cm)		100-achene mass (g)		Achene yield/plant (g)		Oil yield/plant (g)	
	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
GIMSUN-603 x GIMSUN-856	5.67**	1.25**	0.80**	0.63**	0.37**	0.20**	0.36	0.86**	0.17	0.41**
GIMSUN-764 x GIMSUN-856	-9.38**	-9.40**	-1.54**	-0.78**	0.03	0.05**	0.97**	0.45**	0.37*	0.26**
GIMSUN-790 x GIMSUN-856	-1.97*	-0.96*	-0.44**	0.05	0.31**	0.31**	1.08**	0.72**	0.49**	0.19**
GIMSUN-232 x GIMSUN-856	-2.59**	-0.77	0.19*	0.51**	-0.11**	-0.10**	0.11	0.05	-0.15	-0.24**
GIMSUN-157 x GIMSUN-856	13.39**	13.65**	1.08**	1.41**	0.19**	0.12**	3.52**	0.35*	1.05**	-0.15*
GIMSUN-764 x GIMSUN-603	8.57**	4.47**	1.18**	1.37**	-0.18**	-0.14**	1.81**	2.13**	0.81**	1.02**
GIMSUN-790 x GIMSUN-603	-10.72**	-6.26**	0.17	0.21**	0.28**	0.27**	0.55*	0.65**	0.42**	0.42**
GIMSUN-232 x GIMSUN-603	-1.53	0.53	0.61**	0.72**	0.55**	0.53**	2.38**	1.28**	1.00**	0.52**
GIMSUN-157 x GIMSUN-603	1.79	3.09**	1.02**	1.56**	0.30**	0.30**	-0.64*	-0.60**	-0.15	-0.17*
GIMSUN-790 x GIMSUN-764	-4.30**	-3.69**	-0.58**	-0.41**	0.42**	0.42**	-1.70**	-1.12**	-0.65**	-0.38**
GIMSUN-232 x GIMSUN-764	7.52**	8.29**	0.04	0.21**	0.40**	0.38**	0.83**	0.87**	0.31*	0.36**
GIMSUN-157 x GIMSUN-764	1.44	3.70**	1.13**	0.07	0.13**	0.13**	0.86**	0.74**	0.32*	0.29**
GIMSUN-232 x GIMSUN-790	4.48**	1.66**	1.26**	1.52**	0.62**	0.13**	1.55**	-0.35**	0.62**	-0.05
GIMSUN-157 x GIMSUN-790	4.64**	2.87**	-0.03	0.49**	-0.09**	-0.07**	-1.34**	-1.59**	-0.49**	-0.59**
GIMSUN-157 x GIMSUN-232	12.13**	10.09**	0.98**	0.90**	-0.37**	-0.35**	-2.55**	-0.92**	-1.03**	-0.49**
SE ( $f_{ij}$ ) <sup>a</sup>	0.94	0.45	0.09	0.07	0.02	0.02	0.27	0.17	0.15	0.07
SE ( $f_{ij-k}$ ) <sup>b</sup>	1.33	0.64	0.13	0.10	0.04	0.03	0.38	0.24	0.21	0.10

<sup>a</sup> Standard error for individual reciprocal effects ( $f_{ij}$ ), <sup>b</sup> for difference between two cross combinations ( $f_{ij}$ ,  $k$ ,  $i$ ,  $j \neq k$ ,  $i$ ,  $k \neq j$ )  
 \*\*, \* - Significant at 0.01 and 0.05 probability level

saline soil conditions than non-saline soils. The inbreds and their combinations failed to show uniform performance under different environments. Only GIMSUN-856 invariably showed high general combining ability, under non-saline and saline soil conditions. Similarly to GIMSUN-856, the reciprocal combination GIMSUN-790 x GIMSUN-603 was performed steadily under different soil conditions.

## REFERENCES

- Abel, G.H. and Mackenzie, A.T., 1964. Salt tolerance of soybean (*Glycine max*) varieties during germination and later growth. *Crop Sci.*, 4, pp. 157-162.
- Ahmed, A.M., Heikal, M.M. and Shadad, M.A., 1979. Changes in some plant water relation parameters of some oil producing plants over a range of salinity stresses. *Biologia Plantarum*, 21 (4), pp. 259-265.
- Asaliev, A., 1976. Formation of seed and oil in sunflower on saline soil. *Nauchnye Trudy, Stavropol, Stil Selsko Hozyaistvennyi Insitute*, 39 (1), pp. 128-131.
- Blamey, F.P.C., Asher, C.J. and Edwards, D.G., 1986. Salinity effects on sunflower growth in solution culture. In: *Proc. Aust. Sunflower Assoc. Workshop, 6<sup>th</sup> Gunnedah, New South Wales. Australian Sunflower Association, Toowoomba, Australia*, pp. 67-71.
- Cheng, S.F., 1984. Effect of salinity, fertility and water on the production and nutrients uptake of sunflower (*Helianthus annuus* L.). *Diss. Abst. Int.*, 44 (12), pp. 3600-3601.
- Dua, R.P. and Yadava, T.P., 1982. Gene effects for some quantitative characters in sunflower. *Indian J. Agric. Sci.*, 52 (7), pp. 439-443.
- Farah, M.A., Daud, A.M., Barakat, A.M. and Bakhati, H.K., 1980. Salt tolerance of 14 varieties of sunflower. *Agric. Res. Rev.*, 58 (5), pp. 99-111.
- Fick, G.N., 1978. Breeding and genetics. In: J.F. Carter (ed.), *Sunflower Science and Technology*. Am. Soc. of Agron., Crop Sci. Soc. of Am. and Soil Sci. Soc. of Am., Inc. Publ. Madison, Wisconsin, U.S.A., pp. 279-338.
- Gharsalli, M., Djemai-Dasoudi, F. and Cherif, A., 1982. The effect of sodium chloride on the lipid composition of sunflower. In: J.K. Kochman (coordinator), *Proc. 10<sup>th</sup> Int. Sunflower Conf.*, Toowoomba, Australia, Aust. Sunflower Assoc., pp. 71-72.
- Girdhar, I.K., 1989. Response of sunflower (*Helianthus annuus* L.) to saline water irrigation and changing root-zone salinity. *Ind. J. Agric. Sci.*, 59 (8), pp. 500-503.
- Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Aust. J. Biol.*, 9, pp. 463-493.
- Hardwick, R. and Ferguson, D., 1978. Germination and hypocotyl growth in *Helianthus annuus* L. as influenced by differential salt treatments. In: *Proc. 8<sup>th</sup> Int. Sunflower Conf.*, Minneapolis, MN. 23-27 July. Int. Sunflower Assoc., Paris, France, pp. 385-399.
- Heikal, M.M., Ahmad, A.M. and Shaddad, A., 1980. Changes in dry weight and mineral composition of some oil producing plants over a range of salinity stresses. *Biologia Plantarum*, 22 (1), pp. 25-33.
- Hussain, M.K. and Rehman, O.U., 1992. Breeding sunflower for salt tolerance: Genetic variability for yield and yield components for salt tolerance in sunflower. In: *Proc. All Pak. Sci. Conf.*, Khanspur (Ayubia), 16-21 May, pp. 112-115.
- Hussain, M.K. and Rehman, O.U., 1993. Breeding sunflower for salt tolerance: Physiological basis for salt tolerance in sunflower (*Helianthus annuus* L.). *Helia*, 16 (18), pp. 77-80.
- Hussain, M.K. and Rehman, O.U., 1994. Breeding sunflower for salt tolerance: Physiogenetic mechanism of salt tolerance in sunflower (*Helianthus annuus* L.). In: *Proc. Towards Solutions for Stressed Lands*. Bhurban, Pakistan, 7-10 May, U.S. Nat. Academy of Sciences and Board on Sci. and Tech. for Inter. Dev., Washington, D.C.
- Khair, M.D.I., Hussain, M.K. and Mehdi, S.S., 1992. Heterosis, heritability and genetic advance in sunflower. *Pak. J. Agric. Res.*, 13 (3), pp. 232-238.
- Marinković, R., 1993. Components of genetic variability for characters affecting oil yield of sunflower (*Helianthus annuus* L.). *J. Genet. Breed.*, 47 (4), pp. 289-293.
- Putt, E.D., 1966. Heterosis, combining ability and predicted synthetic from a diallel cross in sunflowers (*Helianthus annuus* L.). *Can. J. Plant Sci.*, 46, pp. 59-67.
- Rao, U.R., Pawar, B.B. and Dumbre, A.D., 1992. Heritability and gene action studies in sunflower. *J. Maharashtra Agric. Univ.*, 17 (3), pp. 504-505.

- Rehman, O.U. and Hussain, M.K., 1992. Breeding sunflower for salt tolerance: Effect of salinity on growth and development of cultivated sunflower (*Helianthus annuus* L.). In: Proc. All Pak. Sci. Conf., Khanspur (Ayubia), 14-16 May, pp. 118-123.
- Rehman, O.U. and Hussain, M.K., 1993. Breeding sunflower for salt tolerance: Genetic variability for seedling vigour and salt tolerance in sunflower (*Helianthus annuus* L.). Sci. Int., 5, pp. 203-205.
- Rehman, O.U. and Hussain, M.K., 1994. Breeding sunflower for salt tolerance: Estimation of ion concentration in sunflower (*Helianthus annuus* L.) seedlings. Sci. Int., 6 (4), pp. 365-371.
- Rehman, O.U. and Hussain, M.K., 1995. Breeding sunflower for salt tolerance: Morphogenetic studies of sunflower genotypes for salt tolerance at seedling stage. Sci. Int., 7 (2), pp. 169-171.
- Steel, R.G.D. and Torrie, J.H., 1980. Principles and Procedures of Statistics. McGraw Hill Book Co., Inc., New York.
- Unrau, J., 1947. Heterosis in relation to sunflower breeding. Sci. Agric., 27, pp. 414-427.
- Voskoboinik, L.K. and Soldatov, K.I., 1974. The research trends in the field of sunflower breeding at the Institute for Oil Crops (VNIIMK). In: Proc. 6<sup>th</sup> Int. Sunflower Conf., Bucharest, Romania, pp. 383-389.

## **ESTIMACIÓN DE CAPACIDADES DE COMBINACIÓN EN LOS GENÓTIPOS DE GIRASOL (*Helianthus annuus* L.) TOLERANTES Y SENSIBLES A LA SALINIDAD Y PARAMETROS MORFOLÓGICOS**

### **RESUMEN**

En el periodo de 1992-94 fueron realizados los experimentos con dialilo completo incluyendo seis líneas inbred de girasol (*Helianthus annuus* L.). Los experimentos se realizaban en los suelos salino y no salino. Las líneas inbred eran seleccionadas a base de la tolerancia de salinidad incluyendo dos líneas tolerantes, dos modicamente tolerantes y dos sensibles. Los experimentos con los padres y la generación F<sub>1</sub> y F<sub>2</sub>, realizados en los suelos no salino y salino, eran repetidos en los años sucesivos. Fué notado que los efectos aditivos y no aditivos de genes eran frecuentes en ambas localidades. La herencia de citoplasma era más manifestada en las condiciones de salinidad que en esas de no salinidad. Las performances de las líneas inbred variaban en dependencia de localidad. GIMSUN-856 mostro la más grande capacidad de combinación sin consideración con la localidad. Similmente, la combinación reciproca de GIMSUN-790 x GIMSUN-630 no se cambiaba bajo el influjo de diversas condiciones del suelo. Los cruces directos entre las líneas modicamente tolerantes y esas sensibles se mostraron prometedores en las condiciones de salinidad, como lo mostraron también los cruces reciprocos entre las líneas tolerantes y resistentes. Los cruces directos se mostraron mejores en la parcela salina. Parece que el padre masculino contribuye al potencial de resistencia a la salinidad más que ese femenino.

**ESTIMATION DES APTITUDES COMBINATOIRES DANS  
LES GENOTYPES DE TOURNESOL TOLERANTS OU  
SENSIBLES A LA SALINITE ET PARAMETRES  
MORPHOLOGIQUES**

RÉSUMÉ

Entre 1992 et 1994, des expériences diallèles complètes ont été menées sur six lignes inbred de tournesol (*Helianthus annuus* L.) dans des sols salins et non salins. Les lignes inbred avaient été choisies pour leur tolérance à la salinité et comprenaient deux lignes tolérantes, deux lignes modérément tolérantes et deux lignes sensibles. Les expériences sur les parents et leurs générations  $F_1$  et  $F_2$  menées dans des sols salins et non salins ont été répétées les années suivantes. On a pu observer que les effets additifs et non additifs des gènes étaient fréquents dans les deux environnements. L'héritage cytoplasmique était plus prononcé dans les conditions de salinité que dans les conditions de non salinité. Les performances des lignes inbred variaient selon la localité. GIMSUN-856 a montré la plus grande aptitude à la combinaison, indépendamment de la localité. De façon semblable, la combinaison réciproque GIMSUN-790 X GIMSUN-630 est restée inchangée dans des conditions différentes. Les croisements directs entre des lignes modérément tolérantes et des lignes sensibles se sont montrés prometteurs dans les conditions de salinité de même que des croisements réciproques entre les lignes modérément tolérantes et les lignes résistantes. Les croisements directs se sont montrés meilleurs dans les parcelles non salines, les croisements réciproques, eux, dans les parcelles salines. Il semble que le parent mâle contribue pour une plus grande part au potentiel de résistance à la salinité que le parent femelle.

