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# SCREENING OF SESAME (*Sesamum indicum*) GENOTYPES AGAINST SALINITY AT GERMINATION, FLOWERING AND HARVESTING STAGES

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***Abstract***

*The objective of the study was to identify salt-tolerant sesame genotypes suitable for moderately saline condition. Eighty-six of sesame accessions were evaluated at a salinity level of 7.5 dS/m and six genotypes (BD-6980, BD-7009, BD-7011, BD-6994, BD-6983, and BD-6999) with higher germination rates advanced to flowering and harvesting stages. Physiological, biochemical, and yield performances were assessed. Results revealed that salt stress gradually raises intercellular $CO_2$ because it lowers transpiration rate and stomatal conductance, both of which lead to a drop in sesame plant photosynthesis. Salinity also disrupted plant water relations, reducing relative water content (RWC%) and increasing water saturation deficit (WSD%), while lowering leaf chlorophyll content. On the other hand, osmoprotectants such as proline accumulation rise in response to salt stress, enhancing sesame tolerance to salinity. Different genotypes showed variations in physiological, biochemical, and yield properties. Notably, BD-7011 emerged as the most salt-tolerant genotype. Further testing of this BD-7011 genotype to serve as donor parents for sesame crop improvement initiatives aimed at to improve salt tolerance and develop resilient sesame varieties.*

***Key words**: selection, physio biochemical markers, salinity, oilseed.*

## INTRODUCTION

Salt is a major abiotic stress that significantly affects plant growth, development, and productivity (Gharsallah et al., 2016; Mannan et al., 2009; Mannan et al., 2010). Soil salinization is primarily caused by the build-up of water-soluble salts in the root zone, such as potassium ($K^+$), sodium ($Na^{+)}$, chloride ($Cl^-$), and sulfate ($SO_4^{2-}$). This leads to osmotic fluctuations, which diminish plant root cells' capacity to hold onto water in the soil (Kamran et al., 2019; Stavi et al., 2021). The effects of salinity on germination and growth stages are detrimental and complex, primarily because osmotic stress, ionic stress, nutritional imbalances, or a combination of these factors impair plant physiological and metabolic activities (Zhang et al., 2013; Rahneshan et al., 2018). Furthermore, plant nutrients like N, P, K, Ca, or Mg are not as bioavailable in salt-affected soils (Fageria et al., 2011; Daliakopoulos et al., 2016; Alam et al., 2017). Increased osmotic potential of the soil solution due to high soil salinity is caused by excess soluble $Na^+$ and $Cl^-$. This inhibits root water uptake, reduces leaf expansion and stomatal closure, and limits photosynthesis and respiration in plants (Zhong et al., 2019; Ma et al., 2021). As a result, plant morphology, physiology, and yield are all negatively impacted by salinity (Singh et al., 2015; Mannan et al., 2013a). Under different saline conditions, the stomatal conductance (gs) and photosynthesis (Pn) decrease simultaneously (Mbarki et al., 2018; Yan et al., 2013). Evidence suggests that salt stress affects both the amount of chlorophyll and important photosynthetic enzyme activity (Stępień & Kłbus, 2006). One of the main variables influencing photosynthetic capacity is the amount of chlorophyll. Several plant species have shown reduced or unchanged chlorophyll content when under stress; the degree of stress varies depending on the rate and duration of the stress (Ganji et al., 2012; Rasul et al., 2022). The amount of chlorophyll in a leaf serves as a gauge for the plant tissues' capacity for photosynthetic processes (Nageswara et al., 2001). After plant water potential was abandoned in favor of RWC %, which more accurately represents the ratio of water absorbed by plants to water transpired. RWC was proposed as the best criterion for plant water status (Ghogdi et al., 2012). According to Liang et al. (2013), plants gather osmolytes to shield the internal processes of their cells from disruptive external changes. By raising the osmotic concentration within the cell, proline and soluble carbohydrates aid in the elimination of free radicals from cells and lessen the impact of stress on physiological processes (Tiryakī, 2016). Osmotic adjustment, which preserves homeostasis by transferring extra $Na^+$ ions to the vacuole, is the second mechanism, while the first is the synthesis of osmolyte in response to this condition (Silva et al., 2015; Rahneshan et al., 2018).

Sesame (*Sesamum indicum* L.) is an important oilseed crop in Bangladesh next to rapeseed and soybean (BBS, 2022). It produces various chemical components that are unavailable in other edible oils offers resistance to oxidative rancidity and has made sesame well known as the “Queen of oilseed crops” (Bouremia et al., 2011). Bangladesh's geographic location makes it extremely vulnerable to salinization of the soil and water. In 1973, 0.83million hectares of Bangladeshi land were affected by salinity; by 2000, that number had increased to 1.02 million hectares, and by 2009, it had reached 1.05 million hectares (Brammer, 2014). Currently, varying levels of soil salinity affect about 37% of arable seaside land. Moreover, a general variation in soil salinity affects 1.02 million hectares, or roughly 70%, of this arable land along the coast (Dasgupta et al., 2014). Salt-tolerance sesame cultivars could be an option for its cultivation in salt-affected areas (Masuma et al., 2023). Therefore, screening of the most salt-tolerant sesame cultivars would be of great value for agriculture by increasing sesame cultivation area. Plants might respond differently to salt stress overall because even within the same species, cultivars and genotype phenological stages can change (Sanchez et al., 2004; Carmen et al., 2023) and genotypic variability was observed by Arshadi et al. (2018) under stress conditions. According to Abbasdokht et al. (2012), sesame is a plant with a moderate tolerance to salt. Therefore, the objectives of this study were to (a) examine the germination capability, physio-biochemical and yield responses of sesame genotypes grown under two different soil conditions, namely irrigation with non-saline water and irrigation with 7.5 dS/m saline water; and (b) identify the sesame genotypes that responded most favourably to salt stress.

## MATERIALS AND METHODS

### Description of the study area

The experiments were carried out during February to June 2023 in the Department of Agronomy at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. The experimental site is situated at latitude 24º09’ N and longitude 90º26’ E, and it lies 8.4 m above sea level. The daily temperature and relative humidity (RH%) during experimentation are presented in Figure 1 (BRRI, 2023).

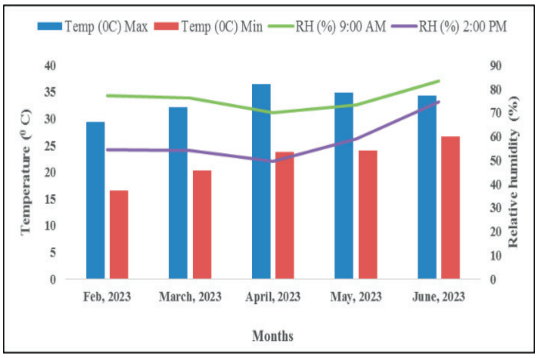

Figure 1. Temperature and relative humidity during experimentation

### Germination stage screening

Screening of sesame accessions at the germination stage was carried out at the laboratory. Saline solutions having (0 and 7.5 dS/m) was prepared from NaCl salt, and arranged in CRD design with three replicates. Eighty-six accessions were collected from the Genetic Resource Centre, Bangladesh Agricultural Research Institute, Bangladesh. Twenty-five seeds of each accession were placed on a Petri dish lined with filter paper. Germination counts were conducted at 5, 7, and 10th days of germination time.

Germination percentage was determined by dividing germinated seeds to total number of seeds sown on each petri dish. Relative germination (% of control) was used as screening parameters and all the genotypes were categorized as follows (adapted from Ashraf & Waheed, 1990):

| Scale | Relative germination | Tolerance group |
|---|---|---|
| 1 | >80 | Tolerant |
| 2 | 60-80 | Moderately tolerant |
| 3 | 40-59 | Moderately susceptible |
| 4 | <40 | Susceptible |

### *Flowering and harvesting stage screening*

During the germination stage, six genotypes (BD-6980, BD-7009, BD-7011, BD-6994, BD-6983, and BD-6999) were selected from 86 genotypes under 7.5 dS/m salinity and these six sesame genotypes used in this investigation. Ten seeds of each genotype were sown in each pot on February 5, 2023 having a height of 24 cm and a diameter of 30 cm. It held 14 kg of air-dried soil and a 4:1 soil-to-cow dung mixture. The characteristics of the soil used in the pot are presented in Table 1. The potting soil was treated with 0.64 g, 0.62 g, 0.52 g, and 0.20 g of urea, TSP (Triple Super Phosphate), MoP (Muriate of Porash) and gypsum. These amounts were based on 50.0-20.0-40.0-14.0 kg N-P-K-S /ha, respectively (FRG, 2018). Half of the N and all other fertilizers were applied as basal and the other half of N was applied at 15 DAE (days after emergence).

Table 1. Physical and chemical properties of the experimental soil

| Soil characteristics | Analytical value |
|---|---|
| Soil Texture | Sandy loam |
| Moisture at field capacity | 28% |
| pH | 7.02 |
| Electrical conductivity (EC) (dS/m) | 0.04 |
| Total nitrogen (N) (mg/100 g soil) | 0.06 |
| Exchangeable potassium (K%) | 0.07 |
| Phosphorus (P) (cmoles/kg of dry soil) | 0.79 |
| Cation exchange capacity (CEC) (cmoles/kg of dry soil) | 13.05 |

## Experimental factors and design

The experiment consisted of two factors: i) six sesame genotypes and ii) two saline conditions - control (irrigating the potting soil with tap water) and saline stress (irrigating the potting soil with 7.5 dS/m NaCl solution) following a completely randomized design (CRD) with three replications. Mild irrigation with tap water was used after seed sowing to ensure uniform germination. The cultivation technique advised by BARI (2000) was applied to the crops.

## Salinity treatment imposition

Fourteen days after the seeds emerged, three plants per pot were kept and subjected to both non-salty (tap water irrigation) and salt treatment (7.5 dS/m saline water irrigation) for the whole growing season. A 7.5 dS/m saline solution was prepared by combining tap water with the necessary quantity of NaCl. Using a portable digital moisture meter (POGO Soil Sensor II, Stevens, USA), the soil salinity of each pot was observed.

## Data collection

Data on relative water content, water saturation deficit, chlorophyll content, intercellular $CO_2$ concentration, stomatal conductance, rate of photosynthesis, transpiration rate, and proline content were measured in both control and salt-treated plants at the flowering stage. At the maturity stage, yield and yield contributing parameters to yield were measured.

## Measurement of relative water content and water saturation deficit

The earlier technique created by Yamasaki and Dillenburg (1999) was used to quantify the relative water content (RWC) and water saturation deficit (WSD) of leaves at the flowering stage. Fully grown leaves from plants in each treatment under control and salt were utilized to quantify it at midday. The leaves were trimmed, then sent straight to the lab, wrapped in plastic bags, and kept in an ice box. After that, their initial fresh weight (FW) was noted. A turgid weight (TW) was obtained by immersing leaves in distilled water in beakers for an entire day in the laboratory at room temperature and with low light levels. After submerging the leaves in water, their turgid weight was determined by quickly and gently blotting them dry with tissue paper. Subsequently, the leaf samples were oven-dried for 72 hours at 70 °C to ascertain their dry weight (DW). The formula used to measure relative water content:

$RWC\ \% = [(FW-DW)/(TW-DW)] \times 100$ where, FW = Fresh weight (mg), DW= Dry weight (mg), and TW = Turgid weight (mg).

According to Sangakkara et al. (1996), the following method was used to measure water saturation deficit (WSD).

$WSD\ \% = [(TW - FW) / (TW - DW)] \times 100$

## Leaf chlorophyll content measurement

A single fully developed leaf was sampled from the top of the plant to determine the quantity of chlorophyll in each replication and was measured following the method described by Mannan et al. (2023). Twenty milligrams of fresh leaf material were taken, placed in vials with twenty milliliters of 80% acetone, sealed with aluminum foil, and exposed to the dark for seventy-two hours. Utilizing a Thermo Fisher Scientific double-beam spectrometer (model 20020), we were able to measure the wavelengths at 663 nm and 645 nm. To present the data, fresh weight mg/g was used. Utilizing the following formula, the amounts of total chlorophyll were determined:

Total chlorophyll (mg/g fresh weight) = [20.2 (D645) - 8.02 (D663)] × [V/100 × W] where,

D (663, 645) = optical density of the chlorophyll extract at a wavelength of 663 and 645 nm, respectively,

V = final volume (mL) of 80% acetone with chlorophyll extract,

W = weight of fresh leaf sample in g.

### Proline content measurement

The proline content was ascertained using the procedure described by Bates et al. (1973). The proline content was measured using two (2.0) milliliters of proline extract, two milliliters of acid ninhydrin, and two milliliters of glacial acetic acid. The absorbance was measured at 520 nm. A standard curve was found using actual proline at a given concentration.

### Measurement of photosynthesis rate, intercellular $CO_2$ concentration, stomatal conductance, and transpiration rate

A portable photosynthetic system (Li-COR, 6400, Lincon, NE, USA) was used to quantify the transpiration rate (Tr), photosynthetic rate (Pn), stomata conductance (Gs), and intercellular $CO_2$ concentration for each genotype across all treatments using their fully expanded topmost leaves. Photosynthetically active radiation (PAR) values ranged from 11.00 to 12.00 $\mu$mol/m$^2$/s, and all measurements were made on a sunny day between 11:00 am and 1 pm.

### Yield and yield contributing parameters

At the ripening stage, three plants were taken from each replicate of the treatments. 1000-seed weight, seed yield/plant, number of capsules/plants, and number of seeds/capsules were all recorded.

### Statistical analysis

The statistical tool CropStat 7.2 was used to analyze the data. The least significant difference (LSD) test at p=0.05 was used to compare the means of the different treatments (Gomez & Gomez, 1984). An Excel program 2016 was used to create the table and graph.

## RESULTS AND DISCUSSIONS

### Germination stage screening

All the accessions examined in this study were classified into four groups on the basis of their performance in terms of relative germination (germination under saline condition compared to control) is presented in Table 2.

Table 2. Group member of 86 sesame genotypes classified into 4 groups based on Relative germination percent

| Tolerant group | Relative germination (%) | Name of genotypes | Member |
|---|---|---|---|
| Tolerant | >80 | BD-6980, BD-7009, BD-7011, BD-6994, BD-6983, BD-6999 | 06 |
| Moderately tolerant | 60-80 | BD-6985, BD-6986, BD-6993, BD-7003, BD-6991, BD-6963, BD-7008, BD-7012, BD-6989, BD-11634, BD-7019 BD-7001, BD-6971, BD-6974, BD-6995, BD-6998, BD-7016, BD-6979, BD-6990, BD-6970, BD-11642, BD-6981, BD-6962, BD-7019, BD-7020, BD-66984, BD-11633, BD-7013, BD-7006, BD-6987, BD-6992, BD-6961, BD-11637, BD-11639 | 34 |
| Moderately susceptible | 40-59 | BD-6987, BD-6972, BD-6977, BD-6964, BD-11621, BD-6988, BD-6982, BD-6968, BD-7018, BD-11632, BD-7000, BD-11622, BD-11630, BD-7014, BD-11640, BD-6960, BD-11634, BD-6997, BD-10167, BD-BARI-3, BD-6959, BD-6966, BD-BARI-4, BD-11632, BD-10857, BD-7005, BD-11643, BD-6996, BD-11624, BD-6969 | 30 |
| Susceptible | <40 | BD-11629, BD-7015, BD-7004, BD-BARI-1, BD-7007, BD-11641, BD-10166, BD-11635, BD-11623, BD-6978, BD-6967, BD-11625, BD-10164, BD-10165, BD-10859, BD-11644 | 16 |

Six genotypes were grouped as tolerant; they germinated more than 80% of the seeds under salinity stress, while 16 genotypes (less than 40%) were grouped as susceptible. Thirty-four

(34) accessions in the second group (moderately tolerant) exhibited relative germination between 60 and 80 percent. However, in the third (moderately susceptible) group, 30 accessions had relative germination in the range of 40-59 %. Such type of screening was carried out and grouping was made at the seedling stages by Al-Muttawa (2003) in chickpea, Ashraf and Wahid (1990) in lentil and Aziz (2003) in mungbean.

The genotypes were evaluated for their relative germination (percent of control) at 7.5 dS/m salinity. Among tested lines, six accessions (BD-6980, BD-7009, BD-7011, BD-6994, BD-6983, and BD-6999) showed higher (>.80%) relative germination percentage considered as tolerant promoted to flowering and maturity stages screening in simulated saline conditions (Figure 2).

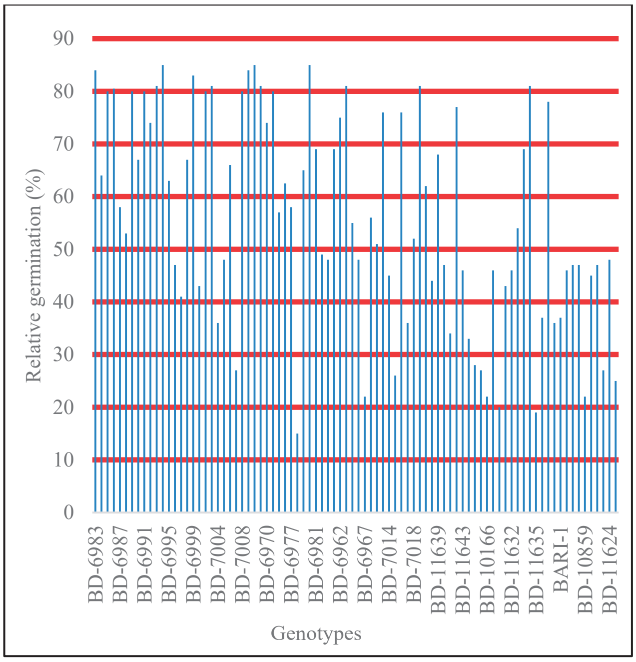

Figure 2. Effects of salinity on germination of sesame genotypes

## Flowering and harvesting stages screening

### *Effect of salinity on relative water content*

Relative water content is a crucial sign of a plant's resilience to dehydration.

The genotypes had an impact on the decline in sesame's relative water content brought on by salinity (Figure 3). In the control condition, genotype BD-6999 had the highest reported RWC, followed by BD-6980, while genotype BD-6994 had the lowest. BD-7011 was determined to have the largest RWC, whereas BD-6980 and BD-6983 had the lowest RWCs under salinity conditions, respectively. BD-7011 had the lowest RWC decline (13%), followed by BD-6980 (19%), while BD-6983 (40%) had the most RWC loss in saline conditions throughout the sesame at flowering stage.

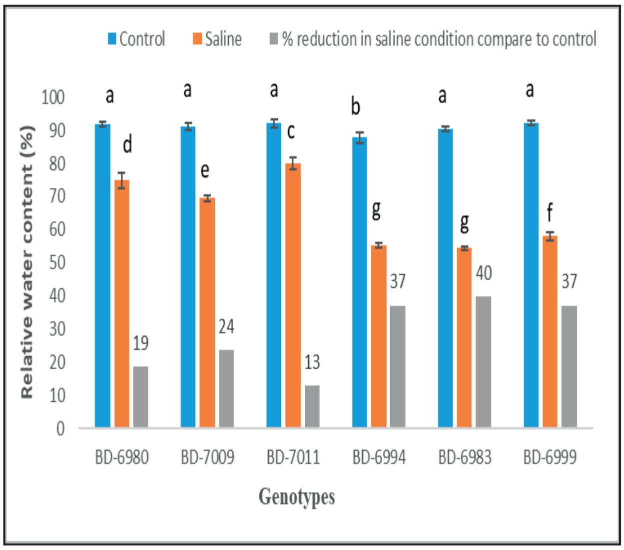

Figure 3. Relative water content in selected sesame genotypes influenced by salinity. Bars indicate (± SE). Different letters show significant differences at $p < 0.05$

In our results, the relative water content falls due to salinity in all the genotypes. It seems first, osmotic stress, which lowers root water intake, occurs in plants exposed to salinity. Furthermore, low relative water content in the cell and poor or nonexistent water uptake by roots are the outcomes of transpiration pull brought on by ABA-mediated stomatal closure (Blatt & Armstrong, 1993). According to Bacarin et al. (2011), salt stress decreased water intake and RWC. It also decreased the water potential and availability of plant roots in the soil. According to Sheoran et al. (2021), relative water content (RWC) is critical for physiological plant metabolism, illustrates the degree of cellular and tissue hydration, and explains how plants regulate or maintain cell hydration at a suitable level during stress. It seems that cultivars with high RWC can withstand salt stress, as seen in sesame genotype BD-7011. Because of the osmotic action, salt stress has a negative impact on water intake. Because of a drop in osmotic potential brought on by salt accumulation in the root zone, there is less water in the leaves. Acosta-Moto et al. (2017) have reported that plants can reduce their osmotic capacity to balance water potential by losing water which results was supported by Pattanagul and Thitisaksaku (2008) in rice and sorghum leaves as well as Mannan et al. (2013b) in soybean.

### *Effect of salinity on water saturation deficit*

Plants' degree of water scarcity is indicated by their water saturation deficit (WSD %). RWC trend was inverted according to WSD. At a salinity level of 7.5 dS/m, BD-7011 displayed the lowest WSD (150%) and BD-6999 the highest WSD (445%) (Table 3). This finding implies that genotype BD-6999 had more water deficit than other genotypes, that value was less in genotype BD-7011. Because of the high salt concentration in the soil solution, plants' capacity to absorb water is reduced, a phenomenon known as the osmotic or water-deficient impact of salinity. Damage happens when concentrations are high enough to prevent plant growth. Munns (2002) claim that the metabolic alterations brought on by salinity's osmotic action are comparable to those brought on by water stress-induced plant "wilting." Plant roots' capacity to absorb water is hampered by salt buildup in the root zone, which causes osmotic stress (Paranychianakis & Chartzoulakis, 2005).

### *Effect of salinity on leaf chlorophylls*

Six genotypes of sesame plants differed in the amount of chlorophyll in their leaves due to salinity. All genotypes showed a significant reduction in chlorophyll content at a salinity level of 7.5 dS/m (Table 3). BD-7011 had the lowest expected drop in chlorophyll (9%) out of all the genotypes examined, and BD-6999 had the highest predicted reduction (59%).

Our results demonstrate that salt stress significantly lowered the amount of chlorophyll in leaves across all genotypes, which may be related to a high rate of chlorophyll breakdown or a decrease in pigment production (Sharma et al., 1986; Ferdous et al., 2018). Genotype BD-7011 displayed more chlorophyll than the other genotypes under salinity conditions, indicating that it is a relatively salt-tolerant genotype. NaCl lowers the amount of chlorophyll in sesame leaves, as reported by Yadav et al. (2020).

Table 3. Effect of salinity on water saturation deficit, total chlorophyll, and proline content of sesame genotypes at flowering stage

| Genotypes | Water saturation deficit (%) | | Total chlorophyll (mg/g fresh wt. of leaf) | | Proline content (µg/g fresh wt. of leaf) | |
|---|---|---|---|---|---|---|
| | Control | Saline | Control | Saline | Control | Saline |
| BD-6980 | 8.08g | 25.18c<br>(311) | 1.22b | 0.91d<br>(74) | 3.27c | 4.33a<br>(132) |
| BD-7009 | 8.87g | 30.51b<br>(344) | 1.53a | 0.97d<br>(64) | 3.83b | 4.10a<br>(107) |
| BD-7011 | 7.94g | 19.89d<br>(250) | 1.44a | 1.30d<br>(90) | 3.27c | 4.50a<br>(137) |
| BD-6994 | 12.25e | 44.82a<br>(365) | 1.13c | 0.70e<br>(62) | 3.77b | 4.10a<br>(108) |
| BD-6983 | 9.64f | 45.56a<br>(472) | 1.34b | 0.64e<br>(46) | 3.50b | 3.00c<br>(85) |
| BD-6999 | 7.70g | 41.97a<br>(545 | 1.41a | 0.58e<br>(41) | 2.93c | 3.27c<br>(111) |
| CV (%) | 7.0 | | 16.3 | | 20.1 | |

Values in parentheses indicate the percent of control. Different letters show significant differences at $p < 0.05$.

Reduced production of chlorophyll, hunger, and elevated activity of the enzyme chlorophyllase are indicators of the inhibitory effect of salt on the amount of chlorophyll in leaves (Shin et al., 2020; Mannan & Khan, 2020). The drop in Chl content may be caused by the inhibition of photosynthetic pigment production, as suggested by Singh & Dubey (1995), Garcia-Sánchez et al. (2002), Nicolae et al. (2023) and Rao & Rao (1981), who attribute the rise in chlorophyllase activity and degradation.

### *Effect of salinity on proline accumulation*

Salinity had a substantial effect on proline accumulation in all sesame genotypes (Table 3). Under control settings, genotype BD-7009 accumulated a higher proline content compared to all other genotypes. Proline accumulation increased in all genotypes when exposed to salinity, but genotype BD-7011 grew at the quickest rate (37%). However, the proline accumulation rate (0.85%) was lowest for genotype BD-6983. Proline, one of the most important osmoprotectants, is required to control the osmotic pressure in plant cells. All cultivars have greater proline concentrations, suggesting that proline is one of the first substances to develop tolerance to salt stress. Plant cells containing proline exhibit a higher water potential compared to saline soils due to their higher osmotic potential (Bian et al., 1988). Proline also functions as a shielding molecule against protein structures, which can increase the activity of enzymes (Ashraf & Foolad, 2013; Szabados & Savoure, 2009). Proline may be crucial for controlling osmotic pressure in sesame plants, as evidenced by the high proline level of the comparatively resistant genotype BD-7011. Due to their osmosis regulation or tolerance to salinity stress, cultivars with excellent seed yields in salinity were combined with other osmoprotectants (Poustini et al., 2007).

### *Effect of salinity on intercellular $CO_2$ concentration*

The intercellular $CO_2$ concentrations of sesame leaves varied among genotypes. As per Figure 4, the genotype BD-6983 had the highest $CO_2$ reading (246.04 ppm) under control, followed by BD-7009 (235.47 ppm) and genotype BD-6999 (180.35 ppm).

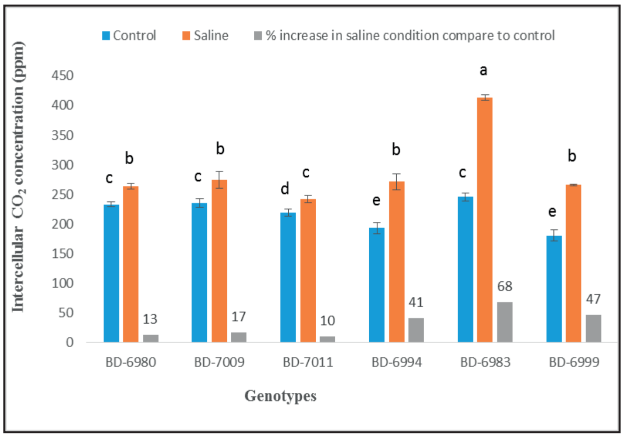

Figure 4. Intercellular $CO_2$ in some selected sesame genotypes influenced by salinity. Bars indicates (±SE). Different letters show significant difference at $p < 0.05$

The presence of salinity led to stomatal closure, which increased the leaf's $CO_2$ content. The $CO_2$ concentration was highest (68%), for the genotype BD-6983, and lowest (10%) for the genotype BD-7011. This shows that in salinized environments, the BD-7011 genotype is more suitable for photosynthesis. In saline environments, stomata are almost entirely close, indicating that the plant may have gone through some osmotic stress; nevertheless, the opposite is also true, and intracellular $CO_2$ level rises as external salt increases. Centritto et al. (2003) stated that mesenchymal and stomatal conductance are both impacted by salt stress. The buildup of $CO_2$ in the intercellular space would suggest that, rather than a loss in photosynthesis and carboxylation capacity, the reason for the current decline in photosynthetic activity is still the diffusion constraint of photosynthesis.

### *Effect of salinity on the rate of photosynthesis*

The photosynthetic rates of the several genotypes of sesame varied significantly during the blooming stage (Table 4). In comparison to the control condition, the salinity resulted in a reduced net photosynthetic rate. In the control group, photosynthesis (Pn) ranged from 5.19 to 8.86 $\mu mol/m^2/s$ $CO_2$, while in the saline group, it varied from 1.96 to 2.98. Under saline conditions, the Pn rate decreased for every genotype that was studied. The genotypes with the lowest net photosynthesis reduction were BD-7011 (54%), BD-6980 (57%), and BD-6999 (69%), respectively. Genotype BD-7011 had the least reduction in photosynthesis when compared to other genotypes, indicating that it is a genotype that can withstand salinity rather well. Many factors, including leaf water and biochemical components like osmotic pressure, stomatal conductance, transpiration rate, relative leaf water content of proteins, photosynthetic pigments like chlorophyll and soluble carbohydrates, and reduction of available $CO_2$ due to stomatal closure, can influence plants and cause a decrease in photosynthesis (Garg et al., 2005). A higher salinity significantly lowers the net photosynthetic rate. A study by Hnilickova et al. (2021) found that salinity indirectly reduces photosynthesis in plants, which is one of the main factors limiting plant development. Photosynthesis is strongly linked to stomatal conductance, chlorophyll content, transpiration, and water potential. Reduced stomatal conductance caused by an imbalance in water under salinity stress can prevent leaves from photosynthesizing (Hannachi et al., 2022). Salt-tolerant species frequently have less of an impact on photosynthetic rates than salt-sensitive ones (Garg et al., 2005). According to our research, distinct genotypes display varying degrees of photosynthetic characteristics. Specifically, the genotype BD-7011, which is salt-tolerant, has a lower effect on photosynthetic rates in comparison to other genotypes. Salinity has several effects on photosynthesis, including the lowering of chlorophyll levels (Degl'Innocenti et al., 2009), which is what our study found, and the suppression of $CO_2$ uptake because of stomatal closure (Hnilickova et al., 2021). When salt stress inhibited stomatal and/or non-stomatal photosynthesis, many additional salt-sensitive species displayed decreased photosynthesis (Qados, 2011; Downton, 1977; Seemann and Critchley, 1985; Llyod et al., 1990; Garcia et al., 1993). As far as we are aware, photo assimilation did not result in a decrease in intercellular $CO_2$ in any of the sesame genotypes examined in this investigation. It is well accepted that stresses on photosynthetic ability directly cause the loss of photosynthesis associated with elevated intercellular $CO_2$ levels.

### *Effect of salinity on stomatal conductance*

Significant variations in stomatal conductance were observed amongst the genotypes of sesame (Table 4).

Table 4. Photosynthetic rate, stomatal conductance, and transpiration of sesame genotypes influenced by salinity

| Genotypes | Rate of photosynthesis ($\mu molCO_2/m^2/S$) | | Stomatal conductance (mol $H_2O/m^2/S$) | | Transpiration rate (mg $H_2O$ /$m^2/S$) | |
|---|---|---|---|---|---|---|
| | Control | Saline | Control | Saline | Control | Saline |
| BD-6980 | 5.86b | 2.49c<br>(57.50) | 0.90a | 0.71b<br>(21.09) | 1.44b | 1.11b<br>(22.99) |
| BD-7009 | 5.19b | 1.96c<br>(62.27) | 1.02a | 0.61b<br>(39.87) | 1.02c | 0.66c<br>(35.98) |
| BD-7011 | 6.30b | 2.98c<br>(54.52) | 1.04a | 0.91a<br>(12.89) | 1.84a | 1.51b<br>(18.25) |
| BD-6994 | 8.11a | 2.88c<br>(64.49) | 0.98a | 0.75b<br>(23.95) | 2.04a | 1.39b<br>(31.73) |
| BD-6983 | 7.44a | 2.86c<br>(59.93) | 1.09a | 0.76b<br>(30.25) | 2.14a | 1.30b<br>(39.53) |
| BD-6999 | 8.86a | 2.71c<br>(69.48) | 1.05a | 0.59b<br>(43.65) | 1.88a | 0.93c<br>(50.50) |
| CV (%) | 17.8 | | 15.5 | | 18.5 | |

Values in parenthesis indicate a percent reduction in saline stress compared to control. Different letters show significant differences at $p<0.05$.

In control plants, the range of stomatal conductance is 0.90 to 1.09 mol $H_2O/m^2/s$; however, in saline circumstances, this range is 0.59 to 0.91. Salinity reduced the stomatal conductance in all genotypes. About reduction, the genotype BD-6999 exhibited the highest reduction (43%), and the genotype BD-7011 was the lowest (12%). Since sesame is a plant with a $C_3$ photosynthetic metabolism and needs to keep its stomata open for $CO_2$ to be fixed by the RuBisCO enzyme of the Calvin cycle, stomatal closure by salt results in an imbalance in the photosynthetic process (Ray et al., 2022). Excess salt lowers plant transpiration, photosynthesis, stomatal conductance, and $CO_2$ assimilation rates, affecting agricultural yields and production, as seen in this research work and reported by Lima et al. (2012). According to Manns and Tester (2008), the most noticeable and dramatic whole-plant response to salinity is stomatal reduction, which is brought on by the osmotic effects of salt causing a stomatal response outside the roots. Salt concentration had less of an impact on the stomatal components of photosynthesis in the genotype BD-7011, which is considered salt-tolerant.

### *Effect of salinity on transpiration rate*

The transpiration rate likewise dropped with the salinization of sesame genotypes (Table 4). The genotype BD-6999 displayed the largest reduction (50%) and the genotype BD-7011 was the lowest (18%). Under salinity, genotype BD-7011 shows the least reduction in transpiration rate, indicating that it is a genotype that is comparatively salt-tolerant. Salinity decreases transpiration as stomata partially close, according to studies employing genotypes from sesame plants (Coelho et al., 2018). Liu et al. (2015) claim that salinity has a direct impact on the interactions between water and photosynthetic processes in sorghum leaves. This is in line with the findings of our study. Heidari (2009) discovered that the salt-affected sorghum leaves' negative water potential caused the plants under study to transpire less. Plant development is directly impacted by transpiration rate, stomatal regulation, and photosynthesis. Our results demonstrate that the genotypes under investigation have various transpiration rates (Table 4). These findings imply that by better controlling stomatal parameters, BD-7011 was able to sustain the photosynthetic process and retain a higher output capacity. These factors may be used to find plants that are more resilient to stress (Gupta et al., 2001).

### *Effect of salinity on yield and yield contributing traits*

Comparing the six genotypes under investigation to the control, salinity dramatically decreased the number of capsules per plant. In comparison to the control, genotype BD-6983 showed the largest reduction (65%) and genotype BD-7011 the least (29%) presented in Table 5.

Table 5. Salinity effects on the number of capsules/plant and number of seeds/capsules of sesame genotypes

| Genotypes | Number of capsules/plants | | Number of seeds/capsules | |
|---|---|---|---|---|
| | Control | Saline | Control | Saline |
| BD-6980 | 27.67b | 15.67b<br>(43.37) | 69.67b | 57.00b<br>(18.18) |
| BD-7009 | 27.33b | 15.00b<br>(45.12) | 73.33c | 56.33b<br>(23.18) |
| BD-7011 | 32.33a | 22.67b<br>(29.87) | 58.33c | 48.67a<br>(16.57) |
| BD-6994 | 27.67c | 14.00c<br>(49.40) | 76.00c | 51.67c<br>(32.02) |
| BD-6983 | 44.00c | 15.33c<br>(65.15) | 59.00d | 39.33c<br>(33.33) |
| BD-6999 | 30.00c | 17.33c<br>(42.22) | 87.67d | 59.33c<br>(32.32) |
| CV (%) | 16.5 | | 9.4 | |

Values in parenthesis indicate a percent reduction in saline stress compared to control. Different letters show significant differences at *p* <0.05.

For every sesame genotype under study, salinity also markedly decreased the average number of seeds/capsules. The greatest drop was seen in the genotype BD-6983 (33.33%), which was followed by BD-6980 (18.18%), BD-6999 (32.32%), BD-6994 (32.02%), and BD-7009 (23.18%). The genotype with the lowest reduction was BD-7011 (16.57%). With salt, seed weight decreased significantly for all genotypes of sesame (Table 6). A sample of 1000 seeds had weight variations of 2.83 g to 3.33 g in control conditions and 1.33 g to 2.33 g at a salinity of 7.5 dS/NaCl. The reduction in seed weight at 7.5 dS/m salinity was highest in BD-6994 (52%), followed by BD-7009 (48%), and BD-6999 (36%), whereas the lowest reduction was observed in BD-7011 (24%) (Table 6). Salt reduced seed yield in all genotypes of sesame that were studied. In terms of seed yield per plant, BD-7009 suffered the biggest loss (78%) whereas BD-7011 had the lowest (52%). The best relative seed yield of genotype BD-7011 was mostly attributed to its maximum capsule number/plant and individual seed weight. Plants that are subjected to salt stress change their morphology, physiology, and biochemistry. Reproductive characteristics suffer and plant yield is reduced (Hasanuzzaman et al., 2021).

Table 6. Salinity effects on 1000-seed weight and seed yield of sesame genotypes

| Genotypes | 1000 - seed weight (g) | | Seed yield (g) /plant | |
|---|---|---|---|---|
| | Control | Saline | Control | Saline |
| BD-6980 | 2.90a | 1.97a<br>(32.11) | 5.31a | 2.22b<br>(58.29) |
| BD-7009 | 3.20a | 1.63b<br>(48.96) | 4.24c | 0.92b<br>(78.40) |
| BD-7011 | 3.10a | 2.33a<br>(24.73) | 3.04b | 1.44a<br>(52.68) |
| BD-6994 | 2.83c | 1.33d<br>(52.94) | 4.13d | 1.43a<br>(65.43) |
| BD-6983 | 3.27c | 2.13d<br>(34.69) | 3.35e | 1.19e<br>(64.34) |
| BD-6999 | 3.30c | 2.10c<br>(36.36) | 4.79e | 1.68e<br>(64.83) |
| CV (%) | 10.2 | | 20.2 | |

Values in parenthesis indicate a percent reduction in saline stress compared to control. Different letters show significant differences at *p* <0.05.

Salt stress causes rapid water loss from the cells of sesame plants, which significantly affects their reproductive stages. Both flowers and capsules require water to thrive. Affected factors also include flower number, capsule number, weight per 1000 seeds, and seed output. In addition, salinity damages water conductivity, changes the overall nutritional condition, and stresses plants' osmotic processes. Additionally, plants that experience osmotic stress due to salt have altered nutritional status overall and experienced a negative impact on hydraulic conductivity (Babu & Thirumurugan, 2001). Thus, the yield characteristics of sesame plants are impacted by growth retardation, ion and nutrient imbalance, changes in water conditions, and inhibition of photosynthesis. Therefore, cell division, hypertrophy, differentiation and growth, wilting, and stomata induced by the removal of water from the cells by osmotic pressure are the reasons for the reduction in height, yield, composition, and seed production of sesame when exposed to salt. Reduced cell closure and water removal from the cells can account for it. Salinity can limit how many seeds are generated by reducing the growth of leaves, increasing the negative water potential of the soil, and preventing the uptake of nutrients and water (Poustini et al., 2007). Shani & Dudley (2001) observed similar outcomes, stating that reduced photosynthetic activity owing to saline conditions, higher energy and carbohydrate consumption in osmoregulation, and altered cellular function caused the yield. Ghadiri et al. (2006) voiced worry regarding salt-induced reductions in water intake. Salinity is caused by elevated osmotic potential and elevated concentrations of certain ions in the soil, which can cause physiological issues in plant tissues and reduce yields. The bulk of previous studies on sesame by Babu & Thirumurugan (2001); Ali et al. (2005); Garg et al. (2005); and Benzaidi et al. (2014) are in agreement with our findings. When there was water stress, the associations were stronger than when there was control. Plant development is impacted by delicate physiological processes such as turgor pressure, cell division, expansion, and differentiation in a water-stressed environment (Poustini et al., 2007).

## CONCLUSIONS

The physiological, biochemical, and agronomic responses of various sesame genotypes to salt stress varied significantly. The maximum seed yield of genotype BD-7011 is largely attributed to its high leaf water content, proline content, leaf chlorophyll content, photosynthesis, and transpiration rate, all of which contribute to its strong tolerance to salt stress. Since this genotype has the highest tolerance to salinity, it can be considered a good candidate for further field testing. They can be used as donor parents in studies to increase sesame's tolerance to salinity, or they can be introduced as a variety.

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