

Effect of Salt Stress on Seedling Growth of Sunflower (*Helianthus annuus L.*)



Biotechnology

KEYWORDS : sunflower, salinity, germination and seedling growth.

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ABSTRACT

Sunflower (Helianthus annuus L.) is becoming an increasingly important source of edible vegetable oil throughout the world because of its high polyunsaturated fatty acid content and no cholesterol. The increasing demand for this oil may promote increased hectare of sunflower in the India, where some soils are saline or have the potential to become so. Effects of salt stress on seed germination and seedling growth characteristics were evaluated for twelve Helianthus annuus L. genotypes in Five treatments of salinity including 0.0 (control), 0.0 (Control), 0.4, 0.9, 1.3 and 1.7 dS/m concentration of NaCl in a three replicated randomized completely block design (RCBD). ANOVA revealed highly significant differences for fresh weight and dry weight and leaf area etc., under various salt concentrations. However, the differences among the genotypes for all the parameters studied were highly significant. The findings suggest that, SFL-07 and PKVSH-27 genotypes were found to be tolerate moderate levels of salinity and can be tried for cultivation on marginal salted soils.

Introduction

Sunflower (*Helianthus annuus L.*) is most important oil seed crop of the world next to groundnut, rapeseed and mustard (Virupakshappa and Somasekhar, 1997). It is valued for its anticholesterol properties. Sunflower (*Helianthus annuus L.*), a New World plant, has been developed into a valuable source of edible oil and meal. Salt stress is a major environmental stress, which affects seed germinating, plant growth and development, metabolic processes and productivity (Prado et al., 2000; Pujari and Chanda, 2002; Al-Taisan, 2010). Crop salinity sensitivity varies with species, genotypes and growth stages (Prado et al., 2000; Pujari and Chanda, 2002). Salt stress induced inhibition of seed germination, seedling growth and metabolic processes were reported in maize (Azevedo et al., 2004), wheat (Brini et al., 2009), safflower (Demir et al., 2003), cotton (Diego et al., 2003), sunflower (Mehmet et al., 2006), etc. Saline soils remarkably reduce oil production potential and oil yield of sunflower (Szabolcs, 1994). Self sufficiency, stability in production and increasing demand for food could be realized only by bringing marginal and saline soils into cultivation. So, screening and identification of salt tolerant genotypes, incorporation of these traits into economically important crops like sunflower needs urgent attention. Based on the salt tolerance, sunflower is classified as moderately tolerant (Francois, 1996).

Hussein and Rehman (1997) reported that emergence percent, emergence index; shoot length and fresh weight of the seedling can be used as selection criteria for salt tolerance in sunflower at seedling stage. Use of laboratory techniques for screening genotypes for salt tolerance was found efficient due to these potential advantages over conventional methods. In several studies of salinity a single salt solution of sodium chloride had attracted great attention (Ashraf et al., 1987). The present study was undertaken with an objective to screen and characterize the selected sunflower genotypes for salinity tolerance based on seedling growth parameters and invitro studies.

Method and materials

Twelve genotypes of sunflower namely CMS-7-1A, CMS-7-1B, RHA-271, APSH-11, 234-A, 234-B, 6D-1, KBSH-1, PKVSH-27, SFL-04, SFL-07 and Morden were selected for screening. Twenty healthy and uniform seeds of each genotype were surface sterilized with 0.1 % HgCl₂ for 15 minutes and then rinsed with sterile distilled water. The sterilized seeds were placed on wet germination paper in petriplates and were placed in dark for 2 days for sprouting. Plastic trays (40 cm x 27 cm) were thoroughly washed with water and then filled up to the rim with salt (NaCl) solution of different concentrations. The various concentrations of salt (NaCl) solution tested are presented in Table 1. Thermocol sheets of 1.5 cm thickness were taken and perforations were made with a spacing of 3 x 5 cm between

and within the rows respectively. The thermocol sheets were placed on plastic tray so that they floated on the salt solution. The sprouted seeds were then transferred on to these perforated thermocol sheets and placed floating on plastic trays containing various salt concentration at the rate of 20 seeds of each genotype per treatment. The trays were placed under fluorescent tubes to provide 14 light/10 dark hours with 800 ± 50 m mol photons m⁻² s⁻¹ light. Day and night temperatures were maintained at 30/20 ± 1°C with R.H. of 50/95 ± 5 per cent. The following observations were recorded 15 days after transferring to the salt (NaCl) solutions. Percentage of Germination, Mean time of seed germination, Fresh weight of the seedling (root, shoot and total seedling), Dry weight of seedlings (root, shoot and total seedling), root/shoot ratio, leaf area and Seedling vigour index.

Germination (%)

Germination test was conducted on pure seed fraction using 100 seeds in three replicates following between paper (BP) method at 25°C temperature and 93±2 per cent relative humidity (ISTA, 1985). Three replications of hundred seeds each were used for germination test. The numbers of normal seedlings were counted on 5th day (first count) and 14th day (final count) of germination from all the replications. The average of three replications was expressed as germination percentage. The germination per cent was calculated based on the number of normal seedlings produced.

No. of normal seedlings

$$\text{Germination (\%)} = \frac{\text{Total no. of normal seedlings}}{\text{Total no. of seeds}} \times 100$$

Mean time of seed germination:

Mean time of seed germination (MTSG) was also calculated according to the formula: $MTSG = \frac{\sum n_i \times T_i}{\sum n_i}$

T_i is the initial time and n_i the number of germinated seeds between T_{i-1} and T_i

Vigour index I

Vigour index of the seedlings obtained from the germination test was calculated using the formula suggested by Abdul-Baki and Anderson (1973).

Vigour index = Percentage of Seed germination x Mean seedling length (cm)

Mean seedling length (cm) = (Mean of root length + Mean of Shoot length)

Growth parameters

The fresh weights of the shoots and roots of the seedlings were

measured immediately after 15 days. The dry weights were measured after drying the shoot and root at 80°C for 24 h, to standardize the weight. The third leaf blade from each shoot bottom was taken to determine leaf area with an area meter (model 1671-VHA). The result of leaf area was expressed in cm² piece⁻¹.

Statistical analysis

The experimental design was CRD (completely randomized design) with three replicates. For all the parameters, data were analyzed by two way analysis of variance (ANOVA) using COSTAT (Cohort Software, Berkeley, California) statistical software. Standard error was applied to compare means to determine significant differences.

Results and Discussion

Table 2 shows that seed germination of CMS-7-1A, CMS-7-1B, RHA-271, APSH-11, 234-A, 234-B, 6D-1, KBSH-1, PKVSH-27, SFL-04, SFL-07 and Morden were affected differently by salt treatments. Increased salt concentration caused a decrease in germination percentage. Vigor index was almost declined significantly with the induction of salinity concentrations. The reduction of germination percentage and vigor index was strongest particularly at highest levels of salt concentration compared to the control. Influence of salt stress on seedling height and root length during early seedling growth varied with NaCl concentrations. Compared with the controls, seedling height of twelve genotypes was inhibited severely as NaCl concentration raised from 0.3 – 1.7dS/m.

The data on average root length of all genotypes showed a strong inhibition with increasing level of salt solution. The inhibition of seedling growth of all genotypes was strongest especially at highest levels of salinity as compared with the control.

At different salt concentrations, 6D-1 and Morden had the highest and lowest germination percentage as 100% and 7% respectively. SFL-09 had the second highest germination percentage (99.66 %) and PKVSH-27 had the third highest germination percentage (98.66%). 6D-1 demonstrated better tolerance to salt stress than other cultivars for germination percentage. Rahman et al. (2000) reported that maize cultivars were significantly more tolerant to salt stress at germination than at later stages of growth. Seeds in the control dishes (0 dS/m NaCl) had the highest germination percentage (100%), and as the salt concentration increased, germination percentage decreased up to 1.7dS/m NaCl concentration (Table 2). Higher germination percentages of cultivars at control (0 dS/m NaCl) were due to lack of salt in the medium. High concentration of NaCl in the salt solution increases its osmotic potential. In addition, high absorption of Na and Cl ions during seed germination can be due to cell toxicity that finally inhibits or slows the rate of germination and thus decreases germination percentage (Taiz and Zeiger, 2002). In this study, the responses of cultivars to different salt concentrations were found significantly different. This condition caused significant interactions between salt treatments and cultivars. This means that there are genetical differences among cultivars in respect of tolerance to salt stress. However, increasing salinity decreased the germination percentage in all cultivars, some of the cultivars were more tolerant than the others. As the result of this fact, the germination percentages of cultivars at 1.7dS/m NaCl were arranged in gradually decreasing way as 6D-1 > SFL-07 > PKVSH-27 > SFL-03 > 7-1B > 7-1A > 234-A>rha271> APSH-11> 234-B> Morden, when they were compared with control (Table 1). Our results were supported by many researches conducted on this subject (Rahman et al., 2000; Gill et al., 2002; Almodares et al., 2007; Blanco et al., 2007).

Mean time of seed germination (MTSG) calculated over 15 days of incubation (Table 3) was significantly affected by salt treat-

ments (P=0.0000) and genotypes (P=0.0000). Increasing NaCl concentration resulted in an increase of MTSG. Mean values varied from 4.53 days (control) to 9.25 days (1.7 dS/m) which is equivalent to an increase of 104.19%. Mean comparisons of NaCl treatments gave: 1.7 > 1.3 > 0.9 > 0.4 > control. Significant differences were also recorded among genotypes with 6D-1 having the lowest MTSG and Morden the highest. This result suggested that seeds of Morden needed a significantly longer duration to germinate under saline conditions than the other genotypes. As for the percent of seed germination, the sensitivity of the genotypes increased when NaCl concentration was increased in the medium.

The results of seedling growth showed highly significant differences for the concentrations applied and the test genotypes (Table 5 & 6). The average value for shoot length was maximum (8.24 cm) in control condition, which decreased gradually with increasing salt concentration to 1.62 cm at 1.7 dS/m concentration. However, the decrease in shoot length was highly significant beyond 1.3 dS/m. The maximum average shoot length (9.570 cm) was recorded for SFL-07 which was followed by pkvsh-27 (8.70 cm), 6D-1 (7.34cm) and 7-1B (6.51 cm) (Table 6). The root length significantly differed among the applied salinity doses and genotypes (Table 5). The root length showed a reduction with increased salt concentration. The root length was maximum for SFL-07 (11.00 cm) that was followed by 7-1B (10.60cm), PKVSH-27 and Morden (8.50 cm), which differed significantly from that of RHA - 271 (3.00cm) and 234-A and B (5.50 cm) (Table 5).

Significantly reduced shoot length with increasing salt levels in the present study agrees with the findings of Khan et al., (1994), Ibrar et al., (2003) and Jabeen et al., (2003) who also reported significant decline in shoot length at 10 dS/m and higher salinity levels. Root length also decreased and this is in line with Ibrar et al., (2003) and Jabeen et al., (2003) who reported decline in radicle growth under saline conditions. The present findings also agree with Ali et al., (1992) and Khan et al., (1994) who reported similar results for other medicinal plants. Low salt concentrations either improved or had no pronounced effect on root and/or shoot length possibly due to their nutrient like action (Hussain & Ilahi, 1992).

The highest seedling length (26.00cm) and lowest (9.00cm) were observed in SFL-07 and RHA 271 at controlled conditions. The seedling length was decreased with increased salt stress. The maximum seedling length of 26.00cm was recorded in SFL-07 at control and lowest was observed at 0.00cm in 234-B. Seedling length was observed at 1.7 dS/m which caused 79.83% reduction over control (Table 7). Differential response of genotypes to salt stress was also observed. The effect of salinity was more pronounced on 234-B as compared to SFL-07, as the reduction in seedling length of 234-B was more than SFL-07, showing that salt stress was more detrimental for 234-B compared to SFL-07.

Data presented in (Table 8 & 9) for root and shoot fresh weight of 12 genotypes of sunflower showed that salt stress significantly reduced root and shoot fresh weight of all genotypes. Sunflower genotypes were markedly inconsistent from each other with respect to these growth parameters. Among tested sunflower genotypes, SFL-03, 7-1B and SFL-07 were high and RHA-271, 234-A, 234-B, KBSH-1 and 6D-1 low in root fresh weight under saline conditions (Table 8). Interestingly genotypes APSH-11 showed a great increase in root fresh weight at highest salt concentration 1.3 dS/m (0.23) as compared to control. Although, these cultivars exhibited lower shoot and root fresh weights at highest level of salinity, but they performed better when grown under non-stress conditions. It is imperative to mention here that SFL-03 was very high in root fresh weight and PKVSH-27 and KBSH-1 was consistently high in their shoot fresh weight

particularly under saline condition. Maximum Shoot fresh weight was recorded in SFL-07, PKVSH-27, SFL-03 with 1.10, 0.97, 0.85gm and lowest in 234-B, APSH-11 and RHa -271 with 0.00, 0.06, 0.09 respectively (Table 9). Percentage of reduction in root fresh weight is very high as compared to shoot fresh weight. 100% reduction in root fresh was recorded in 234-B followed by 6D-1 and 7-1B (99.67%). Similarly, the genotype 234-B was showed 100 % reduction in shoot fresh weight and followed by SFL-03 (96.47%) , APSH-11(89.47%). According to these values, the genotypes were arranged as following: 7-1A >7-1B > PKVSH-27> RHA-271 > 234-A > KBSH-1 > 6D-1> SFL-07 > Morden > APSH-11 > 234B.

The results are clearly indicated significant differences for the seedling fresh weight among the concentration applied the genotypes (Table 10). The average value for seedling fresh weight decreased with increased concentrations and maximum reduction was observed at concentration of 1.7 dS/m. SFL- 07 exhibited maximum average value (0.79 g) for seedling fresh weight, that was significantly greater than PKVSH-27 (0.67 G), which in turn was significantly higher than 7-1B (0.65g) and SFL- 03 (0.58g) (Table 10). The mean values with respect to treatments were significant and were ranged from 0.18 (1.7 dS/m) to 0.80 (0.00 dS/m).

Generally the fresh weight of seedlings was affected and decreased at higher salt concentrations. Ali et al., (1992) and Lyra et al., (1992) also reported a similar trend in the fresh weight of *Trigonella* and *Sesamum* seedlings. Reduction in fresh biomass at higher concentration might be due to poor absorption of water from the growth medium due to physiological drought (Hussain & Ilahi, 1992).

Shoot dry weights of genotypes were negatively affected by increasing salt treatments. The average shoot dry weight of genotypes was 0.040 g at control and this value gradually decreased throughout the increasing salt concentrations, and reached to 0.014g at 1.7 dS/m NaCl.

The reduction rate in shoot dry weights of genotypes at 1.7 dS/m NaCl when compared with the control were detected in 234-B with 100%, 234-A with 96.30%, morden with 86.81%, 6D-1 with 83.64% and 7-1A with 63.89%. According to these values, the cultivars were arranged as following: 7-1B > RHA-271 > APSH-11 > KBSH-1 > SFL-03 > SFL-07. Our results are in agreement with the results of other researchers. For example, Hussein et al. (2007), reported that a negative relationship was detected between vegetative growth parameters and increasing salinity. In same study, shoot dry weight was 52.01 mg plant⁻¹ at control while it decreased linearly to 25.26 mg plant⁻¹ at 4000 ppm. The same results were also obtained by other researchers (Alberico and Cramer, 1993; Cramer, 1993; Cramer et al., 1994; Mansour et al., 2005).

Root dry weight of genotypes was decreased significantly as the levels of salinity increased from 0 to 1.7dS/m NaCl. Thus, the highest root dry weight was determined at control and the lowest root dry weight at the highest salinity level. Among the cultivars, SFL-07 and PKVSH-27 were affected least by salinity and showed a stimulatory effect with treatments 0.9 and 1.3dS/m as compared to control.

The rate of reduction in root dry weight at 1.7 dS/m NaCl in comparison with the control was detected in RHA-271, 234-B, 6D-1, KBSH-1 with 100%, PKVSH-27 with 92.31%, 7-1A with 91.67%, APSH-11, 234-A, SFL-03 with 87.50%, morden with 83.33% and SFL-07 with 76.92%. Akram et al. (2007) reported that root dry weight of all corn hybrids showed a decline towards increase in salinity level. On the other hand, reduction in plant growth as a result of salt stress has also been reported in

several other plant species (Ashraf and McNeilly, 1990; Mishra et al., 1991; Ashraf and O'leary, 1997).

Highly significant differences for dry weight of seedling among different levels of salt concentration and genotypes were observed (Table 13). Average value for the dry weight of seedling was minimum in salt level 1.7dS/m (0.011g). It showed slight decrease with each increase in concentration of the salt that reached to the minimum (0.011g) at the highest salt concentration. The average dry weight (Table 6) was maximum in KBSH-1 (0.056 g), followed by SFL -07 (0.044 g), 6D-1 (0.036 g) and PKVSH-27 (0.034 g). The decrease in the dry weight of seedlings with increasing salt concentration is in similar to the findings of Younis et al., (1987) and Lyra et al., (1992) who reported decreased dry weight of *Linum* and *Sesamum* seedlings as a result of salt stress.

Leaf area was selected as growth parameter. Leaf area closely relates to photosynthetic production on which growth depends. The growth parameter of sunflower seedlings decreased with increasing salinity. Leaf area of control is greater than all the treatments, which indicates that the growth of sunflower seedlings was inhibited under salinity. The growth of sunflower seedlings was inhibited by high salinity and this effect tended to be more serious with increasing salinity, the Genotypes, treatments and their interaction showed significant difference on Leaf area. The leaf area of control (salinity = 0 dS/m) was 4.41, but the Leaf area of D5 (salinity = 1.7dS/m) was 1.10. The genotype SFL -07 was showed the maximum leaf area of 9.30 (SFL-07) at control, followed by PKVSH-27 (6.84), 7-1B (6.47), 7-1A (5.05) and 6D-1(4.98). Whereas the Lowest leaf area was recorded at higher dose of salinity of 1.7dS/m in 234-B (0.00) followed by 234-A (0.06), SFL-03(0.23), RHA - 271(0.27). The results showed that the effect of salinity on leaf area was significant (Table 14). Significant individual effects of the genotype, salt (NaCl) concentration/E C level and their interactions were observed with respect to leaf area. Genotypes with less reduced leaf area at higher stress conditions may be considered as the one which is salt tolerant, as the photosynthetic ability of a plant in mainly determined by its leaf area and thus the economic yield. Similar varietal differences were reported by Delgado et al., (1996)

Fresh weight and dry weight of seedlings (root, shoot and total seedling) of all the twelve genotypes decreased significantly with increased salt (NaCl) stress. This may be due to diversion of energy in the process of osmotic adjustment. The results are in confirmation with the findings of Ashraf and Leary (1997). Significant differences were observed among genotypes , treatments and their interactions with respect to root/shoot ratio in terms of length, fresh weight and dry weight which are also reported by Farghali (1996). Soil salinity reduces water availability of plant roots via negative (low) osmosis potential, as well as decrease of germination dynamics of plant seeds by ionic toxicity of Na⁺ and Cl⁻ (Munnset al., 1988). Deep and thick root system has been recommended as selection criteria in screening for salt tolerance in early generations of breeding program. salinity tolerance of sunflower does not vary with stage of plant cycle, so selection for increased salt tolerance can be carried out at the initial growth stage (Ashraf and tufail,1995) . This genotypic variation for seedling parameters could be ascribed to their inherent capacity to tolerate higher salinity levels. Based on seedling growth parameters and invetro studies the twelve sunflower genotypes studied are categorized into four salinity response groups.

Salinity group	Genotypes
Relatively tolerant	SFL-07, PKVSH-27
Moderately tolerant	6D-1D, 7-1B, SFL-03
Moderately sensitive	7-1A, APSH-11, KBSH-1
Sensitive	234-A, 234-B, RHA-271, Morden

Conclusion

The genotypes which exhibited tolerance under laboratory conditions could be further evaluated in field conditions. Significant and conspicuous differences among various genotypes for most of the characters were brought about at salt (NaCl) concentration of 0.07% E.C. level of 1.3 dS/m. Hence these parameters and salt (NaCl) concentration / E.C. level can be suggested for large scale screening of sunflower germplasm for NaCl induced salt tolerance. Significant advance in salt stress of sunflower could be expected through further cycles of selection. However, further research is necessary at molecular level.

Table 2: Effect of salinity stress on the germination percent of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	73.33	89.00	72.66	79.66	82.66	73.33	100.00	95.00	98.66	95.33	99.66	76.00	86.27
T2	71.00	82.00	69.00	72.00	80.33	60.66	95.00	90.00	89.66	90.66	94.00	64.33	79.88
T3	52.33	61.33	58.66	60.66	67.33	52.33	92.33	83.33	76.66	73.33	87.33	44.66	67.53
T4	36.00	46.66	42.33	43.33	48.00	39.66	71.33	54.33	61.66	60.33	65.00	30.67	49.94
T5	21.33	26.00	20.00	19.66	21.00	11.33	50.33	40.33	47.00	42.00	47.66	7.00	29.47
Mean	50.80	61.00	52.53	55.07	59.87	47.47	81.80	72.60	74.73	72.33	78.73	44.53	62.62
Grand Mean	62.62												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			1.37		0.88		3.66						
S.E.+			0.70		0.45		1.56						

Table 3: Effect of salinity stress on Mean time of seed germination of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	5.00	5.00	4.67	4.67	4.67	5.00	3.00	5.33	3.00	4.67	3.33	6.00	4.53
T2	5.67	6.00	6.33	5.67	6.00	6.67	3.67	6.67	5.00	6.00	4.33	8.00	5.83
T3	7.00	6.67	7.67	7.00	7.33	8.67	5.33	8.67	6.00	7.00	5.00	9.00	7.11
T4	8.00	6.67	8.67	8.00	8.67	9.33	6.33	10.00	6.67	7.66	5.67	11.00	8.06
T5	8.00	8.00	9.00	9.33	10.00	10.00	7.00	11.33	8.67	9.33	7.33	13.00	9.25
Mean	6.73	6.47	7.27	6.93	7.33	7.93	5.07	8.40	5.87	6.93	5.13	9.40	6.96
Grand Mean	6.96												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.54		0.35		1.20						
S.E.±			0.27		0.18		0.61						

Table 4: Effect of salinity stress on seedling vigour index of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	3813.33	2491.00	2084.00	3017.00	3138.00	3372.00	6200.00	4370.00	5228.00	4577.00	5680.00	2355.00	3860.44
T2	3030.00	2213.00	1334.00	2515.00	2250.00	2326.00	4470.00	3060.00	4213.00	3174.00	4983.00	1284.00	2904.33
T3	1891.00	1454.00	704.00	1617.00	1661.00	1833.00	3139.00	2081.00	2605.00	1857.00	4689.00	1204.00	2061.25
T4	959.00	1135.00	268.00	1084.00	1054.00	357.00	1925.00	5055.00	1686.00	1346.00	2532.00	582.00	1498.58
T5	191.00	505.00	60.00	393.00	42.00	0.00	453.00	563.00	470.00	678.00	812.00	35.00	350.17
Mean	1976.87	1559.60	890.00	1725.20	1629.00	1577.60	3237.40	3025.80	2840.40	2326.40	3739.20	1092.00	2134.96
Grand Mean	2134.96												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			173.92		112.25		388.90						
S.E.+			88.74		57.24		198.42						

Table 5: Effect of salinity stress on Root length (cm) of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	7.33	10.60	3.00	7.60	5.50	5.50	8.00	5.50	8.50	8.00	11.00	8.50	7.42
T2	7.33	10.20	2.50	7.30	4.50	3.50	6.50	4.00	7.50	5.50	9.00	7.20	6.25
T3	6.13	1.40	2.00	6.73	3.47	1.50	4.00	2.00	6.00	3.00	7.50	4.00	3.98
T4	3.60	2.60	2.00	2.80	3.00	0.50	3.00	1.00	5.00	1.50	5.50	3.50	2.83
T5	1.60	1.40	1.23	1.53	0.50	0.00	0.50	0.10	4.00	0.50	3.50	1.00	1.32
Mean	5.20	5.24	2.15	5.19	3.39	2.20	4.40	2.52	6.20	3.70	7.30	4.84	4.36
Grand Mean	4.36												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.19		0.12		0.42						
S.E. _±			0.10		0.06		0.21						

Table 6: Effect of salinity stress on Shoot length (cm) of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	4.90	10.60	6.00	6.90	7.00	6.00	11.50	7.50	12.00	4.00	15.00	7.50	8.24
T2	3.23	9.00	4.50	6.00	4.00	4.00	10.00	5.00	9.50	2.50	10.50	6.50	6.23
T3	3.30	7.80	4.00	5.33	3.50	2.00	8.60	3.00	9.00	1.50	8.97	3.50	5.04
T4	1.17	3.23	3.00	1.63	2.50	1.47	5.10	1.50	8.10	0.47	8.50	2.50	3.26
T5	0.50	1.93	2.00	1.00	1.50	0.00	1.50	0.50	4.90	0.17	4.90	0.50	1.62
Mean	2.62	6.51	3.90	4.17	3.70	2.69	7.34	3.50	8.70	1.73	9.57	4.10	4.88
Grand Mean	4.88												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.25		0.16		0.55						
S.E. _±			0.13		0.08		0.28						

Table 7: Effect of salinity stress on Seedling length (cm) of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	12.23	21.20	9.00	14.50	12.50	11.50	19.50	13.00	20.50	12.00	26.00	16.00	15.66
T2	10.57	19.23	7.00	13.30	8.50	7.50	16.50	9.00	17.00	8.00	17.00	13.70	12.28
T3	9.43	15.20	6.00	12.07	5.86	3.50	12.60	5.00	15.00	4.50	15.00	7.50	9.31
T4	4.77	5.83	5.00	4.43	5.50	1.97	8.10	2.50	13.10	1.97	13.10	6.00	6.02
T5	2.10	3.33	3.20	2.53	2.00	0.00	2.00	0.60	10.00	0.67	10.00	1.50	3.16
Mean	7.82	12.96	6.04	9.37	6.87	4.89	11.74	6.02	15.12	5.43	16.22	8.94	9.28
Grand Mean	9.28												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.33		0.21		0.74						
S.E. _±			0.17		0.12		0.38						

Table 8: Effect of salinity stress on Root fresh weight of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	0.20	0.24	0.01	0.11	0.16	0.08	0.06	0.20	0.13	0.31	0.22	0.12	0.15
T2	0.11	0.16	0.01	0.05	0.08	0.02	0.05	0.10	0.11	0.24	0.15	0.09	0.10
T3	0.04	0.10	0.01	0.08	0.01	0.01	0.04	0.03	0.08	0.02	0.10	0.05	0.05

T4	0.03	0.08	0.06	0.23	0.01	0.00	0.03	0.08	0.06	0.21	0.04	0.04	0.07
T5	0.02	0.01	0.00	0.21	0.00	0.00	0.00	0.00	0.04	0.11	0.03	0.02	0.04
Mean	0.08	0.12	0.02	0.14	0.05	0.02	0.04	0.08	0.08	0.18	0.11	0.06	0.08
Grand Mean	0.08												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.006		0.004		0.013						
S.E. _±			0.003		0.002		0.007						

Table 9: Effect of salinity stress on Shoot fresh weight of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	0.49	0.70	0.31	0.57	0.57	0.44	0.66	0.49	0.97	0.85	1.10	0.54	0.64
T2	0.42	0.60	0.20	0.54	0.42	0.29	0.54	0.31	0.57	0.70	0.88	0.42	0.49
T3	0.41	0.57	0.15	0.48	0.28	0.18	0.47	0.20	0.48	0.16	0.77	0.30	0.37
T4	0.29	0.48	0.11	0.16	0.21	0.09	0.37	0.11	0.47	0.06	0.48	0.26	0.26
T5	0.21	0.30	0.09	0.06	0.12	0.00	0.13	0.10	0.41	0.03	0.21	0.08	0.15
Mean	0.36	0.53	0.17	0.36	0.32	0.20	0.43	0.24	0.58	0.36	0.69	0.32	0.38
Grand Mean	0.38												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.008		0.005		0.020						
S.E. _±			0.004		0.003		0.009						

Table 10: Effect of salinity stress on Seedling fresh weight of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	0.69	0.95	0.32	0.68	0.73	0.52	0.72	0.69	1.10	1.16	1.32	0.67	0.80
T2	0.53	0.76	0.21	0.59	0.53	0.31	0.59	0.41	0.68	0.94	1.03	0.95	0.63
T3	0.45	0.67	0.16	0.56	0.29	0.19	0.51	0.23	0.57	0.38	0.87	0.35	0.44
T4	0.32	0.56	0.11	0.38	0.22	0.38	0.39	0.11	0.53	0.27	0.51	0.30	0.34
T5	0.23	0.31	0.10	0.27	0.12	0.00	0.13	0.10	0.45	0.14	0.24	0.10	0.18
Mean	0.44	0.65	0.18	0.50	0.38	0.28	0.47	0.31	0.67	0.58	0.79	0.47	0.48
Grand Mean	0.48												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.050		0.030		0.100						
S.E. _±			0.023		0.015		0.052						

Table 11: Effect of salinity stress on Root dry weight of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	0.012	0.004	0.005	0.008	0.008	0.005	0.007	0.048	0.013	0.008	0.013	0.006	0.011
T2	0.009	0.003	0.003	0.006	0.006	0.003	0.005	0.006	0.033	0.005	0.012	0.004	0.008
T3	0.006	0.002	0.002	0.004	0.004	0.002	0.003	0.004	0.082	0.003	0.047	0.013	0.014
T4	0.005	0.001	0.001	0.004	0.003	0.000	0.002	0.002	0.004	0.002	0.006	0.003	0.003
T5	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.001	0.003	0.001	0.001
Mean	0.007	0.002	0.002	0.005	0.004	0.002	0.003	0.012	0.027	0.004	0.016	0.005	0.007
Grand Mean	0.007												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.010		0.007		0.020						
S.E. _±			0.005		0.003		0.012						

Table 12: Effect of salinity stress on Shoot dry weight of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	0.036	0.024	0.021	0.030	0.027	0.041	0.055	0.033	0.039	0.036	0.043	0.091	0.040
T2	0.033	0.171	0.014	0.028	0.022	0.035	0.042	0.250	0.035	0.027	0.040	0.015	0.059
T3	0.061	0.023	0.008	0.023	0.344	0.033	0.031	0.045	0.027	0.023	0.040	0.014	0.056
T4	0.018	0.023	0.004	0.021	0.019	0.009	0.025	0.065	0.087	0.020	0.030	0.013	0.028
T5	0.013	0.028	0.016	0.019	0.001	0.000	0.009	0.019	0.014	0.020	0.022	0.012	0.014
Mean	0.032	0.054	0.013	0.024	0.083	0.024	0.032	0.082	0.040	0.025	0.035	0.029	0.039
Grand Mean	0.039												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.060		0.040		0.130						
S.E.±			0.030		0.020		0.060						

Table 13: Effect of salinity stress on Seedling dry weight of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	0.052	0.028	0.029	0.038	0.038	0.046	0.062	0.116	0.053	0.048	0.057	0.031	0.050
T2	0.043	0.027	0.019	0.034	0.028	0.038	0.047	0.034	0.047	0.035	0.053	0.020	0.035
T3	0.036	0.024	0.012	0.027	0.025	0.035	0.034	0.025	0.034	0.025	0.052	0.020	0.029
T4	0.027	0.023	0.008	0.025	0.022	0.009	0.027	0.093	0.027	0.022	0.039	0.019	0.028
T5	0.009	0.019	0.006	0.020	0.002	0.000	0.009	0.014	0.010	0.016	0.017	0.005	0.011
Mean	0.033	0.024	0.015	0.029	0.023	0.026	0.036	0.056	0.034	0.029	0.044	0.019	0.031
Grand Mean	0.031												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.020		0.013		0.044						
S.E.±			0.010		0.006		0.022						

Table 14: Effect of salinity stress on Leaf area of sunflower genotypes

	7-1A	7-1B	RHA-271	APSH-11	234-A	234-B	6D-1	KBSH-1	PKVSH-27	SFL-03	SFL-07	MORDEN	Mean
T1	5.05	6.47	1.35	4.45	3.70	1.77	4.98	1.89	6.84	3.47	9.30	3.63	4.41
T2	3.71	4.61	0.69	3.13	3.20	2.15	3.71	1.72	5.60	2.22	7.77	3.06	3.46
T3	3.34	4.40	0.65	2.60	2.20	1.53	3.14	0.68	5.10	2.02	5.64	1.78	2.76
T4	2.70	3.50	0.56	1.84	1.46	0.96	2.69	0.50	4.24	1.20	4.17	0.55	2.03
T5	1.71	2.00	0.27	1.03	0.06	0.00	0.96	0.43	3.39	0.23	2.65	0.48	1.10
Mean	3.30	4.20	0.70	2.61	2.12	1.28	3.10	1.04	5.03	1.83	5.91	1.90	2.75
Grand Mean	2.75												
			Genotype		Treatment		Interaction						
C.D(P=0.05)			0.20		0.13		0.45						
S.E.±			0.10		0.07		0.23						

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