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Performance of different sugar beet genotypes under salinity stress

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ABSTRACT

Soil salinity is one of the major threats which pose a detrimental threat against successful crop production. To tackle the salinity problem, intensive research is indispensable for sustainable crop production. A study was carried out to investigate the suitability of sugar beet genotypes and elucidate their yield-related characteristics in response to different saline conditions at the Sylhet region, Bangladesh, from October 2019 to March 2020. The treatment consists of four sugar beet genotypes viz., HI-0044, HI-0473, KWS-Allanya, and KWS-Serendara, and four NaCl levels viz., 0 mM NaCl (S0), 100 mM NaCl (S1), 200 mM NaCl (S2) and 300 mM NaCl (S3). In case of SPAD value for the chlorophyll content, all the genotypes showed their steady state in response to salinity stress. Based on growth pattern and yield performance, the highest values for all the parameters observed in the HI-0044 genotype followed by HI-0473, while KWS-Allanya and KWS-Serenada were the worst performers under different salinity stress. All the sugar beet genotypes showed the potentiality to maintain their growth and yield under low to high salinity levels with decreasing trends where HI-0044 genotype was the best performer under salinity stress.

Key Words: *Soil salinity, Abiotic stress, Genotypes, Yield and Sugar beet.*

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I. Introduction

Plants have evolved with a versatile capacity to regulate their physiology, growth and development that facilitates survival in a constantly changing environment and stress (Horie and Schroeder, 2004; Sairam and Tyagi, 2004). Plant stress is a physiological state that destabilizes plant functions, displaces metabolism from normal homeostasis and decreases fitness. Among the different abiotic stresses, soil salinity is one of the major environmental stresses that strongly impair crop productivity worldwide (Hossain and Dietz, 2016; Zhu, 2016; Sathee et al., 2015; Munns et al., 2012). Usually, plants have evolved complex mechanisms to adapt to osmotic and ionic stress caused by high salinity (Hossain and Dietz, 2016; Horie et al., 2012; Horie and Schroeder, 2004; Sairam and Tyagi, 2004).

Soil salinity is a major constraint to growing crops, and about one-fifth of the country's land has been characterized as saline (BBS, 2019; Chen and Mueller, 2018; BARC, 2018), thus resulting in poor performance crop species. Sugar beet (*Beta vulgaris* L.) is an herbaceous, dicotyledonous, glycophytic, C3-plant that belongs to the family Amaranthaceae (formerly Chenopodiaceae) (Watson and Dallwitz, 1992). It is the second most important sugar crop after sugarcane, accounting for about 30% of world sugar production (Iqbal and Saleem, 2015). It is also a short duration crop containing high concentration of sucrose and processed into white sugar, pulp and molasses used in chemicals and pharmaceuticals industries (Tan et al., 2015; Ahmad et al., 2012). It is not only important as food, fodder and biomass but also to produce renewable energy, e.g., bioethanol (Magaña et al., 2011). It is considered a cash crop that requires careful agronomic practices and breeding for adaptation to biotic and abiotic stresses. Traits of interest for sugar beet improvement concern the acclimation ability to abiotic stresses such as drought and salt stress (Hossain et al., 2017a; Hossain et al., 2017b; Babaee et al., 2013; Vastarelli et al., 2013). Sugar beet is a temperate crop, generally grown in Europe, North America and temperate zones of Asia. France, Germany, Russia, USA and Ukraine are top sugar beet producing countries (FAO, 2010). Although sugar beet is a temperate crop, Syngenta has developed and successfully introduced new sugar beet that can be grown under tropical climatic conditions. Beets growing in the tropical condition bring significant agronomic, environmental, and ample advantages to many tropical countries like India, Pakistan, Sudan, Bangladesh etc. (FAO, 2010; BSRI, 2011). It is a fast growing crop (5-6 months) and can be harvested after five months allowing farmers to grow a second crop on the same land. Sugar beet can be introduced and adopted in existing cropping patterns to develop a sustainable production system that will help increase cropping intensity and sugar crop production in Bangladesh.

In Bangladesh, sugarcane holds the first position as a sugar crop but only supplies one-fourth of the country's total demand (Rahman et al., 2016). Moreover, due to an acute shortage of raw materials (cane), most sugar industries remain out of operation for a particular time throughout the year. In this context, sugar beet might be a suitable alternative to sugarcane in Bangladesh by incorporating processing facilities in the sugar mills. Most importantly, sugar beet is a salt tolerant terrestrial crop species that can tolerate up to 300 mM (Hossain et al., 2017a; Hossain et al., 2017b; Yang et al., 2013). So, tropical sugar beet cultivation might be a good alternative crop for growing around Bangladesh's salinity prone coastal area. Bangladesh Sugar Crop Research Institute (BSRI), in collaboration with Syngenta (an international company), has introduced some tropical genotypes (BSRI, 2013). All sugar beet genotypes are not equally potential in different environment and soil conditions (Hossain et al., 2017a; Hossain et al., 2017b). So, the present study was undertaken to investigate the growth and yield of four sugar beet genotypes (BSRI recommended) under different salinity stress.

II. Materials and Methods

Experimental site and weather

A pot experiment was conducted from November 2018 to April 2019 at the field laboratory of Sylhet Agricultural University, Sylhet, Bangladesh (24^{0}89'N, 91^{0}88'E). The area is located in the north-eastern part of the country and belongs to Agro-Ecological Zone-20 (AEZ-20) named Eastern Surma-Kushiyara Floodplain and is characterized by a sub-tropical climate. During the experimental period, the area's average maximum and minimum temperature range from 25.0 to 30.8°C and from 12.1 to 23.3°C, respectively (Table 01). The amount of rainfall was maximum in October 2019 and minimum during December 2019 and January 2020. Relative humidity varied between 64 and 82% throughout the study period and was highest in October 2019 (82%) (Table 01).

Experimental details

Four sugar beet genotypes viz., HI-0044 (G1), HI-0473 (G2), KWS-Allanya (G3) and KWS-Serendara (G4) were collected from the Bangladesh Sugar crop Research Institute (BSRI) and used in the experiment. Salinity stress was introduced using laboratory grade NaCl. Four level of salinity viz., 0 mM NaCl (S0), 100 mM NaCl(S1), 200 mM NaCl(S2) and 300 mM NaCl(S3) were applied in this

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experiment. Salinity stress treatment was applied at 35 DAS. Recommended doses of fertilizer for sugar beet were used to grow the plant in all salinity levels. The recommended dose of inorganic fertilizer for this region is 120-30-100-12-3.5-1.2 kg ha^{-1} for N-P-K-S-Zn-B, respectively (BARC, 2018). 30% of N, P and K was supplied from the compost. The experiment was laid out following Completely Randomized Design (CRD) with four replications. Thus, the total number of pots used in the experiment were 64 and the individual pot size was 24 cm (diameter) × 32 cm (depth). Two third portions of the pots were filled with 8 kg of thoroughly mixed soil.

Table 01. Weather condition during the experimental period (October 2019- March 2020)

Month	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Rainfall (mm)	Relative Humidity (%)
October	30.6	22.3	227.0	82.0
November	28.7	17.7	31.0	80.0
December	26.1	13.6	9.0	80.0
January	25.0	12.1	13.0	77.0
February	27.3	13.8	27.3	68.0
March	30.8	17.8	108.0	64.0

Crop husbandry

The soil was sandy loam having pH 6.8, which was adjusted by using $CaCO_3$. Fertilizers were applied as basal dose during final soil preparation. After liming, soil was mixed thoroughly with compost, one third of Urea and whole Triple superphosphate (TSP), Muriate of Potash (MoP), Gypsum, Zinc Sulphate and Boric acid. The rest of the Urea was applied in two splits at 60 and 90 days after sowing (DAS). Two seeds were sown in each pot at three cm soil depth from the surface. During the full crop growing period, care was taken to avoid moisture stress and control weeds, pests and diseases when necessary in the field condition. Therefore the growing conditions would be considered near potential. The first irrigation was done just after seed sowing and the subsequent irrigation was done four times at 45, 70, 95 and 120 DAS. At the earlier stage, excess water was drained out to avoid water logging conditions due to heavy rain. One extra sugar beet seedling was removed to keep one plant per pot (if both the seeds were germinated) and one seedling was transplanted (if both the seeds failed to germinate) within 13 DAS. Sugar beet is susceptible to weeds at an earlier stage until the sugar beet leaves provide shade over the ground. Hence, weeds were removed from the pot manually at 15, 30, 45 and 60 DAS. Dithane M 45 at the rate of 2.2 kg ha^{-1} and Score 250 EC 0.5 ml L^{-1} of water were applied at 15 day intervals from 30 DAS by hand sprayer to control damping-off and sclerotium root rot diseases. For controlling cut warm, tobacco caterpillar and army warm, Durshban was applied at the rate of 2.5ml L^{-1} of water at 15 days intervals from 30 DAS by hand sprayer.

Data collection

The data were collected on different growth and yield contributing characters viz. number of leaves (no. per plant), leaf chlorophyll content (relative unit), shoot length (cm), shoot dry weight (g), beet length (cm) beet girth (cm), beet dry weight (g) and total dry matter (g). Data on plant growth, yield contributing attributes, and yield were recorded by following the tropical sugar beet production technology guidelines in Bangladesh (BSRI, 2013). A total number of leaves plant^{-1} were counted from each pot at 165 DAS. Length of shoot (the petiole and leaf blade) (cm) of each plant was measured from the base to the top of the leaf by a measuring scale.

Leaf chlorophyll content

Leaf chlorophyll content was continuously measured after introducing salinity treatment. Leaf chlorophyll content was measured using portable Soil Plant Analysis Development (SPAD) meter (SPAD-502, Minolta Camera, Tokyo, Japan) at five different points of five fully expanded leaves between 11:00 am to 12:00 pm.

Yield contributing characters

A total number of leaves plant^{-1} were counted in every pot at 165 DAS. Shoot (from the base to the tip of the plant) length (cm) of every plant was measured by a measuring scale. The beetroot length (cm) and girth (cm) of every pot were measured using a measuring scale and slide callipers, respectively. For beetroot girth, three measurements were taken at the basal, middle and top part of the beetroot and the average was recorded. Shoot of each plant was separated to determine the fresh weight (g plant^{-1}). Beet root of each plant was harvested, cleaned to determine the fresh weight of beetroot (g plant-1). Shoot of each plant was separated, sun dried for several days and then oven-dried till constant weight at 70⁰ C to determine the dry weight (g plant-1). Beetroot of each plant was harvested, cleaned, cut into small pieces and sun dried for several days. After that, oven-dried to till constant weight at 70⁰ C to determine the dry weight of beetroot (g plant-1)

Statistical analysis

Leaf chlorophyll content among different genotypes and salinity levels along 14 days of measurements were analyzed through repeated measure ANOVA. Variation among the genotypes and salinity treatments were analyzed through two-way ANOVA. In case of significant effect, means were separated through post hoc test (using LSD value). Values were reported as significant at p-values <0.05. All the analysis was performed in R (R Core Team, 2014).

III. Results and Discussion

Leaf chlorophyll content (SPAD value)

SPAD values varied between 33 and 38 among different treatments (Figure 01). SPAD value differed significantly among sugar beet genotypes and time, but no substantial differences were observed over time in different salinity stress (Table 02). Post hoc analysis revealed that chlorophyll content was slightly higher in G3 than other genotypes (Figure 01).

Table 2. Repeated measure ANOVA table for chlorophyll data

	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr(>F)
Time	83.786	83.786	1	831	23.1626	1.768e-06 ***
Genotype	52.807	17.602	3	57	4.8662	0.004408 **
Treatment	19.164	6.388	3	57	1.7660	0.163932

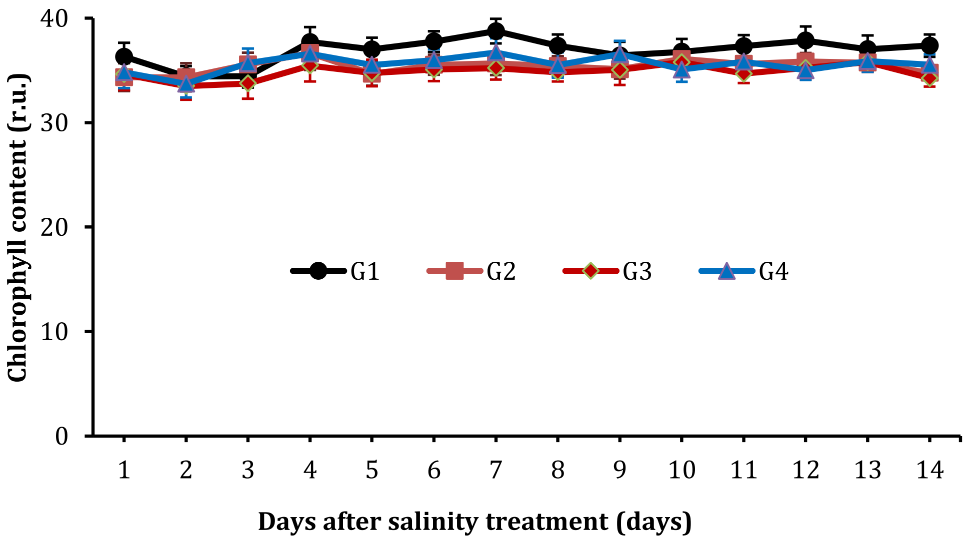

Figure 01. Variation in chlorophyll content of sugar beet under salinity stress among different genotypes.

Different sugar beet genotypes showed their steady state in response to the salinity stress (Figure 01). Although beet root development started simultaneously in all genotypes, the highest beet yield was obtained by HI-0044 under control conditions. It might be attributed to the steady state of chlorophyll content of different sugar beet genotypes under salinity stress, demonstrating the high acclimation ability of sugar beet to strongly raised NaCl levels (Hossain et al., 2017a). Leaf chlorophyll content and carbohydrate accumulation enhance length, diameter, TSS%, and fresh weight and dry weight of beet root (Sanghera et al., 2016; Özbay and Yildirim, 2018).

Variation among the sugar beet genotypes

Number of leaves plant-1 and root height were not significantly varied among the sugar beet genotypes (Table 03). The sugar beet genotypes significantly varied for shoot height, shoot fresh weight, shoot dry weight, beet root diameter, beet root fresh weight and beet root dry weight (Table 03). The highest values were found in the genotype HI-0044 (G1) followed by HI-0473 (G2) for all cases (Table 03).

Overall, the genotype KWS-Allanya and KWS-Serenada gave lower values for all the parameters (Table 03).

Table 03. Variation in crop characters, yield components and yield of sugar beet among different genotypes

Genotypes	LP	SH	SFW	SDW	RD	RH	RFW	RDW
G1	8.3 (0.6)	22.8 (1.9) a	246.6 (10.9) a	113.6 (5.4) a	11.3 (0.6) a	11.2 (0.7)	522.2 (32.6) a	309.8 (16.8) a
G2	8.3 (0.3)	20.2 (1.9) b	231.9 (6.0) b	104.6 (3.1) b	10.6 (1.1) a	11.6 (0.9)	400.7 (19.2) b	238 (11.8) b
G3	7.6 (0.4)	17.7 (1.9) d	219.5 (8.3) c	98.8 (3.8) c	9.4 (0.3) b	11.3 (1)	370.2 (19.3) c	250.7 (12.2) b
G4	8.1 (0.3)	18.8 (1.9) c	235.2 (11.8) b	105.5 (6.5) b	7.9 (0.5) c	11.3 (0.8)	352.1 (20.3) c	196.3 (11.8) c
p-value	0.09	<0.01	<0.01	<0.01	<0.01	0.85	<0.01	<0.01

Here, G1: HI-0044, G2: HI-0473, G3: KWS-Allanya, G4: KWS-Serenada, LP: Number of leaves plant^{-1}, SH: Shootheight, SFW: Shoot fresh weight, SDW: Shoot dry weight, RD: Beet root diameter, RH: Beet root height, RFW: Beet root fresh weight and RDW: beet root dry weight).

Effect of soil salinity on sugar beet performance

Different soil salinity levels significantly affected all the variables measured compared to the control (Table 04). The highest values were found in the control condition (SO) for all cases (Table 04). The salt treated (100 mM, 200 mM and 300 mM NaCl) sugar beet plants showed the lowest values of a similar trend, indicating the negative effect of salinity stress (Table 04). Overall, sugar beet plants showed poor performance under salinity stress compared to untreated plants.

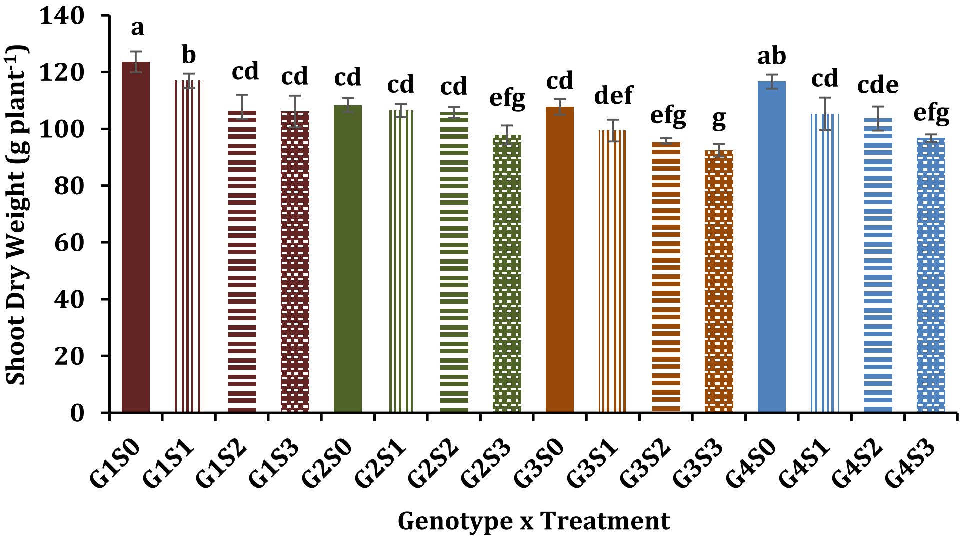

Figure 02. Interaction effect of soil salinity and genotypes on the shoot dry weight of sugar beet.
Here, G1: HI-0044, G2: HI-0473, G3: KWS-Allanya, G4: KWS-Serenada, S0: 0 mM NaCl, S1: 100 mM NaCl, S2: 200 mM NaCl, S3: 300 mM NaCl.

Table 04. Variation in crop characters, yield components and yield of sugar beet in response to different salinity levels

Treatments	LP	SH	SFW	SDW	RH	RD	RFW	RDW
S0	8.5 (0.4) a	24.7 (1) a	250.2 (7.9) a	114 (3.4) a	12.8 (1.1) a	11.3 (0.7) a	521.2 (64) a	297.5 (38.3) a
S1	8.3 (0.5) ab	21 (1.1) b	232.2 (15.7) b	103 (6.8) ab	11.3 (0.8) bc	10.6 (1.1) a	387.5 (55.3) b	227.6 (33.1) b
S2	7.9 (0.3) ab	19 (1.1) c	228.7 (8) b	102.8 (3.6) b	11.0 (0.4) bc	9.4 (1) a	368.7 (83.3) b	223.9 (37.2) b
S3	7.6 (0.4) bc	15 (1.4) d	222.2 (9.3) b	99.8 (4.2) b	10.2 (0.6) c	7.4 (0.9) b	368.3 (61.7) b	216.3 (46.8) b
p-value	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01

(Here, S0: 0 mM NaCl, S1: 100 mM NaCl, S2: 200 mM NaCl, S3: 300 mM NaCl, LP: Number of leaves plant^{-1}, SH: Shoot height, SFW: Shoot fresh weight, SDW: Shoot dry weight, RD: Beet root diameter, RH: Beet root height, RFW: Beet root fresh weight and RDW: beet root dry weight).

Genotypes performance in different soil salinity levels
Genotypes showed different responses across the salinity levels for crop characters, yield components, and yield of sugar beet except for the number of leaves plant^{-1}, shoot height and root height (Table 05; Figure 02; Figure 03). All the genotypes under the control condition yielded better results where G1S0 showed maximum performance in all cases (Table 05; Figure 02; Figure 03). On the other hand, the lowest values for all the parameters were obtained in G4S3 followed by G3S3 combination (Table 05; Figure 02; Figure 03).

The results indicated that the lowest growth and yield attributes were obtained from the sugar beet genotypes grown in a plot with salt treatment. The growth and yield attributes of all the sugar beet genotypes were highly affected by the salinity stress. HI-0044 showed the highest performance (Table 03; Table 05; Figure 02; Figure 03). In other cases salinity stress showed negative effects but not huge changes at the very high salinity levels. It might be due to higher salinity tolerance of sugar beet which was confirmed by several studies on sugar beet and salinity tolerance (Liu et al., 2020; Zhao et al., 2020; Hossain et al., 2017a; Hossain et al., 2017b; Yang et al., 2013). In line with previous studies, our results revealed efficient growth and yield of sugar beet.

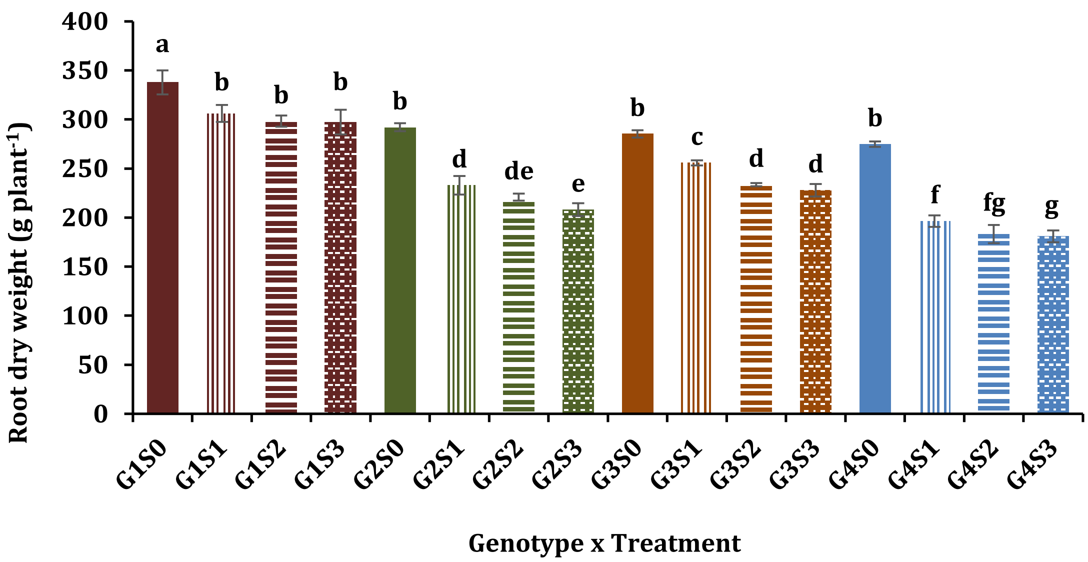

Figure 03. Interaction effect of soil salinity and genotypes on the root dry weight of sugar beet. Here, G1: HI-0044, G2: HI-0473, G3: KWS-Allanya, G4: KWS-Serenada, S0: 0 mM NaCl, S1: 100 mM NaCl, S2: 200 mM NaCl, S3: 300 mM NaCl.

Table 05. Interaction effect of genotypes and soil salinity on the crop characters, yield components and yield of sugar beet.

G x T	Leaves plant^{-1}	Shoot		Root (Beet)		
		Length	Fresh weight	Length	Diameter	Fresh weight
G1S0	8 (0)	27.6 (0.2)	278.5 (12.2) a	12.6 (0.9)	12.1 (0.6) a	597.1 (20.1) a
G1S1	8 (0)	23.9 (0.4)	262.8 (4.5) a	11.2 (0.6)	11.7 (0.5) a	500.9 (25.7) b
G1S2	7.5 (0.5)	21.9 (0.7)	229.9 (9.5) cdef	10.9 (0.4)	11.1 (0.7) ab	495.4 (14.4) b
G1S3	7 (0.6)	18 (1.1)	215.4 (2.9) defg	10.1 (0.4)	10.5 (0.4) bc	495.2 (21.1) b
G2S0	8.5 (0.5)	25.1 (0.2)	239.9 (5.5) bc	13.3 (1.3)	12.1 (0.4) a	496.8 (6.9) b
G2S1	8.5 (0.5)	21.2 (0.5)	235.9 (3.8) cd	11.5 (1)	11.7 (1.7) a	388.1 (10.7) c
G2S2	8 (0)	19.1 (0.7)	234.2 (7.4) cd	11.4 (0.2)	9.8 (0.5) bcd	368 (15.7) cd
G2S3	8 (0)	15.4 (1.1)	217.6 (5) defg	10.4 (0.6)	8.7 (0.5) de	350 (6) de
G3S0	9.0 (0.5)	22.6 (0.2)	239 (6.1) bc	12.6 (1.4)	9.5 (0.4) bcde	498.3 (6.4) b
G3S1	8 (0.8)	18.7 (0.5)	220.4 (8.5) cdefg	11.3 (1)	9.4 (0.3) cde	359.8 (4.3) d
G3S2	8 (0)	16.9 (0.7)	212.8 (2.2) efg	11 (0.8)	9.4 (0.3) cde	322.8 (5.9) e
G3S3	7.5 (0.5)	12.8 (1.1)	205.8 (4.9) g	10.2 (1)	9.1 (0.3) cde	302 (10.5) f
G4S0	8.5 (0.5)	23.4 (0.4)	259 (8.1) b	12.8 (1.1)	8.9 (0.3) cde	492.7 (4.5) b
G4S1	8 (0)	20.1 (0.4)	236.2 (9.3) cd	11.4 (0.8)	8.1 (0.3) def	326.7 (9.8) e
G4S2	8 (0)	18 (0.6)	233.4 (12.4) cde	11 (0.3)	8 (0.3) ef	301.1 (15.6) f
G4S3	8 (0)	13.8 (1.1)	212.4 (5.5) fg	10.2 (0.6)	6.8 (0.5) f	288.1 (9.9) g
p-value	NS	NS	<0.01	NS	0.02	<0.01

(Here, G1: HI-0044, G2: HI-0473, G3: KWS-Allanya, G4: KWS-Serenada, S0: 0 mM NaCl, S1: 100 mM NaCl, S2: 200 mM NaCl, S3: 300 mM NaCl).

IV. Conclusion

This study has revealed that tropical sugar beet genotypes viz. HI-0044, HI-0473, KWS-Allanya, KWS-Serenada can be grown in saline soil. The cultivar, HI-0044, was the best performer in all growth and yield attributes cases, followed by HI-0473. While the worst performance was recorded in KWS-Serenada followed by KWS-Allanya. HI-0044 was the best performer in acidic soil when amended with $CaCO_3$ @ both 1 and 2 t ha^{-1} along with the recommended rate of inorganic fertilizers (Akter et al., 2021). These findings hint about the potentiality of HI-0044 genotypes of sugar beet to acclimate to different adverse environmental conditions.

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