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BREEDING SUNFLOWER FOR SALT TOLERANCE: ASSOCIATION OF SEEDLING GROWTH AND MATURE PLANT TRAITS FOR SALT TOLERANCE IN CULTIVATED SUNFLOWER (*Helianthus annuus* L)[1]

Medhet Kamil Hussain and Obaid Ur Rehman[2]

[2] *Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad (Pakistan)*
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SUMMARY

The relationships of different seedling growth parameters with yield and yield components were studied in cultivated sunflower under non-saline (EC_e 2 dSm^{-1}) and saline conditions (EC_e 10 dSm^{-1}). Inbred lines having shallow roots with low fresh weight and greater shoot length at the seedling stage produced higher seed yield under non-saline conditions. Seedling parameters showed very complex associations with seed yield under saline conditions. It was rather difficult to select high-yielding lines at the seedling stage under saline conditions, but oil yield could be increased indirectly through more seed weight, greater head diameter, and high oil content by selecting lines with shallow roots having more dry weight, and longer shoots having more fresh and dry weight. Selection of inbred lines having longer shoots with more fresh and dry weight under non-saline conditions appeared to be effective for achieving high seed-yielding lines for saline soils.

Key words: ***Helianthus annuus*** **L., correlations, seedling growth, seed yield, saline conditions.**

INTRODUCTION

Soil salinity is a common problem in irrigated production areas of the world. It is seriously affecting the economy of Pakistan by limiting crop productivity to a large extent over a vast area. All phases of plant growth, from germination to maturity, are affected by the environment in which the plant grows. Saline soils contain a sufficient amount of salts to impair the growth of plants (Ponnamperuma and Bandyopadhya, 1980). Salt tolerance is the ability of crops to produce an economic yield under the adverse soil conditions caused by excessive salts in the root zone (Bresler et al., 1982).

Sunflower seedlings have shown severe reductions in shoot growth (Charsalli and Cherif, 1979) and shoot dry matter (Cheng, 1984), while root growth was comparatively less affected (Charsalli and Cherif, 1979). However, root dry matter yield was reduced when sunflower was grown in soils with high salinity levels (Heikal et al., 1980). Similarly,

1 Contribution of Dep. of Plant Breeding and Genetics, University of Agriculture, Faisalabad (Pakistan) in collaboration with National Academy of Sciences/BOSTID, Washington, D.C., U.S.A.

2 Associate Professor and Ph. D. Research Fellow, .

increasing levels of salinity have been shown to reduce 100-seed weight, head diameter (Mehmood, 1986), seed yield and oil percentage (Girdhar, 1988). Seedling dry matter has been positively correlated with seed yield (Chaudhry and Anand, 1985), as has 100-seed weight, both at phenotypic and genotypic levels (Singh et al.,1985).

The screening of salt-tolerant lines/cultivars has been attempted by many researchers in various species on the basis of their root and shoot growth at the seedling stage (Wu, 1981; Ashraf et al., 1986, 1989; Ab-Shukor et al., 1988). The relationships of various seedling growth parameters to seed yield and yield components under saline conditions are important for the development of salt-tolerant cultivars for production under saline conditions. The present study was undertaken because information is not available for sunflower regarding development of salt-tolerant cultivars. The objective was to identify seedling plant growth parameters of sunflower that could be used as selection criteria for early evaluation of different lines for salt tolerance.

MATERIALS AND METHODS

Fifteen sunflower (*Helianthus annuus L.*) lines were evaluated for salt tolerance at the seedling and mature plant stages under normal and saline conditions. The sunflower lines included the inbreds GIMSUN-4, -76, -198, -476, and -671 developed from open-pollinated Russian and Romanian cultivars, and the inbreds GIMSUN-157, -232, -343, -403, -603, -740, -764, -790, -802, and -856, developed from segregating populations of commercial hybrids from the United States, after six successive years of self-pollination. The study was divided into two experiments for management simplicity.

Experiment 1. Seedling studies

The first experiment initiated to study sunflower seedlings, utilized a randomized complete block design with three replications and two salinity treatments. Ten seedlings of each genotype were grown in each salinity treatment in polyethylene bags (25 x 13 cm) filled with 1.25 kg of an air-dried and sieved sand and soil mixture in the ratio of 3:1 to facilitate harvesting and recording of data on root growth parameters. Two basal salinity levels, EC_e[3] 2 (control) and 10 dSm^{-1}, were developed using a mixture of NaCl, Na_2SO_4, $CaCl_2$, $MgSO_4$ in a ratio of 5:9:5:1, respectively. The fertilizer required was calculated as 86 and 62kg ha^{-1} of nitrogen and phosphorus, respectively (Chaudhry, 1985) and applied before sowing. Irrigation water (EC[4] 0.29 dSm^{-1}) was applied throughout the experiment as required. Similar cultural and agronomic procedures were used for all entries. Seedlings were uprooted 21 days after planting, and data were recorded for the following parameters on five randomly selected seedlings:

1. Root length (cm)
2. Root fresh weight (g)
3. Root dry weight (g)
4. Shoot length (cm)
5. Shoot fresh weight (g)
6. Shoot dry weight (g)

3 Electrical conductivity of saturation extract at 25°C
4 Electrical conductivity of solution at 25°C

Experiment 2. Mature plant studies

The second experiment studying mature plants, was conducted in polyethylene-lined clay pots, 26 cm in diameter and depth, filled with 8 kg of the same sand and soil mixture as that used in the seedling experiment. The experiment utilized a randomized complete block design with three replications and two salinity levels. There were 5 pots each of 3 replications of all combinations of 15 lines at the 2 salinity levels making a total of 450 pots in the study. All other procedures were similar to the seedling experiment, except that the nitrogen fertilizer was applied in two doses, one-half before sowing and the other half at flowering. Data were recorded on the following parameters at physiological maturity:

1. Head diameter (cm)
2. 100-seed weight (g)
3. Seed yield per plant (g)
4. Oil content (%)

Statistical analysis

The data were subjected to analysis of variance and covariance (Steel and Torrie, 1980). Phenotypic and genotypic correlation coefficients were computed between seedling growth parameters (Experiment 1) and mature plant traits (Experiment 2) as proposed by Kwon and Torrie (1964). The significance of the phenotypic correlation coefficient was tested using the t-test as proposed by Steel and Torrie (1980). The standard error of the genotypic correlation coefficient was calculated using the procedure of Reeve (1955) and Robertson (1959). The estimates of genotypic correlation coefficient were considered significant if their absolute value exceeded twice their respective standard error.

RESULTS AND DISCUSSION

The results presented in Table 1 show the relationships between seedling growth parameters and mature plant traits under non-saline conditions. These results indicate that root length at the seedling stage was nagatively correlated with seed weight, seed yield, and oil content at the phenotypic level under non-saline conditions. Root fresh weight showed negative phenotypic and genotypic correlation with 100-seed weight and seed yield. All other root growth parameters had a non-significant correlation with mature plant traits under non-saline conditions. The results on root growth parameters show that lines having comparatively smaller roots at the seedling stage with high fresh weight produce higher seed yield under non-saline conditions.

The results obtained for shoot growth parameters (Table 1) show that shoot length was positively correlated phenotypically with head diameter and seed yield, but genotypically with head diameter only. All other shoot growth parameters had a non-significant association with mature plant traits under non-saline conditions. The results on shoot growth parameters show that lines with greater shoot length may also produce higher seed yield by increasing their head diameter.

Table.1. Phenotypic and genotypic correlation coefficients between seedling and seed yield parameters under non-saline conditions in sunflower.

SEEDLING PARAMETER		SEED YIELD PARAMETER			
		Head diameter (cm)	Seed weight (g)	Seed yield (g)	Oil content (%)
Root length	P!	-0.276^{NS}	-0.530**	-0.616**	-0.297*
	G#	-0.294^{NS}	-1.010^{NS}	-1.352^{NS}	+0.479^{NS}
Root fresh weight	P	+0.011^{NS}	-0.449**	-0.482**	+0.083^{NS}
	G	-0.025^{NS}	-0.939*	-1.059*	+0.084^{NS}
Root dry weight	P	+0.207^{NS}	+0.139^{NS}	-0.248^{NS}	-0.140^{NS}
	G	+0.306^{NS}	+0.236^{NS}	-0.309^{NS}	-0.148^{NS}
Shoot length	P	+0.315*	+0.174^{NS}	+0.297*	+0.032^{NS}
	G	+0.867*	+0.471^{NS}	+0.649^{NS}	+0.099^{NS}
Shoot fresh weight	P	+0.225^{NS}	+0.286^{NS}	-0.060^{NS}	+0.166^{NS}
	G	+0.458^{NS}	+0.556^{NS}	-0.117^{NS}	+0.259^{NS}
Shoot dry weight	P	+0.249^{NS}	+0.194^{NS}	-0.092^{NS}	-0.043^{NS}
	G	+0.065^{NS}	+0.475^{NS}	-0.109^{NS}	-0.028^{NS}
*, ** - p< 0.05 and 0.01, respectively.					
NS - Non-significant.					
! - Phenotypic correlation coefficient.					
# - Genotypic correlation coefficient.					

Table 2. Phenotypic and genotypic correlation coefficients between seedling and seed yield parameters under saline conditions in sunflower.

SEEDLING PARAMETER		SEED YIELD PARAMETER			
		Head diameter (cm)	Seed weight (g)	Seed yield (g)	Oil content(%)
Root length	P !	-0.339*	+0.226^{NS}	-0.253^{NS}	+0.303*
	G #	-1.162*	-0.655^{NS}	-1.056*	+1.023*
Root fresh weight	P	-0.445**	+0.010^{NS}	-0.284^{NS}	+0.382*
	G	-1.834^{NS}	-0.043^{NS}	-0.850*	+1.169*
Root dry weight	P	+0.017^{NS}	+0.416*	+0.145^{NS}	+0.715**
	G	+0.206^{NS}	-0.826*	-0.171^{NS}	+0.047^{NS}
Shoot length	P	-0.081^{NS}	+0.385*	-0.044^{NS}	+0.646**
	G	-0.103^{NS}	+0.443^{NS}	-0.044^{NS}	+0.799*
Shoot fresh weight	P	+0.019^{NS}	+0.402*	-0.043^{NS}	+0.308*
	G	-0.142^{NS}	+0.582^{NS}	-0.034^{NS}	+0.448^{NS}
Shoot dry weight	P	-0.184^{NS}	+0.418*	-0.027^{NS}	+0.403*
	G	-0.166^{NS}	+0.538^{NS}	-0.044^{NS}	+0.536^{NS}
*, ** - p< 0.05 and 0.01, respectively.					
NS - Non-significant.					
! - Phenotypic correlation coefficient.					
# - Genotypic correlation coefficient.					

Therefore, the results presented in Table 1 suggest that lines having comparatively small roots with low fresh weight and greater shoot length at the seedling stage may produce more seed yield under non-saline conditions.

The results for root growth parameters under saline conditions (Table 2) show that root length was correlated negatively with head diameter and positively with oil content at the phenotypic and genotypic levels. Root length also showed a negative genotypic correlation with seed yield. Root fresh weight showed a negative phenotypic correlation with head diameter and a positive phenotypic correlation with oil content. Root fresh weight showed a negative genotypic correlation with both seed yield and oil content. Root dry weight showed positive associations with seed weight and oil content at the phenotypic level and negative associations with seed weight at the genotypic level. All other root growth parameters had non-significant associations with mature plants under saline conditions.

The results for root growth parameters under saline conditions reveal that lines with comparatively small roots having low fresh weight and more dry weight may produce higher seed yield.

The results obtained for shoot growth parameters under saline conditions (Table 2) show that shoot length was positively correlated with 100-seed weight at the phenotypic level and with oil content at both the phenotypic and genotypic levels. Shoot fresh weight showed a positive phenotypic correlation with both 100-seed weight and oil content. Similarly, shoot dry weight showed a positive phenotypic correlation with 100-seed weight and oil content. All other shoot growth parameters had a non-significant relationship with mature plant traits under saline conditions. The results on shoot growth parameters under saline conditions reveal that lines having longer shoots with more fresh and dry weight may produce higher seed yield.

The results presented in Table 2 suggest that seedling parameters have very complex associations with seed yield, and it is rather difficult to select high seed-yielding lines at the seedling stage. However, oil yield can be increased through more seed weight, larger head diameter, and higher oil content. This can be achieved by selecting lines with comparatively small roots having low fresh and high dry weight, and longer shoots having higher fresh and dry weight.

Another set of correlations between seedling growth parameters under non-saline conditions and seed yield and its components under saline conditions was attempted in order to determine whether, if seleciton is made under normal conditions, the improvement achieved will be carried over when the later generations are transferred to saline conditions. The idea of genetic correlation provides the basis for an answer to this question (Falconer, 1989) where phenotypic correlation falls out of significance.

The results presented in Table 3 show the relationship of seedling growth parameters measured under non-saline conditions with mature plant traits under saline conditions. The results on shoot growth parameters show that shoot length under non-saline conditions was correlated positively with 100-seed weight under saline conditions at the genotypic level. Shoot fresh weight showed a positive correlation with head diameter and 100-seed weight at the genotypic level. Similarly, shoot dry weight showed a positive genotypic correlation with 100-seed weight and seed yield. All other shoot growth parameters had a non-significant association with mature plant traits. Similarly, all root growth parameters had a non-significant association with mature plant traits. Therefore, the results presented in Table 3 suggest that shoot growth parameters at the seedling stage under non-saline conditions are more important than root growth parameters when

Table 3. Phenotypic and genotypic correlation coefficients between seedling parameters measured under non-saline conditions and seed yield parameters under saline conditions in sunflower.

SEEDLING PARAMETER		SEED YIELD PARAMETER			
		Head diameter (cm)	Seed weight (g)	Seed yield (g)	Oil content (%)
Root length	P !	-0.105NS	+0.005NS	-0.237NS	-0.332*
	G #	-0.230NS	+0.009NS	-0.488NS	-0.646NS
Root fresh weight	P	-0.578**	+0.069NS	-0.136NS	-0.373*
	G	+0.295NS	+0.119NS	-0.239NS	-0.669NS
Root dry weight	P	+0.148NS	+0.379*	-0.729**	+0.029NS
	G	+0.166NS	+0.489NS	-0.066NS	-0.619NS
Shoot length	P	+0.410*	+0.525**	+0.311*	-0.063NS
	G	+0.645NS	+0.882*	+0.765NS	+0.053NS
Shoot fresh weight	P	+0.269NS	+0.657**	+0.353*	+0.273NS
	G	+0.938*	+0.959*	+0.389NS	+0.316NS
Shoot dry weight	P	+0.275NS	+0.649**	+0.283NS	+0.128NS
	G	+0.568NS	+0.927*	+1.209*	+0.120NS

*, ** - $p<0.05$ and 0.01, respectively.
NS - Non-significant.
! - Phenotypic correlation coefficient.
- Genotypic correlation coefficient.

selecting high seed-yielding lines for saline conditions. It is further suggested that inbred lines having longer shoots with higher fresh and dry weight may produce higher seed yield under saline conditions.

CONCLUSIONS

The results presented above suggest that high seed-yielding sunflower lines could be identified at the seedling stage. Shoot growth parameters are relatively more important than root growth parameters. It was found that lines with longer shoots at the seedling stage may produce more yield under non-saline conditions. Seedling parameters showed no direct association with seed yield under saline conditions. However, seed yield, as well as oil yield, can be improved by increasing head diameter,100-seed weight, and oil content through selection of lines having comparatively small roots with lower fresh and higher dry weight, and longer shoots with higher fresh and dry weight. It is further suggested that selection of high seed-yielding lines for saline soils is also possible under non-saline conditions by selecting lines having longer shoots with higher fresh and dry weight. These selection criteria can save considerable time in identifying salt-tolerant sunflower lines at the seedling stage. These criteria will be further evaluated in field nurseries in the future.

MANAGEMENT IMPLICATIONS

The menace of soil salinity is not confined to Pakistan, but is a global problem. Each year about 0.2 to 0.4% of the Pakistan's total arable land is being removed from cultivation because of salinity and waterlogging (Qureshi, 1978). Identification of salt-tolerant lines on the basis of economic yield production is a time-consuming process. The results of this study show that the association of seedling growth parameters with seed yield and yield components can be used to evaluate sunflower lines for salt tolerance at the seedling stage. Selection of salt-tolerant lines is possible when seedlings are grown under bothsaline and non-saline conditions. The procedures suggested here can provide a time-saving tool in the early evaluation of sunflower for salt tolerance. These can enhance the screening efficiency for large numbers of germplasms for salt tolerance, so that only selected lines will be taken to physiological maturity for conformation.

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MEJORA DEL GIRASOL CULTIVADO (*Helianthus annuus* L.) PARA TOLERANCIA A LA SALINIDAD: ASOCIACIÓN DE CRECIMIENTO DE PLÁNTULAS Y CARACTERES DE PLANTAS MADURAS

RESUMEN

Las relaciones de diferentes parámetros de crecimiento de plántulas con rendimiento y sus componentes fueron estudiados en girasol cultivado en condiciones de salinidad ($EC_e 10 dSm^{-1}$) y no salinidad ($EC_e 2 dSm^{-1}$). Líneas puras con raíces poco profundas con bajo peso fresco y mayor longitud de tallo en el estado de plántula produjeron un mayor rendimiento en semilla en condiciones no salinas. Los parámetros de plántulas mostraron unas asociaciones muy complejas con el rendimiento en condiciones salinas. Fue difícil seleccionar líneas con alto rendimiento en el estado de plántulas en condiciones salinas pero el rendimiento de aceite pudo ser incrementado indirectamente con un mayor peso de semilla, un mayor diámetro del capítulo y alto contenido de aceite mediante la selección de líneas con raíces superficiales con mayor peso seco, y tallos mas largos con mayor peso seco y fresco. La selección de líneas puras con tallos mas largos con mayor peso fresco y seco en condiciones no salinas parece ser efectivo para obtener líneas con alto rendimiento para suelos salinos.

SÉLECTION DU TOURNESOL POUR LA RÉSISTANCE À LA SALINITÉ. RELATION ENTRE LA CROISSANCE DE JEUNES PLANTULES ET LES CARACTÈRES DES PLANTES À MATURITÉ POUR LA TOLÉRANCE À LA SALINITÉ DU TOURNESOL CULTIVÉ (*Helianthus annuus* L.)

RÉSUMÉ

Les relations entre différents paramètres de vigueur de plantules et le rendement ou ses composantes ont été étudiées chez le tournesol cultivé, en conditions non salines (EC_e 2 dSm-1) ou salines (EC_e 10 dSm-1). Des lignées fixées possédant au stade plantule des racines superficielles avec un poids frais faible et un développement plus important des parties aériennes produisent un rendement en graines supérieur, en conditions non salines. Les paramètres mesurés sur les plantules révèlent l'existence de relations trés complexes avec la production grainière en conditions salines. Il est difficile de sélectionner des lignées à fort potentiel de productivité au stade plantule et en milieu salin. Cependant, le rendement en huile peut être indirectement augmenté par l'intermédiaire d'un accroissement de la densité du grain, du diamètre du capitule et de la teneur en huile grâce à la sélection de lignées à racines superficielles élaborant plus de matière sèche ainsi que des parties aériennes plus développées produisant plus de matière fraîche et sèche. La sélection de lignées présentant, en l'absence de stress salin, des parties aériennes plus développées (avec plus de matière fraiche et sèche), apparait plus efficace pour obtenir des lignées à fort potentiel de rendement, en milieu salin.