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GROWTH AND IONIC RELATIONS OF VARIOUS SUNFLOWER CULTIVARS UNDER SALINE ENVIRONMENT

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SUMMARY

A field trial was conducted in Pindi Bhattian area on sandy loam soil (EC 4.85 dSm^{-1}; pH 7.95; hydraulic conductivity 3.92 cm h^{-1}; bulk density 1.42 g cm^{-3}) to evaluate the growth performance of ten commercially cultivated sunflower genotypes under saline conditions. Ten sunflower genotypes were sown in plots (2.25 m x 15 m) according to a randomized complete block design (RCBD) in three replicates keeping the line-to-line distance of 75 cm and the plant-to-plant distance of 30 cm. The P_2O_5 (60 kg ha^{-1}) and K_2O (100 kg ha^{-1}) fertilizers were applied as SSP and SOP, respectively, at the time of sowing, while N (60 kg ha^{-1}) was applied in two equal splits (one half at sowing time and the other half at first irrigation). Five plants from each plot were randomly selected at maturity to get data on plant height (cm), shoot fresh weight (g), head fresh weight (g), and head diameter (cm). The upper fully matured leaves along with petiole (each from five plants) were collected for leaf area (cm^2). Sodium, K, Ca and Mg were analyzed in digested samples using an atomic absorption spectrophotometer. Maximum shoot fresh weights by DK-3915, PARSUN-1 and CRN-1435 closely followed by PARC-9707 were 695.9, 682.3, 669.9 and 578.4 g per plant, respectively. Head fresh weights were highest in CRN-1435, 6451 and DK-3915. The cultivar 6451 produced a comparatively low shoot fresh weight but was significantly ($p<0.0001$) superior in seed yield (2475 kg ha^{-1}) that was 47% higher than the maximum shoot biomass producing variety DK-3915. The cultivars CRN-1435 and HU-777 were also among the highest seed yielding genotypes. K^+ concentrations in leaves, petiole and stem of the genotype Super-25 and cultivar 6451 were maximum compared with the other genotypes. Generally, the cultivars having high concentration of K^+ maintained a low concentration of Na^+ in its leaves. The high potassium concentrations in leaves, petioles and stems suppressed the detrimental effect of Na^+ ions on 1000-grain weight and percentage of oil. High Ca^{2+} concentrations were observed in leaves, petioles and stems of PARC-9707 and PARC-9706.

Key words: **growth performance, *Helianthus annuus*, oil content, seed yield, NaCl salinity, sunflower genotypes**

INTRODUCTION

The demand for oilseeds has increased several times for the last few years but the acreage cannot be increased because of increasing competition with major cereals crops especially in many developing countries. In Pakistan, during 1991-92, US$ 172 millions have been spent on the import of edible oil. During 1998-99, this amount increased to US$ 724 millions as a result of 9% annual increase in the consumption of edible oil (GOP, 2000). Hence, in Pakistan, edible oil import takes the second position after petroleum products. Self-sufficiency in edible vegetable oil can be achieved by growing crops of high yield potential and higher oil content on marginally salt affected lands. Among the oilseed crops, sunflower (*Helianthus annuus* L.) is an important source of high quality vegetable oil and it gains popularity among consumers for its good cooking quality. It has recently been introduced and received well in Pakistan. Because of its tremendous yield potential and high oil content, this crop offers great promise to meet the edible oil deficit in the country.

In many countries with arid/semi-arid climatic conditions, soil salinity, low soil fertility, low organic matter content and drought are major constraints that impair crop yields. In this respect, development/identification of crop species and varieties tolerant to salinity and adaptable to nutrient deficient soils is being considered a promising tool for sustaining crop yields in resource-poor environment (Sandhu and Quershi, 1986; Foy, 1993). Growing salt tolerant cultivars on marginal lands provides an additional benefit of transforming these marginal lands into productive agricultural lands. This can be achieved with the strategy of "tailoring the plant to fit the soil" in contrast to the older strategy of "tailoring the soil to fit the plant" (Foy, 1983). Salinity exerts a number of different effects on plant growth and metabolism through reduced water uptake, nutritional imbalances and toxic effects of some of the ions. Uptake and translocation of nutrient ions like K^+ and Ca^+ are greatly reduced by salinity stress (Rengel, 1992; Nawaz *et al.*, 2002). These can be improved by overcoming the facing problems and adoption of appropriate technology such as addition of optimum fertilizers and growing of tolerant crops those are able to produce high yields on such marginal lands (Sandhu and Qureshi, 1986).

To cope with the nutritional requirements of the growing population, effective utilization of problem and marginal soils has become imperative. In this context, the genetic potential and varietal differences with respect to salt tolerance are of great practical interest when introducing new crop varieties in a saline area. This emphasizes the screening of different crop varieties of great demand for their salt tolerance. Therefore, the present study was planned to identify high yielding sunflower cultivars that are tolerant to salinity under natural saline and marginal soils.

MATERIAL AND METHODS

A field trial was conducted in Pindi Bhattian area on sandy loam soil (EC 4.85 dSm^{-1}; pH 7.95; hydraulic conductivity 3.92 cm h^{-1}; bulk density 1.42 g cm^3) to evaluate the growth performance of ten commercially cultivated sunflower genotypes under saline conditions. Seeds of ten sunflower genotypes were sown in plots (2.25 m x 15 m) according to a randomized complete block design (RCBD) in three replicates with the help of a single row drill keeping a line-to-line distance of 75 cm. The plant-to-plant distance was maintained at 30 cm by thinning at four leaves stage. The P_2O_5 (60 kg ha^{-1}) and K_2O (100 kg ha^{-1}) fertilizers were applied as SSP and SOP, respectively, at the time of sowing, while N (6kg ha^{-1}) was applied in two equal splits (one half at sowing time and the other half at first irrigation). The general protocol of the experiment (plant protection measures, cultural practices and irrigation) was carried out as and when needed up to the harvest.

Five plants from each plot were randomly selected at maturity to get data on plant height (cm), shoot fresh weight (g), head fresh weight (g) and head diameter (cm). The upper fully matured leaves along with petiole (each from five plants) were collected for leaf area measurement (cm^2). After washing with distilled water, the petioles were separated from leaves. The leaves, petioles and stem (2 cm portions just before head) were oven dried, ground and digested in di-acid mixture (HNO_3:$HClO_3$ in 3:1 ratio) (Miller, 1998). Sodium, K, Ca and Mg were analyzed in the digested samples using an atomic absorption spectrophotometer. Seed yield from each plot was extrapolated as kg ha^{-1}. Oil content in the seed samples was determined by Soxhlet apparatus following AOAC (1984) methods. The data thus collected were subjected to standard procedures of statistics and means were compared by Duncan's multiple range test at $p<0.05$ (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Growth and yield

Maximum shoot fresh weights of DK-3915, PARSUN-1 and CRN-1435 closely followed by PARC-9707 were 695.9, 682.3, 669.9 and 578.4 g per plant, respectively (Table 1). Head fresh weights were highest in CRN-1435, 6451 and DK-3915. The cultivar 6451 produced a comparatively low shoot fresh weight but it was significantly ($P<0.0001$) superior in seed yield (2475 kg ha^{-1}) that was 47% higher than maximum shoot biomass producing variety DK-3915. The cultivars CRN-1435 and HU-777 were also among the highest seed yielding genotypes. Tarnab-1 produced a significantly lower seed yield (1203.2 kg ha^{-1}) followed by PARC-9707 (1333.0 kg ha^{-1}). Although the cultivar Tarnab-1 statistically had a poor performance in terms of achene yield, it showed a higher oil percentage (Figure 1). DK-3915 and HU-777 had minimum percentages of oil. Several environmental and genotypic factors can influence the oil content. In addition, a combination of yield compo-

Table 1: Intervarietal differences in growth parameters of different sunflower cultivars

Cultivar	Plant length (cm)	Stem girth (mm)	Shoot fresh weight (g)	Head fresh weight (g)	Head diameter (cm)	Leaf area (m^2)	1000-grain weight (g)	Seed yield (kg ha^{-1})
HU-777	149.67 ab* (±7.72)	17.47 de (±1.51)**	422.5 cd (±55.3)**	322.1 cd (±73.1)**	17.87 cd (±1.85)	196.9 b-d (±32.34)	44.37 b-d (±3.76)	2248.7 a (±6.1)
CRN-1435	148.73 ab (±16.04)	21.33 bc (±1.68)	669.9 a (±78.2)	517.3 a (±58.1)	20.87 a (±1.73)	249.8 b (±48.45)	47.33 bc (±1.69)	2402.2 a (±16.5)
DK-3915	154.00 ab (±27.84)	20.33 bc (±2.50)	6695.9 a (±132.1)	498.8 a (±77.0)	19.10 a-c (±1.93)	238.1 bc (±38.58)	49.87 ab (±3.52)	1681.0 b (±31.9)
Super-25	97.07 d (±11.60)	18.67 c-e (±0.82)	203.3 e (±59.5)	252.2 de (±54.7)	14.53 e (±1.73)	148.5 de (±29.89)	54.63 a (±2.40)	1616.1 b (±20.5)
6451	120.20 c (±10.03)	24.13 a (±3.07)	526.9 bc (±124.3)	501.8 a (±90.4)	20.27 ab (±2.22)	317.6 a (±55.08)	49.17 b (±4.02)	2475.4 a (±10.0)
SF-177	139.20 b (±10.67)	17.40 de (±2.23)	366.0 d (±66.8)	305.9 cd (±58.8)	16.60 d (±2.32)	203.3 b-d (±42.25)	47.87 bc (±0.60)	1668.6 b (±18.1)
Tarnab-I	88.80 d (±7.07)	16.27 e (±1.71)	151.3 e (±57.8)	171.7 e (±40.6)	12.97 e (±1.63)	136.3 e (±31.22)	41.57 d (±2.71)	1203.2 c (±22.2)
PARC-9707	142.67 ab (±11.73)	22.73 ab (± 2.91)	578.4 ab (±95.0)	428.3 ab (±54.6)	18.80 a-c (±1.86)	200.1 b-d (±36.02)	42.43 cd (±3.52)	1333.0 bc (±10.1)
PARC-9706	160.93 a (±12.40)	20.80 bc (±2.04)	466.0 b-d (±121.7)	385.1 bc (±71.0)	18.67 bc (±1.63)	186.2 c-e (±24.31)	46.90 b-d (±3.92)	1642.5 b (±21.8)
PARSUN-I	148.33 b (± 11.36)	19.87 cd (±2.26)	682.3 a (±109.47)	455.1 ab (±58.2)	19.67 a-c (±1.76)	231.3 bc (±39.00)	43.23 cd (±0.84)	1546.8 b (±13.5)
LSD	17.86	2.49	115	83.5	1.92	54.3	5.06	315.2
Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Coeff. Var.	10.14%	6.94%	14.67%	12.31%	6.18%	14.86%	6.33%	10.39%

* means with same letter(s) in each column are statistically similar at 5% probability
** standard deviation (n=15)
*** standard deviation (n=3)

nents in a given plant determines the allocation of photosynthesis and seed oil content (Grafius, 1964; Connor and Sadras, 1992). The results suggest that differences in oil content were probably due to differences in leaf area and head diameter. Moreover, increases in head and shoot fresh weights tended to decrease the percentage of oil (Figure 1). Perhaps it is due to increased utilization of oil-forming compounds for vegetative growth, ultimately resulting in lower percentage of oil. Similar results have been discussed by Akhtar *et al. (*1992).

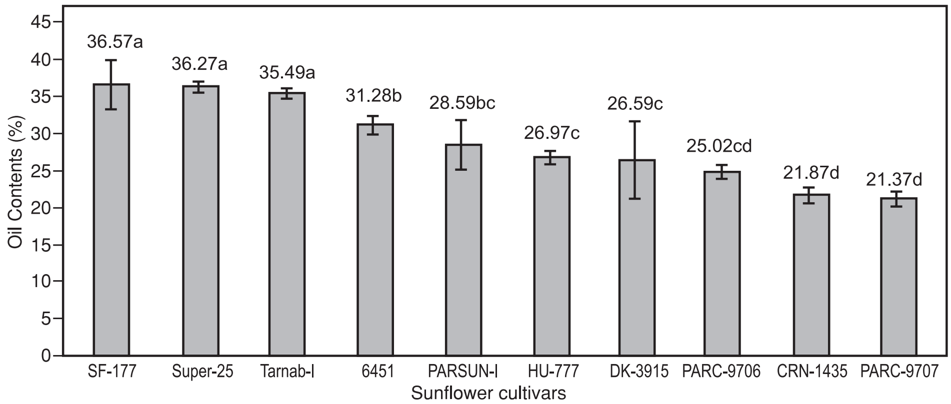

Figure 1: Intervarietal differences in oil content (%) of different sunflower cultivars (n=3)

Concerning the 1000-grain weight, it was statistically highest in Super-25, closely followed by DK-3915 and the cultivar 6451. Tarnab-1 produced the minimum 1000-grain weight which was 31% less than that of the high yielding cultivar Super-25. The reason could be a genetic variation causing low tolerance to salinity hazard. Increased sensitivity to salinity at grain formation stage compared with the stage of vegetative growth has been reported by Wyn Jones (1985), Gorham *et al.* (1985), Flowers (1985) and Nawaz *et al.* (2002).

Ionic composition

Potassium concentration

Maximum mean concentration of K^+ ions was observed in leaves followed by petiole (Table 2). K^+ concentrations in leaves, petiole and stem of the genotype Super-25 and cultivar 6451 were maximum compared with the rest of the genotype. It is clear from Table 1 that the cultivar 6451 had highest seed yield. The parameters stem girth, head fresh weight, leaf area and K^+ concentration (Figure 2) in petioles and stems followed by leaves might have contributed to improved seed yield under saline conditions. A similar trend was observed in the case of Super-25, which had a low seed yield but maintained significantly high 1000-grain weight and percentage of oil (Table 1). Leaves of all cultivars had increased K^+ concentrations except SF-177, Tarnab-1 and PARSUN-1. Tarnab-1 contained the lowest K^+ concentration in petioles. On the other hand, the cultivars PARC-9706 and PARSUN-1

Table 2: Intervarietal differences in ionic composition of different sunflower cultivars

Cultivar	Sodium content (mg kg^{-1})			Potassium content (%)			Calcium content (%)			Magnesium content (%)		
	Leaf	Petiole	Stem	Leaf	Petiole	Stem	Leaf	Petiole	Stem	Leaf	Petiole	Stem
HU-777	111.5 b* (±8.4)**	82.9 bc (±18.1)	51.6 d (±14.0)	3.70 b (±0.33)	4.48 bcd (±0.31)	4.37 bc (±0.37)	2.86 bc (±0.40)	2.58 ab (±0.17)	1.09 ab (±0.11)	1.07^{NS} (±0.08)	1.07 b-e (±0.07)	0.21 ab (±0.01)
CRN-1435	113.1 b (±33.4)	110.7 a (±16.5)	35.0 d (±17.2)	3.78 ab (±0.27)	4.99 ab (±0.30)	4.37 bc (±0.35)	2.64 c (±0.19)	2.49 abc (±0.23)	1.09 ab (±0.08)	1.04 (±0.03)	0.95 e (±0.07)	0.21 a (±0.03)
DK-3915	99.4 b (±27.4)	103.2 ab (±9.2)	51.8 d (±10.2)	3.73 b (±0.34)	4.92 ab (±0.33)	4.19 c (±0.30)	2.68 c (±0.06)	2.38 bcd (±0.21)	0.90 c (±0.11)	1.02 (±0.08)	0.99 de (±0.06)	0.13 cd (±0.02)
Super-25	169.3 a (±12.0)	74.7 c (±19.1)	67.5 bcd (±28.2)	4.35 a (±0.30)	5.19 a (±0.25)	4.86 ab (±0.10)	2.99 bc (±0.21)	2.17 d (±0.15)	0.93 bc (±0.07)	1.05 (±0.13)	1.07 cde (±0.07)	0.06 e (±0.02)
6451	112.0 b (±28.7)	65.1 cd (±15.8)	84.9 abc (±17.7)	4.08 ab (±0.15)	5.15 a (±0.15)	4.99 a (±0.44)	2.90 bc (±0.34)	2.41 bcd (±0.07)	0.93 bc (±0.11)	1.03 (±0.08)	1.08 bcd (±0.06)	0.06 e (±0.03)
SF-177	90.2 b (±25.6)	40.6 d (±8.2)	65.2 bc (±6.1)	2.83 c (±0.32)	4.47 bcd (±0.44)	4.51 abc (±0.44)	2.79 bc (±0.18)	2.48 abc (±0.07)	1.11 a (±0.03)	1.13 (±0.08)	1.19 b (±0.06)	0.24 a (±0.02)
Tarnab-I	108.3 b (±12.9)	57.5 cd (±12.0)	62.0 cd (±4.2)	3.09 c (±0.68)	3.97 d (±0.26)	4.33 bc (±0.36)	3.06 abc (±0.14)	2.25 cd (±0.22)	0.82 c (±0.07)	1.23 (±0.05)	1.33 a (±0.06)	0.15 bc (±0.03)
PARC-9707	113.5 b (±12.1)	64.7 cd (±3.9)	45.3 d (±15.7)	3.92 ab (±0.20)	4.74 abc (±0.35)	4.24 c (±0.32)	3.21 ab (±0.18)	2.50 abc (±0.04)	1.14 a (±0.03)	1.05 (±0.05)	0.96 de (±0.05)	0.21 ab (±0.02)
PARC-9706	112.6 b (±21.2)	73.8 c (±12.4)	94.5 ab (±21.8)	3.81 ab (±0.09)	4.26 cd (±0.38)	2.91 d (±0.02)	3.43 a (±0.31)	2.60 ab (±0.25)	1.11 a (±0.13)	1.13 (±0.08)	1.02 cde (±0.02)	0.25 a (±0.04)
PARSUN-I	125.3 b (±24.0)	68.6 c (±15.6)	99.8 a (±19.7)	2.79 c (±0.09)	4.79 abc (±0.14)	2.63 d (±0.16)	2.92 bc (±0.17)	2.74 a (±0.04)	0.92 bc (±0.10)	1.23 (±0.09)	1.12 bc (±0.06)	0.09 de (±0.01)
LSD	37.81	23.61	28.86	0.55	0.52	0.54	0.40	0.28	0.15	0.13	0.11	0.05
Prob.	0.031	0.0002	0.0017	0.001	0.0012	0.0000	0.0165	0.0172	0.0019	0.0681	0.0000	0.0000
Coeff. Var.	19.21%	18.69%	25.77%	8.88%	6.49%	7.67%	8.06%	6.73%	8.96%	6.95%	5.54%	14.49%
Mean	115.52 A	74.18 B	65.76 B	3.61 A	4.69 B	4.14 C	2.95 A	2.46 B	1.00 C	1.09 A	1.08 A	0.16B

* Means with same letter(s) in each column are statistically similar at 5% probability
** Standard deviation (n=3)

had the lowest K^+ concentrations in stems. High concentrations of K^+ were observed in leaves of PARC-9706 and petioles of PARSUN-1. Overall, the cultivars having low K^+ concentrations either in their leaves, petioles or stems also had significantly low seed yields. Thus it could be assumed that K^+ plays a role in improving yield and plant health under adverse conditions. Similar observations have been made by various workers (Ravikovitch and Porath, 1967; Devitt *et al.*, 1981; Munns and Termaat, 1986; Bilts and Gallagher, 1990; Flowers *et al.*, 1991; Sharma, 1995; Aslam *et al.*, 2001).

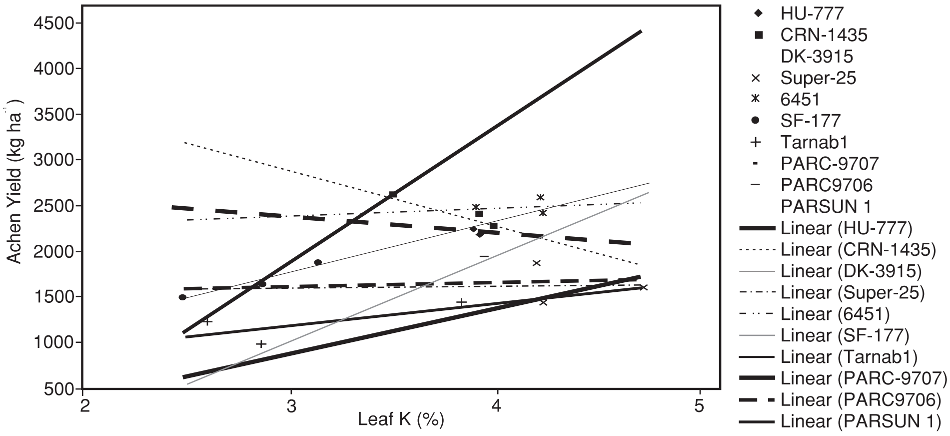

Figure 2: Relationship between leaf K and achene yield in ten sunflower cultivars (n=3)

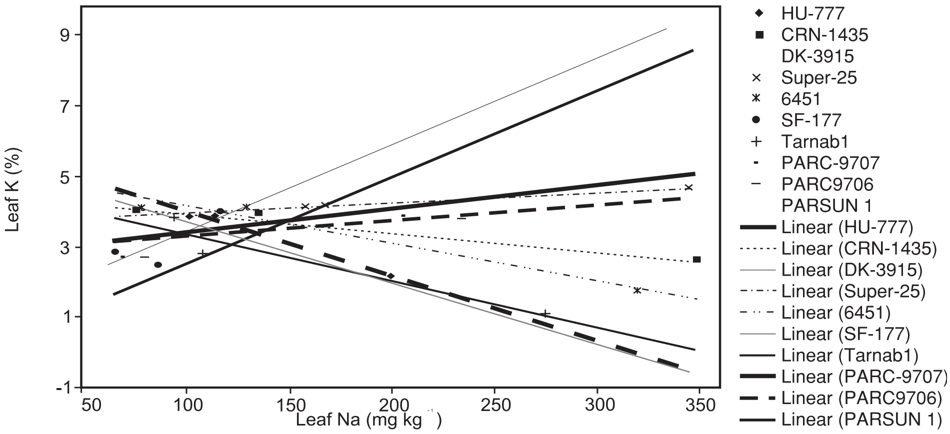

Figure 3: Relationship between leaf Na and leaf K in ten sunflower cultivars (n=3)

Sodium concentration

Comparatively low average Na^+ concentrations were observed in petioles and stems. Highest average mean values for sodium ions were found in leaves (Table 2). Generally, the cultivars having a high concentration of K^+ maintained a low concentration of Na^+, except Super-25 that showed an increased Na^+ concentration in leaves (Figure 3). High potassium concentrations in leaves, petioles and stems suppressed the detrimental effect of Na^+ ions on 1000-grain weight and percentage of oil. It was evident from the obtained data that high concentrations of Na^+ in petioles and/or stems may have caused a lower percentage of oil and poor growth (Table 2). The reduction in growth varied with cultivars, indicating their genetic specificity for salt tolerance (Devitt *et al.*, 1981; Yeo *et al.*, 1990, 1993). Plants growing on saline soils have to face a high osmotic stress, high concentrations of potentially toxic ions such as Na^+ and Cl^- and unfavorable combinations of ions which may ultimately cause reductions in growth and yield. Ion absorption, though it facilitates osmotic adjustment, may nevertheless lead to ion toxicity and nutritional imbalance that could be minimized through a judicious supply of plant nutrients. Ravikovitch and Porath (1967), Flowers *et al.* (1991), Yeo (1992), Sharma (1995) and Lutts *et al.* (1996) have provided similar results.

Calcium concentration

High Ca^{2+} concentrations were observed in all plant parts, *i.e.*, leaves, petioles and stems, of PARC-9707 and PARC-9706. The cultivars HU-777, CRN-1435 and SF-177 showed higher Ca^{2+} concentrations in petioles and stems than in leaves. All other sunflower cultivars had comparatively low Ca^{2+} concentrations. Generally, the plants having high Ca^{2+} concentration showed poor performance under saline environment (Table 1). Accordingly, reductions in growth and yield were severe in the cultivars PARC-9707 and PARC-9706. Adverse affects on growth and yield due to high Ca^{2+} ion accumulation may have been caused by the accumulation of toxic ions in association with Ca^{2+} and suppression of other required ions needed for growth under stress condition. On the other hand, adverse affects may also be due to the genetic ability of cultivars to withstand saline conditions. Cultivars within species differ much in salt tolerance. Data from this experiment revealed that Ca^{2+} concentration reduced the uptake of Na^+ ions to some extent but the reduction in growth and yield was also observed. The cultivars DK-3915, Super-25 and 6451 accumulated less Ca^{2+} ions as compared with the rest of the genotypes and hence their 1000-grain weight increased more than any other parameter. This unexpected behavior of Ca^{2+} accumulation might be due to genetic ability of sunflower to cope with salt stress. These data do not support the observations reported by Drake *et al.* (1941), Eck and Campbell (1962), Rengel (1992), Aslam *et al.* (2000) and Ali *et al.* (2001) who stated that a low reduction in yield under saline conditions might be due to a better Ca^{2+}/Na^+ ratio and a high level of Ca^{2+} ions which tend to provide relief from other kinds of ion toxicity.

Magnesium concentration

Mg^{2+} status in leaves of all genotypes was non-significant but varietals means showed maximum Mg^{2+} concentrations in leaves and petioles (Table 2). The cultivar Tarnab-1 stored a maximum Mg^{2+} concentration in its petioles while PARC-9706, SF-177 and CRN-1435 had high concentrations of this ion in their stems closely followed by HU-777 and PARC-9707 and both were at par regarding the concentration of this ion in their stems. Minimum concentrations of Mg^{2+} ions were observed in the stems of Super-25 and cultivar 6451. From these data it was evident that Mg^{2+} ions played no role for the improvement of growth and yield of sunflower cultivars grown under saline conditions. The cultivars having lower concentration of Mg^{2+} ions in their stems (Super-25 and 6451) were found to be better in maintaining yield and percentage of oil. The most adverse affect of toxic ions in saline soil may be governed by a variety of factors, one of which is the effect of associated ions. The role of Mg^{2+} is very important in this regard and its seems that high level of Mg^{2+} in plant tissue results in the uptake of Cl^- ions that may cause reduction in growth and yield.

CONCLUSIONS

The cultivar 6451 produced a comparatively low shoot fresh weight but it was significantly ($P<0.0001$) superior in seed yield (2475 kg ha^{-1}) that was 47% higher than the maximum shoot biomass producing variety DK-3915 under saline conditions. The cultivars CRN-1435 and HU-777 were among the genotypes with highest seed yields. K^+ concentrations in leaves, petioles and stems of genotypes Super-25 and cultivar 6451 were maximum compared with the other genotypes. Generally, the cultivars having a high concentration of K^+ maintained a low concentration of Na^+ under saline conditions except Super-25, which showed high Na^+ concentration in leaves.

REFERENCES

Akhtar, M., Nadeem, A., Ahmad, S. and Tanweer, A., 1992. Effect of nitrogen on seed yield and quality of sunflower (*Helianthus annuus* L.). J. Agron. Res. 30(4): 479-484.

Ali, A., Badr-uz-Zaman and Salim, M., 2001. Evaluation and performance of different commercial sunflower hybrids under saline conditions. Helia 24(35): 149-158.

AOAC, 1984. Official Methods of Analysis. Association of Official Analytical Chemist. 14^{th} Ed. Washington DC, USA, pp. 770-771.

Aslam, M., Mahmood, I.H., Qureshi, R.H., Nawaz, S., Akhtar, J. and Ahmad, Z., 2001. Nutritional role of calcium in improving rice growth and yield under adverse conditions. Int. J. Agri. Biol. 3: 292-297.

Aslam, M., Muhammad, N., Qureshi, R.H., Nawaz, S., Akhtar, J. and Ahmad, Z., 2000. Role of Ca^{2+} in salinity tolerance of rice. Symp. on Integ. Plant Management No. 8-10 (1998), Islamabad.

Bilts, K.C. and Gallagher, J.L., 1990. Salinity tolerance of *Kosteletzkya virginica.* 1. Shoot growth ion and water relations. Plant Cell Environ. 13: 409-418.

Connor, D.J. and Sadras, V.O., 1992. Physiology of yield expression in sunflower. Field Crops Res. 30: 333-389.

Devitt, D.W., Jarrell, M. and Stevens, K.L., 1981. Sodium potassium ratios in soil solution and plant response under saline conditions. Soil Sci. Soc. Am. J. 45: 80-86.

Drake M., Sieling, D.H. and Scarseth, G.D., 1941. Calcium-boron ratio as an important factor in controlling the starvation of plants. J. Am. Soc. Agron. 33: 454-462.

Eck, P. and Campbell, F.J., 1962. Effect of high calcium application on boron tolerance of carnation *Dianthus carycphyllus*. Proc. Am. Soc. Hort. Sci. 81: 510-517.
Flowers, T.J., 1985. Physiology of halophytes. Plant and Soil 89: 41-56.
Flowers, T.J., Hajibagheri, M.A. and Yeo, A.R., 1991. Ion accumulation in the cell walls of rice plants growing under saline conditions: evidence for the Oertli hypothesis. Plant Cell Environ. 14: 319-325.
Foy, C.D., 1983. The physiology of plant adaptation to mineral stress. Iowa State J. Res. 54: 355-391.
Foy, C.D., 1993. Role of Soil Scientists in Genetic Improvement of Plants for Problems Soils. In: Adaptation of Plants to Soil Stresses. INTSORMIL Pub., No. 94-2, University of Nebraska, Lincoln, USA, pp. 185-206.
Steel, R.G.D. and Torrie, J.H., 1980. Principles and Procedures of Statistics. McGrow-Hill, New York, USA.
Gorham, J.E., McDonnell, Budrewicz, E. and Wyn Jones, R.G., 1985. Salt tolerance in the *Triticeae*: Growth and salt accumulation in leaves of *Thynopyrum bessarabicum*. J. Exp. Bot. 36(168): 1021-1031.
GOP, 2000. Agricultural statistics of Pakistan. Min. Food Agric., Economic Wing, Gov. of Pak., Islamabad.
Grafius, J.E., 1964. A geometry for plant breeding. Crop Sci. 4: 241-246.
Lutts, S., Kinet, J.M. and Bouharmont, J., 1996. NaCl-induced senescence in leaves of rice (*Oryza sativa* L.) cultivars differing in salinity resistance. Ann. Bot. 78: 389-398.
Miiler, R.O., 1998. Nitric-perchloric acid wet digestion in an open vessel. In: Kalra, Y.P. (Ed.), Hand Book of Reference Methods for Plant Analysis, Soil and Plant Analysis Council, Inc, CRC Press, Washington DC, USA.
Munns, R. and Termaat, A., 1986. Whole–plant responses to salinity. Aus. J. Plant Physiol. 13: 143-160.
Nawaz, S., Akhtar, N., Aslam, M., Qureshi, R.H. and Akhtar, J., 2002. Anatomical, morphological and physiological changes in sunflower varieties because of NaCl. Pak. J. Soil Sci. 21(1-2): 87-93.
Ravikovitch, S. and Porath, A., 1967. The effect of nutrients on the salt tolerance of crops. Plant and Soil 26: 49-71.
Rengel, Z., 1992. The role of calcium in salt toxicity. Plant Cell Environ. 15: 625-632.
Sandhu, G.R. and Quereshi, R.H., 1986. Salt-affected soils of Pakistan and their utilization. Reclam. Reveg. Res. 5: 105-113.
Sharm, S.K., 1995. Effects of salinity on growth performance and internal distribution of sodium, potassium and chloride in *Vicia faba* L. Div. of Crop Improvement, Central Soil Salinity Institute, Kernal 132001, India, Indian J. Plant Physiol. 38(1): 69-72.
Wyn Jones, R.G., 1985. Salt tolerance. Chemistry in Britain, pp. 454-459.
Yeo, A.R., 1992. Variation and inheritance of sodium transport in rice. Plant and Soil 146: 104-116.
Yeo, A.R., 1993. Variation and inheritance of sodium transport in rice. In: Genetic Aspect of Plant Mineral Nutrition (P.J. Randall, E. Delhaize, R.A. Richard and R. Munns, eds.), Kluwe Academier, Dordrecht, The Netherland, pp. 143-150.
Yeo, A.R., Yeo, M.E., Flowers, S.A. and Flowers, T.J., 1990. Screening of rice (*Oryza sativa* L.) genotypes for physiological characters contributing to salinity resistance and their relationship to overall performance. Theor. Appl. Gen. 79: 377-384.

CRECIMIENTO Y RELACIONES IÓNICAS EN LAS VARIEDADES DE GIRASOL CULTIVADAS EN LAS CONDICIONES DE SALINIDAD

RESUMEN

El ensayo de campo fue realizado en la localidad de Pindi Bhattian en la arcilla arenosa (EC 4,85 dSm^{-1}, pH 7,95, conductibilidad hidráulica de 3,92 cm hr^{-1}, masa volumétrica de 1,42 g cm^{-3}) para evaluar el crecimiento de 10 genotipos de girasol comerciales en las condiciones de salinidad. La semilla de 10 genotipos fue sembrada en parcelitas (2,25 m × 15 m) en el sistema de bloques al azar completos en tres repeticiones, con la distancia de 75 cm entre filas y 30 cm en fila. P_2O_5 (60 kg ha^{-1}) y K_2O (100 kg ha^{-1}) fueron aplicados como SSP y SOP en el tiempo de siembra, mientras que N (60 kg ha^{-1}) fue aplicado en dos partes iguales (la primera mitad en el tiempo de la siembra, la otra mitad en el tiempo del primer riego). Cinco plantas de cada parcelita fueron elegidas al azar en la fase de madurez para que se obtuvieran los datos sobre la altura de la planta (cm), masa fresca del brote (g), masa fresca de la cabeza (g) y diámetro de la cabeza (cm). Las hojas superiores, totalmente desarrolladas, incluyendo los pecíolos (de cinco plantas) fueron tomadas con el fin de determinar la superficie foliar (cm^2). Tras la digestión de las muestras, Na, K, Ca y Mg fueron analizados por el espectrofotómetro atómico de absorción. Los valores máximos de la masa fresca del brote en DK-3915, PARSUN-1 y CRN-1435 acompañados por PARC-9707, eran 695,9, 682,3, 669,9 y 578,4 g por planta. La masa fresca de la cabeza fue más alta en CRN-1435, 6451 y DK-3915. La variedad 6451 tenía comparativamente el menor peso del brote fresco, pero era significativamente superior ($P<0.0001$) en cuanto al rendimiento de la semilla (2475 kg ha^{-1}) lo que era 47% más de la biomasa máxima del brote, en la variedad DK-3915. Las variedades CRN-1435 y HU-777, también estaban en el grupo de genotipos con el mayor rendimiento de semilla. La concentración K^+ en las hojas, en pecíolos y en el tallo del genotipo Super-25 y de la variedad 6451, era la más alta en relación con los demás genotipos. En general, las variedades con altas concentraciones de K^+, tenían las concentraciones de Na^+ más bajas, excepto Super-25 que tenía la concentración de Na^+ en las hojas aumentada. La concentración de K era aumentada en las hojas, los pecíolos y el tallo, lo que suprimió la influencia negativa de los iones Na^+ en el peso de 1000 granos y porcentaje de aceite. La alta concentración de Ca^{2+} fue determinada en los pecíolos y en los tallos en PARC-9701 y PARC-9706.

CROISSANCE ET RAPPORTS IONIQUES DE DIFFÉRENTS CULTIVARS DE TOURNESOL DANS UN ENVIRONNEMENT SALIN

RÉSUME

Nous avons effectué une expérience dans un champ de la région de Pindi Bhattian sur un sol argileux sableux (EC 4,85 dSm^{-1}, pH 7,95, conductivité hydraulique 3,92 cm hr^{-1}, volume de la masse 1,42 g cm^{-3}) pour évaluer la croissance de dix génotypes de tournesol commerciaux cultivés dans des conditions salines. Les graines de tournesol de dix génotypes ont été semées sur des parcelles (2,25 m x 15 m) en trois fois et selon le système de blocs complets randomisés avec une distance de 75 cm entre les rangées et de 30 cm entre les plantes. Les engrais P_2O_5 (60 kg ha^{-1}) et K_2O (100 kg ha^{-1}) ont été utilisés comme SSP et SOP au temps des semailles tandis que N (60 kg ha^{-1}) a été utilisé en deux parties égales (la première moitié au temps des semailles et la deuxième au temps de la première irrigation). À leur maturité, nous avons choisi cinq plantes de chaque parcelle au hasard pour obtenir des données sur la hauteur de la plante (cm), la masse fraîche de la pousse (g), la masse fraîche de la tête (g) et le diamètre de la tête (cm). Pour mesurer la surface feuillue (cm^2), nous avons recueilli les feuilles supérieures arrivées à complète maturité en incluant le pétiole (des cinq plantes). Après la digestion des échantillons, le sodium, K, Ca et Mg ont été analysés par le spectrophotomètre d'absorption atomique. Le poids maximal de la masse fraîche des pousses pro-

duite par DK-3915, PARSUN-1 et CRN-1435 suivis de près par PARC-9707 était de 695,9, 682,3, 669,9 et 578, 4 g par plante. Le poids de la masse fraîche de la tête était le plus important dans le cas de CNR-1435, 6451 et DK-3915. Comparativement, le cultivar 6451 avait produit un moindre poids pour la pousse fraîche mais avait été significativement supérieur ($P<0,0001$) pour le rendement en graines (2475 kg ha^{-1}) ce qui est 47% de plus que la biomasse maximale de la pousse de la variété DK-3915. Les cultivars CRN-1435 et HU-777 étaient aussi parmi les génotypes produisant le plus grand rendement en graines. Comparativement à celle des autres génotypes, la concentration K^+ dans les feuilles, le pétiole et la tige du génotype Super-25 et du cultivar 6451 était la plus importante. En général, les cultivars ayant une grande concentration de K^+ avaient gardé une moindre concentration de Na^+ à l'exception du Super-25 qui avait montré une plus grande concentration de Na^+ dans les feuilles. La concentration de potassium était aussi plus élevée dans les feuilles, le pétiole et la tige, ce qui neutralisait l'effet négatif des ions Na^+ sur le poids de 1000 graines et le pourcentage du contenu d'huile. Une grande concentration de Ca^{2+} a été constatée dans les pétioles des feuilles et dans la tige de PARC-9701 et PARC-9706.