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Estimation of genetic variability and trait association in sunflower genotypes under salt stress conditions

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Abstract
A greenhouse and field research was conducted to evaluate twenty accessions for identification of salt tolerant genotypes of sunflower (*Helianthus annuus* L.) as well as their characteristics. The experiment was conducted in completely randomized design with three repeats. Salinity was developed with NaCl to achieve the final levels of 3 dSm^{-1}, 6 dSm^{-1} and 9 dSm^{-1} salinity, whereas control contained tap water. After 60 days of planting ten seedling of each accession from each treatment and replication were uprooted and data was recorded. Sunflower genotypes G-36, G-61, A-23, A-6 and A-185 performed better in both controlled and saline conditions. These genotypes showed better shoot and root growth and biomass by least concentration of Na^+ and higher concentration of K^+ and Cl^- in leaf sap resulting in better K^+:Na^+

Keywords: Helianthus annuus, Salt tolerant, Dsm^{-1}, ions, K^+, Cl^-, Na^+

Introduction
Salinity is one of the major obstacles to increasing production in crop growing areas throughout the world. In spite of this extensive literature there is still a controversy with regard to the mechanisms of salt tolerance in plants. Salinity in soil or water is one of the major stresses and especially in arid and semi arid regions, can severely limit crop production. High levels of soil salinity negatively affect productivity of most field crops (Munns, 1993) [44]. Saline soils remarkably reduce oil production potential and oil yield of sunflower (Szabolcs, 1994) [65]. Salinity can affect germination and seedling growth either by creating an osmotic pressure that prevents water uptake or by toxic effects of sodium and chloride ions (Hopper *et al.*, 1979) [22]. About 7% of arable lands of the world are under salinity pressure (Jumsoon *et al.*, 1996) [28]. 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- (Munns *et al.*, 1988) [43]. Salinity is also considered as a major abiotic stress and significant factor affecting crop production all over the world and especially in arid and semi-arid region (Davidson and Chevalier, 1987 [15]; Khajeh-Hosseini *et al.*, 2003). To increase production from salt affected soils as well as from normal soils there is a need to identify salt tolerant genotypes of potential oil seed crops. Sunflower is documented as moderately salt tolerant crop (Francois, 1996; Qureshi and Barrett-Lennard, 1998; Katerji *et al*, 2000 [30]; Ramzan *et al.*, 2015a,b) [57]. The situation necessitates a regular selection/ screening of new genotypes. Low quality irrigation water is one of the factors leading to decline sunflower productivity in Pakistan. Estimates show that about 70–80% of pumped water (67,842 million m^3) contains soluble salts and/or sodium ions (Na^+) levels above the permissible limits for irrigation water (Latif and Beg, 2004) [35]. Each unit in EC_e above 4.8 dS m^{-1} resulted in yield reduction by 4.5% in sunflower (Flagella *et al.*, 2004) [16]. Salt water was used by many investigators to study tolerance or sensitivity of many crops to salinity. Compared with other crops, sunflower is considered as a slightly tolerant crop (Katerji *et al*. 2000) [30]. Sunflower genotypes exhibit considerable genetic diversity for salinity tolerance, which can be exploited for the selection of salt tolerant material using optimum selection tools (Ashraf and Tufail, 1995).

The present study is a scientific attempt to understand the genetic behavior and response of different accessions of sunflower to tolerate salt stress at seedling stage. The information so obtained will be useful in formulating criteria for salt stress tolerance and high yield. The objective is also the development of selection criteria through correlation and path analysis studies. Higher harvest of edible oil thus achieved certainly will have great economic impact on farmers and country.

Materials and Methods
The present study was carried out using 20 accessions of sunflower (G-16, G-30, G-32, G-36, G-44, G-45, G-61, G-64, G-66, G-68, G-86, A-2, A-14, A-23, A-56, A-60, A-61, A-79, A-133 and A-185) developed by the Oilseed Research Programme of the Department. Experiment was conducted in a glass house and no control of humidity, temperature and

light. The experiment was laid out following factorial complete randomized design in three replications. The sunflower seed planted in iron trays. Each tray was filled with soil and sand the ratio of 1:1. The seeds sown at the depth of 1.5 cm by maintaining distance of 2.5 cm each for row to row and plant to plant. Normal soil of free from any salinity and sodicity hazards was collected from the research area of Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. The mixture of sand and soil was air dried ground and passed through 2 mm sieve and analyzed for chemical characters. The EC of soil is calculated having the value of 1.23 dS m^{-1} and saturation percentage was 25.7 and total soluble salt was 17.7 me L^{-1}. Tap water was applied for irrigation for 15 days according to requirement. After germination, four salt (NaCl) levels of irrigation water were maintained i.e., Normal water (Tap water), 3 dsm^{-1}, 6 dsm^{-1}, 9 dsm^{-1}. the tap comprise of EC 1.036 me L^{-1}, Na^{+} 3.83, Ca^{+} + Mg^{++} 6.53 me L^{-1} and Total soluble salts 10.36 me L^{-1}. The ten randomly selected plants per replication and per treatment for each genotype were uprooted after through irrigation to facilitate the process of uprooting. Two lower leaves (form the basal node) and two upper leaves (from the top node) were collected. The collected samples were washed with tap water to remove the soil residues and then dipped instantly in distilled water for a short period of time. The samples were blotted dry with the help of a sheet of blotting paper, placed in polyethylene bags, marked with the spirit marker and stored in the deep freezer for tissue sap extraction. Frozen leaf samples were taken out from freezer, sample were thawed, after washing with distilled water the tissue sap was extracted by using metal rod. The tissue sap oozing out from the samples was collected in epindroph tubes and immediately stored back in the deep freezer. The epindroph tubes were taken out from the freezer and placed at the room temperature for a while to thaw. Then the thawed tissue sap was centrifuged at the 6500 rpm for five minutes. The supernatant tissue sap samples from epindroph tubes were analyzed for chloride, sodium and potassium ions. Chloride ions in the tissue sap were determined using Sherwood chloride analyzer 926. The tissue sap was diluted as required with distilled water. Sodium ions were determined using Sherwood flame photometer 410). The tissue sap in the tubes was diluted as required with distilled water. Potassium ions were determined using Sherwood flame photometer 410. After 60 days of planting ten seedlings of each accession from each treatment and replication were uprooted with intensive care. Data were recorded from the experiment on following parameters. Data from experiment was subjected to statistical analysis by using complete randomized design with factorial classification (Steel and Torrie, 1980) [64] using MSTATC software. Treatment means were comprised by LSD test.

Results and Discussion

Shoot Length (cm)

Interaction of genotypes and treatments was found significant. Results showed that accession G-36 closely followed by G-66 and A-23 had maximum shoot length and accession A-60 followed by A-2 and G-30 had minimum shoot length under normal condition (Table 1). Accession A-23 closely followed by G-36 and G-64 had maximum shoot length and accession A-2 followed by A-60 and G-66 had minimum shoot length under salt stress level 1 (3dsm^{-1}). Accessions G-36 closely followed by G-45 and G-44 had maximum shoot length and accession A-60 followed by G-133 and A-2 had minimum shoot length under salt stress level 2 (6dsm^{-1}). Accession G-86 closely followed by G-30 and A-14 had maximum shoot length and accession A-60 followed by A-2 and A-133 had minimum shoot length under salt stress level 3 (9dsm^{-1}). Jiang *et al.* (2005) [27] in cotton, Oreghi *et al.* (1991) and Ghumman (2000) [20] in sunflower also found that shoot length and relative shoot length decreased with increase in salinity. Further, the secondary cells appear sooner and cell wall becomes rigid (Aslam, 1993 [9], Mustafa *et al*., 2018 [45]; Saqib *et al.* 2002) [60]. Causes of growth suppression under saline conditions may include shrinkage of cell contents, reduced developments and differentiation of tissues, unbalanced nutrition and damage to membrane integrity (Kent and Lauchli, 1985) [14]. Osmolytes synthesis to withstand salinity stress utilizes much of carbon and reduces metabolites synthesis and thus ultimately biomass production is decreased (Cheesman, 1988) [13]. Many scientists found that high concentration of salt in rooting medium cause unusual growth retardation (Garg and Gupta, 1997 [18]; Ali *et al*., 2017). Mickelbart and Marter (1998) also demonstrated that salinity in nutrient solution reduced the growth of black spot (*Diospyros digvna* Jacq). Overall growth retardation of many plants seedlings at higher salinity/ sodicity levels has been reported by numerous researchers (Ramoliya and Panday, 2003 [55]; Mer *et al.*, 2000).

Root Length (cm)

Table 2 showed that accession A-133 closely followed by A-60 and A-185 had maximum root length and accession A-56 followed by A-2 and G-16 had minimum root length under normal condition (Table 2). Accession G-66 closely followed by A-2 and A-79 had maximum root length and accession G-32 followed by A-14 and A-44 had minimum root length under salt stress level 1 (3dsm^{-1}). Accessions G-36 closely followed by A-2 and A-23 had maximum root length and accession G-45 followed by G-64 and G-30 had minimum root length under salt stress level 2 (6 dsm^{-1}). Accession G-44 closely followed by G-36 and A-185 had maximum root length and accession A-133 followed by A-60 and G-31 had minimum root length under salt stress level 3 (9dsm^{-1}). Qureshi *et al.* (1998) [54] reported reduction in root length in response to salinity may be due to Na^{+} and Cl^{-} which affect root permeability and integrity due to the displacement of Ca^{+} from the plasma lemma, which inhibits root growth and root length (Azaizeh and Stendele, 1991). The saturation level and concentration of salts in the soil solution cause the dispersion of clay particles which leads to clogging of soil pores and consequently results in reduction of soil permeability, porosity and hydraulic conductivity (Shainberg and Levy, 1992 [63]; Amezketa, 1999) [7], which, in turn, reduce the root development and cause growth retardation.

Fresh Shoot Weight (g/plant)

Table 3 showed that accession G-36 closely followed by G-66 and G-68 had maximum fresh shoot weight and accession A-2 followed by A-60 and G-30 had minimum fresh shoot weight under normal condition. Accession A-79 closely followed by G-61 and G-64 had maximum fresh shoot weight and accession A-60 followed by A-2 and A-185 had minimum fresh shoot weight under salt stress level

1 (3dsm^{-1}). Accessions G-61 closely followed by G-36 and G-56 had maximum fresh shoot weight and accession A-2 followed by A-185 and A-60 had minimum fresh shoot weight under salt stress level 2 (6 dsm^{-1}). Accession G-44 closely followed by G-32 and G-36 had maximum fresh shoot weight and accession G-45 followed by G-64 and A-2 had minimum fresh shoot weight under salt stress level 3 (9dsm^{-1}). Andria *et al.* (1997) found that shoot fresh of sunflower reduced up to 21% due to increase in salinity (Parveen and Qureshi, 1992 [51]; Qasrani *et al* 2014 [53]; Shafqat *et al.,* 1998). High Na^+ and Cl^- concentration in the rooting medium could have suppressed K^+, Ca^+ and NO_3 etc. and ultimately the growth (Gorham and Wyn Jones, 1993 [19]; Grieve *et al.,* 1994). Under salinity, plant cell turgor pressure decreases and stomatal closure takes place resulting in decreased photosynthesis (Gale and Zeroni, 1984). But when salts accumulate to toxic level in leaves again the growth inhibition takes place, so ion toxicity of Na^+ and Cl^- could be the second reason for decreased SFW with increased salinity (Ibrahim, 2003) [24].

Fresh Root Weight (g/plant)

Results showed that accession G-16 closely followed by G-36 and G-86 had maximum fresh root weight and accession A-2 followed by A-68 and G-66 had minimum fresh root weight under normal condition (Table 4). Accession A-68 closely followed by G-86 and G-185 had maximum fresh root weight and accession G-32 followed by A-61 and A-60 had minimum fresh root weight under salt stress level 1 (3dsm^{-1}). Accessions G-30 closely followed by G-23 and G-36 had maximum fresh root weight and accession G-45 followed by G-16 and G-32 had minimum fresh root weight under salt stress level 2 (6 dsm $^{-1}$). Accession A-23 closely followed by G-61 and A-185 had maximum fresh root weight and accession A-2 followed by A-14 and G-32 had minimum fresh root weight under salt stress level 3 (9dsm^{-1}). The reduction in root fresh weight may be due to the osmotic potential of salts in the soil solution which reduced cell water required from the soil solution (Mohamedin *et al.* 2006) [42].

Dry Shoot Weight (g/plant)

Results showed that accession A-23 closely followed by G-64 and G-36 had maximum dry shoot weight and accession G-44 followed by A-60 and A-79 had minimum dry shoot weight under normal condition (Table 5). Accession G-36 closely followed by G-61 and G-16 had maximum dry shoot weight and accession A-60 followed by G-32 and G-30 had minimum dry shoot weight under salt stress level 1 (3dsm^{-1}). Accessions G-61 closely followed by G-36 and A-185 had maximum dry shoot weight and accession G-31 followed by G-16 and G-45 had minimum dry shoot weight under salt stress level 2 (6 dsm $^{-1}$). Accession G-61 closely followed by A-23 and G-36 had maximum dry shoot weight and accession A-133 followed by G-44 and G-30 had minimum dry shoot weight under salt stress level 3 (9dsm^{-1}). Asma (1998) [10] and Khatoon *et al.* (2000) [34] in sunflower also reported that shoot dry weight and relative shoot dry weight decreased significantly with increase in salinity. The decrease in DSW under saline condition was due to reduced growth as a result of decreased water uptake, toxicity of Na^+ and CF in shoot cells as well as reduced photosynthesis (Brugnoly and Lauter, 1991). The decrease in dry weight of shoot with increasing salinity may be because of unbalanced nutrients, solute suction in toxic quantities and use of metabolites (Azhar and McNeilly, 2001).

Dry Root Weight (g/ plant)

Differences among different genotypes at various salinity levels were also significant (Table 6). Results showed that accession A-79 closely followed by A-185 and G-86 had maximum dry root weight and accession G-64 followed by A-68 and A-61 had minimum dry root weight under normal condition. Accession G-36 closely followed by A-14 and G-61 had maximum dry root weight and accession G-16 followed by G-64 and A-61 had minimum dry root weight under salt stress level 1 (3dsm^{-1}). Accessions A-185 closely followed by G-36 and G-86 had maximum dry root weight and accession G-68 followed by A-61 and A-14 had minimum dry root weight under salt stress level 2 (6 dsm^{-1}). Accession G-86 closely followed by G-61 and G-36 had maximum dry root weight and accession G-66 followed by A-60 and A-79 had minimum dry root weight under salt stress level 3 (9dsm^{-1}). Afzal (2002), Oureghi (1991) and Khalil (1991) [33] noted that root dry weight decreased with increase in salinity. The reduction in DRW under saline conditions was due to reduced growth as a result of decline in water uptake, toxicity of Na^+ and Cl^- in root cells (Brugnoly and Lautery, 1991). Reduction in DRW was correlated with reduction in FRW. High Na^+ and Cl^- concentration in rooting medium could suppress the uptake of K^+, Ca^+ and NO^-_3 and ultimately the growth (Gorham and Wyn Jones, 1993) [19].

Chlorophyll Content

Results showed that accession A-79 closely followed by G-68 and G-32 had maximum chlorophyll and accession G-36 followed by G-45 and G-64 had minimum chlorophyll under normal condition (Table 7). Accession G-86 closely followed by G-68 and A-23 had maximum chlorophyll and accession G-30 followed by G-32 and A-16 had minimum chlorophyll under salt stress level 1 (3dsm^{-1}). Accessions A-61 closely followed by A-185 and A-60 had maximum chlorophyll and accession A-133 followed by G-30 and G-32 had minimum chlorophyll under salt stress level 2 (6 dsm^{-1}). Accession G-68 closely followed by A-185 and G-66 had maximum chlorophyll and accession G-16 followed by A-61 and G-36 had minimum chlorophyll under salt stress level 3 (9dsm^{-1}).

Sodium Concentration (mol m^{-3}) in Extracted Leaf Sap

It is clear from the data that Na^+ concentration significantly increased with increasing salinity (Table 8). Result showed that accession A-23 closely followed by A-14 and A-61 had maximum Na^+ content and accession G-45 followed by G-61 and G-30 had minimum Na^+ content under normal condition. Accession A-56 closely followed by A-133 and A-61 had maximum Na^+ content and accession G-16 followed by G-61 and G-36 had minimum Na^+ content under salt stress level 1 (3dsm^{-1}). Accessions A-133 closely followed by A-56 and A-60 had maximum Na^+ content and accession G-44 followed by A-79 and G-32 had minimum Na^+ content under salt stress level 2 (6 dsm $^{-1}$). Accession A-133 closely followed by A-56 and A-60 had maximum Na^+ content and accession G-44 followed by G-32 and A-79 had minimum Na^+ content under salt stress level 3 (9 dsm^{-1}). Parakash *et al.* (1996) [50] and Nawaz *et al.* (2002) [48] in

sunflower also reported that sodium concentration increased significantly with increase in salinity. Sodium being a monovalent is very effective for osmotic adjustment (Gorham *et al.* 1984; Akhtar *et al.,* 2005). Efficient Na^+ exclusion is a good selection criterion for salt tolerance in sunflower and other glycophytes.

Potassium Concentration (mol m^{-3}) in Extracted Leaf Sap

Table 9 showed that accession A-60 closely followed by G-68 and G-32 had maximum K^+ content and accession G-30 followed by G-36 and G-64 had minimum K^+ content under normal condition. Accession G-32 closely followed by G-44 and G-45 had maximum K^+ content and accession A -2 followed by A -60 and A -14 had minimum K^+ content under salt stress level 1 ($3dsm^{-1}$). Accessions A-56 closely followed by G-61 and G-44 had maximum K^+ content and accession A-23 followed by A-2 and G-64 had minimum K^+ content under salt stress level 2 (6 dsm^{-1}). Accession G-68 closely followed by G-66 and A-56 had maximum K^+ content and accession A-79 followed by A-61 and G-86 had minimum K^+ content under salt stress level 3 (9 dsm^{-1}). Decrease in K^+ concentration with increasing salinity was also reported by, Akhtar *et al.* (2002) [48], and Khalil (1991) [33]. These results were also similar to the results of Thimmaiah (2002) who reported a significant reduction of potassium in sorghum with increasing salinity. There is a debate that K^+ influx could be used as an index to salinity tolerance (Silberbush, 2001).

Chloride Concentration (mol m^{-3}) in Extracted Leaf Sap

Results showed that accession G-30 closely followed by G-185 and G-68 had maximum Cl^- content and accession A-79 followed by G-86 and A-133 had minimum Cl^- content under normal condition (Table 10). Accession G-68 closely followed by A-2 and A-56 had maximum Cl^- content and accession G-32 followed by A-14 and A-60 had minimum Cl^- content under salt stress level 1 (3 d Sm^{-1}). Accessions G-32 closely followed by G-36 and A-61 had maximum Cl^- content and accession G-44 followed by A-14 and A-133 had minimum Cl^- content under salt stress level 2 (6 dSm^{-1}). Accession A-185 closely followed by G-36 and G-61 had maximum Cl^- content and accession G-44 followed by G-45 and A-133 had minimum Cl^- content under salt stress level 3 (9 dsm^{-1}).

Mortality (%)

Results showed that accession G-32 closely followed by G-30 and G-45 had maximum mortality % and accession A-185 followed by A-66 and A-79 had minimum mortality % under normal condition (Table 11). Accession G-32 closely followed by G-66 and G-68 had maximum mortality % and accession G -14 followed by G-61 and G-45 had minimum mortality % under salt stress level 1 ($3dsm^{-1}$). Accessions A-185 closely followed by A-2 and G-66 had maximum mortality % and accession G-44 followed by A-79 and G-16 had minimum mortality % under salt stress level 2 (6 dsm^{-1}). Accession G-32 closely followed by A-133 and G-86 had maximum mortality % and accession G-30 followed by A-79 and G-68 had minimum mortality % under salt stress level 3 (9 dsm^{-1}).

Root/Shoot Ratio

Results showed that accession A-79 closely followed by G-86 and A-185 had maximum root/ shoot ratio and accession G-64 followed by A-61 and G-68 had minimum root/ shoot ratio under normal condition (Table 12). Accession A-60 closely followed by G-96 and A-14 had maximum root/ shoot ratio and accession G -16 followed by G -64 and A -61 had minimum root/ shoot ratio under salt stress level 1 ($3dsm^{-1}$). Accessions G-32 closely followed by G-86 and A-60 had maximum root/ shoot ratio and accession G-68 followed by A-14 and A-61 had minimum root/ shoot ratio under salt stress level 2 (6 d Sm^{-1}). Accession A-133 closely followed by G-86 and A-185 had maximum root/ shoot ratio and accession G-64 followed by G-66 and A-14 had minimum root/ shoot ratio under salt stress level 3 (9 d Sm^{-1}).

K^+: Na^+ Ratio in Extracted Leaf

Results showed that accession G-68 closely followed by G-45 and A-60 had maximum K^+/Na^+ Ratio and accession G-30 followed by A-23 and G-64 had minimum K^+/Na^+ Ratio under normal condition (Table 13). Accession G-61 closely followed by G-44 and G-32 had maximum K^+/Na^+ Ratio and accession A -61 followed by A -2 and A -133 had minimum K^+/Na^+ ratio under salt stress level 1 ($3dsm^{-1}$). Accessions G-44 closely followed by G-68 and G-32had maximum K^+/Na^+ Ratio. Accession A-133 followed by A-60 and A-23 had minimum K^+/Na^+ Ratio under salt stress level 2 (6 dsm^{-1}). Accession G-44 closely followed by G-68 and G-32 had maximum K^+/Na^+ Ratio and accession G-86 followed by A-133 and A-2 had minimum K^+/Na^+ Ratio under salt stress level 3 (9 dsm^{-1}). his K^+ leakage from the cell lowers the K^+ Na^+ ratio in the tissue (Kent and Lauchli, 1985 [14]; Cramer *et al.* 1985). K^+ Na^+ ratio decreased with increasing levels of salinity (Akhtar *et al.,* 2005). K^+: Na^+ selectivity is an important criterion of salt tolerance (Lauchli and Stelter, 1982) [36], because tolerant varieties maintain high K^+: Na^+ ratio (Iram *et al.* 1998) [26]. Potassium uptake by plant roots is often suppressed by sodium (Na^+) in the growth medium. High salinity conditions are mainly characterized by low nutrient on ion activities and extreme ratios of K^+/ Na^+ cause nutritional imbalances and restrict the plant growth (Ali *et al*., 2010; Mahmood and Malik, 1987; Grattan and Grieve, 1992) [21]. Davenport *et al.,* (2005) have also reported that plants with ability of accumulating higher K^+:Na^+ ratio and maintaining lesser Na^+ and Cl^- contents in leaves possess more salt tolerance and show good growth under salt-affected conditions. Ionic imbalance of K^+/ Na^+ can also cause multiple metabolic problems and physiological malfunctioning within plant body (Serrano and Rodrigvez-Navarro, 2001 [61]; Maathuis and Amtmann, 1999; White ad Boradly, 2001).

Biomass of Sunflower Genotypes

Results showed that accession A-79 closely followed by A-23 and A-185 had maximum biomass and accession G-44 followed by A-60 and A-2 had minimum biomass under normal condition (Table 14). Accession G-36 closely followed by G-61 and A-23 had maximum biomass and accession A -60 followed by G -32 and A -30 had minimum

biomass under salt stress level 1 (3 d Sm^{-1}). Accessions G-36 closely followed by G-45 and G-44 had maximum biomass and accession A-60 followed by A-133 and A-2 had minimum biomass under salt stress level 2 (6dSm^{-1}). Accession G-61 closely followed by A-23 and G-36 had maximum biomass and accession A-A33 followed by G-30 and G-44 had minimum biomass under salt stress level 3 (9dsm^{-1}). Rogers *et al.*, (2003) [59] indicated a reduction in an overall growth and biomass production of Lucerne at high salinity level. Primavesi (1984) [52] has also documented poor biomass production under saline conditions. Hussain *et al.*, (1994) noticed a significant decrease in total biomass yield of Prosopis juliflora, Casuarina equiselifolia and Eucalyptus camaldulesis with an increase in soil salinity.

Table 1: Statistical Comparison of Varietal Means for Shoot Length for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	43.44	de	39.19	a-f	30.97	d-g	24.52	ef
G-30	40.78	gh	40.70	a-e	34.57	b-e	29.81	ab
G-32	43.54	de	37.68	b-f	30.23	d-g	27.60	b-d
G-36	51.14	a	42.76	ab	42.21	a	26.77	c-e
G-44	43.16	d-f	41.46	a-c	37.85	a-c	26.97	c-e
G-45	45.86	c	41.65	a-c	38.66	ab	24.22	ef
G-61	44.30	cd	41.34	a-c	32.24	c-g	27.40	b-d
G-64	46.22	c	42.11	a-c	35.89	b-d	24.89	d-f
G-66	48.87	b	33.95	fg	31.85	c-g	24.54	ef
G-68	44.32	cd	35.52	d-g	28.93	e-g	23.15	fg
G-86	44.40	cd	41.82	a-c	36.46	b-d	30.34	a
A-2	40.29	gh	30.82	g	28.37	e-g	21.00	gh
A-14	43.22	d-f	39.29	a-f	34.37	b-e	27.87	a-c
A-23	46.41	c	43.45	a	33.28	b-f	23.02	fg
A-56	43.44	de	40.89	a-d	30.94	d-g	26.48	c-e
A-60	39.57	h	31.76	g	26.18	g	20.14	h
A-61	41.81	e-g	36.98	c-f	30.32	d-g	26.81	c-e
A-79	43.64	de	35.90	d-g	29.11	e-g	26.27	c-e
A-133	40.84	gh	35.53	e-g	27.54	fg	22.75	fg
A-185	41.23	f-h	37.74	b-f	31.54	d-g	24.47	ef
LSD	1.898		4.589		5.283		2.400	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 2: Statistical Comparison of Varietal Means for Root Length for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	6.730	j	6.540	c-e	6.349	c-f	5.93	b-d
G-30	6.730	j	6.650	c-e	6.117	ef	5.47	f-h
G-32	7.097	g-i	5.533	f	6.553	b-e	5.20	h
G-36	7.357	de	7.117	a-c	7.717	a	6.25	ab
G-44	7.130	gh	6.233	de	6.473	b-f	6.54	a
G-45	7.407	d	7.147	a-c	6.067	f	5.92	b-d
G-61	7.283	d-f	6.850	b-d	6.207	d-f	5.90	b-d
G-64	7.117	g-i	6.623	c-e	6.097	ef	5.66	d-g
G-66	7.080	g-i	7.690	a	6.260	d-f	5.45	f-h
G-68	6.973	i	7.160	a-c	6.273	d-f	5.44	f-h
G-86	7.187	f-h	6.790	c-e	6.343	c-f	5.89	b-e
A-2	6.593	jk	7.630	a	7.513	a	5.51	e-h
A-14	7.217	e-g	6.210	e	6.570	b-e	5.50	f-h
A-23	7.620	c	7.417	ab	6.870	b	5.78	c-f
A-56	6.497	k	6.250	de	6.443	b-f	5.57	d-h
A-60	7.797	ab	6.597	c-e	6.773	bc	5.29	gh
A-61	7.227	e-g	6.917	bc	6.327	c-f	5.45	f-h
A-79	7.053	hi	7.537	a	6.580	b-e	5.42	f-h
A-133	7.883	a	6.530	c-e	6.627	b-d	5.33	gh
A-185	7.703	bc	7.080	a-c	6.797	bc	6.07	bc
LSD	0.138		0.537		0.408		0.338	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 3: Statistical Comparison of Varietal Means for Fresh Shoot Weight for salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	2.111	a-d	2.111	b-d	1.407	d-f	1.175	b-f
G-30	1.687	c-e	1.687	de	1.646	b-f	1.428	a-c
G-32	1.853	c-e	1.853	c-e	1.831	a-f	1.652	ab
G-36	2.413	a	2.413	ab	2.505	a	1.539	a-c
G-44	2.344	a-e	2.344	a-c	1.776	a-f	1.723	a
G-45	2.455	b-e	2.455	ab	2.253	a-c	0.619	g

G-61	2.660	a-c	2.660	a	2.574	a	1.174	b-f
G-64	2.567	a-d	2.567	ab	2.311	a-c	0.684	fg
G-66	2.336	ab	2.336	a-c	2.145	a-d	0.793	e-g
G-68	2.475	a-c	2.475	ab	1.908	a-f	0.816	e-g
G-86	2.384	a-d	2.384	ab	1.645	b-f	1.378	a-d
A-2	1.463	e	1.463	e	1.212	f	0.725	fg
A-14	2.549	a-e	2.549	ab	2.322	ab	0.736	fg
A-23	2.436	b-e	2.436	ab	2.203	a-d	1.139	c-f
A-56	2.537	b-e	2.537	ab	2.494	a	1.490	a-c
A-60	1.437	de	1.437	e	1.298	ef	0.796	e-g
A-61	2.402	b-e	2.402	ab	2.064	a-e	1.140	c-f
A-79	2.776	a-c	2.776	a	1.798	a-f	1.250	a-e
A-133	1.805	a-d	1.805	de	1.484	c-f	0.899	d-g
A-185	1.612	c-e	1.612	de	1.243	ef	1.088	c-g
LSD	0.856		0.458		0.702		0.433	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 4: Statistical Comparison of Varietal Means for Fresh root weight for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	0.467	a	0.298	a	0.185	gh	0.170	f
G-30	0.348	c-e	0.258	a	0.520	a	0.213	c-f
G-32	0.318	c-f	0.216	a	0.192	f-h	0.166	f
G-36	0.457	ab	0.341	a	0.347	bc	0.300	a-c
G-44	0.393	a-c	0.268	a	0.273	de	0.279	a-e
G-45	0.375	b-d	0.260	a	0.143	h	0.285	a-d
G-61	0.388	a-d	0.382	a	0.267	de	0.375	a
G-64	0.315	c-f	0.343	a	0.253	de	0.196	c-f
G-66	0.331	c-f	0.271	a	0.263	de	0.217	c-f
G-68	0.257	fg	0.553	a	0.263	de	0.286	a-d
G-86	0.453	ab	0.441	a	0.305	cd	0.199	c-f
A-2	0.223	g	0.263	a	0.267	de	0.134	f
A-14	0.302	d-g	0.273	a	0.275	de	0.150	f
A-23	0.449	ab	0.378	a	0.378	b	0.379	a
A-56	0.276	e-g	0.255	a	0.275	de	0.176	ef
A-60	0.331	c-f	0.249	a	0.267	de	0.188	d-f
A-61	0.344	c-e	0.245	a	0.243	d-f	0.236	b-f
A-79	0.383	a-d	0.272	a	0.248	d-f	0.193	d-f
A-133	0.324	c-f	0.253	a	0.215	e-g	0.167	f
A-185	0.435	ab	0.404	a	0.268	de	0.332	ab
LSD	0.074		0.411		0.052		0.090	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 5: Statistical Comparison of Varietal Means for Dry shoot weight for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	0.419	a-c	0.393	ab	0.258	j	0.192	e-h
G-30	0.406	a-d	0.282	g-i	0.263	j	0.156	ij
G-32	0.361	c-g	0.260	hi	0.252	j	0.182	f-i
G-36	0.423	ab	0.418	a	0.382	b	0.249	bc
G-44	0.308	g	0.282	g-i	0.277	i	0.154	ij
G-45	0.352	d-g	0.323	d-g	0.259	j	0.174	f-i
G-61	0.413	a-c	0.414	a	0.397	a	0.294	a
G-64	0.433	ab	0.390	a-c	0.320	e	0.247	bc
G-66	0.344	e-g	0.315	d-h	0.260	j	0.206	d-f
G-68	0.360	c-g	0.318	d-h	0.335	d	0.190	e-h
G-86	0.346	d-g	0.311	e-h	0.292	gh	0.217	c-e
A-2	0.359	c-g	0.289	f-i	0.280	i	0.170	g-j
A-14	0.388	b-e	0.349	b-f	0.322	e	0.243	bc
A-23	0.451	a	0.389	a-c	0.304	fg	0.265	ab
A-56	0.373	b-f	0.374	a-d	0.313	ef	0.167	h-j
A-60	0.317	fg	0.247	i	0.289	hi	0.198	e-h
A-61	0.414	a-c	0.348	b-f	0.305	f	0.234	b-d
A-79	0.338	e-g	0.326	d-g	0.307	f	0.169	g-j
A-133	0.362	c-g	0.331	c-g	0.310	ef	0.139	j
A-185	0.421	a-c	0.362	a-e	0.350	c	0.202	d-g
LSD	0.052		0.053		0.012		0.030	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 6: Statistical Comparison of Varietal Means Dry Root weight for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	0.023	b	0.018	e	0.018	g-i	0.013	def
G-30	0.033	b	0.022	b-e	0.019	fg	0.015	de
G-32	0.031	b	0.019	c-e	0.026	bc	0.013	def
G-36	0.035	b	0.036	a	0.029	a	0.022	a-c
G-44	0.025	b	0.019	c-e	0.018	g-i	0.015	de
G-45	0.026	b	0.022	a-e	0.018	g-i	0.014	d-f
G-61	0.036	b	0.033	a-c	0.028	ab	0.024	ab
G-64	0.017	b	0.018	de	0.021	ef	0.012	ef
G-66	0.030	b	0.026	a-e	0.023	de	0.011	f
G-68	0.020	b	0.023	a-e	0.016	i	0.014	d-f
G-86	0.037	b	0.030	a-e	0.028	ab	0.025	a
A-2	0.025	b	0.029	a-e	0.019	f-h	0.014	d-f
A-14	0.033	b	0.033	ab	0.017	hi	0.014	d-f
A-23	0.032	b	0.030	a-e	0.019	g-i	0.022	bc
A-56	0.031	b	0.026	a-e	0.024	cd	0.016	d
A-60	0.028	b	0.032	a-d	0.028	ab	0.012	ef
A-61	0.020	b	0.018	de	0.016	i	0.014	d-f
A-79	0.125	a	0.020	b-e	0.020	fg	0.012	ef
A-133	0.032	b	0.026	a-e	0.019	f-h	0.016	d
A-185	0.040	b	0.029	a-e	0.029	a	0.021	c
LSD	0.052		0.012		0.002		0.003	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 7: Statistical Comparison of Varietal Means for Chlorophyll for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	31.73	e-g	31.39	e-g	35.79	de	30.81	l
G-30	35.44	a-c	28.24	g	33.06	ef	36.07	hi
G-32	36.14	ab	30.24	fg	34.65	de	35.18	ij
G-36	24.96	i	34.19	c-f	40.38	ab	34.63	j
G-44	31.22	f-h	33.38	def	35.35	de	36.42	gh
G-45	29.02	h	32.84	ef	41.28	ab	37.48	fg
G-61	34.77	a-d	35.03	b-e	40.69	ab	37.52	fg
G-64	29.66	gh	37.57	a-d	35.85	de	36.18	hi
G-66	32.76	d-f	35.32	b-e	41.91	ab	39.59	c
G-68	37.02	a	39.11	ab	39.57	bc	46.46	a
G-86	31.10	f-h	40.58	a	36.41	d	39.44	cd
A-2	31.74	e-g	37.29	a-d	35.36	de	38.26	d-f
A-14	34.13	b-e	37.11	a-d	36.93	cd	36.42	gh
A-23	35.56	a-c	37.86	a-c	35.72	de	37.91	ef
A-56	32.02	e-g	33.96	c-f	37.47	cd	38.76	c-e
A-60	33.37	c-f	34.28	c-f	42.21	ab	38.98	c-e
A-61	31.45	f-h	34.57	c-e	42.95	a	32.86	k
A-79	37.15	a	37.81	a-c	37.02	cd	38.84	c-e
A-133	32.62	d-f	33.88	c-f	31.75	f	34.81	j
A-185	35.14	a-d	34.71	c-e	42.90	a	44.50	b
LSD	2.297		3.535		2.440		1.087	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 8: Statistical Comparison of Varietal Means for Na^+ concentration (mol m^{-3}) for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	17.67	e-g	23.00	j	55.00	e	72.00	g
G-30	16.00	g	31.00	fg	50.00	gh	62.67	j
G-32	19.00	c-f	40.00	c	44.67	i	49.67	k
G-36	17.33	e-g	24.33	ij	51.67	fg	71.33	g
G-44	17.00	fg	29.00	h	38.67	k	43.33	l
G-45	12.67	h	36.00	de	69.00	b	68.33	h
G-61	16.00	g	23.00	j	50.00	gh	73.33	fg
G-64	20.00	b-d	25.33	i	52.00	f	65.00	i
G-66	19.00	c-f	38.67	c	59.67	c	73.33	fg
G-68	17.00	fg	29.67	gh	45.33	i	90.00	c
G-86	16.00	g	26.00	i	60.67	c	91.00	c
A-2	17.00	fg	36.67	d	59.00	c	83.00	d
A-14	21.33	b	34.33	e	51.00	fg	77.00	e
A-23	30.33	a	35.00	de	49.00	h	75.00	ef

A-56	19.00	c-f	46.33	a	70.00	b	100.00	a
A-60	18.00	d-g	31.67	f	69.67	b	95.00	b
A-61	20.67	bc	41.67	b	59.00	c	65.33	i
A-79	17.00	fg	31.00	fg	41.00	j	51.67	k
A-133	19.33	b-e	43.00	b	72.33	a	101.30	a
A-185	19.00	c-f	31.00	fg	57.00	d	73.00	fg
LSD	1.894		1.608		1.594		2.032	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 9: Statistical Comparison of Varietal Means for K^+ concentration (mol m^{-3}) for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	57.33	ij	27.00	h	28.33	ef	21.00	hi
G-30	31.33	l	25.67	i	29.00	ef	21.33	hi
G-32	82.67	bc	61.67	a	36.33	bc	22.00	g-i
G-36	50.33	k	35.33	e	35.67	bc	27.00	de
G-44	76.67	d	60.00	b	38.33	ab	27.00	de
G-45	62.00	h	51.67	c	36.00	bc	27.00	de
G-61	67.67	fg	51.00	c	40.33	a	23.00	f-h
G-64	55.00	j	29.67	g	27.33	f	23.67	fg
G-66	60.33	hi	31.33	f	31.33	de	31.33	b
G-68	84.33	ab	25.33	i	38.00	ab	43.00	a
G-86	59.00	hi	35.33	e	34.00	cd	20.33	i
A-2	70.00	f	20.67	l	27.00	f	20.67	i
A-14	80.00	c	22.33	k	31.67	de	24.00	fg
A-23	65.67	g	32.33	f	22.33	g	20.67	hi
A-56	59.67	hi	51.33	c	41.33	a	30.33	b
A-60	86.00	a	21.00	l	31.00	de	27.33	cd
A-61	74.33	de	23.33	jk	29.67	ef	20.00	i
A-79	73.00	e	24.00	j	32.00	de	14.33	j
A-133	67.00	fg	27.33	h	29.00	ef	25.00	ef
A-185	74.00	de	37.67	d	31.67	de	29.33	bc
LSD	2.990		1.167		3.174		2.098	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 10: Statistical Comparison of Varietal Means for Cl^- concentration (mol m^{-3}) for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	46.00	j	80.67	k	152.30	f	128.00	hi
G-30	98.00	a	71.00	m	136.30	h	126.70	i
G-32	61.00	g	41.00	q	169.70	a	173.70	c
G-36	78.67	e	71.33	m	166.00	b	181.70	b
G-44	66.00	f	67.67	no	76.67	o	82.67	l
G-45	82.67	d	74.00	l	150.00	f	83.00	l
G-61	78.33	e	117.00	f	126.30	k	175.00	c
G-64	47.00	j	87.33	j	141.70	g	152.30	e
G-66	39.00	l	119.00	e	150.30	f	155.70	e
G-68	86.00	c	145.70	a	135.00	h	165.00	d
G-86	33.00	m	123.70	d	128.70	j	147.30	f
A-2	38.00	l	137.70	b	152.00	f	131.00	h
A-14	42.00	k	56.67	p	100.30	n	144.70	fg
A-23	57.00	h	73.33	l	132.00	i	147.00	f
A-56	39.67	l	134.00	c	158.00	d	93.67	k
A-60	54.67	i	66.00	o	152.30	f	124.70	i
A-61	55.00	hi	68.33	n	160.30	c	141.00	g
A-79	32.33	m	101.00	g	114.70	l	111.30	j
A-133	34.00	m	91.00	i	103.00	m	91.67	k
A-185	88.67	b	93.67	h	154.70	e	196.00	a
LSD	2.162		1.795		2.131		3.974	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 11: Statistical Comparison of Varietal Means for Mortality (%) for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	0.00	c	7.41	bc	14.81	d	36.70	de
G-30	3.33	b	6.33	bc	20.00	c	16.67	i
G-32	6.67	a	13.33	a	23.33	a-c	50.00	a
G-36	0.00	c	10.37	ab	21.48	bc	36.30	de
G-44	0.00	c	6.67	bc	10.00	e	40.00	cd

G-45	3.33	b	3.33	c	23.33	a-c	36.67	de
G-61	0.00	c	3.33	c	23.33	a-c	30.00	fg
G-64	0.00	c	6.67	bc	23.33	a-c	33.33	ef
G-66	0.00	c	13.33	a	26.67	a	33.33	ef
G-68	3.33	b	13.33	a	23.33	a-c	26.67	gh
G-86	0.00	c	6.70	bc	24.81	ab	42.59	bc
A-2	0.00	c	3.33	c	26.67	a	26.67	gh
A-14	0.00	c	3.33	c	20.00	c	40.00	cd
A-23	0.00	c	7.04	bc	21.48	bc	28.89	fg
A-56	0.00	c	10.00	ab	20.00	c	33.33	ef
A-60	0.00	c	10.00	ab	20.00	c	26.67	gh
A-61	0.00	c	10.00	ab	20.00	c	36.67	de
A-79	0.00	c	6.67	bc	13.33	de	23.33	h
A-133	3.33	b	10.00	ab	20.00	c	46.67	ab
A-185	0.00	c	10.00	ab	26.67	a	33.33	ef
LSD	0.878		3.656		3955		5.007	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 12: Statistical Comparison of Varietal Means for Root / shoot ratio for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	0.057	b	0.046	e	0.068	e-i	0.069	f-i
G-30	0.084	b	0.076	b-e	0.073	e-g	0.096	b-e
G-32	0.086	b	0.073	b-e	0.103	a	0.072	e-i
G-36	0.083	b	0.085	b-d	0.075	ef	0.089	c-f
G-44	0.081	b	0.065	b-e	0.065	f-i	0.100	a-d
G-45	0.073	b	0.071	b-e	0.068	e-i	0.078	d-h
G-61	0.090	b	0.083	b-e	0.071	e-h	0.081	d-g
G-64	0.039	b	0.047	de	0.067	f-i	0.051	i
G-66	0.085	b	0.082	b-e	0.088	bc	0.053	hi
G-68	0.053	b	0.070	b-e	0.049	k	0.075	d-i
G-86	0.108	b	0.102	ab	0.095	ab	0.119	ab
A-2	0.072	b	0.092	bc	0.069	e-i	0.086	d-f
A-14	0.083	b	0.092	bc	0.051	k	0.059	g-i
A-23	0.073	b	0.076	b-e	0.061	ij	0.086	d-f
A-56	0.081	b	0.069	b-e	0.076	de	0.090	c-f
A-60	0.089	b	0.132	a	0.095	ab	0.066	f-i
A-61	0.049	b	0.053	c-e	0.053	jk	0.060	g-i
A-79	0.368	a	0.062	c-e	0.065	g-i	0.071	e-i
A-133	0.086	b	0.079	b-e	0.062	hi	0.120	A
A-185	0.095	b	0.079	b-e	0.083	cd	0.112	a-c
LSD	0.117		0.030		0.008		0.022	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 13: Statistical Comparison of Varietal Means for K^+/Na^+ ratio for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	3.25	h-j	1.18	fg	0.516	e-g	0.292	i-k
G-30	1.97	l	0.83	i	0.580	d-f	0.340	gh
G-32	4.36	cd	1.54	c	0.814	b	0.443	c
G-36	2.92	jk	1.45	d	0.691	c	0.379	ef
G-44	4.52	b-d	2.07	b	0.992	a	0.624	a
G-45	4.90	ab	1.44	d	0.522	e-g	0.395	d-f
G-61	4.24	de	2.22	a	0.807	b	0.314	hi
G-64	2.76	k	1.17	fg	0.526	e-g	0.364	fg
G-66	3.18	h-k	0.81	i	0.525	e-g	0.427	cd
G-68	4.97	a	0.85	hi	0.839	b	0.478	b
G-86	3.70	fg	1.36	e	0.561	d-f	0.223	m
A-2	4.13	d-f	0.56	k	0.458	gh	0.249	lm
A-14	3.76	fg	0.65	j	0.621	cd	0.312	h-j
A-23	2.17	l	0.92	h	0.456	gh	0.276	kl
A-56	3.15	i-k	1.11	g	0.591	de	0.303	i-k
A-60	4.79	a-c	0.66	j	0.445	gh	0.288	i-k
A-61	3.61	gh	0.56	k	0.503	fg	0.307	i-k
A-79	4.31	de	0.78	i	0.783	b	0.278	j-l
A-133	3.48	g-i	0.64	jk	0.401	h	0.247	lm
A-185	3.90	e-g	1.22	f	0.556	d-f	0.402	de
LSD	0.408		0.074		0.074		0.031	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Table 14: Statistical Comparison of Varietal Means for Biomass for various salt stress levels

Genotypes	Normal (0 dsm^{-1})		Salt stress Level 1 (3 dsm^{-1})		Salt stress Level 2 (6 dsm^{-1})		Salt stress Level 3 (9 dsm^{-1})	
G-16	0.433	a-e	0.404	ab	0.276	f	0.208	c-g
G-30	0.428	a-e	0.307	e-g	0.281	ef	0.168	fg
G-32	0.405	a-f	0.280	fg	0.277	f	0.201	c-g
G-36	0.463	a-c	0.452	a	0.411	a	0.274	ab
G-44	0.331	f	0.310	e-g	0.298	e	0.169	fg
G-45	0.389	a-f	0.340	c-e	0.276	f	0.193	d-g
G-61	0.444	a-d	0.430	a	0.426	a	0.319	a
G-64	0.452	a-d	0.407	ab	0.339	cd	0.258	bc
G-66	0.387	b-f	0.343	c-e	0.283	ef	0.220	b-f
G-68	0.386	b-f	0.358	b-e	0.344	c	0.208	c-g
G-86	0.382	c-f	0.334	d-f	0.325	cd	0.239	b-e
A-2	0.374	d-f	0.336	d-f	0.292	ef	0.179	e-g
A-14	0.437	a-d	0.393	a-d	0.340	cd	0.252	b-d
A-23	0.472	ab	0.425	a	0.322	d	0.278	ab
A-56	0.409	a-f	0.398	a-c	0.336	cd	0.198	c-g
A-60	0.346	ef	0.275	g	0.319	d	0.196	d-g
A-61	0.433	a-e	0.360	b-e	0.322	d	0.251	b-d
A-79	0.476	a	0.342	c-e	0.322	d	0.187	e-g
A-133	0.402	a-f	0.350	b-e	0.324	cd	0.151	g
A-185	0.465	a-c	0.394	a-d	0.379	b	0.210	c-g
LSD	0.074		0.052		0.018		0.052	

Means sharing common letters do not differ significantly at 5% probability level using LSD

Trait association studies

The strongest correlation of seed yield was observed with 1000-Ggrain weight at genotypic (r = 0.762) level (Table 15). 1000 Grain weight and Oil contents were positively and significantly correlated, at phenotypic (r = 0.511 and 0.369 respectively) and genotypic (r = 0.762 and 0.447 respectively) levels with Total achene weight, which is in earlier finding of Kaya *et al*., (2008). 1000-Grain weight revealed significant and positive correlation with Oil contents and Total achene weight per plant under discussion at both genotypic and phenotypic levels. Total achene weight per plant exhibited a high correlation with 1000 Grain weight (r = 0.0.511) at phenotypic level. The highest and positive correlation of Total achene weight per plant was observed with 1000 Grain weight followed by Oil Contents, Fresh head diameter, Plant height and Days to 50 % flowering. Plant height was positively but non-significantly correlated with total ache weight per plant and Chlorophyll except dry head diameter and Oil contents at both levels. Chlorophyll was positively but non-significantly correlated with Dry head diameter, 1000-grain weight, and oil content except fresh head diameter and Total achene weight per plant at both levels. Days to 50 % flowering showed negative genotypic association with plant height and fresh head diameter at both genotypic and phenotypic levels. Ali *et al*., 2013, 2014, 2106; Ali *et al*., (2015) and Habib *et al*. (2007) also reported similar results in their respective studies. The results suggest that 1000-seed weight and oil contents are important yield components and could be used as selection criteria to improve seed yield. Path coefficients (Table 16) revealed that Oil contents exerted positive direct effect on total achene weight along with its positive indirect effects through days to 50% flowering. Oil contents had negative indirect effect through plant height, chlorophyll, fresh head diameter, dry head diameter, 1000 grain weight. Habib *et al*. (2007) also reported similar results in their respective studies. Highest positive indirect effect after its direct effect was through days to 50% flowering. Highest negative indirect effect of oil contents was exerted through fresh head diameter. Days to 50% flowering exerted positive direct effect on total achene weight along with its positive indirect effects through oil content. Days to 50% flowering has negative indirect effect through plant height, chlorophyll, fresh head diameter, dry head meter, 1000 grain weight. Highest positive indirect effect of days to 50% flowering was exerted through oil content. Highest negative indirect effect of days to 50% flowering was exerted through fresh head diameter. Plant height exerted positive direct effect on total achene weight along with its positive indirect effects through dry head diameter. The positive direct effects of Plant height and Head diameter established in this study supports the statements of Ali *et al*., (2010); Kaya and Atakisi (2003), Kaya *et al*. (2003), Vidhyavathi, *et al.* (2005), Göksoy and Turan (2007) that breeding for increased Seed yield seems to the most effective method to get higher sunflower yields. Plant height has negative indirect effect through days to 50% flowering, chlorophyll, fresh head diameter, 1000 grain weight, oil content. Highest positive indirect effect plant height was exerted through dry head diameter. Highest negative indirect effect of plant height was exerted through oil content. Chlorophyll exerted positive direct effect on total achene weight along with its positive indirect effects through days to 50% flowering, plant height, oil contents. Chlorophyll has negative indirect effect through fresh head diameter, dry head diameter, 1000 grain weight. Highest positive indirect effect of chlorophyll was through oil content followed by plant height. Highest negative indirect effect of chlorophyll was exerted through fresh head diameter. Fresh head diameter has negative indirect effect through days to 50% flowering, plant height, 1000 grain weight and oil contents. Highest positive indirect effect after its direct effect was through chlorophyll followed by dry head diameter. Highest negative indirect effect of fresh head diameter was exerted through oil contents. Dry head diameter exerted negative direct effect on total achene weight along with its positive indirect effects through days to 50% flowering, 1000 grain weight and oil contents. Highest negative indirect effect of dry head diameter was exerted through plant height. 1000 grain weight exerted negative direct effect on total achene weight.

Direct negative effects were reported (Alba & Greco, 1979, Lakshmanrao *et al*., 1985; Kanwal *et al*., 2019) [29]. However, direct positive effects of the weight of 1000 seeds on seed yield were also discussed by Alba *et al*. (1979); Imran *et al*., (2015) [25]; Naseem *et al*., (2015a,b) [46,47]; Giriraj *et al*. (1979) and Varshney *et al*., (1977). In addition to the 1000-grain weight had its positive indirect effects through days to 50% flowering, plant height, fresh head diameter, dry head diameter and oil contents. 1000 grain weight has negative indirect effect through chlorophyll. Highest positive indirect effect of 1000 grain weight was exerted through oil contents followed by fresh head diameter. Highest negative indirect effect of 1000 grain weight was exerted through

chlorophyll. Direct selection for Oil contents, Fresh head diameter, Plant height and Days to 50% flowering will give the best results for Total achene weight per plant.

Table 15: Genotypic (r_g) and phenotypic (r_p) correlation coefficient among eight yield characters of sunflower

Traits		Plant height	Chlorophyll	Fresh Head Diameter	Dry Head Diameter	1000-grain weight	Oil Content	Total weight
Days to 50% flowering	r(g)	-0.12442	0.165906	-0.42936	0.085064	0.010228	0.246103	0.082045
	r(p)	0.045828	0.205996	-0.22609	0.057014	-0.05967	0.217259	0.100227
Plant Height	r(g)		0.205536	-0.17849	-0.27084	0.018488	-0.27358	0.219557
	r(p)		0.130963	0.051382	-0.14829	-0.05049	-0.15186	0.142587
Chlorophyll	r(g)			-0.16324	0.232316	0.321855	0.254884	-0.10247
	r(p)			-0.04302	0.114786	0.142471	0.175251	-0.10106
Fresh Head Diameter	r(g)				-0.10434	0.154038	-0.4079	0.310418
	r(p)				0.007261	0.125599	-0.23155	0.197946
Dry Head Diameter	r(g)					-0.17646	0.159699	-0.272
	r(p)					-0.11011	0.107439	-0.24756
1000 Grain Weight	r(g)						0.659684*	0.762426*
	r(p)						0.408677*	0.511395**
Oil Content	r(g)							0.447272*
	r(p)							0.369817*

* = Significant (P≤ 0.05)
**= Highly significant (P≤0.01)

Table 16: Direct (Diagonal Bold) and Indirect Path Effects of Yield Character in Sunflower

Traits	Days to 50% Flowering	Plant height	Chlorophyll	Fresh Head Diameter	Dry Head Diameter	1000-grain weight	Oil Contents	Total Achene weight	rg
Days to 50% Flowering	0.434161	-0.10661	-0.07347	-0.45333	-0.00513	-0.00059	0.28702	0.082045	0.082045
Plant Height	-0.05402	0.856863	-0.09102	-0.18845	0.016327	-0.00107	-0.31907	0.219557	0.219557
Chlorophyll	0.07203	0.176117	-0.44286	-0.17235	-0.01401	-0.01865	0.29726	-0.10247	-0.10247
Fresh Head Diameter	-0.18641	-0.15294	0.072293	1.055828	0.00629	-0.00893	-0.47572	0.310418	0.310418
Dry Head Diameter	0.036931	-0.23207	-0.10288	-0.11017	-0.06028	0.010227	0.186249	-0.272	-0.272
1000-grain weight	0.00444	0.015842	-0.14254	0.162638	0.010638	-0.05795	0.769361	0.762426	0.762426
Oil Content	0.106849	-0.23442	-0.11288	-0.43067	-0.00963	-0.03823	1.166256	0.447272	0.447272

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