**Assessment of Sunflower (*Helianthus annuus* L.) Genotypes for Salinity Tolerance during Germination: A Physiological Traits Analysis**

**Abstract**

Sunflower (*Helianthus annuus* L.) is considered a moderately salt-tolerant crop; however, salinity stress remains a major limiting factor affecting germination, growth, and yield. The crop’s ability to perform under saline conditions varies with genotype, growth stage, and environmental influences. Among these, seed germination is one of the most sensitive and critical stages, as successful germination ensures uniform seedling establishment and overall crop performance. The present study aimed to assess of Sunflower genotypes for Salinity Tolerance during Germination. The study was conducted at the College of Agriculture, Raichur, Karnataka, to examine the physiological response of sunflower genotypes to salt stress during germination. A Factorial Completely Randomized Design (FCRD) was adopted, involving twenty-two sunflower genotypes and five NaCl concentrations (0, 100, 200, 300 and 400 mM). Seed physiological parameters such as germination rate (GR), germination index (GI), germination vigor index (GVI), water content (WC) and seedling vigor index-II (SVI-II) were evaluated to assess the impact of salinity. The results indicated considerable variation among genotypes in their response to salt stress, with certain genotypes maintaining better germination and physiological traits even under higher NaCl concentrations. Enhanced water uptake or retention may explain CMS-38B’s resilience. RCR-9 exhibited a sharp decline in water content from 77.41 % in the control to 55.96 % at 200 mM NaCl, indicating low salinity tolerance. This suggests difficulty in maintaining hydration under osmotic stress. Such susceptibility may restrict its growth and seed development in saline conditions. The findings enhance our understanding of genotypic variability in response to salinity during the early growth stage of sunflower.

Key words: Salinity, sunflower, germination and genotypes

**Introduction**

Plant adaptation to saline conditions includes genetic variability and mechanisms that contribute to access restriction of these and other potentially deleterious ions to metabolically active sites, both at the organ and subcellular levels. The plant also responds to salinity by upregulating the level of endogenous phytohormones, i.e., abscisic acid, auxins, cytokinins, salicylic acid, jasmonic acid, polyamines, gibberellins, and brassinosteroids (Céccoli et al., 2022). Sunflower (*Helianthus annuus* L.), a member of the family *Asteraceae*, is an important crop cultivated worldwide due to its short growing season and wider adaptability. Ranking as the fourth most important oilseed crop globally after soybean, mustard and safflower. It is considered as one of the most profitable and economic oilseed crops due to its high oil content (35 to 42 %). Its productivity varies significantly across regions, primarily due to various abiotic and biotic challenges. Biotic stresses include competition from weeds, infestations by insects and pests and diseases. Key abiotic stresses involve temperature extremes, water scarcity and soil issues such as salinity, alkalinity, poor fertility and nutrient deficiencies. Sunflowers thrive in light-textured sandy loam soils with a neutral pH, under optimal temperatures ranging from 20 to 25 ºC, and require 500 to 750 mm of evenly distributed rainfall (Thomaz *et al.,* 2012). Being a heavy feeder crop, sunflowers have high nutrient requirements, particularly for nitrogen, phosphorus and potassium, to support their growth and seed production. However, these ideal conditions are often disrupted by soil salinization. Globally, soil salinization is a major factor contributing to soil degradation. Poor soil and water management practices, coupled with arid and semi-arid climates characterized by low rainfall, high evaporation rates and elevated temperatures, accelerate the soil salinization process. Salt-affected soils are classified into saline, sodic and saline-sodic, depending on the concentration and composition of salts. Saline soils have high levels of soluble salts, composed of Cl- and SO2-4 of Na+, Ca2+ and Mg2+ and EC (of the saturated paste extract) values > 4 dS/m, ESP <15 %, SAR < 13 and pH values < 8.5. These soils are often found in arid and semi-arid regions. In agricultural systems, salinity is a growing concern due to irrigation practices that leave salts behind after water evaporation, further increasing the concentration of salts over time (Michael, 2009 and Seifi *et al.,* 2020).

Salinity stress significantly affects plants by disrupting their physiological and biochemical processes, leading to reduced growth and productivity. One of the primary effects is osmotic stress, where high salt concentrations in the soil make it difficult for plant roots to absorb water, leading to dehydration and wilting. Additionally, ionic toxicity occurs as excessive sodium (Na+) and chloride (Cl−) ions accumulate in plant tissues, interfering with nutrient uptake, enzyme activity and metabolic functions. Salinity also causes nutrient imbalances, as sodium competes with essential nutrients like potassium (K+), calcium (Ca2+) and magnesium (Mg2+), reducing their availability to the plant. This results in stunted growth, leaf chlorosis, premature leaf senescence and reduced photosynthesis (Boyer, 1992; Meloni *et al.,* 2003; Pal *et al.,* 2004). Under salt stress, salt-tolerant potatoes can maintain a high K+/Na+ ratio, improve photosynthetic activity, and exhibit elevated levels of osmotic regulators along with increased activity of antioxidant enzymes, all of which are crucial for their resilience to salt stress. Furthermore, some organizational structures of plants can also be changed in response to salt stress. For instance, the increase in stomatal density and the development of palisade and spongy parenchyma can help maintain plant photosynthesis under salinity (Chen et al., 2024). In severe cases, salinity stress can cause cell death and complete crop failure, severely limiting agricultural productivity in salt-affected regions. Over time, plants exposed to salinity may also experience oxidative stress, where the production of reactive oxygen species (ROS) such as superoxide anion (O-2), hydrogen peroxide (H2O2) and the hydroxyl radicals (OH-) particularly in chloroplast and mitochondria (Mittler, 2002; Masood *et al.,* 2006) leads to cellular damage, further weakening the plant’s resilience. As a result, salinity is recognized as a major abiotic stress affecting plant growth and development, leading to significant yield losses. Sunflower is a crop with moderate salt tolerance (Hardwick and Ferugson, 1978; Blamey *et al.,* 1986; Miller, 1995 and Francois, 1996). However, salinity stress is still a major constraint in sunflower production owing to inadequate rainfall failing to leach salt from the root zone and high evapotranspiration often exceeding rainfall. The study of genotypic variation in seed physiological traits under induced salinity stress during germination is faster and more cost-effective than field trials, helping to identify salt-tolerant genotypes for further testing.

**MATERIAL AND METHODS**

### **Material & experimental design**

The experiment was conducted at the College of Agriculture, Raichur, to evaluate the salt tolerance of sunflower using a Factorial Completely Randomized Design (FCRD). The study involved twenty-two sunflower genotypes (RSFH-1887, CMS-38B, R-127-1, RSFH-700, RGM-49, KBSH-78, CMS-1103B, RHA-92, KBSH-44, CMS-17B, RHA-95C-1, RCB-2, RCB-6, RCB-16, RCB-32, RCB-33, RCR-1, RCR-2, RCR-4, RCR-9, RCR-31, and RCR-41) and five NaCl concentrations (0, 100, 200, 300 and 400 mM). The seeds of 22 sunflower germplasms (maintained by AICRP on Sunflower, MARS, Raichur) were collected to conduct the experiment. These germplasms were developed using interspecific crosses involving *H. argophyllus* a wild sunflower species known for its abiotic stress tolerance viz., moisture stress tolerance and biotic stress tolerance (powdery mildew). RCB lines are mono-headed and used as inbred lines, whereas RCR lines are multi-headed lines used as R-lines. A pre-experiment was first conducted to ensure the viability of all seeds based on high germination rates (>99%). Only such high-quality seeds were used in the subsequent experiment to evaluate salt tolerance at the germination stage.

To assess germination, sunflower seeds were sown in 9-cm-diameter petri dishes and cultured in an incubator at 28°C/18°C (day/night) with a 16-hour light/8-hour dark cycle (ISTA, 1996). The NaCl concentrations tested were 100, 200, 300 and 400 mM, while seeds treated with distilled water (0 mM NaCl) served as controls. Fifteen seeds from each germplasm line were sown, and four biological replicates were conducted for each treatment. On the seventh day, seedling growth parameters, including fresh and dry weights of both roots and shoots, were measured to evaluate the impact of salinity on early plant development (Li *et al.* 2020).

**Methodolgy**

**Seed physiological parameters under salt stress during germination:** evaluated the salt tolerance of sunflower genotypes at the seed germination stage, germination rate (GR), germination index (GI), germination vigor index (GVI), (Alvarado *et al.* 1987; Ruan *et al.* 2002 and Atık *et al.* 2007) and seedling vigour index-II (SVI-II) were calculated (Abdul- Baki and Anderson, 1973)

**i) Germination rate (%)**

The germination rate (%) was calculated by dividing the total number of seeds germinated by the total number of seeds sown and multiplying by 100. For sunflower, the standard germination test was conducted under controlled conditions with a temperature of 25°C and a 12-hour light/dark cycle for 7 days. Germination is defined by visible radicle emergence, and the final count of germinated seeds was recorded on the 7th day.

G7

Germination rate (%)= ————× 100

N

Where,

G7 = total number of seeds germinated on the 7th days after sowing

N = total number of seeds

**ii) Germination index (GI)**

The Germination Index (GI) was calculated by summing the number of seeds germinated on each day (Gt) and dividing it by the corresponding day after sowing (T), as expressed in the formula:

Gt

Germination index= ∑ ———

T

Where,

Gt = total number of germinated seeds on the Tth day,

T = number of days after sowing

**iii) Germination vigor index (GVI)**

Germination vigor index (GVI) was calculated by summing the total number of seeds germinated on each day (Gt) divided by the corresponding days after sowing (T) and then multiplying the result by the average fresh weight of ten seedlings (AFW). The formula was expressed as:

Gt

Germination vigor index= ∑ ———× AFW (g)

T

Where,

Gt = total number of germinated seeds on the Tth day,

T = number of days after sowing

AFW = average fresh weight of seedlings (g)

**iv) Seedling vigour index-II (SVI-II)**

The seedling vigour index-II (SVI-II) was determined by multiplying the germination percentage with the dry weight of ten seedlings and the formula was expressed as:

Seedling vigor index-II = Germination (%) x seedling dry weight (g)

**v) Water content (%)**

The water content (%) was calculated by subtracting the dry weight (DW) of ten seedlings from their fresh weight (FW), dividing the result by the fresh weight (FW), and then multiplying by 100. The formula was expressed as:

FW - DW

Water content (%)= ————× 100

FW

Where,

FW = fresh weight of seedlings (g)

DW = dry weight of seedlings (g)

**Results and discussion**

**Germination rate (%)**

The effect of salinity on the germination rate of sunflower genotypes was significant. The germination rate decreased with increasing salinity levels (Table 1). The mean germination rate decreased from 95.95 % in the control to 10.23 % at 300 mM NaCl. No germination occurred at 400 mM NaCl across all genotypes. Among the genotypes, CMS-38B recorded the highest mean germination rate (81.34 %), while RCR-9 recorded the lowest (46.58 %). The interaction between genotypes and salinity levels was significant. CMS-38B recorded a relatively higher germination rate, decreasing from 98.67 % under control to 47.67 % at 300 mM NaCl. In contrast, RCR-9 showed lower germination, decreasing from 93.33 % in the control to zero at 300 mM NaCl. This indicates that CMS-38B has better tolerance to salinity stress, while RCR-9 is highly sensitive. In general, salinity negatively affects seed germination through osmotic stress, ion toxicity and oxidative damage, which collectively reduce germination rates and extend germination time. The significant reduction in germination rate observed in the study, from 95.95 % in the control to 10.23 % at 300 mM NaCl, reflects the mechanisms. High salinity increases the external osmotic potential, limiting water uptake during imbibition (Munns and Tester, 2008). Excess sodium and chloride ions damage embryo viability, further suppressing germination (Jahromi, 2008; Daszkowska-Golec, 2011). This was evident in the complete absence of germination at 400 mM NaCl across all genotypes.

Salinity also slows down the water absorption and reduces α-amylase activity, which is crucial for starch breakdown (Kaneko *et al.,* 2002). The superior performance of CMS-38B under saline conditions might be attributed to its ability to mitigate such effects better than RCR-9. Additionally, salinity interferes with germination hormones by reducing gibberellins (GA) and increasing abscisic acid (ABA), altering membrane permeability and water behavior within seeds (Lee and Luan, 2012). The hormonal disruptions could explain the drastic reduction in germination rates of RCR-9, especially at higher salinity levels. The findings align with previous studies. Ittah *et al.* (2019) reported that salinity reduces germination by 65 to 95 % at EC above 15.6 dS/m, emphasizing the suppressive effect of salt stress. The observed germination rates in this study support the findings, particularly the significant drop from 95.95 % in the control to 10.23 % at 300 mM NaCl. The studies also demonstrate that osmotic stress impairs water absorption and nutrient uptake in seeds (Torabi, 2014). Similarly, Luan *et al.* (2014) found that sunflower varieties achieve 50 % germination even at 300 mM NaCl, but only under optimal temperatures of 10°C to 20°C. This highlights the critical threshold for sunflower germination around 200 mM NaCl, reinforcing the adverse effects of salinity levels beyond this concentration as observed in the present study.

**Germination index**

The effect of salinity on the germination index of sunflower genotypes was significant. The germination index decreased with increasing salinity levels (Table 2). The mean germination index decreased significantly from 219.86 under control to 8.17 at 300 mM NaCl. Among the genotypes, CMS-38B recorded the highest mean germination index (133.45), while RCR-9 had the lowest (73.79). The interaction between genotypes and salinity levels was significant. CMS-38B recorded a higher germination index, decreasing from 255.83 under control to 36.20 at 300 mM NaCl, compared to the other genotypes. In contrast, RCR-9 showed germination index decreasing from 164.33 in the control to 0.00 at 300 mM NaCl, indicating poor tolerance to high salinity levels. The significant reduction in germination index observed in the study aligns with findings from Chowdhury *et al.* (2018), who reported a similar inhibitory effect of salinity on seed germination, with the germination index decreasing from 100.00 in the control to 59.26 at 200 mM NaCl. Karim *et al.* (1992) and Mondal *et al.* (1988) documented that salinity delays germination and reduces the germination index. Similarly, Francois *et al.* (1986) observed that high salinity levels significantly delayed germination and reduced the final germination percentage. The findings confirm the results of the current study, demonstrating that salinity adversely affects seed germination and germination indices.

**Germination vigor index**

The effect of salinity on the germination vigor index of sunflower genotypes was significant (Table 3). The significant decline in germination vigor index occurred as salinity levels increased, with the mean germination vigor index decreasing from 297.30 under control to 37.46 at 200 mM NaCl. Among the genotypes, the highest mean germination vigor index was recorded in CMS-38B (230.00), while the lowest was observed in RCR-9 (61.04). The interaction between genotypes and salinity levels was significant. CMS-38B recorded a relatively higher germination vigor index, decreasing from 422.63 under control to 69.95 at 200 mM NaCl, compared to the other genotypes. In contrast, RCR-9 showed a lower germination vigor index, reducing from 144.61 in the control to 7.07 at 200 mM NaCl, indicating poor tolerance to high salinity levels. Salinity stress significantly reduces the germination vigor index of sunflower genotypes, as increased salt concentrations disrupt water uptake, delay germination and impair seedling establishment. The observed decline in vigor index across all genotypes indicates the adverse effects of osmotic stress, ion toxicity and oxidative damage under saline conditions (Wu *et al.,* 2019). Among the genotypes, CMS-38B exhibited the highest vigor index and recorded better performance even at 200 mM NaCl, suggesting its ability to regulate ion balance and osmotic adjustment. In contrast, RCR-9 recorded the lowest vigor index, showing a sharp decline, which reflects its sensitivity to salinity. The variations highlight differences in genetic potential for salinity tolerance, possibly linked to mechanisms such as Na⁺ exclusion, antioxidant defense and osmotic regulation (Li *et al.,* 2020). The significant interaction between genotypes and salinity levels further emphasizes that sunflower genotypes respond differently to salt stress (Ding *et al.,* 2018).

**Seedling vigor index-II**

The effect of salinity on the seedling vigor index-II of sunflower genotypes was significant (Table 4). The significant decline in seedling vigor index-II occurred as salinity levels increased, with the mean seedling vigor index-II decreasing from 64.27 under control to 17.46 at 200 mM NaCl. Among the genotypes, the highest mean seedling vigor index-II was recorded in CMS-38B (59.41), while the lowest was observed in RCR-9 (19.00). The interaction between genotypes and salinity levels was significant. CMS-38B recorded a relatively higher seedling vigor index-II, decreasing from 83.47 under control to 32.13 at 200 mM NaCl, compared to the other genotypes. In contrast, RCR-9 showed a lower seedling vigor index-II, reducing from 42.33 in the control to 3.56 at 200 mM NaCl, indicating poor tolerance to high salinity levels. The significant decline in germination vigor index observed in the present study, with the mean germination vigor index decreasing from 64.27 in the control to 17.46 at 200 mM NaCl, is consistent with findings of Chowdhury *et al.* (2018), reported the detrimental effects of salinity on seedling growth, observing that shoot dry weight decreased significantly at 200 mM NaCl. Similar results have been reported by Cramer *et al.* (1986), Halim *et al.* (2004) and Mansour *et al.* (2005), who found comparable declines in shoot biomass under saline conditions. Since shoot dry weight is a reliable indicator of seedling vigor, the reductions emphasize the negative effect of salinity on plant growth (Blum, 1988; Karim *et al.,* 1992). Furthermore, root dry weight also decreases significantly with increasing salinity levels, as demonstrated by Akram *et al.* (2007) in corn hybrids. The findings confirm that higher salinity levels reduce seedling vigor.

**4.1.6 Water content (%)**

The effect of salinity on the water content (%) of sunflower genotypes was significant (Table 5). The significant reduction in water content occurred with increasing salinity, with the mean water content decreasing from 79.56 % under control conditions to 62.60 % at 200 mM NaCl. Among the genotypes, the highest mean water content was recorded in CMS-38B (74.77 %), while the lowest was observed in RCR-9 (66.87 %). The interaction between genotypes and salinity levels was significant. CMS-38B recorded a relatively higher water content, decreasing from 81.23 % under control conditions to 67.12 % at 200 mM NaCl, compared to the other genotypes. In contrast, RCR-9 showed lower water content, decreasing from 77.41 % in the control to 53.96 % at 200 mM NaCl, indicating poor tolerance to high salinity levels. The results from the study clearly show that increasing salinity significantly reduces the water content of sunflower genotypes, as evidenced by the decline in water content from 79.56 % under control conditions to 0.00 % at 300 mM NaCl. This reduction highlights the detrimental effect of salinity on seed water retention and supports the findings of Cramer *et al.* (1994), Halim *et al.* (2004) and Mansour *et al.* (2005), who also reported a decrease in water content with increased salinity. This observation is consistent with the physiological effects of osmotic stress caused by high salinity, which impairs normal cellular functions such as nutrient absorption and water retention. CMS-38B recorded a relatively higher water content than other genotypes, suggesting better water balance under salinity. This aligns with Torabi (2014), linked salinity-induced osmotic stress to changes in seed water content. Enhanced water uptake or retention may explain CMS-38B’s resilience. RCR-9 exhibited a sharp decline in water content from 77.41 % in the control to 55.96 % at 200 mM NaCl, indicating low salinity tolerance. This suggests difficulty in maintaining hydration under osmotic stress. Such susceptibility may restrict its growth and seed development in saline conditions.

**Conclusion**

The present study demonstrated notable genotypic differences in the physiological responses of sunflower seeds to induced salinity stress during germination. The variation in traits such as germination rate, germination index, water content, and seedling vigor index-II across the twenty-two genotypes highlights the sensitivity of this stage to saline conditions. Genotype CMS-38B maintained superior physiological performance under increasing salt concentrations, indicating its potential adaptability to saline environments. In contrast, genotype RCR-9 exhibited marked sensitivity. These results emphasize the importance of identifying and utilizing salt-tolerant genotypes to ensure better seedling establishment and crop performance under stress conditions, contributing to improved management of sunflower cultivation in salt-affected areas.

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**Table 1: Effect of sodium chloride (NaCl) induced salt stress on germination rate (%) in sunflower genotypes**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SI. NO.** | **Genotype (G)** | **Salinity levels (S)** | | | | |
| **0 mM** | **100 mM** | **200 mM** | **300 mM** | **Mean** |
| 1 | **RSFH-1887** | 9.87 (96.33) | 8.74 (75.33) | 7.87 (61.00) | 4.28 (17.33) | **7.69 (62.50)** |
| 2 | **CMS-38B** | 9.98 (98.67) | 9.81 (95.33) | 9.20 (83.67) | 6.98 (47.67) | **8.99 (81.34)** |
| 3 | **R-127-1** | 9.83 (95.67) | 8.68 (74.33) | 7.48 (55.00) | 1.00 (0.00) | **6.75 (56.25)** |
| 4 | **RSFH-700** | 9.83 (95.67) | 8.70 (74.67) | 7.57 (56.33) | 1.00 (0.00) | **6.78 (56.67)** |
| 5 | **RGM-49** | 9.83 (95.67) | 8.68 (74.33) | 7.48 (55.00) | 1.00 (0.00) | **6.75 (56.25)** |
| 6 | **KBSH-78** | 9.92 (97.33) | 9.47 (88.67) | 8.47 (70.67) | 3.56 (11.67) | **7.85 (67.09)** |
| 7 | **CMS-1103B** | 9.92 (97.33) | 9.36 (86.67) | 8.47 (70.67) | 3.56 (11.67) | **7.83 (66.59)** |
| 8 | **RHA-92** | 9.85 (96.00) | 8.73 (75.30) | 7.60 (56.70) | 1.00 (0.00) | **6.80 (57.00)** |
| 9 | **KBSH-44** | 9.87 (96.33) | 8.76 (75.67) | 7.92 (61.67) | 3.51 (11.33) | **7.51 (61.25)** |
| 10 | **CMS-17B** | 9.97 (98.33) | 9.47 (88.67) | 8.64 (73.67) | 5.03 (24.33) | **8.28 (71.25)** |
| 11 | **RHA-95C-1** | 9.83 (95.67) | 8.70 (74.67) | 7.59 (56.67) | 1.00 (0.00) | **6.78 (56.75)** |
| 12 | **RCB-2** | 9.97 (98.33) | 9.71 (93.33) | 8.76 (75.67) | 5.60 (30.33) | **8.51 (74.42)** |
| 13 | **RCB-6** | 9.81 (95.33) | 8.64 (73.67) | 7.37 (53.33) | 1.00 (0.00) | **6.71 (55.58)** |
| 14 | **RCB-16** | 9.71 (93.33) | 7.92 (61.67) | 6.32 (39.00) | 1.00 (0.00) | **6.24 (48.50)** |
| 15 | **RCB-32** | 9.97 (98.33) | 9.57 (90.67) | 8.64 (73.67) | 5.51 (29.33) | **8.42 (73.00)** |
| 16 | **RCB-33** | 9.78 (94.67) | 8.62 (73.33) | 7.02 (48.33) | 1.00 (0.00) | **6.61 (54.08)** |
| 17 | **RCR-1** | 9.73 (93.67) | 8.14 (65.33) | 6.35 (39.33) | 1.00 (0.00) | **6.31 (49.58)** |
| 18 | **RCR-2** | 9.73 (93.67) | 8.14 (65.33) | 6.58 (42.33) | 1.00 (0.00) | **6.36 (50.33)** |
| 19 | **RCR-4** | 9.81 (95.33) | 8.62 (73.33) | 7.16 (50.33) | 1.00 (0.00) | **6.65 (54.75)** |
| 20 | **RCR-9** | 9.71 (93.33) | 7.85 (60.67) | 5.77 (32.33) | 1.00 (0.00) | **6.09 (46.58)** |
| 21 | **RCR-31** | 9.97 (98.33) | 9.71 (93.33) | 8.93 (78.67) | 6.51 (41.33) | **8.78 (77.92)** |
| 22 | **RCR-41** | 9.73 (93.67) | 7.98 (62.67) | 6.32 (39.00) | 1.00 (0.00) | **6.26 (48.84)** |
|  | **Mean** | **9.85 (95.95)** | **8.84 (77.14)** | **7.67 (57.87)** | **3.35 (10.23)** |  |
|  | **Factors** | **S. Em. ±** | | | **CD @ 5 %** | |
|  | **Genotype (G)** | 0.17 | | | 0.46 | |
|  | **Salinity levels (S)** | 0.07 | | | 0.20 | |
|  | **G X S** | 0.33 | | | 0.93 | |

**Note**: Figures in the parenthesis indicate original values.

**Table 2: Effect of sodium chloride (NaCl) induced salt stress on germination index (GI) in sunflower genotypes**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SI. NO.** | **Genotype (S)** | **Salinity levels (S)** | | | | |
| **0 mM** | **100 mM** | **200 mM** | **300 mM** | **Mean** |
| 1 | **RSFH-1887** | 15.30 (233.12) | 10.89 (117.50) | 8.16 (65.66) | 3.95 (14.57) | **9.57 (107.71)** |
| 2 | **CMS-38B** | 16.03 (255.83) | 12.30 (150.35) | 9.61 (91.42) | 6.10 (36.20) | **11.01 (133.45)** |
| 3 | **R-127-1** | 14.11 (198.05) | 10.81 (115.90) | 7.73 (58.77) | 1.00 (0.00) | **8.41 (93.18)** |
| 4 | **RSFH-700** | 14.12 (198.46) | 10.84 (116.43) | 7.85 (60.56) | 1.00 (0.00) | **8.45 (93.76)** |
| 5 | **RGM-49** | 15.20 (230.05) | 10.82 (116.07) | 7.73 (58.78) | 1.00 (0.00) | **8.69 (101.22)** |
| 6 | **KBSH-78** | 15.22 (230.70) | 11.86 (139.73) | 8.81 (76.56) | 3.36 (10.26) | **9.81 (114.32)** |
| 7 | **CMS-1103B** | 15.92 (252.37) | 11.73 (136.55) | 8.81 (76.54) | 3.33 (10.12) | **9.95 (118.94)** |
| 8 | **RHA-92** | 14.65 (213.58) | 10.89 (117.50) | 7.87 (60.93) | 1.00 (0.00) | **8.60 (98.00)** |
| 9 | **KBSH-44** | 15.17 (229.11) | 10.91 (118.03) | 8.21 (66.39) | 3.32 (10.01) | **9.40 (105.89)** |
| 10 | **CMS-17B** | 15.92 (252.30) | 11.86 (139.72) | 8.99 (79.84) | 4.55 (19.68) | **10.33 (122.89)** |
| 11 | **RHA-95C-1** | 15.19 (229.72) | 10.84 (116.43) | 7.87 (60.93) | 1.00 (0.00) | **8.72 (101.77)** |
| 12 | **RCB-2** | 15.94 (252.96) | 12.17 (147.17) | 9.15 (82.69) | 4.95 (23.49) | **10.55 (126.58)** |
| 13 | **RCB-6** | 13.12 (171.19) | 10.76 (114.84) | 7.61 (56.95) | 1.00 (0.00) | **8.12 (85.75)** |
| 14 | **RCB-16** | 13.19 (173.00) | 9.94 (97.73) | 6.55 (41.95) | 1.00 (0.00) | **7.67 (78.17)** |
| 15 | **RCB-32** | 15.27 (232.30) | 12.00 (142.92) | 8.99 (79.84) | 4.93 (23.33) | **10.29 (119.60)** |
| 16 | **RCB-33** | 14.58 (211.46) | 10.74 (114.31) | 7.24 (51.48) | 1.00 (0.00) | **8.39 (94.31)** |
| 17 | **RCR-1** | 15.08 (226.53) | 10.22 (103.54) | 6.63 (42.99) | 1.00 (0.00) | **8.24 (93.27)** |
| 18 | **RCR-2** | 14.10 (197.86) | 10.23 (103.57) | 6.87 (46.26) | 1.00 (0.00) | **8.05 (86.92)** |
| 19 | **RCR-4** | 15.25 (231.52) | 10.74 (114.31) | 7.39 (53.67) | 1.00 (0.00) | **8.59 (99.88)** |
| 20 | **RCR-9** | 12.86 (164.33) | 9.86 (96.13) | 5.97 (34.67) | 1.00 (0.00) | **7.42 (73.79)** |
| 21 | **RCR-31** | 15.99 (254.72) | 12.17 (147.17) | 9.33 (85.97) | 5.73 (31.84) | **10.80 (129.99)** |
| 22 | **RCR-41** | 14.10 (197.86) | 10.02 (99.32) | 6.55 (41.95) | 1.00 (0.00) | **7.92 (84.79)** |
|  | **Mean** | **14.86 (219.86)** | **11.05 (121.15)** | **7.97 (62.49)** | **3.03 (8.17)** |  |
|  | **Factors** | **S. Em. ±** | | | **CD @ 5 %** | |
|  | **Genotype (G)** | 2.02 | | | 5.64 | |
|  | **Salinity levels (S)** | 0.86 | | | 2.40 | |
|  | **G X S** | 4.04 | | | 11.28 | |

**Note**: Figures in the parenthesis indicate original value.

**Table 3: Effect of sodium chloride (NaCl) induced salt stress on germination vigor index (GVI) in sunflower genotypes**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SI. NO.** | **Genotype (G)** | **Salinity levels (S)** | | | |
| **0 mM** | **100 mM** | **200 mM** | **Mean** |
| 1 | **RSFH-1887** | 319.36 | 100.34 | 45.77 | **155.16** |
| 2 | **CMS-38B** | 422.63 | 199.97 | 69.95 | **230.00** |
| 3 | **R-127-1** | 263.41 | 91.45 | 31.91 | **128.92** |
| 4 | **RSFH-700** | 269.94 | 95.71 | 39.06 | **134.91** |
| 5 | **RGM-49** | 312.18 | 95.18 | 35.15 | **147.50** |
| 6 | **KBSH-78** | 341.43 | 128.41 | 55.03 | **174.97** |
| 7 | **CMS-1103B** | 365.94 | 121.25 | 53.90 | **180.36** |
| 8 | **RHA-92** | 290.47 | 99.87 | 40.58 | **143.64** |
| 9 | **KBSH-44** | 326.94 | 103.26 | 46.41 | **158.88** |
| 10 | **CMS-17B** | 376.93 | 128.55 | 57.56 | **187.68** |
| 11 | **RHA-95C-1** | 312.87 | 96.17 | 39.85 | **149.63** |
| 12 | **RCB-2** | 389.58 | 153.79 | 60.45 | **201.27** |
| 13 | **RCB-6** | 227.85 | 86.58 | 28.93 | **114.46** |
| 14 | **RCB-16** | 156.91 | 33.42 | 8.77 | **66.37** |
| 15 | **RCB-32** | 355.88 | 135.49 | 58.04 | **183.14** |
| 16 | **RCB-33** | 277.85 | 65.84 | 22.55 | **122.08** |
| 17 | **RCR-1** | 249.41 | 45.36 | 10.44 | **101.74** |
| 18 | **RCR-2** | 223.59 | 58.10 | 14.57 | **98.75** |
| 19 | **RCR-4** | 305.61 | 85.62 | 24.31 | **138.51** |
| 20 | **RCR-9** | 144.61 | 31.44 | 7.07 | **61.04** |
| 21 | **RCR-31** | 395.45 | 183.37 | 64.65 | **214.49** |
| 22 | **RCR-41** | 211.71 | 36.35 | 9.19 | **85.75** |
|  | **Mean** | **297.30** | **98.89** | **37.46** |  |
|  | **Factors** | **S. Em. ±** | | **CD @ 5 %** | |
|  | **Genotype (G)** | 3.39 | | 9.49 | |
|  | **Salinity levels (S)** | 1.25 | | 3.50 | |
|  | **G X S** | 5.87 | | 16.44 | |

**Table 4: Effect of sodium chloride (NaCl) induced salt stress on seedling vigor index-II (SVI) in sunflower genotypes**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SI. NO.** | **Genotype (G)** | **Salinity levels (S)** | | | |
| **0 mM** | **100 mM** | **200 mM** | **Mean** |
| 1 | **RSFH-1887** | 65.99 | 32.39 | 21.26 | **39.88** |
| 2 | **CMS-38B** | 83.47 | 62.63 | 32.13 | **59.41** |
| 3 | **R-127-1** | 63.62 | 29.32 | 14.93 | **35.96** |
| 4 | **RSFH-700** | 65.06 | 30.54 | 18.17 | **37.92** |
| 5 | **RGM-49** | 64.91 | 29.95 | 15.68 | **36.85** |
| 6 | **KBSH-78** | 71.34 | 41.14 | 25.41 | **45.96** |
| 7 | **CMS-1103B** | 69.98 | 38.83 | 24.88 | **44.56** |
| 8 | **RHA-92** | 64.61 | 31.55 | 19.39 | **38.52** |
| 9 | **KBSH-44** | 68.73 | 33.08 | 21.55 | **41.12** |
| 10 | **CMS-17B** | 73.45 | 42.74 | 26.56 | **47.58** |
| 11 | **RHA-95C-1** | 64.19 | 30.69 | 18.53 | **37.81** |
| 12 | **RCB-2** | 75.62 | 48.62 | 27.77 | **50.67** |
| 13 | **RCB-6** | 63.87 | 27.77 | 13.71 | **35.12** |
| 14 | **RCB-16** | 45.73 | 11.72 | 4.68 | **20.71** |
| 15 | **RCB-32** | 75.32 | 45.06 | 26.78 | **49.05** |
| 16 | **RCB-33** | 62.20 | 20.65 | 10.58 | **31.14** |
| 17 | **RCR-1** | 51.57 | 17.67 | 5.31 | **24.85** |
| 18 | **RCR-2** | 52.92 | 18.35 | 7.41 | **26.23** |
| 19 | **RCR-4** | 62.92 | 27.43 | 11.48 | **33.94** |
| 20 | **RCR-9** | 42.33 | 11.13 | 3.56 | **19.00** |
| 21 | **RCR-31** | 75.91 | 49.09 | 29.58 | **51.53** |
| 22 | **RCR-41** | 50.11 | 22.94 | 4.75 | **25.93** |
|  | **Mean** | 64.27 | 31.97 | 17.46 |  |
|  | **Factors** | **S. Em. ±** | | **CD @ 5 %** | |
|  | **Genotype (G)** | 0.78 | | 2.19 | |
|  | **Salinity levels (S)** | 0.28 | | 0.81 | |
|  | **G X S** | 1.35 | | 3.80 | |

**Table 5: Effect of sodium chloride (NaCl) induced salt stress on water content (%) in sunflower genotypes**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SI. NO.** | **Genotype (S)** | **Salinity levels (S)** | | | |
| **0 mM** | **100 mM** | **200 mM** | **Mean** |
| 1 | **RSFH-1887** | 79.61 | 73.69 | 63.25 | **72.18** |
| 2 | **CMS-38B** | 81.23 | 75.96 | 67.12 | **74.77** |
| 3 | **R-127-1** | 79.15 | 73.09 | 62.61 | **71.62** |
| 4 | **RSFH-700** | 79.61 | 73.67 | 63.25 | **72.18** |
| 5 | **RGM-49** | 79.25 | 73.11 | 62.79 | **71.72** |
| 6 | **KBSH-78** | 80.62 | 74.98 | 65.45 | **73.68** |
| 7 | **CMS-1103B** | 80.56 | 74.45 | 64.57 | **73.19** |
| 8 | **RHA-92** | 79.57 | 73.42 | 63.12 | **72.04** |
| 9 | **KBSH-44** | 79.78 | 73.72 | 63.40 | **72.30** |
| 10 | **CMS-17B** | 81.00 | 75.09 | 66.75 | **74.28** |
| 11 | **RHA-95C-1** | 79.52 | 73.21 | 62.98 | **71.90** |
| 12 | **RCB-2** | 81.11 | 75.23 | 66.96 | **74.43** |
| 13 | **RCB-6** | 79.12 | 73.07 | 62.54 | **71.58** |
| 14 | **RCB-16** | 77.95 | 70.59 | 56.45 | **68.33** |
| 15 | **RCB-32** | 81.07 | 75.11 | 66.83 | **74.33** |
| 16 | **RCB-33** | 79.01 | 72.03 | 61.25 | **70.76** |
| 17 | **RCR-1** | 78.15 | 71.25 | 58.12 | **69.17** |
| 18 | **RCR-2** | 78.20 | 71.48 | 59.68 | **69.79** |
| 19 | **RCR-4** | 79.09 | 73.05 | 61.92 | **71.35** |
| 20 | **RCR-9** | 77.41 | 69.24 | 53.96 | **66.87** |
| 21 | **RCR-31** | 81.13 | 75.57 | 67.09 | **74.60** |
| 22 | **RCR-41** | 78.09 | 71.17 | 57.23 | **68.83** |
|  | **Mean** | **79.56** | **73.28** | **62.60** |  |
|  | **Factors** | **S. Em. ±** | | **CD @ 5 %** | |
|  | **Genotype (G)** | 1.28 | | 3.58 | |
|  | **Salinity levels (S)** | 0.47 | | 1.32 | |
|  | **G X S** | 2.22 | | 6.65 | |