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Research Article

Genotypic differences in plant growth responses and ion accumulations to salt stress conditions of sweet gourd (*Cucurbita moschata*)

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Abstract
The sweet gourd (*Cucurbita moschata* Duch ex Poir) is a rich source of vitamins and minerals, especially high carotenoids. Due to climate change and intensive water use, soil salinization is increasing day by day. Salt stress decreases the growth and quality of many crops. Thus, the objective of the present study was to monitor the growth and ion accumulation of fourteen sweet gourd inbred. The study was conducted in 2018 with 14 sweet gourd inbreds (P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8, P_9, P_{10}, P_{11}, P_{12}, P_{13} and P_{14}) and to identify superior genotypes. Electrical conductivity (EC) based salt was applied at 4, 8, 12 and 16 dS/m NaCl salinity levels for all inbred. Tap water was used as a control. Treatments were imposed at the four to five-leaf stage. Salt stress resulted in significantly decreased growth and essential ion in sweet gourd inbred. Vine length (P_{11}=164.9 to149.5cm, control to 16 dS/m), the number of leaves (P11=31 to 24.33, control to 16 dS/m), internode length (P_{12}=9.67 to 9.83cm, control to 16 dS/m), stem girth (16.38 to 15.87mm, control to 16 dS/m) and K^+ ion accumulations were decreased (P_6=2.09 to 1.44, control to 16 dS/m) compared to the control. But Na^+ ion was increased (P_{13}=0.17 to 1.25, control to 16 dS/m) in all inbred under salt conditions. Sweet gourd inbred showed wide variation in their response to salt tolerance. However, six sweet gourd inbred (P_6, P_8, P_9, P_{11}, P_{12} and P_{14}) were found as promising as salt-tolerant in respect of growth and ion accumulation. These selected promising salt-tolerant sweet gourd genotypes will be used for breeding programmes to develop high yielding varieties for better production in the near future in saline areas of Bangladesh.

Keywords: Growth, Inbred, Ion accumulation, Salinity, Sweet gourd, Tolerant

INTRODUCTION

Salinity is one of the most important abiotic factors that cause a reduction in the growth, development and yield of many crops. Salinity negatively affects plant growth when salts accumulate in the root zone. High levels of salinity affect seed germination plant growth by water deficit (osmotic stress), ion imbalance and ion toxicity (ionic stress) or a combination of these factors (Lauchli and Grattan, 2007). Plant species can differ markedly in their responses to salt tolerance (Dasgan and Koc, 2009; Kusuvuran *et al.,* 2011). Salt toxicity primarily occurs in the older leaves, where Na and Cl build up in the leaves over a long period of time. The cultivable areas in coastal districts are affected with varying degrees of salinity 3.63-27.67 dS/m (Akter *et al*., 2008). In Bangladesh, about 3 million hectares of land are affected by salinity, mainly in the coastal and south-eastern districts, with EC values ranging between 4 to 16 dS/m. The coastal zone of Bangladesh covers an area of 47,201 km, 32% of the country, being the landmass of 19 districts (Ahmad, 2019). Salt stress changes the plants morphological and physiological traits and biochemical responses (Sevengor *et al*., 2011; Kusvuran *et al.,* 2013). Many researchers have reported that long-term salinity causes ion toxicity, water deficiency in older leaves, and carbohydrate deficiency in young leaves (Greenway and Munns, 1980; Franco *et al*., 1993; Kurtar *et al*., 2016). Therefore, salt-resistance often depends on the ability of the plant to develop adaptive strategies under salt stress conditions (Kachout *et al*., 2012; Ors and Suarez, 2016). In excess salt during plant growth, Na^+ and Cl^- are accumulated in different plant organs (Kurtar *et al.,* 2016). Salt resistance often depends on the ability of the plant to develop adaptive strategies under stress conditions (Kachout *et al.,* 2012; Ors and Suarez, 2016).

Sweet gourd (*Cucurbita moschata* Duch. ex Poir.) belongs to the family Cucurbitaceae is a very important and popular vegetable due to the delicious young leaves, flowers, immature and mature fruits and long storability. This vegetable is a good source of vitamins, minerals, fibers, antioxidants, and high medicinal values. The total area under cultivation of sweet gourd in Bangladesh is 0.028 million ha, with a total production of 0.32 million tons in 2018-19 with an average yield of 11.4 tons/ha (Bangladesh Bureau of Statistics (BBS), 2020).

Salinity is a major constraint to vegetable production in the southern districts of Bangladesh. Researchers are trying hard to get the salt tolerant vegetable variety to meet the demand of country people. Excessive soil salinity reduces the productivity of many agricultural crops, including most vegetables, which are particularly sensitive throughout the ontogeny of the plant (Machado and Serralheiro, 2017). Most of the literature indicates that vegetable crops are more sensitive to salt at the vegetative stage than germination. Examples are reported in pumpkin and winter squash (Balkaya *et al*., 2016), melon (Botia *et al*., 1998) pepper (Chartzoulakis and Klapaki, 2000), spinach (Wilson *et al*., 2000), tomato (Del Amor *et al*., 2001), cabbage (Jamil and Rha, 2004) and watermelon (Yetisir and Uygur, 2009). In terms of salt tolerance, genotypic variations were found in pumpkin cultivars in Turkey (Balkaya and Kandemir, 2015). Pumpkin can be grown on unproductive land without irrigation in many regions of Bangladesh. Therefore, pumpkin growing can be considered a suitable alternative for the problem of salinity or drought in areas (Sevengor *et al*., 2011; Kurtar *et al*., 2016). The objective of the present study was to identify the differences in salt tolerance of sweet gourd (*Cucurbita moschata* Duch) by using growth and ion accumulations.

MATERIALS AND METHODS

Planting materials

In this study 14 sweet gourd inbred lines were used (P_1 = BARI Mistikumra-1, P_2 = CM-31-2-4-5-1, P_3 = CM-31-1- 1-12-1, P_4 = CM-75-5-4-2-5, P_5 = CM-31-5-4-2-4, P_6 = CM-34-4-12-9, P_7 = CM-5-4-12-6, P_8 = CM-3-5-4-2-1, P_9 = CM-31-5-4-2-1, P_{10} = CM-3-5-4-2-1-5, P_{11} = BARI Mistikumra-2, P_{12} = CM-75-4-2-1, P_{13} = CM-71-9-B-1 and P_{14} = CM-35-4-2-1-5. These genetic materials were collected from vegetable division of Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

Experimental site and growth conditions

This study was carried out in semi control conditions besides the net house of the Plant Physiology Section, Horticulture Research Centre, Bangladesh Agricultural Research Institute. The experimental area belongs to sub-tropical climatic zone that are characterized by high temperature, low sunshine hour and heavy rainfall during April-September and low temperature, high sun-

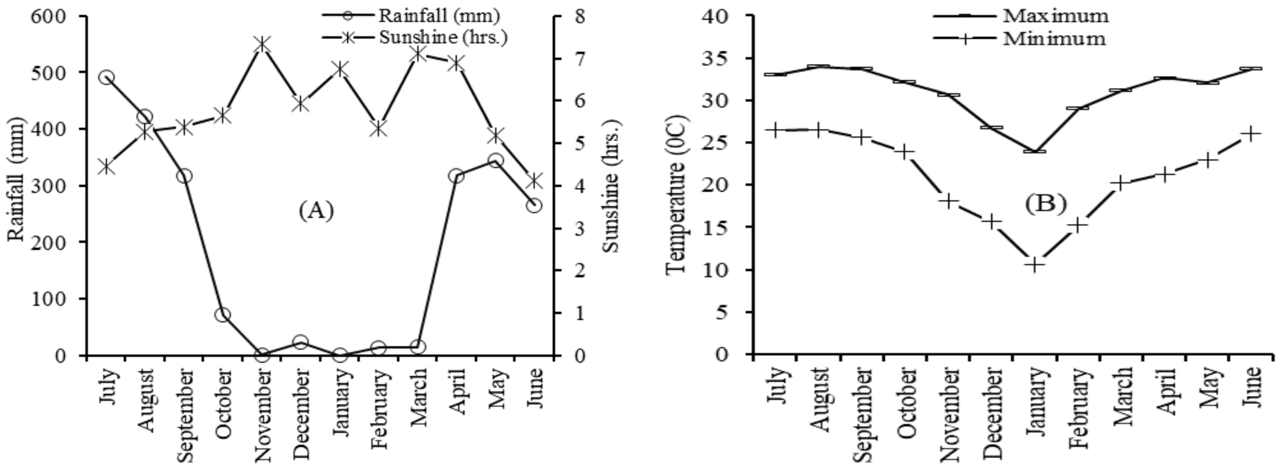


Fig. 1. *Monthly average rainfall, sunshine hours (A) and maximum, minimum temperature (B) of the experimental site during the period from July 2017 to June 2018.*

shine hour and scarce rainfall from October to March (Fig. 1A, 1B) which were favourable for sweet gourd plants. The average temperature during the experimental period was 25.14ºC. Seeds were germinated in a mixture of soil: cow dung 2:1 ratio after 15 days of sowing, seedlings were transferred to plastic pots containing 22 kg air-dried soil (including cow dung 1/4th of the soil volume). The nutrient was ensured by adding a recommended dose of fertilizer (Urea-30g, TSP-90g, MoP-25g, Gypsum-50g, Zn Sulphate-6.5g, Boric acid-6g and MgSO-30g used as a supplement of N, P, K and S, Zn, B, Mg respectively during soil preparation each pot at least 7-10 days before transplanting) by the Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Institute. 60g Urea and 50g MoP were applied per plant into two splits after transplanting. The bottom of each pot was perforated to facilitate drainage.

Salt treatment and experimental design

Salt solutions were applied when the seedlings attained the 4 to 5 leaves stage. Laboratory grade sodium chloride (NaCl) was used as a salt resource. Salt treatments were applied as EC values of 4, 8, 12 and 16 dS/m and every 3 days' salt solution (NaCl) was applied to attain the required level of salinity. Tap water was used as control (EC was 0.3 dS/m).

Plant growth parameters

At the end of the study, stress responses of the experiment genotypes were evaluated by some growth parameters such as vine length (cm), number of leaves, internode length (cm), and stem diameter (mm).

Determination of sodium and potassium ion contents

At the end of the stress treatment, three plant replicates were gently uprooted and rinsed thoroughly with running water and plants were separated into roots and shoots (stems and leaves). The leaves and roots were dried at 75 ^{0}C for 74 hours to a constant weight. The dried samples were then weighed and powdered. The samples were ground to pass a 20 mesh sieve and digested with a mixture of HNO_3+$HClO_4$ (5:1) using microwave energy. The tissue concentrations of Na^+ and K^+ in leaf blades and roots were measured on a dry weight basis. The concentrations of Na^+ and K^+ were determined directly in percent concentration with atomic absorption spectrophotometer (Spectra-55B, Varian Australia) as described by Peterson (2002).

Statistical analysis

The experimental design was randomized completely block design with three replications. The significance of difference between the pair of means was performed by the Duncan's Multiple Range Test (P=0.05) using MSTATC computer program.

RESULTS AND DISCUSSION

Main vine length

The vine length was significantly (P≤0.05) decreased compared to control plants with the increasing salt concentration doses in all sweet gourd genotypes. Increasing salinity levels antagonistically affected vine length. At 45 days after the salt stress of the study, vine length values were found at lower levels in all genotypes under salt stress compared to the control treatment (Fig. 2. A). Main vine length was increased with the increasing growth period in all genotypes (Fig. 2. B). At 45 days after NaCl application, the highest vine length was found in P_{12} (162.3 cm) followed by P_9 and the lowest vine length was observed in P_2 (126.5 cm), which was identical to P_7.

The performance of fourteen sweet gourd genotypes under control and different level of salinity are shown in Table 1. Significant variation among the genotypes and salt stress treatment was observed for vine length. The

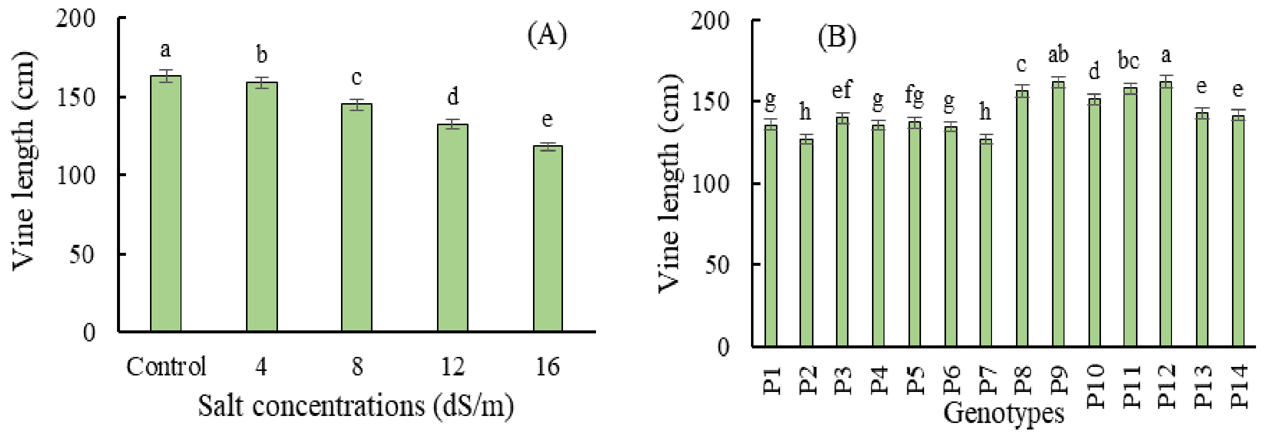


Fig. 2. *Effect of salt stress (A) and genotypes (B) on main vine length of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

Table 1. Combined effect of salt stress and genotypes on main vine length and the number of leaves of sweet gourd

Genotypes	Vine length					Number of leaves				
	NaCl concentrations (dS/m)					NaCl concentrations (dS/m)				
	Control	4	8	12	16	Control	4	8	12	16
P_1	155.2 f	147.0 f	146.8 e	124.7 ef	104.2e-g	22.00	21.33	20.00	18.33	15.33
P_2	147.3 g	140.3 g	127.8 h	114.9 g	102.2 fg	24.67	24.00	23.00	20.67	15.67
P_3	167.5 d	167.3 bc	136.0 g	126.7 e	100.5 g	25.33	24.67	22.67	20.67	18.00
P_4	163.2 e	154.5 e	132.0 g	121.5 f	105.3 ef	26.33	25.67	23.33	20.00	17.67
P_5	168.2 d	155.5 e	142.5 f	115.2 g	103.7 e-g	25.67	24.33	23.33	22.00	17.00
P_6	146.2 g	141.8 g	133.5 g	131.9 d	119.1 c	28.67	27.33	26.67	24.33	22.33
P_7	140.5 h	141.5 g	121.3 i	116.9 g	114.7 d	26.67	25.67	22.33	21.67	17.33
P_8	166.6 de	162.6 d	152.7 d	151.4 b	147.9 a	28.00	27.33	26.67	22.67	21.00
P_9	180.7 a	172.6 a	161.8 b	149.9 b	142.7 b	29.67	28.33	28.00	25.33	23.00
P_{10}	172.1bc	171.2 ab	166.8 a	140.9 c	105.1 ef	26.67	25.33	24.67	21.67	17.67
P_{11}	164.9 de	166.2 cd	156.8 c	151.4 b	149.5 a	31.00	29.33	28.33	26.67	24.33
P_{12}	172.6 b	169.5 a-c	167.0 a	163.2 a	139.2 b	28.33	27.33	26.67	26.67	23.67
P_{13}	173.1 b	165.3 cd	148.0 e	115.2 g	111.7 d	28.67	28.00	25.00	20.00	16.00
P_{14}	168.1 cd	167.8 bc	134.6 g	128.0 e	107.7 e	29.00	27.67	26.00	24.67	22.33
Level of significance	**					NS				

** indicates significant at 1% levels of probability; NS = Not significant. Means with different letters indicate significant differences (P=0.05) by Duncan's Multiple Range Test.

salinity effect reduced the growth rate as compared to the control. The genotype P_9 (180.7 cm) gave the maximum vine length at control and the minimum was in P_7 (140.5 cm). The genotypes performed very poorly regarding vine production under varied saline conditions. At 4 dS/m, P_9 also gave the highest vine length (172.6 cm), followed by P_{10}, P_{12} and the lowest vine length was found in P_2 (140.3 cm). But at 8 and 12 dS/m, P_{12} gave the highest vine length (167.12 cm, 163.2 cm), whereas the minimum in P_2 (127.8 cm, 114.9 cm). At 16 dS/m P_{11} gave the maximum vine length (149.5 cm) identical to P_8 and minimum in P_3 genotypes (100.5 cm).

Number of leaves

Salt treatment had a significant ($P \leq 0.05$) effect on the number of leaves per plant. The result shows a decreasing trend in the number of leaves at salt treatment. The control treatment gave the maximum result and when the salinity level was above 4 dS/m, the number of leaves was also lower than control, and 16 dS/m gave the minimum number of leaves per plant in all genotypes (Fig. 3. A).

The number of leaves per plant of the sweet gourd genotypes also showed significant variability. The number of leaves of sweet gourd genotypes ranged from 19.40 to 27.93. The genotype P_{11} recorded a maximum number of leaves per plant (27.93), followed by P_9 and $P_{12,}$ whereas the genotype P_1 recorded the lowest number of leaves (19.40) (Fig; 3. B).

The performance of fourteen sweet gourd genotypes under control and different level of salinity are shown in Table 1. There was no significant variation among the salt treatment and genotype effects, but the number of leaves decreased with the increasing levels of salt treatment.

Internode length (cm)

Salt treatment had a significant effect on internode length. The result showed decreasing trend in the internode length at salinity treatment. The control treatment gave the maximum result and when the salinity level was 16 dS/m, internode length was also lower (Fig. 4. A).

The genotypes also showed significant variability. The internode length of sweet gourd genotypes ranged from 8.37 cm to 9.90 cm, with an average 9.23 cm. The genotype P_6 recorded the maximum internode length (9.90 cm) followed by P_8, P_9 and P_{12}, whereas the genotype P_3 recorded lowest internode length (8.37 cm) (Fig. 4.

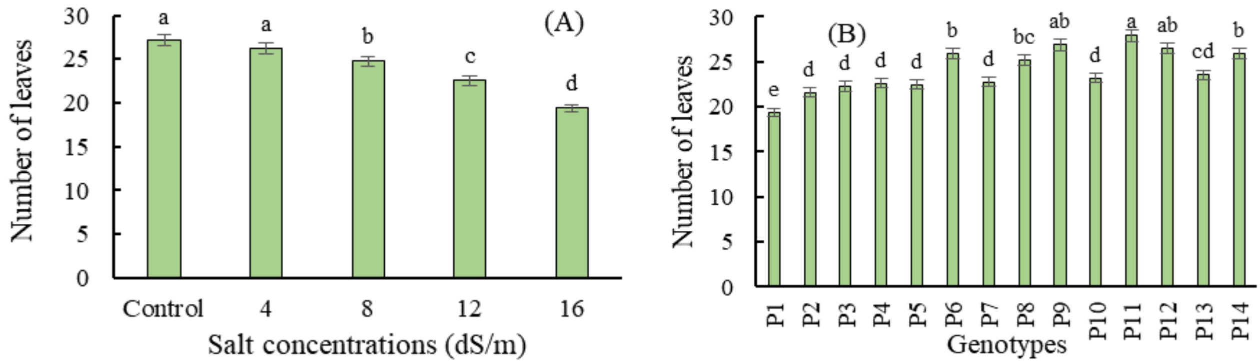


Fig. 3. *Effect of salt stress (A) and genotypes (B) on leaves number of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

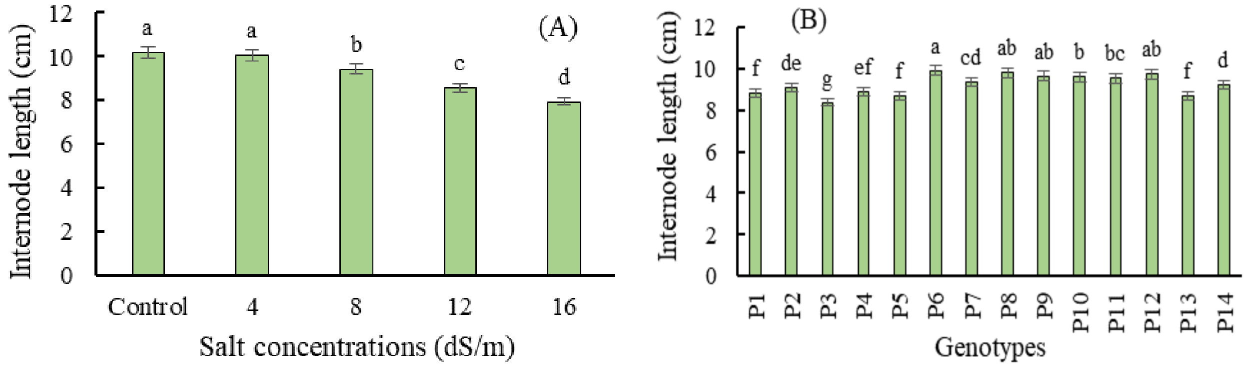


Fig. 4. *Effect of salt stress (A) and genotypes (B) on internode length of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

B).

The combined effects of sweet gourd genotypes and different salt treatments on internode length are shown in Table 2. The salinity effect reduced the growth rate as compared to the control. The genotype P_2 gave a maximum internode length (11.33 cm) identical to P6 and the minimum was in P_{13} (9.50 cm) in the control treatment. At 4 dS/m, P_2 also gave the maximum internode length (10.67 cm), followed by P_6, P_7, P_9 and $P_{14,}$ but at 8 dS/m, P_8 gave the maximum internode length (10.00 cm), followed by P_{10} whereas P_3 gave minimum (8.66 cm). At 12 dS/m, P_{12} (9.67 cm) gave the maximum internode length, which was identical to P_{10}, P_{11} and the lowest internode was found in P_2 (7.66 cm) genotype, but at 16 dS/m, P_{12} (9.83 cm) gave the maximum internode length which was identical with P_8 and minimum was found in P_3 (6.33 cm) followed by P_5.

Stem girth (mm)

Effect of salt treatment had a significant effect on stem girth. Control and 4 dS/m treatment showed significantly better results compared to high salt treatment. In the control treatment, the stem girth was 16.42 mm. But when the salinity level increased, stem girth was decreased and at 16 dS/m, it was recorded as 15.06 mm (Fig. 5. A).

Stem girth of the sweet gourd genotypes also showed significant variability. The maximum stem girth was recorded in P_{11} (16.32 mm) sweet gourd genotype, whereas the shortest stem girth was recorded in P_3 and P_7 (15.71 mm) (Fig. 5. B).

Stem girth of sweet gourd varied significantly ($P \leq 0.05$) among the genotype and different levels of salinity shown in Table 2. The salinity effect reduced the growth rate as compared to the control. In the control treatment, the genotype P_2 gave maximum stem girth (16.78 mm). At 4 dS/m P_{12} gave maximum stem girth (16.57 mm) identical to P_{13}. Stem girth was decreased with the increasing level of salinity. At 8 dS/m, the highest stem girth was recorded in P_{12} (16.43 mm) genotype followed by P_5, P_{13} and the minimum was in P_3 (16.03 mm). At 12 dS/m and 16 dS/m, P_{11} showed better performance than other genotypes.

The vine length, internode length and stem girth were significantly ($P \leq 0.05$) decreased compared to control plants with the increasing salt concentration doses in all sweet gourd genotypes. Increasing salinity levels antagonistically affected vine length. The plants have lower growth rates and their leaves are mostly small, with a dark green colour in salt stress (Greenway and Munns, 1980).

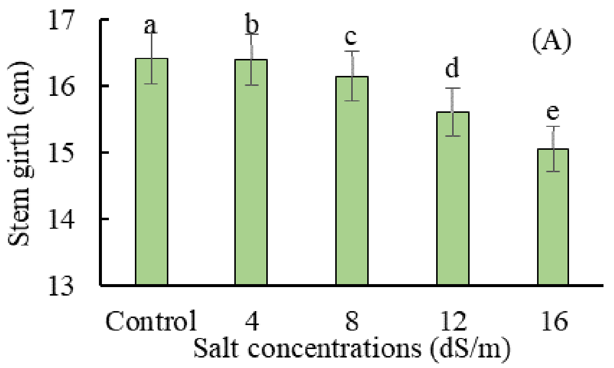
Table 2. Combined effect of salt stress and genotypes on internode length and stem girth of sweet gourd

Genotypes	Internode length (cm)					Stem girth (mm)				
	NaCl concentrations (dS/m)					NaCl concentrations (dS/m)				
	Control	4	8	12	16	Control	4	8	12	16
P_1	10.17 cd	10.00 de	9.17 e	8.00 d	6.66 f	16.46 cd	16.17 f	16.05 d	15.98 bc	14.12 g
P_2	11.33 a	10.67 a	9.17 e	7.66 e	6.67 f	16.78 a	16.40b-e	16.32 bc	15.28 f	14.12 g
P_3	9.50 g	9.17 h	8.66 f	8.16cd	6.33 g	16.56 b	16.47 b	16.03 d	15.35 ef	14.17 g
P_4	10.00 de	9.50 g	9.33de	8.17cd	7.33 e	16.42 c-e	16.30 e	16.08 d	15.27 f	15.32 cd
P_5	10.00 de	9.67 fg	9.16 e	8.16cd	6.50 fg	16.30 fg	16.41b-d	16.40	15.38 e	15.02 f
P_6	11.07 a	10.50 ab	9.66bc	9.00 b	9.16 b	16.40 d-f	16.40b-e	16.25 c	16.03 b	15.46 b
P_7	10.33 c	10.50 ab	9.67bc	8.00 d	8.17 d	16.35 ef	16.05 g	16.50 e	15.40 e	15.28 cd
P_8	10.00 de	10.17 cd	10.00a	9.50 a	9.33 a	16.31 fg	16.19 f	16.23 c	15.45 e	15.50 b
P_9	10.17 cd	10.50 ab	9.50cd	9.16 b	8.83 c	16.36 ef	16.36 c-e	16.26 c	15.40 e	15.35 c
P_{10}	10.17 cd	10.33 bc	9.83ab	9.00 a	8.67 c	16.44 c-e	16.35 de	16.04 d	15.38 e	15.23
P_{11}	9.83 ef	9.83ef	9.67bc	9.50a	8.83 c	16.38 d-f	16.45 bc	16.29 c	16.58 a	15.87 a
P_{12}	9.67 fg	9.83 ef	9.67bc	9.67 a	9.83 a	16.51 bc	16.57 a	16.43 a	15.92 c	15.15 e
P_{13}	9.50g	9.67 fg	9.16 e	7.50 e	7.50 e	16.37 d-f	16.56 a	16.40	15.40 e	14.95 f
P_{14}	10.67 b	9.50 ab	9.17 e	8.33 c	7.51 e	16.22 g	16.15 f	16.07 d	15.56 d	15.26 cd
Level of significance	**					**				

** indicates significant at 1% levels of probability. Means with different letters indicate significant differences (P=0.05) by Duncan's Multiple Range Test

Plant height was significantly lower than the control (all sweet gourd genotypes) in this experiment, which is according to cabbage with Jamil and Rha (2004). Rahaman *et al*. (2018) reported that higher salinity levels and lower plant heights indicated the adverse effects of salinity on plant growth and its physiological process under saline environment and the growth of higher plants in saline soil depends on the salt tolerance of the plants' species. It is reported that saline soil induces physiological and metabolic disturbances in plants, affecting development, growth, yield, and general symptoms of damage by salt stress are growth inhibition, accelerated development and senescence and death during prolonged exposure (Jouyban, 2012).

Salinity affects potato growth and productivity, causing an imbalance in plant physiological processes (Abdelsalam, 2021). There was a significant difference found in terms of plant height of different turmeric genotypes. Plant height increased with time, but growth was lower than the control (Sagor *et al*., 2021). Habib *et al*. (2018) reported that plant height was decreased with the increase of salinity. Salinity also stunts root and stem elongation (Dash and Panda, 2001; Ashraf *et al*., 2002). The response of vegetables to increased amounts of salts was primarily stunted growth (Romero-Aranda *et al.,* 2001). Salt stress significantly reduced shoot and root growths, leaf area, photosynthetic activity, and leaf chlorophyll and carotenoid contents of melons (Ulas *et al*., 2020). Salinity stress significantly reduced all studied parameters of carrot crops as com-



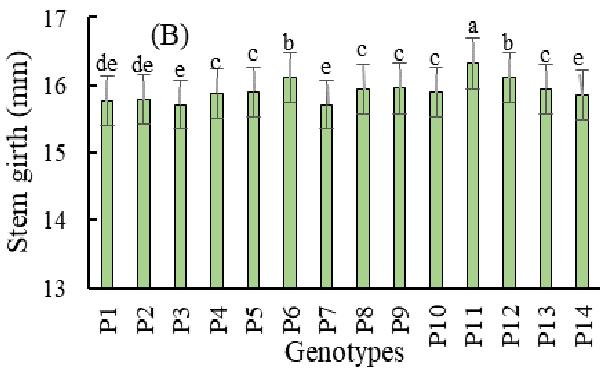


Fig. 5. *Effect of salt stress (A) and genotypes (B) on stem girth of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

Table 3. Combined effect salt stress and genotypes on Na^+ and K^+ in roots of sweet gourd

Genotypes	Na^+ in root					K^+ in root				
	NaCl concentrations (dS/m)					NaCl concentrations (dS/m)				
	Control	4	8	12	16	Control	4	8	12	16
P_1	0.17 a	0.24 ab	0.34 bc	0.91 a	1.25 a	1.67 f	1.56 h	1.37 d	1.25 d	0.97 e
P_2	0.19 a	0.25 ab	0.37 ab	0.83 b	1.24ab	1.73 e	1.58gh	1.25 g	1.09f	0.97 e
P_3	0.15 a	0.20 bc	0.39 ab	0.88 a	1.13 d	1.58 g	1.47 i	1.12 j	1.00 h	0.92 f
P_4	0.19 a	0.24 ab	0.40 a	0.92 a	1.20bc	2.04 c	1.83 e	1.14 ij	1.00 h	0.99de
P_5	0.17 a	0.25 ab	0.38 ab	0.93 a	1.18cd	2.02 c	2.00 c	1.17 hi	1.04gh	1.00de
P_6	0.18 a	0.24 ab	0.30 c	0.69 c	0.69 h	2.09 b	2.01 c	1.79 a	1.53 a	1.44 a
P_7	0.19 a	0.26 a	0.38 ab	0.90 a	0.90 ef	1.75 e	1.61fg	1.19 h	1.00 h	0.79 g
P_8	0.18 a	0.20 a-c	0.30 c	0.68 c	0.87 f	2.03 c	1.80 e	1.38cd	1.25 d	1.21 c
P_9	0.16 a	0.21 a-c	0.31 c	0.69 c	0.86 f	1.65 f	1.62 f	1.42 c	1.33 c	1.22 c
P_{10}	0.18 a	0.25 ab	0.39 ab	0.92 a	1.15 d	2.02 c	1.89 d	1.29 f	1.16 e	1.02 d
P_{11}	0.16 a	0.18 c	0.29 c	0.70 c	0.92 e	2.11 b	2.07 b	1.75 b	1.41 b	1.34 b
P_{12}	0.17 a	0.21 a-c	0.32 c	0.65 c	0.86 f	2.43 a	2.38 a	1.33 e	1.31 c	1.21 c
P_{13}	0.17 a	0.25 ab	0.42 a	0.92 a	1.25 a	1.81 d	1.60f-h	1.27fg	1.14 e	0.80 g
P_{14}	0.17 a	0.24 ab	0.30 c	0.66 c	0.86 f	2.05 c	2.02 c	1.21 h	1.07fg	1.00de
Level of significance	**					**				

** indicates significance at 1% levels of probability. Means with different letters indicate significant differences (P=0.05) by Duncan's Multiple Range Test.

pared to control (Jahan *et al*., 2019). High levels of salinity affect plant growth by water deficit (osmotic stress), ion toxicity and ion imbalance (ionic stress) or a combination of these factors (Lauchli and Grattan, 2007).

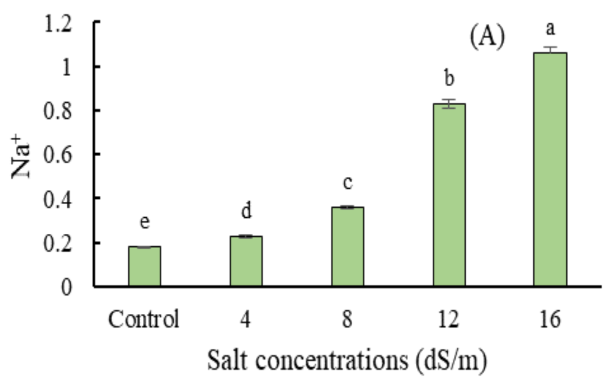
Salinity affects emergence, growth, and plant and is subjected to salt stress. Vegetables are considered sensitive plants; therefore, any increment in salinity levels can reduce their production, both in quality and quantity. However, these reductions occur according to the varieties used because these studies demonstrate that some of the evaluated genotypes are more tolerant to salinity than others.

Na^+ in root

In this study, salt stress treatment had a significant variation on Na^+ in the root. According to the results, Na^+ was significantly increased compared to control (Fig. 6. A). The highest Na^+ was recorded at 16 dS/m (1.06) and gave the lowest value (0.18) in control treatment.

At the end of the stress, Na^+ was increased in all genotypes (Fig. 6. B). In this study, the highest Na^+ ion was found in P_5 (0.60), whereas the lowest was observed in P_8 (0.45), which was identical to P_6, P_9, P_{11}, P_{12} and P_{14}. These genotypes were found to be more selective than other genotypes.

Na^+ ion contents of genotypes showed large variation compared to control (Table 3). In control, all genotypes showed identical values. But at 4 dS/m maximum Na^+ was found in P_7 (0.26) and minimum in P_{11} (0.18). At high saline conditions, Na^+ increased with the increasing salinity level. At 8 dS/m, 12 dS/m and 16 dS/m salt stress, P_{13} gave the maximum Na^+ ion (0.42, 0.92 and 1.25) and P_6 showed minimum Na^+ ion (0.30, 0.69 and 0.65).



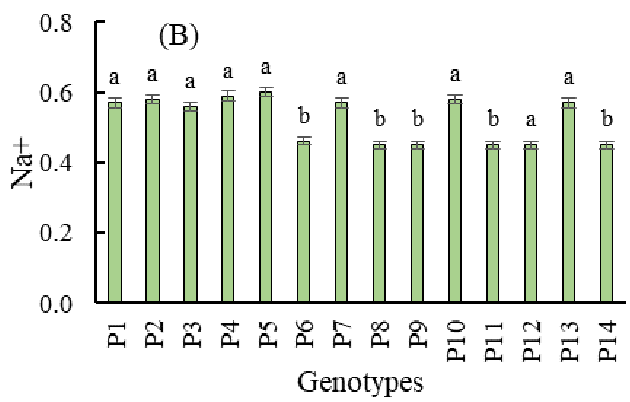


Fig. 6. *Effect of salt stress (A) and genotypes (B) on Na^+ in root of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

K^+ in root

The effect of salt stress on K^+ ion accumulation in the study was significant. In the study K^+ concentration in the root decreased with the increasing salinity levels (Fig. 7. A). Control treatment recorded the highest K^+ in the root (1.93), while 16 dS/m recorded the lowest K^+ concentration in the root (1.07).

In this study, K^+ ion was significantly influenced by all the genotypes in the root. At the end of the salt treatment, K^+ ion values were decreased in all sweet gourd genotypes. These values were found 1.27 to 1.78 (Fig. 6. B). The highest K^+ ion was found in P_6 (1.78) genotype, whereas the lowest was in P_3 (1.22) (Fig. 7. B).

In this study, K+ in the root, salt stress and genotypes were significantly influenced by K^+ in the root. K^+ in all genotypes decreased by salt stress treatment compared to control (Table 3). All genotypes showed the highest K+ in control compared to salt stress treatment. At high saline conditions, K^+ decreased with the increasing salt stress treatment. In control and 4 dS/m, P_{12} gave the maximum K^+ in the root (2.43 and 2.38) and minimum (1.67 and 1.56) in the P_1 genotype. At 8 dS/m, 12 dS/m and 16 dS/m salt stress treatment P_6 (1.79, 1.53 and 1.44) gave the highest K^+ ion in root. P_6 genotypes had the maximum protecting ability of its K^+ ion content.

Na^+ in leaves

Salt stress caused significant increases in Na^+ concentration of leaves in all genotypes compared with control. In control treatment gave the lowest Na^+ in leaf (0.15) and 16 dS/m gave the highest Na^+ (0.31) (Fig. 8. A).

Na^+ ion contents of sweet gourd genotypes showed large variation (Fig. 8. B). Genotypes were significantly influenced by Na^+ ion in leaves. The highest Na^+ ion was found in P_3 (0.24) followed by P_4, whereas the lowest was in P_{11} (0.16).

Salt stress and genotypes were significantly influenced by Na ion in leaves (Table 4). In the control condition, maximum Na ion was found P_2 (0.17) genotypes followed by P_3, P_4, P_5, P_7, P_{10} and the minimum value was found in P_6 (0.13) which was identical with P_8, P_9, P_{11}, P_{12} and P_{14}. At 4 dS/m P_2 (0.18) showed highest Na^+ ion whereas P_{14} (0.12) showed minimum. But at high saline conditions, Na^+ increased with the increasing salinity level. At 8 dS/m, P_{11} (0.14) showed minimum Na^+ ion in leaves and maximum in P_2 genotypes (0.21) followed by P_4, P_{10}. At 12 dS/m P_3 genotype showed the highest (0.33) and lowest in P_8 (0.17), but at 16 dS/m, maximum Na ion was found in P_1 (0.38) genotypes

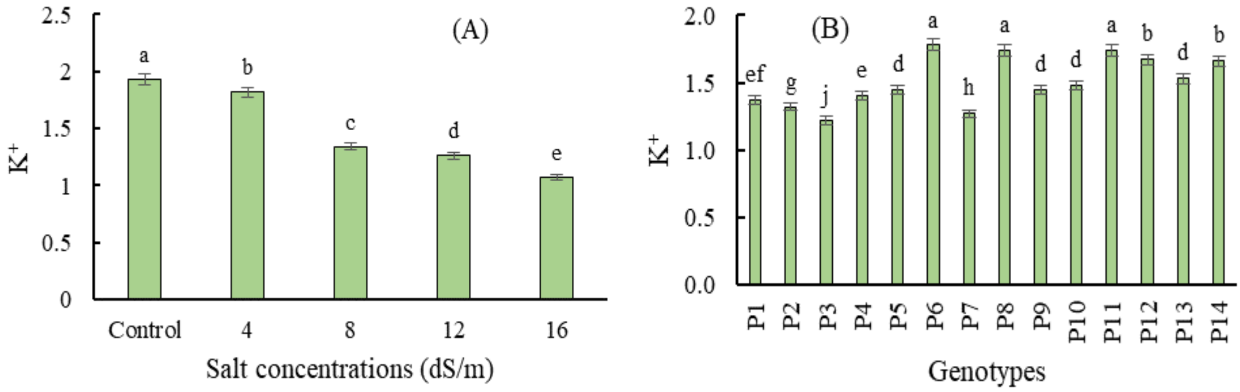


Fig. 7. *Effect of salt stress (A) and genotypes (B) on K^+ in root of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

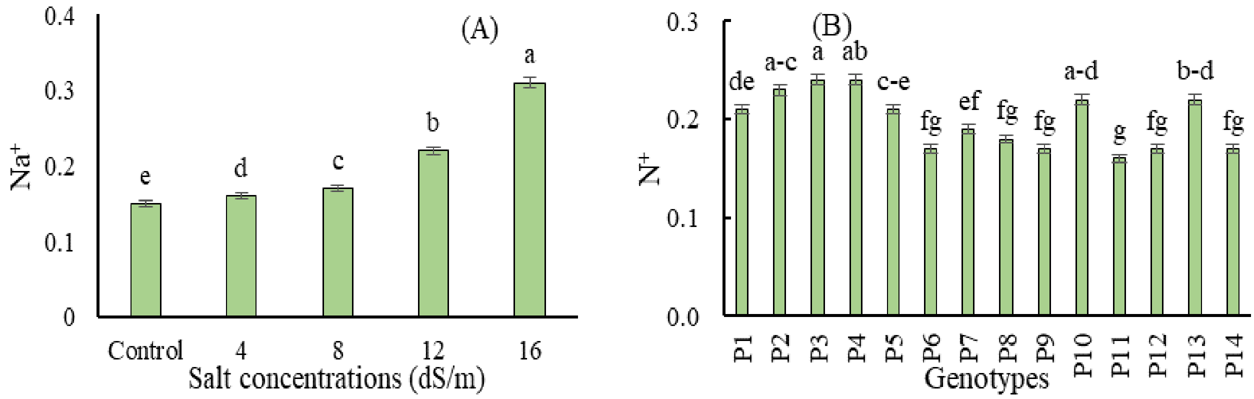


Fig. 8. *Effect of salt stress (A) and genotypes (B) on Na^+ in leaves of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

Table 4. Combined effect of salt stress and genotypes on Na^+ and K^+ in leaves of sweet gourd

Genotypes	Na^+ in leaves NaCl concentrations (dS/m)					K^+ in leaves NaCl concentrations (dS/m)				
	Control	4	8	12	16	Control	4	8	12	16
P_1	0.14b-d	0.13b-d	0.17 c-e	0.22 d	0.38 a	1.67 f	1.59de	1.47 b	1.25 ef	1.03fg
P_2	0.17 a	0.18 a	0.21 a	0.25 bc	0.40 a	1.58 g	1.56 ef	1.33 d-f	1.09 hi	1.32bc
P_3	0.16 ab	0.16 b	0.18 bc	0.33 a	0.25 de	1.51 g	1.49fg	1.25 fg	1.04 i	1.18de
P_4	0.16 ab	0.18 a	0.20 ab	0.27 b	0.23 e	2.19 b	1.29 h	1.26 e-g	1.07 i	1.01 e
P_5	0.15 a-d	0.15 bc	0.16 c-e	0.19 ef	0.35 b	2.03 cd	2.01 b	1.22 g	1.09 hi	1.14 e
P_6	0.13 d	0.13b-d	0.15 e	0.19 ef	0.34 b	2.07 cd	2.02 b	1.74 a	1.53 b	1.01 g
P_7	0.14 a-d	0.15 bc	0.17 c-e	0.21 de	0.38 a	1.58 g	1.57 e	1.23 g	1.04 i	0.98 g
P_8	0.12 d	0.13 cd	0.15 de	0.17 f	0.18 f	2.22 b	1.47g	1.35 c-e	1.40 c	1.00 g
P_9	0.12 d	0.14b-d	0.17 c-e	0.19 ef	0.19 f	1.67 f	1.45 g	1.42 bc	1.38cd	1.04fg
P_{10}	0.16 a-c	0.19 a	0.21 a	0.25 bc	0.24 de	2.00 d	1.82 c	1.30 e-g	1.16gh	0.88 h
P_{11}	0.13 cd	0.14b-d	0.14 e	0.18 ef	0.24 de	2.11 c	2.02 b	1.91 a	1.73 a	1.39ab
P_{12}	0.13 d	0.15 bc	0.15 de	0.19 ef	0.25 de	2.07 cd	2.40 a	1.39 cd	1.32de	1.23 d
P_{13}	0.13b-d	0.14b-d	0.17b-d	0.25 bc	0.26 d	2.32 a	1.66 d	1.27 e-g	1.18fg	1.25cd
P_{14}	0.12 d	0.12 d	0.16 c-e	0.23 cd	0.30 c	1.75 e	2.09 b	1.39 cd	1.38cd	1.40 a
Level of significance	**					**				

** indicates significance at 1% levels of probability. Means with different letters indicate significant differences (P=0.05) by Duncan's Multiple Range Test.

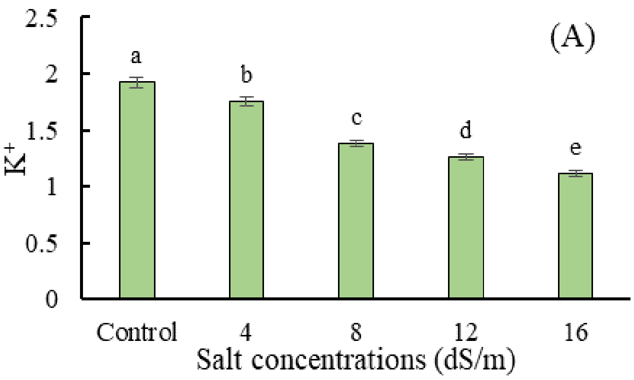
which were identical to P_2 genotypes and the minimum was found in P_8 (0.18) genotype which was identical with P_9.

K^+ in leaves

Salt stress caused significant decreases in K^+ concentration of leaves compared with control. The control application recorded the highest K^+ in leaves (1.92), while 16 dS/m application had the lowest K^+ (1.11) concentration in leaves (Fig. 9. A). K^+ ion contents of genotypes showed large variation (Fig. 9. B). P_6, P_{11}, P_{12} had the maximum K^+ ion content (1.75, 1.74, 1.68), whereas the lowest value of K^+ content was determined in P_7 (1.26). These genotypes had the maximum protecting ability of their K^+ content.

K^+ in all genotypes decreased by salt stress treatment compared to control in leaves (Table 4). All genotypes showed the highest K+ compared to salt stress in the control condition. The P13 (2.32) genotype gave maximum K ion in the control condition, whereas the minimum was in P3 (1.51), identical to P_2 and P_7 genotypes. At 4 dS/m maximum K ion was found in P_{11} (2.40) whereas minimum in P_4 (1.29) genotype. At high saline condition, K^+ decreased with the increasing salinity level. At 8 dS/m, 12 dS/m and 16 dS/m salinity level P_{11} (1.91, 1.73 and 1.39) showed highest K^+ ion in leaves. In this study, the genotype P_{11} accumulated a relatively larger quantity of K^+ ions in their texture than other genotypes.

Plants provide their balance with the help of inorganic ions under salt stress. The osmotic potential in the cell increases and more water can enter the cell by taking K^+ with active absorption and accumulation in plants. Therefore, K^+ content in the cell is important for the



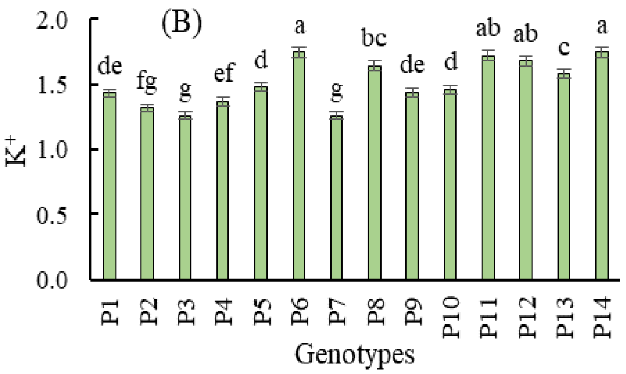


Fig. 9. *Effect of salt stress (A) and genotypes (B) on K^+ in leaves of sweet gourd. Bars with different letters are significantly different (P=0.05) by Duncan's Multiple Range Test.*

maintenance of osmotic equilibrium. Romero *et al*. (1997) reported that increasing Na^+ concentration in leaves causes K^+ deficiency due to the antagonist effect of Na^+ and K^+ ions. Excessive sodium ions at the root surface disrupt plant potassium nutrition. Because of the similar chemical nature of sodium and potassium ions, sodium has a strong inhibitory effect on potassium uptake by the root (Almeida *et al*., 2017; Zhu, 2002).

Salt stress, showing an imbalance in the content of Na^+ and K^+, was observed in the form of lower ratios of K^+/ Na (Hnilickova *et al*., 2019). High Na^+ concentration inhibits the uptake of $K^{+,}$ which is an essential element for plant growth and development (James *et al*., 2011). The salt stress treatment increased leaf and root Na ion concentration. Previous studies showed similar effects of salinity in cucumber (Usanmaz and Abak, 2019), eggplant (Talhouni *et al*., 2019), cucumber (Soubeih *et al*., 2018), maize (Karmoker *et al*., 2008), pepper (Chartzoulakis and Klapaki, 2000) and watermelon (Yetisir and Uygur, 2009).

As found with K^+ concentration in leaves and roots was also decreased by the salt stress treatment. Previous studies showed similar effects of salinity in maize (Karmoker *et al*., 2008), pepper (Chartzoulakis and Klapaki, 2000), and watermelon (Yetisir and Uygur, 2009). Several studies with a wide variety of horticultural crops have shown that the K+ concentration of plant tissue declines as the salinity in the root media increases (Perez-Alfocea *et al*., 1996). In increasing concentrations of salts, some species-specific symptoms may be present, such as necrosis and burns of leaf edges due to the accumulation of Na^+ and Cl^- ions (Wahome, 2001). High NaCl concentrations act antagonistically to the uptake of the other nutrients, such as K^+, Ca^{2+} (Cramer *et al*., 1991, Grattan and Grieve, 1999).

The accumulation of Na^+ and Cl^- cells is extremely toxic and can affect all plant mechanisms and enzymatic actions (Ahmed *et al*., 2020). In the present study, the genotypes P_6, P_8, P_9, P_{11}, P_{12} and P_{14} accumulated a relatively lower quantity of Na^+ ions in their texture. These genotypes have been found to be more selective in terms of salt ion content. Munns (2002) reported that salt-resistant plants had received Na and Cl ions to their texture at lower rates than sensitive plants. Salinity is critical abiotic stress limiting crop production. Sweet gourd may be grown with salinity problems in coastal areas of Bangladesh. In this study sweet gourd inbred exposed to salt stress at increasing EC levels (4, 8, 12 and 16 dS/m) showed that the growth of sweet gourd was decreased with the increasing level of salt treatment. Na ion increased in all sweet gourd genotypes depending on salt treatments. Na ion accumulation has played an important role in salt resistance. It was found that sensitive sweet gourd genotypes had a maximum amount of Na ion accumulation under salt stress. These results showed that salt-tolerant sweet gourd genotypes had taken more K ion than other genotypes. Thus, six sweet gourd inbred lines (P_6, P_8, P_9, P_{11}, P_{12} and P_{14}) were found as salt tolerant.

Conclusion

Sweet gourd, *C. moschata* is a high yielding and vitamin-rich vegetable. Based on the results of the screening of salt tolerance and yield potential of various inbred genotypes, six sweet gourd genotypes (P_6, P_8, P_9, P_{11}, P_{12} and P_{14}) were found as salt tolerant. These findings suggest that the selected promising salt-tolerant sweet gourd genotypes could be used as rootstock and variety in the near future and used for a breeding programme to develop high yielding varieties in the future for saline prone areas of Bangladesh.

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Conflict of interest

The authors declare that they have no conflict of interest.

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