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EVALUATION OF SUNFLOWER (*Helianthus annuus* L.) GERMPLASM FOR SALT TOLERANCE AT THE SEEDLING STAGE

Medhet K. Hussain[1], and Obaid U. Rehman[2]

[1] *Dept. of Plant Breeding & Genetics, University of Agriculture, Faisalabad, Pakistan*
[2] *Maize Research Station, Ayub Agricultural Research Institute Faisalabad, Pakistan*

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SUMMARY

Three hundred and fifty sunflower genotypes were evaluated at the seedling stage for salt tolerance under control (non-saline) and a salinity level of EC_e 12 dSm^{-1}. Eighty-three of them were found sensitive to salinity at emergence and the remaining two hundred and sixty-seven which emerged were further evaluated for seedling growth parameters. Emergence percentage, shoot length, shoot fresh weight and root length exhibited greater variation. The ***genotypic*** components of variance for these seedling traits were also greater in magnitude. The estimates of broad sense heritability for seedling parameters ranged from 78.9 to 96.5 percent. Genotypes were classified from highly tolerant to highly sensitive to salinity on the basis of their performance under salinity as compared with control. It is suggested that emergence percentage, emergence index, shoot length, and shoot fresh weight can be used as selection criteria for salt tolerance in sunflower at seedling stage.

Key words: Sunflower, *Helianthus annuus* L., germplasm, seedling growth, salt tolerance, selection criteria.

INTRODUCTION

Soil salinity is considered one of the major problems confronting irrigated agriculture throughout the world. Salinity seriously limits crop production on 20 million hectares of the world's cultivated land (El-Ashry *et al.*, 1985). Pakistan has an arid/semi-arid subtropical climate and large areas are affected by salinity like many other countries of similar climatic conditions in the world. In Pakistan, about 6.3 million hectares, including about 18.4% of the country's canal irrigated area, is salt-affected (Anonymous, 1989). In addition, another 1.2 million hectare of salt-affected area exists in patches (Chaudhri *et al.*, 1978). Salinity is considered to be an important factor in low crop productivity in Pakistan. The introduction of crop varieties that can sustain moderate to high intensities of salts in the rhizosphere is utmost need for the farmers to receive economic returns.

Pakistan is deficient in edible oil production and meets about one-third of the total requirements of this produce. The cultivated sunflower is the world's most important oilseed crop, which has high achene yield and oil content with good adaptability to a wide range of agro-meteorological conditions. This crop has the potential to transform the situation from edible oil deficit to self-reliance. Available commercial sunflower cultivars in Pakistan are not suited for cultivation in salt affected soils since seed, oil, and dry matter yield of sunflower in the field are significantly reduced by increased salinity (Cheng, 1984). However, significant specific and varietal differences in reaction to different concentrations of salts have been reported in sunflower (Mandy and Paul, 1960; Makhdum and Muhammad, 1971).

Screening of vast number of genotypes under field conditions is a difficult task due to soil heterogeneity in salinity levels, whereas, uniform salinity levels can be maintained under controlled conditions. Salt tolerant genotypes of sunflower have been identified in glasshouse conditions on the basis of germination percentage, seedling vigor and growth (Chandru *et al.*, 1987). Seed germination of sunflower is greatly influenced by increase in salt concentration (Ghorashy and Kheradnam, 1972; Gaur and Tomar, 1975; Jadhav, 1985; Patil and Bangal, 1985). Shoot growth showed severe reduction as compared with root growth when grown under salinity (Gharsalli and Cherif, 1979; Rehman and Hussain, 1995); however, root growth was less affected and even root fresh weight was stimulated at moderate salinity (Rehman and Hussain, 1995). Shoot, root and seedling dry matter in sunflower decreases progressively with increase in soil salinity (Makhdum and Muhammed, 1971; Heikal *et al.*, 1980; Rehman and Hussain, 1995). Based upon these findings, this study was planned to evaluate the effect of salinity on 350 sunflower genotypes at seedling stage.

MATERIALS AND METHODS

These research studies were conducted in Sunflower Research Laboratory, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan, during the years 1993-94. The experimental material comprised 350 sunflower accessions which included inbred lines, parental lines, hybrids, open-pollinated cultivars and wild accessions.

The experiment was laid out in a randomized complete block design in a split plot arrangement with two salinity levels and three replications. EC_e 2 dSm^{-1} of the media was kept as control and EC_e 12 dSm^{-1} was developed before sowing using NaCl and $CaCl_2$ in the ratio of 1:1 on equivalent weight basis. Canal water (EC 0.29 dSm^{-1}) was used for irrigation in small quantity whenever required throughout the experiment and not allowed to drain. Seedling growth media in polyethylene bags was kept almost uniform around field capacity and waterlogging was avoided. N and P_2O_5 equivalent to 86 and 62 kg per hectare of nitrogen and phosphorus, respectively (Chaudhry, 1985) were added per bag before sowing. Five polyethylene bags (25 x 13 cm) filled with 1.25 kg air dried, sieved, sand and soil homogenized mixture in the ratio of 3:1, were arranged for each entry per replication and treatment. Thus fifteen plants in each salinity treatment and thirty plants in total were studied for each entry/ genotype. Two seeds were sown in each bag initially, and thinned to one after seedling emergence. Eighty three accessions did not germinate under salinity and were eliminated, therefore, further seedling studies were continued on 267 accessions. The data on five seedlings of each entry per replication and treatment were recorded for the following parameters.

1. Emergence percentage
2. Emergence index
3. Shoot length (cm)
4. Root length (cm)
5. Shoot fresh weight (g)
6. Root fresh weight (g)
7. Shoot dry weight (g)
8. Root dry weight (g)

The data on emergence were recorded daily up to 13 days after planting (DAP) and the rate of seedling emergence was calculated as emergence index (EI) according to the formula given by Smith and Millet, *et al.*, 1964.

$$EI = \frac{NPD \times NDAP}{TNP\ 13\ DAP}$$

where

EI is emergence index,

NPD is number of plants emerged in a day,

NDAP is number of days after planting, and

TNP 13DAP is total number of plants emerged by 13 DAP.

Seedlings were uprooted carefully and washed free of sand 21 days after sowing. The data thus collected were subjected to analysis of variance (Steel and Torrie, 1980). Ranking of the genotypes was made on the basis of their performance under salinity as compared with control. Estimates of components of variance were calculated using random model as described by Steel and Torrie, (1980) and broad sense heritability (as a ratio of genetic variance to phenotypic variance) were calculated following Lothrop *et al.*, 1985, and Falconer, 1989.

Table 1: Mean squares for various seedling traits of sunflower genotypes across salinity levels

SOV	df	EP	EI	SL	SFW	SDW	RL	RFW	RDW
Salinity(S)	1	62234.85**	162.38**	3261.83**	102.27**	0.689**	1574.96**	3.879**	0.081**
Error(a)	2	509.00	3.21	10.89	0.33	0.004	0.47	0.018	0.001
Genotype(G)	266	2044.15**	23.84**	110.45**	2.05**	0.024**	176.27**	2.056**	0.018**
(S X G)	266	421.78**	1.31**	9.79**	0.28**	0.009**	7.10^{NS}	0.042^{NS}	0.001^{NS}
Error(b)	1064	299.51	0.99	6.04	0.113	0.004	11.99	0.072	0.002

SOV - Source of variation, EP - Emergence percentage, EI - Emergence index, SL - Shoot Length (cm), SFW - Shoot fresh weight (g), SDW - Shoot dry weight (g), RL - Root length (cm), RFW - Root fresh weight (g), and RDW - Root dry weight (g), ** Significant at P > 0.01, NS Non-significant

Table 2: Mean and coefficient of variation for seedling traits among sunflower genotypes evaluated over salinity levels

Seedling trait	Mean				Coefficient of variation (%)
	EC_e 2 dSm^{-1} (Control)	EC_e 12 dSm^{-1}	Increase(+)/Decrease(-) (%)	Grand mean	
Emergence (%)	65.21	52.75	-19.11	58.98	29.34
Emergence index	6.27	6.90	+10.16	6.59	15.09
Shoot length (cm)	13.96	11.11	-20.44	12.53	19.61
Shoot fresh weight (g)	1.56	1.06	-32.33	1.31	25.62
Shoot dry weight (g)	0.16	0.12	-25.92	0.14	44.65
Root length (cm)	19.01	17.03	-10.43	18.02	19.22
Root fresh weight (g)	0.76	0.67	-12.94	0.71	37.49
Root dry weight (g)	0.09	0.07	-16.09	0.08	59.80

Percent increase (+)/decrease (-) in mean performance of different traits at EC_e 12 dSm^{-1} over control

RESULTS AND DISCUSSION

Research work on seedling traits is an important aspect of any plant breeding program, since the final plant stand of a crop primarily depends on seedling growth. Mean squares presented in Table 1 revealed that differences among salinity levels and sunflower genotypes were significant ($P \leq 0.01$) for all the seedling traits studied. The salinity levels X genotypes interaction was significant ($P \leq 0.01$) for all characters except root length, root fresh weight, and root dry weight.

Mean, increase or decrease in mean performance of various traits under salinity over control, and coefficient of variation for seedling traits among sunflower genotypes evaluated over salinity levels are presented in Table 2. The values of coefficient of variation for seedling traits ranged from 15.09 to 59.80 percent. Coefficients of variation were high for root dry weight (59.80%), shoot dry weight (44.65%) and root fresh weight (37.49%), whereas, a relatively low coefficient of variation was observed for emergence index (15.09%). A number of genetically diverse homozygous lines (inbreds) were included in the study which showed large between-line variation, which was confounded in environmental variance for the use of pooled data from 350 accessions/lines to give greater values of coefficient of variation. Reduction in various plant trait values under salinity over control showed that shoot growth parameters were more sensitive to salinity than root growth parameters. Similar findings were also reported by Garsalli and Cherif (1979) and Rehman and Hussain (1995).

Table 3: The estimates of phenotypic variance (σ^2p), genotypic variance (σ^2g), environmental variance (σ^2e), and broad sense heritability (h^2_B) for seedling traits among sunflower genotypes over salinity levels

Seedling trait	σ^2p	σ^2g	σ^2e	h^2_B (%)
Emergence (%)	320.31	270.39	99.84	84.41
Emergence index	3.92	3.75	0.33	95.79
Shoot length	17.78	16.78	2.01	94.53
Shoot fresh weight	0.31	0.29	0.04	93.99
Shoot dry weight	0.0032	0.0025	0.0013	78.95
Root length	30.19	28.19	3.99	93.58
Root fresh weight	0.35	0.34	0.02	96.55
Root dry weight	0.0032	0.0028	0.001	88.47

Total sunflower genotypes evaluated for salt tolerance = 350
Genotypes found sensitive to salinity at emergence = 83
Genotypes found tolerant to salinity at emergence = 267

The components of variance for seedling traits among sunflower genotypes evaluated over salinity levels are given in Table 3. The estimates of genotypic variances among sunflower genotypes (σ^2g) for the seedling traits were greater in magnitude as compared with their respective estimates of environmental variance (σ^2e). The estimates of phenotypic variance (σ^2p) were also greater in magnitude compared with their respective estimates of environmental variance (σ^2e) and high values of genotypic variance (σ^2g) exhibited that maximum variation was controlled by genetic factors. Thus suggesting that the sunflower genotypes had played a greater role for the expression of seedling traits over salinity levels. The estimates of broad sense heritability for these traits ranged from 78.9 to 96.5%. These estimates were high for almost all the traits studied. Earlier studies imparted that variation for salt tolerance in sunflower at seedling stage was predominantly contributed by genetic factors (Rehman and Hussain, 1995). Shoot growth parameters, shoot length, shoot fresh weight and shoot dry weight were found to be highly heritable (Rehman and Hussain, 1995) and showed positive correlation to achene yield and its components under artificially induced soil salinity (Hussain and Rehman, 1995). Therefore, it is suggested that selection criteria based on these seedling traits among sunflower genotypes evaluated over salinity levels is possible.

Table 4: Ranking of 267 sunflower genotypes with respect to salt tolerance at seedling traits

Rank	Criterion	Status	EP	EI	SL	SFW	SDW	RL	RFW	RDW
0	No loss	Highly tolerant	70	207	31	25	38	36	61	51
1	0-25 % loss	Tolerant	95	60	122	88	93	215	172	171
2	>25-50 % loss	Moderately sensitive	73	-	101	92	92	16	32	36
3	>50-75 % loss	Sensitive	26	-	13	61	41	-	2	6
4	> 75 % loss	Highly sensitive	3	-	-	1	3	-	-	3

EP Emergence percentage, EI Emergence index, SL Shoot Length (cm), SFW Shoot fresh weight (g), SDW Shoot dry weight (g), RL Root length (cm), RFW Root fresh weight (g), and RDW Root dry weight (g)

Root growth parameters were found less affected than shoot growth parameters under salinity (Table 4). Reduction in seedling growth was also reported by Makhdum and Mohammed (1971) and Heikal *et al* (1980) although, root growth was less affected than shoot growth (Garsalli and Cherif, 1979; Rehman and Hussain, 1995). The ranking of salt tolerance of different genotypes varied in dependence on the particular seedling parameter used for assessment. There were eight sunflower genotypes which showed better shoot growth under salinity than control in addition to better emergence percentage and emergence index. These genotypes made up a highly tolerant group.

Therefore, it is suggested that emergence percentage, emergence index and shoot growth parameters can be used together as selection criteria for salt tolerance in sunflower at seedling stage. Eight genotypes (Table 5) were ranked in a highly tolerant group on the combined basis of these characters. A tolerant group of genotypes characterized by 25 percent loss at the maximum at EC_e 12 dSm^{-1} comprised of 14 genotypes shown in Table 4. These 22 highly tolerant and tolerant genotypes will be kept under extensive field trials for evaluation and improvement of salt toler-

Table 5: Salt tolerant sunflower genotypes on the basis of their performance at seedling stage

Rank	Criterion	Status	Line Number	Source of origin
0	No loss	Highly toler-ant	GIMSUN-47	Open-pollinated cultivar VNIIMK
			GIMSUN-48	Open-pollinated cultivar VNIIMK
			GIMSUN-225	Segregating population of hybrid RO-53
			GIMSUN-318	Segregating population of hybrid RO-53
			GIMSUN-446	Segregating population of hybrid SF-103
			GIMSUN-469	Segregating population of hybrid SF-103
			GIMSUN-484	Open-pollinated cultivar SUNCOM-90
			GIMSUN-510-B	Open-pollinated cultivar SUNCOM-90
01	0-25 % loss over control	Tolerant	GIMSUN-129	Open-pollinated cultivar Record
			GIMSUN-192	Open-pollinated cultivar Romania
			GIMSUN-342	Segregating population of hybrid DM-2 Seg-
			GIMSUN-373	regating population of hybrid SF-103 Segre-
			GIMSUN-393	gating population of hybrid SF-103
			GIMSUN-459	Open-pollinated cultivar SUNCOM-90
			GIMSUN-464	Open-pollinated cultivar SUNCOM-90
			GIMSUN-477	Open-pollinated cultivar SUNCOM-90
			GIMSUN-495	Open-pollinated cultivar SUNCOM-90
			GIMSUN-686	Open-pollinated cultivar SUNCOM-110
			GIMSUN-767	Segregating population of hybrid MC-212
			GIMSUN-856	Segregating population of hybrid IS-3107
			UAF-5-13/I	Random mating sunflower population
			UAF-5-23/IV	Random mating sunflower population

ance. It will provide basis for developing elite sunflower material through selection and hybridization for use in salt affected areas.

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EVALUACIÓN DE GERMOPLASMA DE GIRASOL (*Helianthus annuus* L.) PARA TOLERANCIA A SALINIDAD EN EL ESTADO DE PLÁNTULA

RESUMEN

Trescientos cincuenta genotipos de girasol fueron evaluados para tolerancia a la salinidad en el estado de plántula bajo condiciones no salinas (control) y en nivel de salinidad de Ece 12 dSm-1. Ochenta y tres genotipos fueron sensitivos a la salinidad en el estado de emergencia y el resto, doscientos sesenta y siete que emergieron fueron evaluados de nuevo para parámetros de crecimiento de plántulas. Porcentaje de emergencia, longitud del tallo, peso fresco del tallo y longitud de raíz mostraron una mayor variación. El componente genotípico de la varianza para estos caracteres de las plántulas fueron también mayores en magnitud. Las estimaciones de la heredabilidad en sentido amplio para parámetros de las plántulas variaron desde 78.9 a 96.5%. Los genotipos fueron clasificados desde altamente tolerantes a altamente sensitivos a la salinidad en base a su comportamiento en condiciones de salinidad en comparación con el control. Se seqiere que el porcentaje de emergencia, índice de emergencia, longitud del tallo y peso fresco del tallo pueden ser usados como criterio de selección para tolerancia a la salinidad en girasol en el estado de plántula.

EVALUATION DES RESSOURCES GÉNÉTIQUES DE TOURNESOL (*Helianthus annuus* L.) POUR LA TOLÉRANCE À LA SALINITÉ AU STADE PLANTULE

RÉSUMÉ

On a évalué trois cent cinquante génotypes de tournesol au stade plantule pour la tolérance au sel par rapport à des conditions témoins (non salées) ou un niveau de salinité de Ece 12 dSm-1. Quatre vingt trois génotypes ont été trouvés sensibles à la levée, en conditions salines et les deux cent soixante sept autres qui avaient levé, ont été évalués plus en détail pour les paramètres de croissance des plantules. Le pourcentage de levée, la longueur des parties aériennes, le poids frais de la partie aérienne et la longueur des racines ont montré la plus forte variation. La composante génétique de la variance pour les caractéristiques de ces plantules était également plus importante. L'estimation de l'héritabilité au sens large pour les paramètres des plantules était comprise entre 78.9 et 96.5 pour-cent. Les génotypes ont été classés de très tolérants à très sensibles à la salinité en fonction de leurs performances en conditions salines par rapport aux témoins. Il est suggéré que le pourcentage de levée, l'indice de levée, la longueur de la partie aérienne et la masse fraîche de la partie aérienne puissent être utilisés au stade plantule comme critères de sélection pour la tolérance du tournesol à la salinité.