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SALINITY-INDUCED CHANGES IN GROWTH, PHYSIOLOGY AND YIELD OF SOYBEAN GENOTYPES

M. S. Tareq[1], M. A. Mannan[1], M. M. Rahman[2], M. A. A. Mamun[1] and M. A. Karim[1*]

Abstract

Soybean (*Glycine max* L.) is mostly grown in the coastal region of Bangladesh, where salinity is a threat for potential harvest. So far there is no salt tolerant variety. In order to extricate high salt tolerant soybean genotypes, 13 selected advanced soybean lines, namely BD 2342, AGS 313, G 00207, Galarsum, G 00209, G 00343, G 00028, G 00221, G 00283, AGS 95, G 00062, G 00041 and BD 2330 along with two varieties viz. BU Soybean 2 and Shohag were grown in pots under polyvinyl house at BSMRAU, Gazipur during February to June 2021 following completely randomized design (CRD) with three replications. The plants were exposed to seawater of electrical conductivity (EC) of 5 dSm^{-1} and 10 dSm^{-1} from 2[nd] trifoliate stage till harvest, where control pots were irrigated with tap water (0.3 dSm^{-1}). Results indicated that there was no significant variation in days to first flowering but significant variation was observed in maturity duration among the genotypes. In saline conditions BD 2330, G 00028 and AGS 313 survived longer days which were 96.36%, 80.29%, and 79.53% days to control at 10 dSm^{-1}, respectively compared to other genotypes. Plants of other genotypes died earlier before reaching maturity, especially at 10 dSm^{-1}. The genotype AGS313 expressed maximum leaf relative water content (RWC) at 5 dSm^{-1} salinity (97.51% of control), while BD2330 showed the highest RWC at 10 dSm^{-1} salinity (94.76%). The SPAD value showed stable or an increasing trends in BD 2330, AGS 313 and G 00028, where it was in decreasing trend in other genotypes under saline conditions. Unexpectedly, the leaf K-Na ratio did not show any significant relationship with the salt-tolerance among the genotypes. In case of number of filled pods/plant BD2330 produced the maximum (23.33) at 5 dSm^{-1} salinity, while the genotype AGS313 showed the highest (16.0) at 10 dSm^{-1} salinity. Genotypes other than BD2330, AGS313 and G00028 did not perform well in pod set, 100-seed weight and grain yield/plant under saline conditions, even at 5 dSm^{-1}. However, even at the highest salinity (10 dSm^{-1}) the genotypes G00028, BD2330 and AGS313 produced 2.0, 1.9 and 1.83 g/plant seeds, respectively. Whereas, most of the genotypes did not produce any seed at 10 dSm^{-1}. It may be concluded that the genotypes BD2330, AGS313 and G00028 were relatively salt tolerant than other tested genotypes, and can be used as potential genetic resources for further field trials.

Keywords: *Glycine max* (L.), K:Na ratio, salinity tolerance.

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[1]Department of Agronmy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh. [2]Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh. *Corresponding author: akarim1506@gmail.com

Introduction

Soybean (*Glycine max* L.) is an important grain legume under Fabaceae family and Papilionoideae subfamily. It is known as the "golden bean" and "miracle crop" of the 21^{st} century (Tambe *et al.*, 2021). It contains 30-50% protein, 18-22% oil, 20-26% carbohydrate and a high amount of Ca, P and vitamin, and that is why it is widely used as vegetable oil, human food and animal feed (Pagano and Miransari, 2016; Singer *et al.,* 2019). Besides the diversified use as food, soybean is also used in many industrial purposes even as biodiesel (Wu *et al.*, 2013). Because of its high usage, it occupies the top position among all oilseeds produced in the world (USDA, 2022). As soybean is a leguminous crop, it also fixes a huge amount of nitrogen in its root nodule and on an average 50–60% of N demand can be met by biological N_2 fixation (Salvagiotti *et al.*, 2008). It also adds a huge amount of organic matter to the soil as the plant sheds leaves before maturity.

The demand of soybean is increasing day by day in Bangladesh, though it is mostly used as an important protein source ingredient of poultry, cattle and fish feed. Diversified use as human food items also increasing in recent time because of development of consciousness among people in Bangladesh about its high nutritional value (Haque *et al.,* 2020). The production of soybean increased substantially from 105000 metric tons (MT) in 2011-12 to 151000 MT in 2021-22. However, it is mostly cultivated in the southern coastal region of Bangladesh (Karim *et al.*, 2012), where salinity is threatening potential harvest of soybean.

Salinity creates physiological drought in plants. When plants are stressed with NaCl, they often exhibit slower growth, premature leaf senescence, reduced tillering or branching, and decreased yield (Franklin *et al.,* 2010; Schmöckel and Jarvis, 2017). According to Food and Agriculture Organization (FAO) about 8.7% of the total land in the world and 20% to 50% of irrigated soils in all the continents are salt affected (FAO, 2022). In Bangladesh it was estimated that out of a total 2.86 million hectare of coastal and off-shore land about 1.056 million ha are affected by varying degrees of salinity (SRDI, 2010). The saline area is increasing every year due to several reasons, like the intrusion of seawater into fresh river during the dry season, rising of salt through capillary movement, inundation of land due to cyclones etc. (Mannan *et al.*, 2012; Khan *et al.,* 2014; Karim, 2015).

Though soybean in general is considered as a moderately salt tolerant legume crop (Maas, 1985) and widely grown in the south-east coastal region, there is no salt tolerant variety in Bangladesh. By selecting salt tolerant genotype(s) the soybean yield can be improved to a great extent in the saline area (Fujii and Higuchi, 2019). Though in the studies of Mannan *et al.* (2013) and Khan *et al.* (2014) different salt tolerant groups of soybean genotypes were documented, precise extrication has not yet been done for supporting the development of a salt tolerant genotype/ variety in Bangladesh. This study was therefore initiated to analyze salinity induced changes in morphological and physiological characters of 13 selected soybean genotypes with an aim to select relatively high salt tolerant genotype(s).

Materials and Methods

Seeds of 13 selected soybean genotypes, namely BD2342, AGS313, G00207, Galarsum, G00209, G00343, G00028, G00221, G00283, AGS95, G00062, G00041, and BD2330, which were selected by screening 170 genotypes against salinity stress by Mannan *et al*. (2012), Khan *et al.* (2013) and Jinzenji (2020), along with two varieties, viz. BU Soybean2 and Shohag were sown on 25 February 2021 in pots inside a plastic-house. The pot size was 24 cm in diameter and 30 cm in height, and contained 12 kg air dried soil-compost (1/4th) mixture. The soil was fertilized with 0.27-0.28-0.20 g of urea, TSP and MoP, respectively following Mannan *et al*. (2012), Khan *et al.* (2013). The salinity treatments were S_0= Control (0.3 dSm^{-1}), S_1= 5 dSm^{-1}, and S_2= 10 dSm^{-1}.

Initially all the pots were irrigated with tap water before imposing salinity treatments. Seawater was collected from the Bay of Bengal at the Cox's Bazar point. The initial EC value of the seawater was 53 dSm^{-1}. The seawater was diluted and a sufficient amount of diluted seawater of 2.5 dSm^{-1} was applied to the pots of S_1 and S_2 treatments from March 16 2021 at 2nd trifoliate stage. Two days later the diluted seawater of 5.0 dSm^{-1} was applied similarly in both the pots of S_1 and S_2. The salinity concentration of the applied solution was increased by 2.5 dSm^{-1} every alternate irrigation to reach 10 dSm^{-1} for pots of S_2. The control pots were irrigated with tap water. Three uniform healthy plants were allowed to grow in each pot. Intercultural operations and pest control measures were taken properly as and when necessary. Data on different morphological and physiological parameters were recorded. The statistical design used for this experiment was a Completely Randomized Design (CRD) maintaining 3 replications.

Data on days to first flowering were counted when at least one flower opened in each genotype. A plant was considered to have maturity when majority of the plant leaves turned yellow and the color of pods became brownish and the seed became hard. After this the plants were harvested. Plant samples were collected from the pots at maturity and plant height was recorded with a meter scale, and pods per plant, seeds per pod, seeds per plant were counted. The samples were oven-dried to a constant weigh at 70°C and dry weight of stems was recorded.

For determining the relative water content (RWC) sampling was done at the flowering stage of each genotype. Fully expanded leaves of each genotype were collected from both control and saline conditions at noon. Immediately after cutting at the base of the lamina, the fresh weight was measured. Turgid weight (TW) was measured after soaking the leaves in distilled water in beakers for 24 hours at room temperature (about 25ºC) and under low light condition in the laboratory. After soaking, leaves were quickly and carefully blotted and dried with tissue paper for determining TW. Dry weight (DW) of leaves was obtained after oven drying the leaf samples for 72 h at 70ºC.

The RWC was calculated following Schonfeld *et al.* (1988).

$$RWC= \frac{FW - DW}{TW - DW} \times 100$$

Where, FW= fresh weight, DW= dry weight and TW= turgid weight of the sample.

The SPAD values were recorded four times, after fifteen days of treatment imposition, at a seven days intervals using Minolta chlorophyll meter (SPAD-502, Japan). The SPAD readings were taken from the middle leaflet of the uppermost fully developed trifoliate. The measurements were done on a randomly selected plant in each pot.

Five genotypes were selected from each of the most tolerant and susceptible genotypes for analyzing sodium and potassium concentration in leaves. The leaf samples were oven-dried to a constant weight at 70 °C and made into a powder using a Willey Mill grinder. Then 0.5 g dried samples were digested with a nitric-perchloric acid solution (1:5) and Na and K were determined with an atomic absorption spectrophotometer (Shimadzu, atomic absorption spectrophotometer) following Hitachi Ltd. (1986).

Total seeds from the sample plants were weighed with an electrical balance. The moisture content of seeds was measured by a hand-held moisture meter. The seed yield was adjusted to 14% moisture content.

The recorded data for different parameters were subjected to analysis of variance (ANOVA) by using "Statistix 10" software to examine the significant variation of the results due to different treatments. Microsoft EXCEL software was used wherever appropriate to perform statistical analysis. The treatment means were compared using the least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984). Standard error was calculated and shown appropriately in graphs.

Results and Discussion

Days to first flowering and maturity

Days to first flowering varied among the genotypes though did not vary due to the different salinity treatments (Fig. 1). Among the genotypes, G00207 flowered the earliest (27 days) in control condition, 26.33 days at 5 dSm^{-1} salinity and in 26.67 days at 10 dSm^{-1}

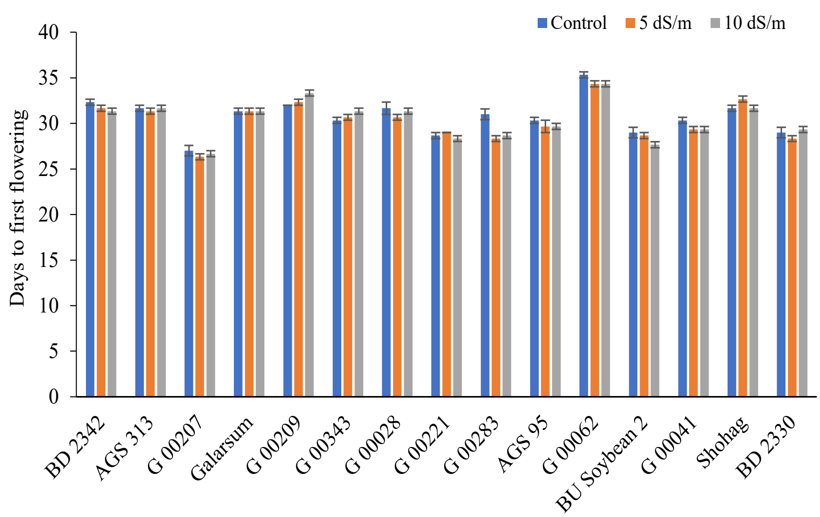

Fig. 1. Effect of salinity on days to first flowering of soybean genotypes. Bars indicate standard error (±SE).

salinity. The maximum days required for first flowering in G00062 which was 35.33 days for control, 34.33 days for 5 dSm^{-1} salinity and 10 dSm^{-1} salinity.

There was a significant different in days to maturity among the treatments (Fig. 2). Plants of most of the genotypes died before reaching maturity in saline conditions. In control condition, Galarsum required maximum days to reach maturity which was 114.67 days followed by BD2342 (102 days). G00221 and G00041 matured in only 80.33 days in the control condition followed by G00207. Most of the plants of different genotypes at both 5 dSm^{-1} and 10 dSm^{-1} saline conditions died much earlier than that of maturity in control treatment. Among the genotypes, BD2330 survived almost same days as compared to control, which was 97.45% and 96.36% days of control at 5 dSm^{-1} and 10 dSm^{-1} saline condition, respectively (Fig. 3). G00028 and AGS313 also showed better performance than others in this character. G00028 matured in 93 days at control and required 88.33 days and 74.67 days in 5 dSm^{-1} and 10 dSm^{-1} saline conditions which was relatively 94.98% and 80.29% days of control. AGS313 survived 90.20% and 79.53% days compared to control at 5 dSm^{-1} and 10 dSm^{-1} saline treatment, respectively. Galarsum died in the shortest time under saline condition, and survived only 59.88% and 53.49 % days compared to control condition at 5 dSm^{-1} and 10 dSm^{-1}, respectively. Salinity is reported to affects water relations and nutrient balance, as well creates Na toxicity in plants. Under extreme conditions the affected plants may die (Schmöckel and Jarvis, 2017; Tareq *et al.*, 2021). Similar to the findings of this study, high salinity also resulted in an early death of soybean plant in the experiments of Phang *et al.* (2008) and Mannan *et al.* (2013).

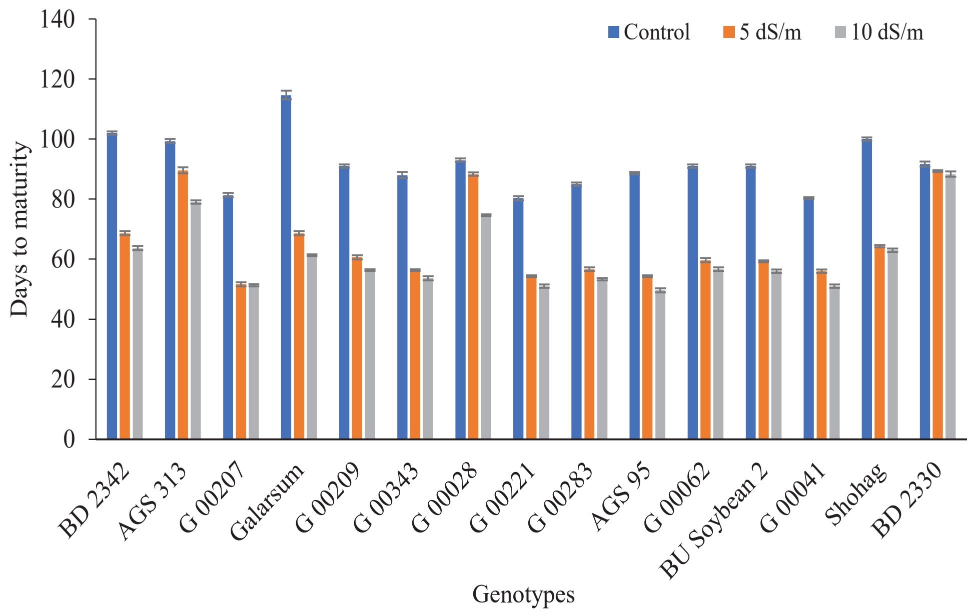

Fig. 2. Effect of salinity on days to maturity of soybean genotypes. Bars indicate standard error (±SE).

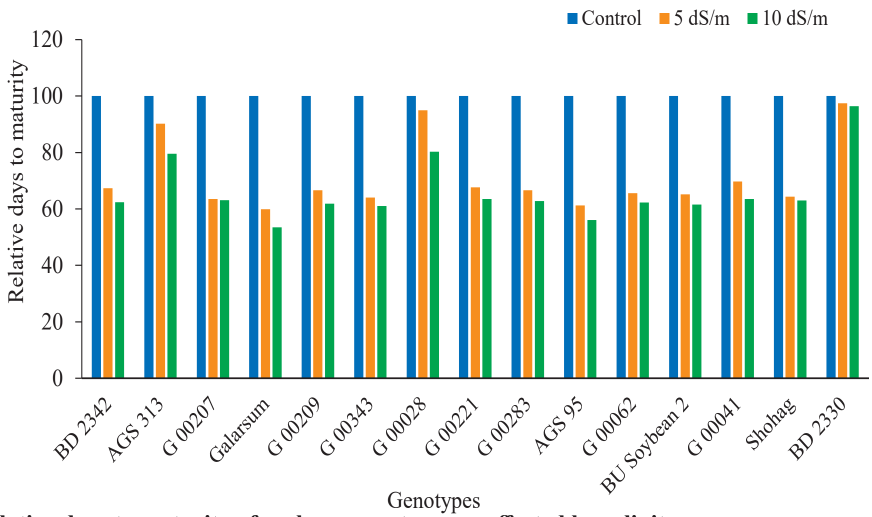

Fig. 3. Relative days to maturity of soybean genotypes as affected by salinity.

Plant height

Plant height in testing soybean genotypes was affected by salinity (Fig. 4). The tallest plants at control were found in G00209 (82.68 cm) followed by AGS313 (74.70 cm), while the shortest plants were found in G00041 (28.54 cm). The tallest plants were found at both 5 dSm^{-1} salinity and 10 dSm^{-1} salinity in genotype AGS313 (61.76 cm and 61.26 cm) followed by G00209 (58.91 cm and 55.22 cm), while the shortest plants were in G00041 (26.27 cm and 24.73 cm). Although application of saline water reduced plant height in all the tested genotypes, there was a significant variation in the reduction among the genotypes.

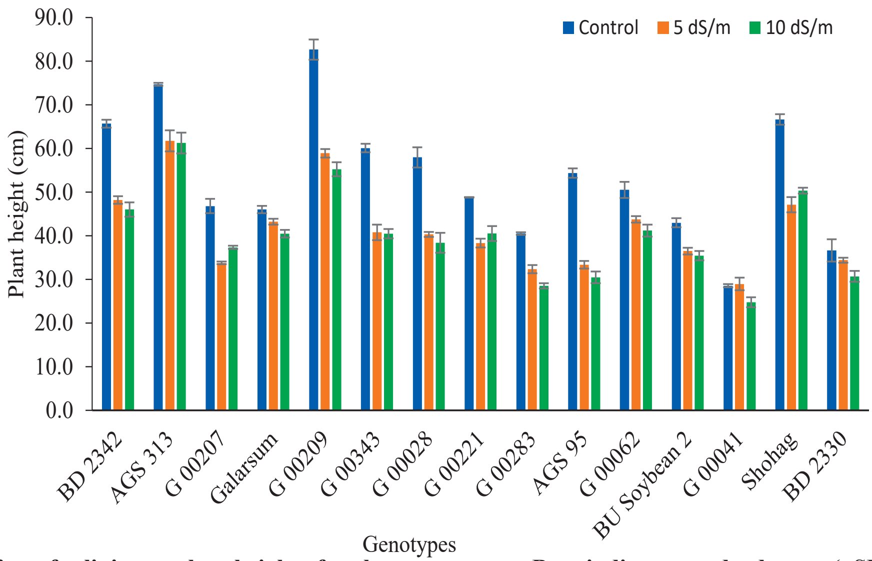

Fig. 4. Effect of salinity on plant height of soybean genotypes. Bars indicate standard error (±SE).

The relative plant height of the tested genotypes ranged from 61.33% to 97% in 5 dSm^{-1} and 56.02% to 88.15% in 10 dSm^{-1} (Fig. 5). Among the 15 soybean genotypes, G00283 showed the highest relative plant height in both the saline treatments (97% and 88.15%). AGS95 had the maximum reduction in plant height for both the treatments and the relative plant height was observed 61.33% at 5 dSm^{-1} and 56.02% at 10 dSm^{-1}. Earlier reports claimed that the reduction of plant height might have been due to the changes in plant-water relationships under salt conditions, which decreased meristem activity of cell and cell elongation (Julkowska and Testerink, 2015).

Stem dry weight per plant

Saline stress decreased stem dry weight to a large extent in soybean genotypes. The maximum stem dry weight per plant was observed in genotype Shohag (5.90g) followed by BD2342 (5.54g) in control treatment (Fig. 6). With the increase of salinity, stem dry weight decreased in all the genotypes. At 5 dSm^{-1} salinity level, stem dry weight reduced from 30.54% to 74.39% in the genotypes compared to that in the control condition (Fig. 7). The maximum reduction was found in the genotype BD2342 which produced only 25.61% stem dry matter compared to its control followed by Galarsum (28.98%) and the reduction was the lowest in genotype G00207 which produced 69.46% relative stem dry weight followed by G00221 (61.98%). The reduction of stem dry weight under saline condition may be ascribed to the fact that salinity affects photosynthesis, mineral nutrition and water relations that hinders normal growth and development of crop plants (Mannan *et al*., 2013; Fujii and Higuchi, 2019; Tareq, 2021).

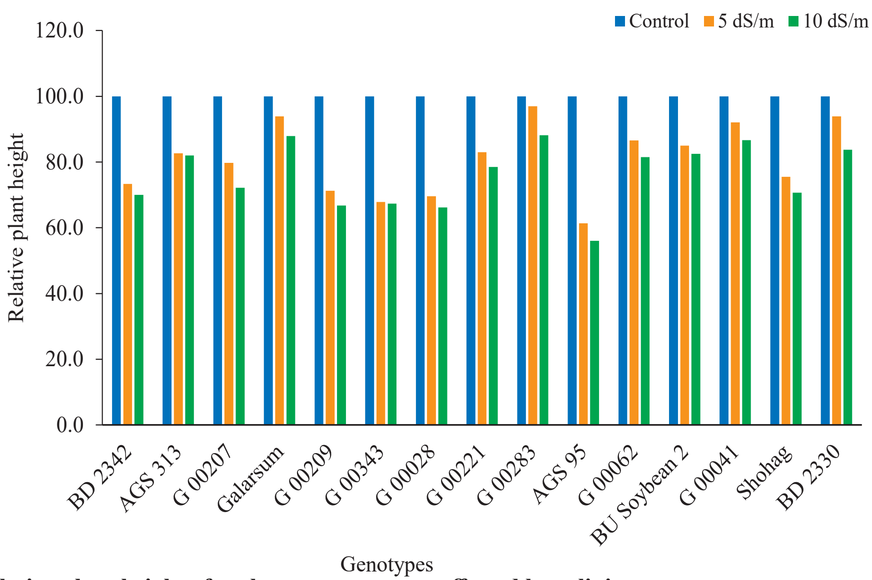

Fig. 5. Relative plant height of soybean genotypes as affected by salinity.

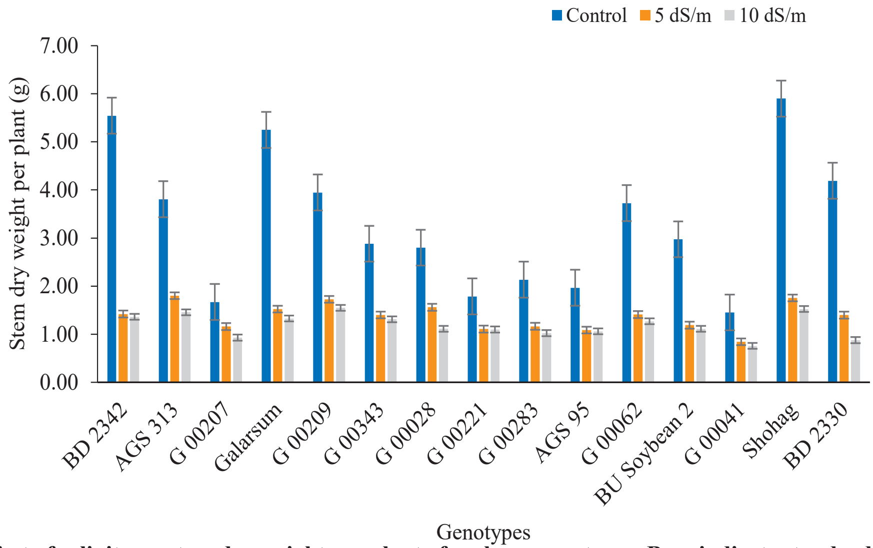

Fig. 6. **Effect of salinity on stem dry weight per plant of soybean genotypes. Bars indicate standard error (±SE).**

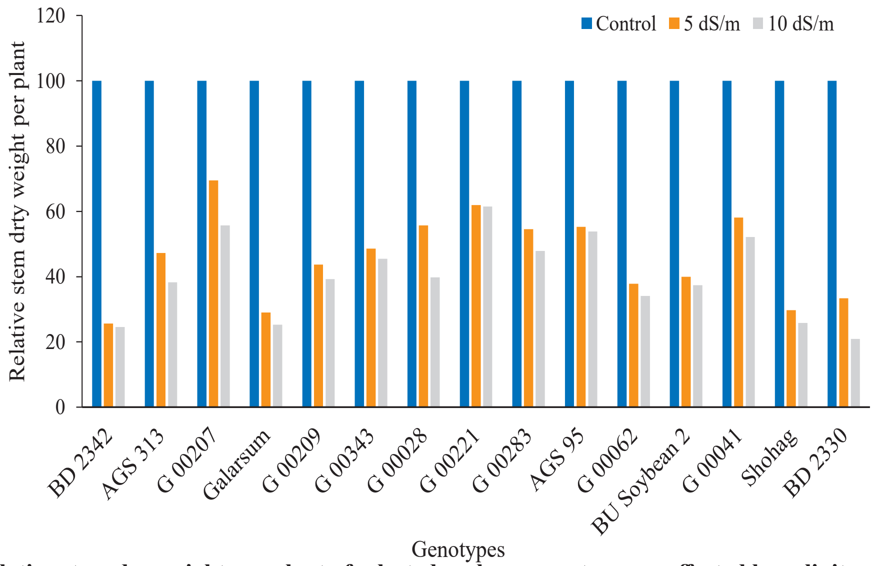

Fig. 7. **Relative stem dry weight per plant of selected soybean genotypes as affected by salinity.**

At 10 dSms^{-1} salinity the reduction of stem dry weight ranged from 38.52% to 79.05%. The maximum reduction was found in BD2330 which produced relatively 20.95% stem dry weight compared to control, followed by BD2342. The minimum reduction was found in G00221 which produced 61.48% relative stem dry matter followed by G00207 (55.65%). The reduction in stem dry matter was attributed due to limited growth of the plants in saline treated condition compared to that of the control condition. Mannan *et al*. (2013) also observed that stem dry weight decreased with the increase of salinity levels.

It was also found by Ferdous *et al*. (2018) and Cao *et al*. (2019) that salinity reduced the dry weight of the stem of soybean. The possible causes could be the result of reduced photosynthesis due to limited leaf area, low water potential, and disturbance in mineral supply and reduced cell size (Alam *et al*., 2004; Mahmood *et al*., 2009).

Relative Water Content of leaves

Relative water content (RWC) of leaves decreased due to salinity in all the genotypes, though there were variations among them (Fig. 8). At 5 dSm^{-1} salinity, AGS313 exhibited the maximum (97.51%) RWC compared to the control treatment. It was followed by BD 2330 and a number of genotypes. Galarsum showed relatively lowest RWC at 5 dSm-1, which was 90.29% of control, followed by G00207 and some others. At 10 dSm^{-1} salinity level, BD2330 was identified as having the highest RWC compared to control which was 94.76%. The RWC of AGS 313 was 92.32% of control followed by G 00209 and G 00028 with a RWC of 92.29% and 92.04% of control, respectively. RWC reduced in the highest amount at 10 dSm^{-1} salinity in AGS95 which was 84.84% of control followed by G00221 (85.60%) and some others. The decreasing relative water content of leaf at saline condition was also identified by El Sabagh *et al*. (2015) and Polash *et al*. (2018). The decrease in leaf RWC could be the result of the reduction of absorbing roots surface and low water availability under stress conditions, which were not able to compensate the transpirational loss of water (Gadallah, 2000; Tareq *et al.,* 2013).

SPAD value of leaves

In control condition, there was almost no change in SPAD reading at different times of observation but a decreasing trend was found under saline conditions among the genotypes except a few (Fig. 9). The highest SPAD value

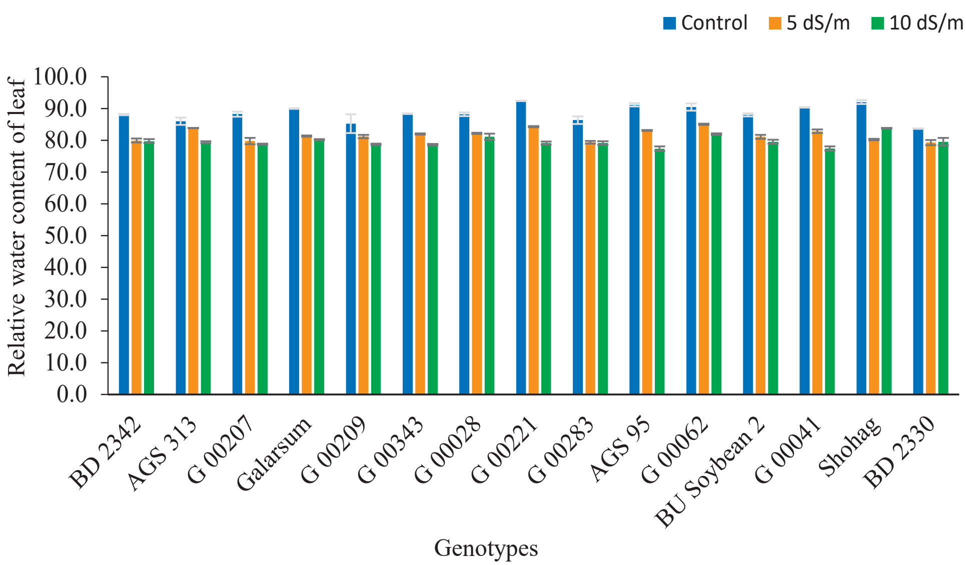

Fig. 8. Effect of salinity on the relative water content of leaves of soybean genotypes. Bars indicate standard error (±SE).

was measured in control condition in G00207 which was 44.48 at initial case followed by G00041 (44.31) where the minimum reading was measured in BD2342 (39.41) followed by Galarsum (39.86). In most of the cases the SPAD reading was near the initial reading in control condition in the next three observations. Under saline conditions

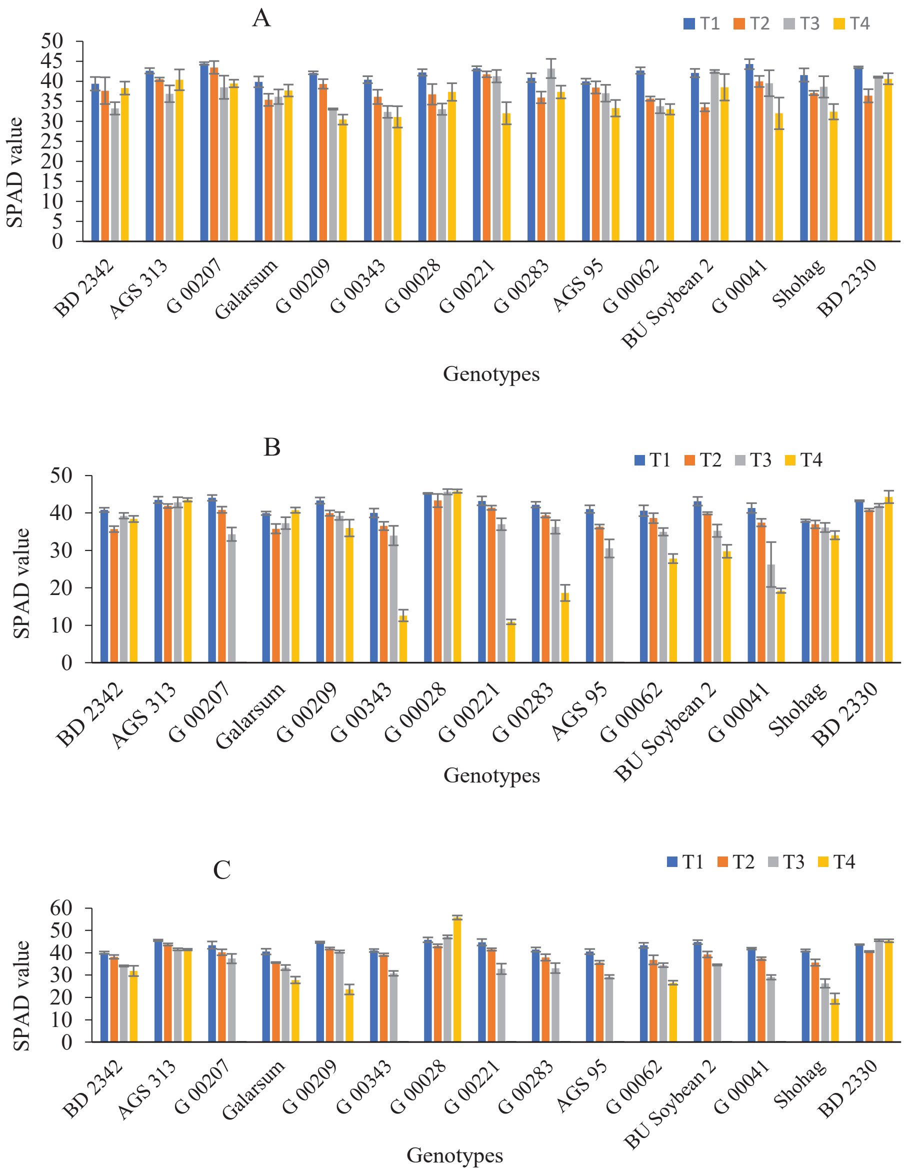

Fig. 9. Effect of salinity on SPAD reading of leaves of soybean genotypes at different times and treatments. A) at control condition, B) at 5 dSm^{-1} salinity and C) at 10 dSm^{-1} salinity. T_1= SPAD reading at 15 days after 1st saline application, T_2= SPAD reading at 21 days after 1st saline application T_3= SPAD reading at 28 days after 1st saline application and T_4= SPAD reading at 35 days after 1st saline application. Bars indicate standard error (±SE).

SPAD readings were not changed much with the time from imposing the salinity in the tolerant genotypes *viz.* AGS313, BD2330 and G00028. It remained stable or sometimes increased with time. For example, at 5 dSm^{-1} salinity G00028 possessed the maximum

SPAD reading at initial time (45.22) where it was 45.8 after four weeks. At 10 dSm^{-1} salinity the initial SPAD reading of G 00028 was 45.8, which increased to 55.77 after four weeks. The SPAD values were decreasing in saline conditions in susceptible genotypes like G 00041, AGS 95, G 00207, G 00343 and G 00221. SPAD values indicate the greenness of leaves and the greenness is directly related with chlorophylls synthesis. Under high salinity level the pigment production of leaves is affected seriously and the salt-susceptible plant suffers more than the tolerant ones (Mannan *et al.,* 2013; Tareq *et al.,* 2021) as found in this study. The decreasing trend of SPAD reading in susceptible genotypes and increasing trend in tolerant genotypes were also observed by Mahlooji *et al*. (2018) in barley.

Potassium and sodium concentrations in leaves

It was found that leaf potassium concentration increased with the increment of salinity in all the tested genotypes at both levels of salinity though at 10 dSm^{-1} salinity BD2330 showed a relatively decreased potassium concentration than the control condition (Fig. 10). The increased rate was found the highest in genotypes AGS95 at both levels of salinity, which was relatively 310.47% and 317.98% of control followed by G00207 in which K concentration increased by 238.29% and 240.30%. It was the lowest in BD2342 (117.65%) at 5 dSm^{-1} salinity and BD2330 (77.02%) at 10 dSm^{-1} salinity.

Leaf sodium concentration also increased with the increment of salinity levels in all the genotypes (Fig. 10). It was found the highest in BD2342 at both levels of salinity which was 736.71% and 1316.46% of control and it was found the lowest in G 00207, in which leaf Na concentration increased only 146.27% and 297.42%, respectively.

When observing the K: Na ratio in leaf it was found that genotype G00207 showed a relatively higher K: Na ratio (167.32% and 85.12% of control) followed by AGS95 (140.16% and 75.58% of control). The ration was found the lowest in AGS313 (16.0%) followed by BD2342 (16.18%) at 5 dSm^{-1} salinity, and at 10 dSm^{-1} the lowest was in BD2330 (15.63%) and AGS313 (19.26%).

Earlier reports revealed that salt tolerant genotypes accumulated relatively less amount of Na and higher amount of K than the susceptible genotypes, and thus show a high K: Na ratio (Mahlooji *et al*., 2018; Polash *et al*., 2018). However, in this study the tolerant genotypes showed lower K: Na ratio than the susceptible genotypes. The findings may be ascribed to fact that the susceptible genotypes died much earlier, and they were exposed to salinity much shorter time than the tolerant genotypes as they took longer time for maturity. However, it suggested for undertaking intensive and comprehensive studies to clarify the unexpected results related to Na and K ration.

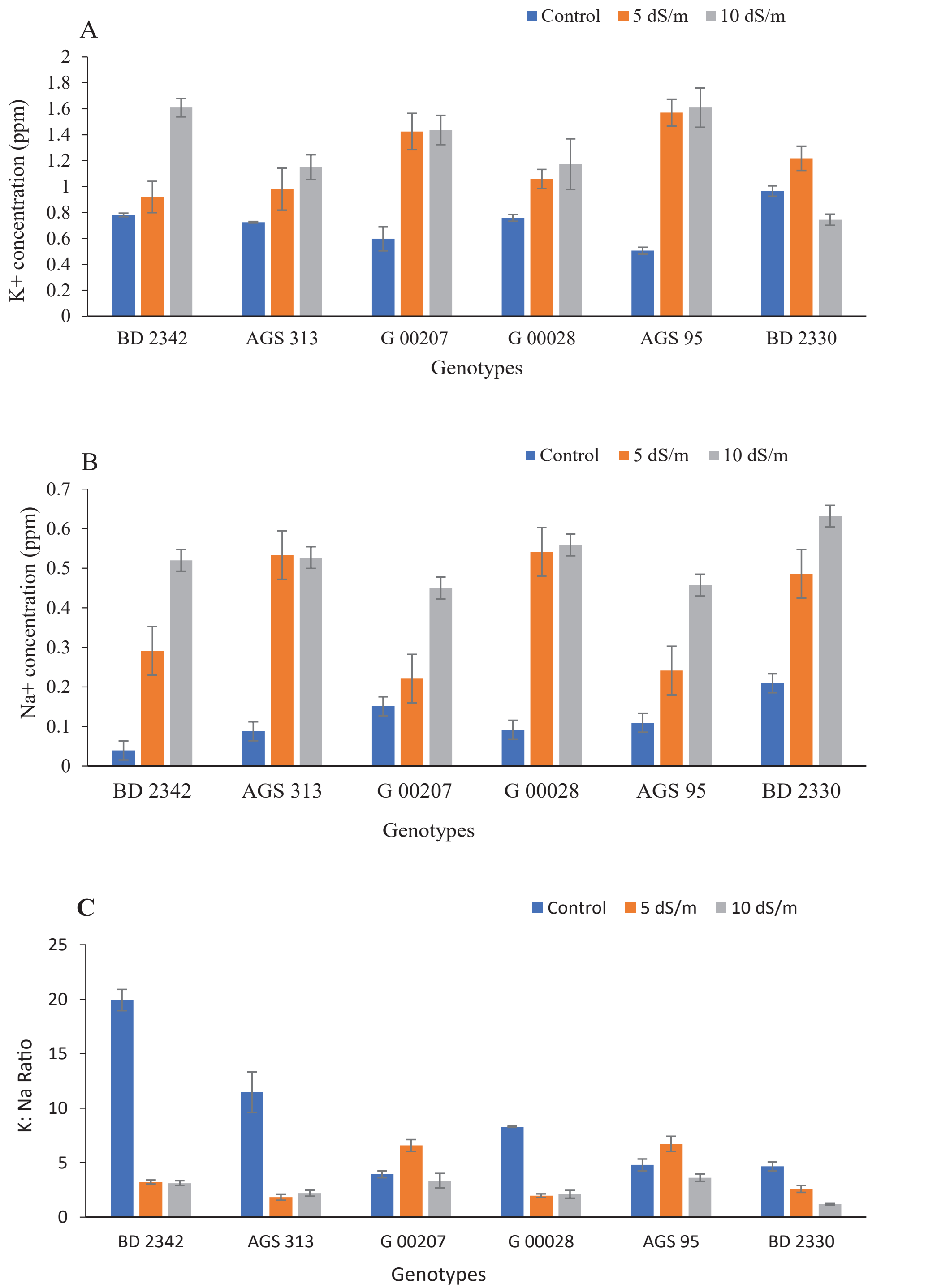

Fig. 10. Leaf mineral concentration in leaves of soybean genotypes. A) Potassium concentration B) Sodium concentration and C) K: Na ratio. Bar indicates standard error (±SE).

Number of pods per plant

Number of pods (both filled and unfilled) per plant decreased with the increase of salinity levels (Table 1). Total number of pods per plant (49.67) was the highest in BD2330 at control condition followed by G00343 (38.33); while the lowest number of pods per plant was counted in G000221 (19). At 5 dSm^{-1} salinity level the highest number of pods per plant (29.67) was found in BD2342

Table 1. Number of pods per plant and number of filled pods per plant of soybean genotypes as affected by salinity

Genotypes	Number of pods per plant			Filled pods per plant		
	Salinity levels (dSm^{-1})			Salinity levels (dSm^{-1})		
	0	5	10	0	5	10
BD 2342	41.67	29.67 (71.2)	15.33 (36.80)	34.67	15.50 (44.71)	2.17 (6.25)
AGS 313	37.00	18.61 (50.90)	18.83 (50.90)	33.67	15.83 (47.03)	16.00 (47.52)
G 00207	27.50	11.28 (41.01)	10.44 (37.98)	25.50	7.44 (29.19)	6.33 (24.84)
Galarsum	35.00	26.50 (75.71)	13.67 (39.05)	30.00	15.50 (51.67)	0.00 (0.00)
G 00209	19.67	8.33 (42.37)	2.44 (12.43)	18.33	4.50 (24.55)	0.00 (0.00)
G 00343	38.33	11.67 (30.44)	7.33 (19.13)	35.67	2.50 (7.01)	0.00 (0.00)
G 00028	26.72	15.50 (58.00)	14.28 (53.43)	26.17	12.33 (47.13)	10.78 (41.19)
G 00221	19.00	12.50 (65.79)	8.89 (46.78)	17.50	7.33 (41.90)	3.00 (17.14)
G 00283	22.94	11.83 (51.57)	12.611 (54.96)	21.83	6.00 (27.48)	5.78 (26.46)
AGS 95	36.00	10.56 (29.32)	5.776 (16.04)	31.50	2.67 (8.47)	0.00 (0.00)
G 00062	37.17	13.11 (25.28)	9.67 (26.01)	33.83	7.33 (21.67)	0.00 (0.00)
BU Soybean 2	32.06	11.11 (34.66)	6.00 (18.72)	30.83	4.33 (14.05)	0.00 (0.00)
G 00041	22.50	11.33 (50.37)	5.33 (23.70)	19.50	6.17 (31.63)	1.78 (9.12)
Shohag	31.72	22.17 (69.88)	3.33 (10.51)	26.50	6.83 (25.77)	0.00 (0.00)
BD 2330	49.67	26.33 (53.02)	15.11 (30.42)	47.67	23.33 (48.95)	12.89 (27.04)
LSD (0.05)		3.11			2.54	
CV (%)		9.97			11.19	

Values presented in parentheses indicate percent values to the control.

followed by Galarsum (26.50), which had however the highest relative number of pods (75.71%). The lowest number of pods was found in G00209. At 10 dSm^{-1} salinity, total number of pods was found the highest (18.83) in AGS313 which was 50.90% of its control. The lowest number of pods per plant (2.44) was found in G00209, which was only 12.43% of control condition. Salinity reduces plant growth, number of pods per plant and yield of soybean by affecting nutrient balance and water relations as also reported by Essa (2002), Hamayun *et al*. (2010) and Mannan *et al.* (2013). BD2330 produced the maximum number of filled pods (23.33) at 5 dSm-1 followed by AGS313 (15.83). Genotypes except AGS313, BD2330 and G00028 did not perform well under salinity and produced very little or no filled pod at all. It was reported earlier that with the increment of salinity levels, the number of filled pods per plant reduced in soybean and the reasons for the low productivity were due to the salinity induced toxicity on plant growth processes (Otie *et al*., 2021; Taufiq *et al*., 2021).

Number of seeds per pod

The number of seeds per pod was not affected by salinity (Table 2). However, G00028 produced the maximum number of seeds per pod in control condition (2.32) which was followed by AGS313 (2.13). On the other hand, the lowest number of seeds per pod was counted in BD2342 (1.50) followed by Galarsum (1.53). The highest number of seeds per pod was found at 5 dSm^{-1} in G00207 which was 2.14 and followed by G 00209 (2.03). The lowest number of seeds per pod at 5 dSm^{-1} was found in G00343 which was 1.26 seeds per pod followed by BU Soybean2 (1.35). At 10 dSm^{-1} saline condition, G00207 produced the maximum 2.29 seeds per pod followed by BD2330 (2.19). Some genotypes did not produce any seed in pod.

Number of seeds per plant

It was observed that BD2330 produced the maximum number of seeds per plant in all the three conditions (Table 2). In control condition, BD2330 produced the maximum (87.5) seeds per plant followed by AGS313 (71.83 seeds per plant). The lowest number of seeds per plant was counted in G00221 (28.67) in control condition. Salinity reduced seed number per plant from 35.27% to 95.44% at 5 dSm^{-1} and 72.22% to 100% at 10 dSm^{-1} salinity. BD2330 produced the highest number of seeds per plant which was 38.67 following by AGS313 and G00028 that produced 31.17 and 24.56 seeds per plant, respectively. On the other hand, G00343 produced only 3.17 seeds per plant.

At 10 dSm^{-1} salinity too BD2330, G00028 and AGS313 performed better than other genotypes by producing 27.78, 24.11 and 23.17 seeds per plant respectively. In that high saline condition, some genotypes, namely Galarsum, G00343, G00209, AGS95, Shohag, G00062 and BU Soybean2 did not produce any seed. The number of seeds per plant decreased with the increase of salinity level in soybean as also reported by Sadak *et al.* (2020) and Otie *et al*. (2021) and the probable reasons are due to imbalance in water relations, plant nutrition and Na toxicity (Tareq *et al.,* 2021).

Table 2. Number of seeds per pod and number of seeds per plant of soybean genotypes as affected by salinity

Genotypes	Number of seeds per pod			Number of seeds per plant		
	Salinity levels (dSm^{-1})			Salinity levels (dSm^{-1})		
	0	5	10	0	5	10
BD 2342	1.50	1.74 (116.15)	1.61 (107.81)	51.67	27.33 (52.90)	3.50 (6.77)
AGS 313	2.13	1.97 (92.33)	1.44 (67.41)	71.83	31.17 (43.39)	23.17 (32.25)
G 00207	2.05	2.14 (104.12)	2.29 (111.64)	52.33	15.78 (30.15)	14.67 (28.03)
Galarsum	1.53	1.92 (125.35)	0.00 (0.00)	45.83	29.67 (64.73)	0.00 (0.00)
G 00209	2.00	2.03 (101.21)	0.00 (0.00)	36.50	9.00 (24.66)	0.00 (0.00)
G 00343	1.95	1.26 (64.44)	0.00 (0.00)	69.50	3.17 (4.56)	0.00 (0.00)
G 00028	2.32	1.99 (85.64)	2.23 (96.13)	60.83	24.56 (40.37)	24.11 (39.63)
G 00221	1.64	1.72 (105.28)	1.99 (121.70)	28.67	12.67 (44.19)	6.00 (20.93)
G 00283	1.80	1.69 (93.90)	0.96 (53.19)	39.33	10.67 (27.12)	4.33 (11.02)
AGS 95	1.93	1.97 (102.39)	0.00 (0.00)	60.67	5.17 (8.52)	0.00 (0.00)
G 00062	1.71	1.75 (101.94)	0.00 (0.00)	58.00	12.83 (22.13)	0.00 (0.00)
BU Soybean 2	1.84	1.35 (73.27)	0.00 (0.00)	56.50	5.83 (10.32)	0.00 (0.00)
G 00041	1.79	1.84 (102.57)	2.06 (114.94)	35.00	11.33 (32.38)	3.67 (10.48)
Shohag	1.63	1.83 (112.34)	0.00 (0.00)	43.17	12.50 (28.96)	0.00 (0.00)
BD 2330	1.84	1.67 (90.94)	2.19 (119.09)	87.50	38.67 (44.19)	27.78 (31.75)
LSD (0.05)		4.58			0.04	
CV (%)		10.99			16.11	

Values presented in parentheses indicate percent values to the control.

100-seed weight

In saline treated conditions the seed size decreased remarkably (Table 3). 100-seed weight was found the maximum in control condition in G00062 which was 17.95g followed by G 00283 (14.61g). The lowest 100-seed weight was observed in AGS95 (9.01 g) followed by BD2330 (9.72g). Though 100-seed weight reduced in saline condition, BD2330, AGS 313 and G 00028 showed

Table 3. 100-seed weight and seed yield per plant of soybean at different levels of salinity

Genotypes	100-seed weight			Seed yield per plant		
	Salinity level (dSm^{-1})			Salinity level (dSm^{-1})		
	0	5	10	0	5	10
BD 2342	11.03	4.78 (43.35)	4.66 (42.27)	5.69	1.33 (23.42)	0.17 (2.95)
AGS 313	13.64	9.82 (72.02)	7.83 (57.51)	9.79	3.06 (31.29)	1.83 (18.69)
G 00207	10.34	5.54 (53.56)	5.39 (0.00)	5.39	0.85 (15.79)	0.79 (14.65)
Galarsum	10.20	3.96 (38.83)	0.00 (0.00)	4.68	1.21 (25.88)	0.00 (0.00)
G 00209	14.19	3.79 (26.69)	0.00 (0.00)	5.18	0.34 (6.56)	0.00 (0.00)
G 00343	12.66	2.88 (22.76)	0.00 (0.00)	8.74	0.10 (1.09)	0.00 (0.00)
G 00028	13.89	9.21 (66.28)	8.21 (59.10)	8.45	2.30 (27.23)	2.00 (23.67)
G 00221	10.99	4.43 (40.34)	2.88 (26.25)	3.15	0.54 (17.02)	0.17 (5.39)
G 00283	14.61	5.00 (34.23)	2.10 (14.34)	5.74	0.51 (8.83)	0.24 (4.16)
AGS 95	9.01	3.29 (36.48)	0.00 (0.00)	5.47	0.17 (3.11)	0.00 (0.00)
G 00062	17.95	2.84 (15.80)	0.00 (0.00)	10.41	0.36 (3.46)	0.00 (0.00)
BU Soybean 2	13.01	3.89 (29.86)	0.00 (0.00)	7.33	0.23 (3.09)	0.00 (0.00)
G 00041	13.31	5.76 (43.30)	2.41 (18.12)	4.68	0.66 (14.11)	0.09 (2.00)
Shohag	10.52	6.10 (57.98)	0.00 (0.00)	4.54	0.77 (16.86)	0.00 (0.00)
BD 2330	9.72	7.67 (78.86)	6.81 (70.02)	8.50	2.97 (34.90)	1.90 (22.35)
LSD (0.05)		1.68			0.61	
CV (%)		15.27			14.19	

Values presented in parentheses indicate percent values to the control.

relatively higher value among the fifteen genotypes. At 5 dSm^{-1} salinity condition the 100-seed weight was the highest in AGS313 (9.82g) which was 72% of the control. At 10 dSm^{-1} saline condition the 100-seed weight of AGS313 was the highest (7.83 g) which was 57.41% of control. The 100-seed weight of G00028 found 9.21g and 8.21g at 5 dSm-1 and 10 dSm-1 salinity which was 66.28% and 59.10% of the control respectively. The 100-seed weight reduced to a lower extent in case of BD2330, and the weight was 7.67 g and 6.81 g at 5 dSm^{-1} and 10 dSm^{-1} saline condition, respectively which was 78.86% and 70.06% of the control, respectively. The 100-seed weight decreased in saline-treated soil probably due to the reduction in individual seed size due to less accumulation of photosynthate. The reduction of 100-seed weight of soybean also been reported earlier (Mannan *et al*., 2013; Linh *et al.*, 2021; Taufiq *et al*., 2021).

Seed yield per plant

Salinity influenced the grain yield per plant to a great extent. Yield reduction in some genotypes under saline conditions was even up to 100% (Table 3). For example, G00062 yielded maximum (10.41 g seed per plant) at control condition among the genotypes, however at 5 dSm-1 and 10 dSm-1 it yielded a very low amount of seed which was 0.36 g and 0.02 g per plant, respectively. AGS313 followed G00062 in control by producing 9.79 g seed per plant. Seed yield was the lowest in G 00221 which was only 3.15 g per plant followed by Shohag (4.54 g per plant). Maximum seed yield was found at 5 dSm^{-1} salinity in AGS313 which was 3.06 g per plant followed by BD2330 (2.97 g) and G00028 (2.30 g), while the minimum was in G00343 (0.10 g) followed by AGS95 (0.17 g). At 10 dSm^{-1} salinity the maximum yield per plant was measured in G00028 (2.0 g) followed by BD2330 (1.90 g) and AGS 313 (1.83 g), whereas Galarsum, G00209, G00343, AGS95 and Shohag did not produce any seed.

It is noteworthy that no seeds or a few number of seeds were produced in the genotypes other than AGS313, BD2330 and G00028 and that was the reason for the low seed yield. The reasons for the reduction in yield were presumably due to low photosynthesis, imbalance in water relations and nutrients (Mannan *et al.,* 2016; Fujii and Higuchi, 2019; Tareq *et al.,* 2021). The reduction in seed yield of soybean due to long exposure of salinity was also observed by Mannan *et al*. (2013), Khan *et al*. (2016) and Sadak *et al*. (2020).

Conclusion

Based on the findings of the study it may be concluded that among the tested genotypes, BD2330, AGS313 and G00028 were relatively higher salt tolerant in relation to seed yield production than others. The genotypes BD2330, AGS313 and G00028 also showed higher RWC and SPAD value under saline conditions. Unexpectedly it was found that the K: Na ratio in leaf increased in a relatively higher amount in susceptible genotypes like G00207 under saline conditions whereas it decreased in relatively tolerant genotypes like AGS313, which probably due to longer duration exposure of the tolerant genotypes to salinity. However, further comprehensive experiment(s) on the accumulation pattern of Na and K is needed to clarify the findings of this experiment. It is also suggested to conduct field adaptation trials of the genotypes BD2330, AGS313 and G00028 in the coastal region to ascertain the findings of this study.

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