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Effect of salinity stress on plant growth and root yield of carrot

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Abstract

This study was carried out at Horticulture Farm of Bangladesh Agricultural University, Mymensingh to evaluate the effects of different levels of NaCl salinity on plant growth and root yield of two carrot varieties during the period from November, 2016 to February, 2017. Four levels of NaCl salt concentration *viz.,* 0 (Control), 50, 100 and 150 mM and two varieties of carrot namely *Shundori* and *Kuruda* were used for this pot experiment. The two-factor experiment was laid out in randomized complete block design with three replications. The yield and yield components varied significantly between two carrot varieties and intensity of salt concentration. The maximum plant height (33.92 cm), length of leaves (14.51 cm), fresh weight of leaves (9.62 g), percent dry matter content of leaves (21.25 %), length of root (9.05 cm), diameter (11.24 cm), dry matter content of roots (18.18 %) were produced by *Shundori*. On the other hand, maximum water content of leaves (80.89 %), water content of roots (84.57 %) and weight of roots (10.76 g) were exhibited by *Kuruda*. Most of the studied parameters showed decreasing trends with the highest level of salinity (200 mM NaCl) producing lowest weight of roots (3.93 g). In case of combined effects of variety and salt concentrations, *Kuruda* with control condition produced maximum weight of roots (20.62 g) while the minimum weight of roots (3.53 g) was obtained by the combination of *Kuruda* with the highest level of salt concentration (200 mM NaCl). The result of the experiment revealed that the salinity stress significantly reduced all studied parameters at 100 mM and 150 mM as compared to control and 50 mM NaCl. Therefore, it can be concluded that the variety of *Kuruda* was found as relatively salt tolerant than *Shundori*.

Key words: Growth, yield contributing traits, salt stress, carrot, *Daucus carota* L.

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Introduction

Carrot (*Daucus carota* L.) is a member of the Apiaceae family and considered to be native of Mediterranean region and its cultivation as a crop also began in that region. It is an important vegetable crop in the world. It is usually orange in color, though purple, black, red, white, and yellow cultivars exist. Carrot is a popular root crop from the nutritional point of view. It contains appreciable amount of carotene (10 mg/100 g), thiamine (0.04 mg/100 g), riboflavin (0.02 mg/100 g), carbohydrates (10.6%), protein (0.9 g/100 g), fat (0.2 g/100 g) and vitamin C (3mg/100 g). Sucrose is most abundant in carrot roots with endogenous sugar contents, 10 times more than glucose and fructose. It has got some important medicinal values (Sadhu, 1993). It is believed that eating carrots improves night vision. It is used as salad and as cooked vegetable in soups, stews, and curries etc. and also used for the preparation of pickles, jam, and sweet dishes (Kabir *et al.,* 2000). The popularity of carrot is increasing day by day and very much confined in urban area of Bangladesh.

In the year 2015-2016, the area under carrot cultivation was 1,768 hectares, total production of 15,679 metric tons in Bangladesh (BBS, 2016). However, Rashid and Sarker (1986) reported an average yield 35 tons of carrot per hectare in Bangladesh. This yield is relatively low as compared to other carrot producing countries like Belgium (47.64 t/ha), Netherlands (61.87 t/ha) and Sweden (43.6 t/ha) (FAO, 2012). The bulk production of carrot is obtained during the winter season in Bangladesh. Being a biennial plant, carrot completes its life cycle in 2 years, producing an edible fleshy taproot in the first year and flowers in the second year after passing through a cold season (Yan and Hunt, 1999). The edible root is an enlarged taproot that includes stem, hypocotyl and root tissue. Initially, the absorbing roots develop rather slowly; but as the edible taproot enlarges, it gives rise to a large number of absorbing lateral roots. Fast-growing cultivars mature within three months (90 days) of sowing the seed, while slower-maturing cultivars are harvested four months later (120 days).

Carrot is grown in most of the districts of Bangladesh mainly Dhaka, Manikgonj, Pabna, Rajshahi, Bogra, Dinajpur, Gaibandha, Rangpur and Panchagar. The low yield of carrot in Bangladesh depends on various factors and the irrigation and soil management are very vital factors in increasing the production of carrot. Salinity is a major abiotic environmental constraint to crop production throughout the arid and semi-arid regions of the world (Foolad and Lin, 1997). Salinity can affect growth and yield of carrot by creating osmotic pressure that prevent water uptake or by toxic effects of sodium and chloride ions (Hopper *et al*., 1979). High salinity causes ion imbalance, toxic levels of cytoplasmic sodium, and drought stress (Ward *et al.*, 2003).

Bangladesh is a deltanic country with total area of 1, 47, 570 km^2. About 20% of the world's irrigated lands are affected by salinity (Zhu, 2001). The major part (80%) of the country consists of alluvial deposited by the rivers Padma, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. All these rivers are directly or indirectly connected with the Bay of Bengal. In the recent years, the sea level of our country is gradually increasing and because of this reason salinity is being increased in the soil of the southern part of our country. A one meter sea level rise will affect the vast coastal area and flood plain zone of Bangladesh (Sarwar, 2005). About of 0.83 million hectares of land under saline area remains fallow for about 4-7 months (middle November-June) in each year (Karim *et al*., 1990).

In an experiment, Yadav *et al.* (1998) showed that carrot can tolerate low salinity condition. But the highest salinity condition (16 dS/m) reduces the plant height, leaf length, fresh weight of leaves and root weight. Salt induces growth reduction of plant which poses major problem in crop productivity in the places where the lands are affected by salt (Chatterjee and Majumder, 2010). Considering the above statements it is necessarily important to find out salt tolerant carrot variety for cultivation in saline prone areas of Bangladesh. Therefore, this study was conducted to find out the effects of different levels of salinity stress on plant growth and root yield of carrot.

Materials and Methods

This pot experiment was conducted at Horticulture Farm of Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from November, 2016 to February, 2017. The experimental area is located at 24.6°N and 90.5°E latitude. The elevation of the area is approximately 18m from average sea level. The climate of the experimental area was sub-tropical, characterized by heavy rainfall during the months of April to October and scanty rainfall during November to March (Anonymous, 1999). The average maximum and minimum temperature of the shade house was recorded 29.5°C and 12.84°C, respectively.

***Treatment and experimental design*:** The two-factor experiment consisted of two varieties of carrot namely

V_1:*Shundori*, V_2:*Kuruda* and four levels of salinity stress viz., T_0:0 mM (Control), T_1:50 mM, T_2:100 mM and T_3:150 mM NaCl solution. The study was carried out following randomized complete block design with three replications. The size of plastic pots was 30cm × 20cm. The pots were cleaned before use with washing powder followed by ringing with tap water. Pot mixture was prepared @ 3:1 ratio of soil and well decomposed cowdung and also added with chemical fertilizers. Thereafter, pots were filled with pot mixture (10 kg mixture/pot). Four levels of salt solutions (0, 50, 100 and 150 mM) were prepared using NaCl salt (laboratory grade) with tap water. Before sowing, the seeds were soaked in water for 24 hours in a piece of thin cloth. Seed priming will assist uniform germination. Seeds were put on a sheet of paper for drying before sown in the pot. Seeds were sown on 1st November, 2016. Healthy and disinfected 30 seeds of each variety were sown in each pot at a depth of 1.5 cm. After sowing, the pots were covered with banana leaf. Seed germination was completed within 10 DAS thereafter excess plants were thinned out remaining 5 plants per pots. It was done twice at 15 and 30 DAS maintaining at a spacing of 10 cm for proper growth and development of plants. Recommended doses of Urea, TSP and MoP were applied at 33 days after seed sowing (DAS). Different soil salinity treatments were applied at 33 DAS. To make saturation of the pot soil, 300 ml salt solution was needed per pot. In case of control pots 300 mL tap water was applied. Weeding was done three times at 15, 30 and 55 DAS to keep the pots free from weeds. Moreover, mulching was done by breaking the crust of the soil for easy aeration and to conserve soil moisture as when needed especially after irrigation. Dithane M-45 @) 2g/L of water was applied to the seedlings after three weeks of germination to keep them diseases free. Harvesting of the crop was done by uprooting the plants manually. The soil and fibrous root adhering to the roots were removed after harvesting.

***Collection of data on different parameters*:** Data on the following parameters were recorded from the sample plants during growing period and after harvesting of carrot.

***Plant height and leaf length*:** Plant height and leaf length were measured periodically by using measuring scale at 7 days intervals from 33 to 103 DAS.

***Fresh weight of leaves and roots*:** Leaves were detached by sharp knife after harvest from the selected plants and fresh weight of leaves and roots were recorded using digital balance and express in grams (g).

***Dry matter content of leaves and roots*:** Twenty five grams (25 g) of fresh leaves and roots were cut into small pieces and air dried at laboratory. Air dried samples were then put in paper packets and oven dried for 72 hours at 80^{o}C in an electric oven. The dried samples were weighted by an electrical balance and percent dry matter content of was calculated using the formula: % dry matter content = 100 - % moisture content

***Water content of leaves and roots*:** Percent water content of leaves and roots were calculated by using the following formula**:**

$$\%\ water\ content = \frac{Fw - Dw}{Fw}\ x\ 100$$

Where, Fw= Fresh weight (g), Dw= Dry weight (g)

***Root fresh weight, length and diameter*:** After harvesting and cleaning of **c**arrot, fresh weigh of roots was taken by digital balance and expressed in grams (g). Then the length of roots was measured by a measuring scale. Diameter of root was recorded by slide calipers and expressed in centimeter (cm).

***Statistical analysis*:** The data obtained from the experiment were statistically analyzed by MSTAT computer program. The mean value for all parameters is calculated and the analysis of variances for the characters was accomplished by F variance test. The significance of difference between pair of means was tested by the least significant difference (LSD) test at 5% and 1% levels of probability (Gomez and Gomez, 1984).

Results

***Plant height*:** Plant height varied significantly with the varieties at different days after sowing (DAS) i.e. at 33, 40, 47, 54, 61, 68, 75, 82, 89, 96 and 103 DAS. In all stages of growth, variety significantly affects the plant height. At harvest (103 DAS), it was observed that plant height was higher in *Shundori* (33.92 cm) than *Kuruda* (33.22 cm) (Figure 1).

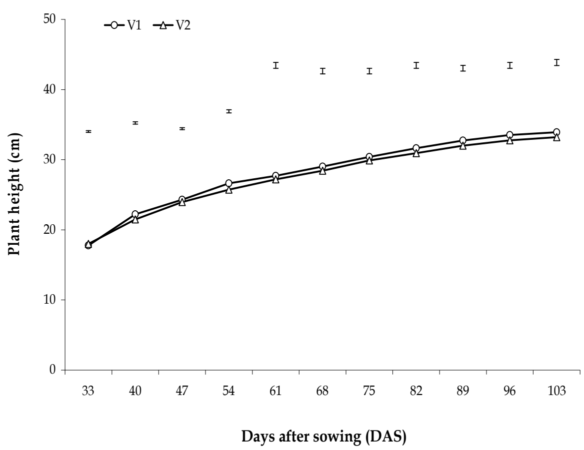

Figure 1. Main effect of variety on plant height of carrot at different days after sowing. Vertical bar represents LSD at 1% level of significance, V_1 = *Shundori*, V_2 = *Kuruda*.

The application of different salt concentrations significantly influenced the plant height of carrot at different stages of growth. Plant height of carrot increased with the advancement of time and was maximum in pots where no salt solution was applied attaining 36.30, 38.05, 39.24 and 40.02 cm at 82, 89, 96 and 103 days after sowing (DAS), respectively (Figure 2). The plant height was recorded minimum 26.33, 26.54, 26.97, 27.45, 27.65, 27.87 and 28.08 cm at 61, 68, 75, 82, 89, 96 and 103 DAS, respectively with highest salt concentration.

The combined effect of variety and different salt concentrations on plant height at different stages of growth (33, 40, 47, 54, 61, 68, 75, 82, 89, 96 and 103 DAS) was found to be statistically significant. At 103 DAS, the tallest plant (40.40 cm) was observed from the treatment combination V_1T_0 (*Shundori* × Control) and the lowest plant height (27.58 cm) was observed from V_2T_3 (*Kuruda* × 150 mM NaCl solution) (Table 1).

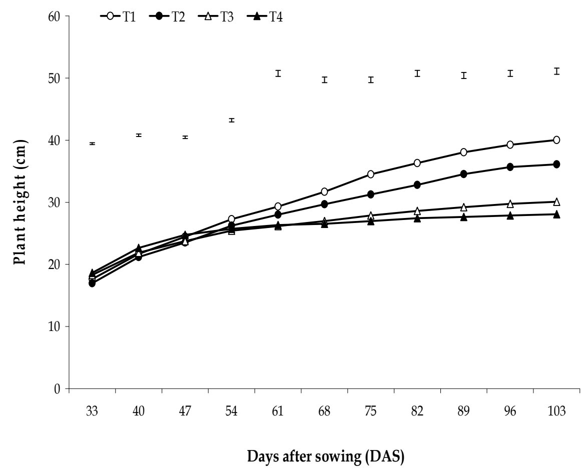

Figure 2. Main effect of treatments on plant height of carrot at different days after sowing. Vertical represents LSD at 1% level of significance. T_0= Control (0 mM), T_1 = 50 mM, T_2 = 100 mM, T_3 = 150 mM NaCl solution.

***Leaf length*:** Leaf length varied significantly at 33, 40, 47, 54, 61, 68, 75, 82, 89 and 96 DAS. The leaf length increased rapidly from 33 DAS to 68 DAS thereafter the rate of increment was slow. It was observed that leaf length was higher in V_1 than V_2 at 96 DAS. The higher leaf length (14.51 cm) was obtained from V_1 and the lower leaf length (12.66 cm) was found from V_2 (Figure 3)

The application of different salt concentrations significantly influenced the leaf length of carrot at different stages of growth. It is evident that leaf length of carrot increased with the advancement of time. The maximum leaf length (14.14 cm) was recorded from salt concentration treatment T_1 (50 mM NaCl) while the minimum leaf length (12.72 cm) was observed from T_2 (100 mM NaCl) treatment at 96 DAS (Figure 4).

Table 1. Combined effect of variety and treatments on plant height of carrot at different days after sowing.

Treatment combination		Plant height (cm) at different days after sowing (DAS)										
		33	40	47	54	61	68	75	82	89	96	103
V1(*Shundori*)	0 mM	17.57	21.47	23.50	26.37	27.92	30.53	33.53	36.18	38.46	39.73	40.40
	50 mM	16.69	20.75	23.83	27.81	29.65	31.20	32.46	33.79	35.13	36.44	36.80
	100 mM	17.80	22.33	23.95	26.11	26.70	27.51	28.24	28.59	29.10	29.49	29.91
	150 mM	19.05	24.35	25.87	26.18	26.55	26.80	27.40	28.04	28.22	28.38	28.57
V_2 (*Kuruda*)	0 mM	17.72	21.93	25.43	28.19	30.67	32.88	35.46	36.41	37.63	38.74	39.63
	50 mM	17.27	21.62	23.18	24.69	26.35	28.15	30.01	31.78	33.90	34.88	35.40
	100 mM	18.78	21.44	23.55	24.74	25.66	26.44	27.54	28.63	29.35	30.03	30.27
	150 mM	18.20	20.93	23.66	25.30	26.10	26.28	26.54	26.86	27.08	27.35	27.58
$LSD_{0.05}$		**0.21**	**0.27**	**0.25**	**0.37**	**0.68**	**0.63**	**0.64**	**0.67**	**0.66**	**0.69**	**0.69**
$LSD_{0.01}$		**0.30**	**0.38**	**0.34**	**0.51**	**0.95**	**0.88**	**0.89**	**0.94**	**0.92**	**0.95**	**0.96**
Level of significance		**	**	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability

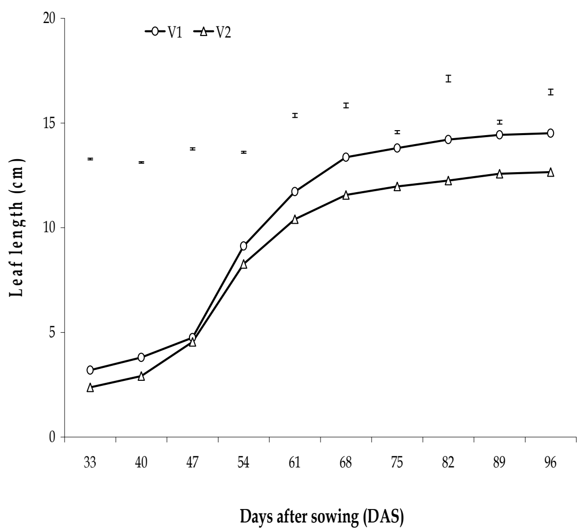

Figure 3. Main effect of variety on leaf length of carrot at different days after sowing. Vertical bar represents LSD at 1% level of significance, V_1 = *Shundori*, V_2 = *Kuruda.*

There was significant combined effect of different salt concentration and variety on leaf length at different stages of (33, 40, 47, 54, 61, 68, 75, 82, 89 and 96 DAS) growth. The maximum leaf length (14.82 cm) was observed from the treatment combination V_1T_3 and lowest leaf length (11.37 cm) was observed from V_2T_2 (Table 2).

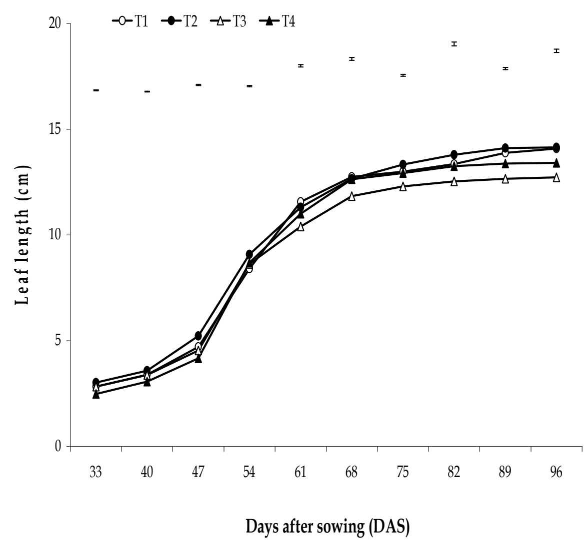

Figure 4. Main effect of treatments on leaf length of carrot at different days after sowing. Vertical bar represents LSD at 1% level of significance. T_0= Control, T_1 = 50 mM, T_2 = 100 mM, T_3 = 150 mM NaCl solution.

Table 2. Combined effect of variety and treatments on leaf length of carrot at different days after sowin.

Treatment combination		Leaf length (cm) at different days after sowing (DAS)									
		33	40	47	54	61	68	75	82	89	96
V1(*Shundori*)	0 mM	3.26	3.89	4.47	8.42	11.92	13.24	13.42	13.80	14.31	14.50
	50 mM	3.19	3.81	5.50	9.79	12.18	13.48	13.99	14.49	14.61	14.65
	100 mM	3.19	3.79	4.49	8.93	11.11	12.86	13.56	13.95	14.04	14.06
	150 mM	3.13	3.71	4.56	9.33	11.66	13.87	14.21	14.59	14.77	14.82
V2 (*Kuruda*)	0 mM	2.38	2.90	4.93	8.37	11.20	12.26	12.55	12.90	13.46	13.65
	50 mM	2.84	3.36	4.94	8.36	10.41	11.82	12.66	13.10	13.60	13.63
	100 mM	2.45	2.98	4.58	8.34	9.67	10.79	11.05	11.12	11.28	11.37
	150 mM	1.82	2.40	3.76	8.03	10.35	11.38	11.63	11.90	11.98	12.00
$LSD_{0.05}$		**0.16**	**0.14**	**0.21**	**0.20**	**0.41**	**0.48**	**0.32**	**0.63**	**0.38**	**0.56**
$LSD_{0.01}$		**0.22**	**0.19**	**0.30**	**0.28**	**0.58**	**0.67**	**0.44**	**0.88**	**0.52**	**0.78**
Level of significance		**	**	**	**	**	**	**	**	**	**

***Fresh weight of leaves*:** Fresh weight of leaves was significantly influenced by two different varieties. The higher fresh weight of leaves (9.62 g) was obtained from *Shundori* (V_1) and the lower fresh weight of leaves (8.16 g) was found from *Kuruda* (V_2) (Table 3).

Table 3. Main effect of variety on fresh weight, dry matter content and water content of carrot leaves.

Variety	Fresh weight of leaves (g)	Dry matter content of leaves (%)	Water content of leaves (%)
V_1 (*Shundori*)	9.62	21.25	78.75
V_2 (*Kuruda*)	8.16	19.11	80.89
$LSD_{0.05}$	**0.13**	**0.09**	**0.24**
$LSD_{0.01}$	**0.18**	**0.12**	**0.33**
Level of significance	**	**	**

** = Significant at 1% level of probability

Fresh weight of leaves was significantly influenced by the application of different levels of salt concentration. Maximum fresh weight of leaves (15.77g) was obtained from where no salt concentration was applied and it was significantly different from the remaining treatments. The lowest fresh weight of leaves (4.77g) was recorded from highest salt treatments (Table 4).

Table 4. Main effect of treatments on fresh weight, dry matter and water content of carrot leaves.

Treatments	Fresh weight of leaves (g)	Dry matter content of leaves (%)	Water content of leaves (%)
T_0 (Control, 0 mM)	15.77	18.58	81.42
T_1 (50 mM)	9.85	18.64	81.37
T_2 (100 mM)	5.18	20.60	79.41
T_3 (150 mM)	4.77	22.91	77.09
$LSD_{0.05}$	0.18	0.12	0.34
$LSD_{0.01}$	0.25	0.17	0.47
Level of significance	**	**	**

** = Significant at 1% level of probability

***Dry matter of leaves (%)*:** Percent dry matter content of leaves was significantly influenced by two different varieties. The higher dry matter content of leaves (21.25 %) was obtained from *Shundori* (V_1) and the lower dry matter content of leaves (19.11 %) was found from *Kuruda* (V_2) (Table 3). There was a significant effect of salt concentrations on the percent of dry matter of leaves. In the treatment applying no salt treatment gave the lowest (18.58 %) percentage of dry matter of leaves and highest (22.91 %) from highest salt concentration (Table 4).

Percent dry matter of leaves was significantly influenced by different salt concentration and variety treatments and the interaction was also statistically significant. The V_1T_3 treatment gave the highest (22.97 %) dry matter of leaves followed by the treatment combination V_2T_1 gave the lowest (17.28 %) (Table 5).

Table 5. Combined effect of variety and treatments on fresh weight, dry matter and water content of carrot leaves.

Treatment combination		Fresh weight of leaves (g)	Dry matter content of leaves (%)	Water content of leaves (%)
V_1(*Shundori*)	Control,0 mM	16.25	19.95	80.05
	50 mM	9.85	19.99	80.01
	100 mM	5.93	22.10	77.90
	150 mM	6.46	22.97	77.03
V_2 (*Kuruda*)	Control	15.28	17.21	82.79
	50 mM	9.85	17.28	82.72
	100 mM	4.43	19.09	80.91
	150 mM	3.07	22.85	77.15
$LSD_{0.05}$		0.25	0.18	0.48
$LSD_{0.01}$		0.35	0.24	0.66
Level of significance		**	**	**

** = Significant at 1% level of probability

***Water content of leaves (%)*:** Two different varieties of carrot showed significant variation on percent water content of leaves. The higher water content of leaves (80.89 %) was obtained from *Kuruda* (V_2) and the lower water content of leaves (78.75 %) was found from *Shundori* (V_1) (Table 3). There was a significant effect of salt concentration levels on the percent water content of leaves. In the treatment applying highest (81.42%) percentage of water content of leaves was obtained from control and lowest (77.09%) percentage of water was found from highest salt treatment (Table 4). The combined effect of variety and different salt concentration had a significant influence on the percent water content of leaves. The maximum water content of leaves (82.79 %) was obtained from treatment combination V_2T_0 and minimum (77.03 %) was found from V_1T_3 treatment combination (Table 5).

***Root length*:** Varieties showed non-significant effect on the root length of carrot. However, longer root length (9.05 cm) was obtained from *Shundori* (V_1) and *Kuruda* (V_2) gave the shorter roots (9.03 cm) (Table 6). Different salt treatment had significant effect on the root length of carrot. The maximum root length (10.12 cm) was obtained from no salt concentration treatment and minimum root length was (7.84 cm) obtained from highest salt concentration treatment (Table 7). Analysis of variance indicates a significant combined effect between variety and salt concentration in respect of root length and the interaction was also significant. The longest and shortest roots (10.26 cm and 7.54 cm) were attained through V_2T_0 and V_1T_2 (Table 8).

***Root diameter*:** Significant variation was observed in diameter of root among two varieties of carrot. The maximum root diameter (11.24 cm) was recorded from *Shundori* (V_1) and the minimum root length (10.81 cm) was found from *Kuruda* (V_2) (Table 6). Significant variation was observed in diameter of root among different salt treatments. The maximum root diameter (13.76 cm) was recorded from where no salt treatment was applied. The minimum root diameter (8.09 cm) was obtained from the treatment of highest salt concentration (Table 7). Analysis of variance indicates a significant combined effect between variety and salt concentration in respect of root diameter development. The maximum root diameter (14.56 cm) was found from V_2T_0 treatment combination and the minimum root diameter (7.16 cm) was recorded from the treatment combination V_2T_3 (Table 8).

Table 6. Effect of variety on root length, diameter, fresh weight, dry matter and water contents of carrot roots**.**

Variety	**Root length (cm)**	**Root diameter (cm)**	**Root fresh weight (g)**	**Dry matter content (%)**	**Water content (%)**
V_1 (*Shundori*)	9.05	11.24	10.18	18.18	81.82
V_2 (*Kuruda*)	9.03	10.81	10.76	15.43	84.57
$LSD_{0.05}$	0.05	0.18	0.17	0.14	0.30
$LSD_{0.01}$	0.06	0.25	0.21	0.19	0.42
Level of significance	ns	**	**	**	**

** = Significant at 1% level of probability, ns= non-significant

Table 7. Main effect of treatments on length, diameter, fresh weight, dry matter and water content of carrot roots.

Treatments	**Root length (cm)**	**Root diameter (cm)**	**Root fresh weight (g)**	**Dry matter content (%)**	**Water content (%)**
T_0 (Control, 0 mM)	10.12	13.76	19.56	13.87	86.13
T_1 (50 mM)	8.97	12.66	13.22	16.21	83.79
T_2 (100 mM)	7.84	9.61	5.16	16.96	83.04
T_3 (150 mM)	9.23	8.09	3.93	20.19	79.82
$LSD_{0.05}$	0.31	0.45	0.45	0.46	0.43
$LSD_{0.01}$	0.43	0.62	0.62	0.63	0.59
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability

***Root fresh weight*:** Weight of roots per plant was significantly influenced by two different varieties. The higher fresh weight of roots (10.76 g) was obtained from *Kuruda* (V_2) and the lower fresh weight of roots (10.18 g) was found from *Shundori* (V_1) (Table 6). Salt concentration treatment exhibited a significant variation in weight of individual root. The highest root weight (19.56 g) was achieved by application of control and the lowest root weight (3.93 g) was produced by the application of highest salt treatment (Table 7). Analysis of variance indicates a significant combined effect between salt concentration and variety in respect of weight of roots. The highest weight of roots (20.62 g) was found from V_2T_0 treatment combination and the lowest weight of roots (3.53 g) was recorded from the treatment combination V_2T_3 (Table 8).

***Dry matter content*:** Dry matter content of roots was significantly influenced by two different varieties. The higher dry matter (18.18%) was obtained from *Shundori* (V_1) while the lower (15.43%) dry matter of roots was obtained from *Kuruda* (V_2) (Table 6). The higher dry matter of roots from *Shundori* (V_1) was due to the lower water inside the roots. Dry matter content of roots was significantly influenced by different salt concentrations. The maximum dry matter (20.19 %) was obtained from the treatment of high salt concentration while the minimum (13.87 %) dry matter of roots was obtained from the treatment of no salt concentration (Table 7). Percent of dry matter of roots was significantly influenced by variety and different salt concentrations treatments and the interaction was also statistically significant. The maximum dry matter (20.61 %) was produced by V_1T_2 and minimum (13.22 %) was produced from V_2T_0 treatment combination (Table 8).

Table 8. Combined effect of variety and treatments on length, diameter, fresh weight, dry matter and water content of carrot roots.

Treatment combination		Root length (cm)	Root diameter (cm)	Root fresh weight (g)	Dry matter content (%)	Water content (%)
V_1 (*Shundori*)	Control, 0 mM	9.98	12.96	18.50	14.52	85.48
	50 mM	9.05	12.42	12.38	17.51	82.49
	100 mM	7.54	10.57	5.50	20.61	79.39
	150 mM	9.63	9.03	4.34	20.09	79.91
V_2 (*Kuruda*)	Control	10.26	14.56	20.62	13.22	86.78
	50 mM	8.90	12.89	14.07	14.91	85.09
	100 mM	8.13	8.65	4.82	13.31	86.69
	150 mM	8.83	7.16	3.53	20.28	79.72
$LSD_{0.05}$		0.44	0.64	0.63	0.65	0.60
$LSD_{0.01}$		0.61	0.88	0.88	0.90	0.83
Level of significance		**	**	**	**	**

** = Significant at 1% level of probability

***Water content of roots*:** Significant variation was observed in percent water content of roots between the two varieties of carrot. Higher water content of roots (84.57 %) was obtained from *Kuruda* (V_2) and the lower water content of roots (81.82 %) was found from *Shundori* (V_1) (Table 6). There was a significant effect of salt concentrations on the percent water content of roots.

Plate 1. Photographs showing shoot and root performance of V1 (*Shundori*) and V2 (*Kuruda*) under different concentrations of salt treatments.

The highest (86.13 %) percentage water content of roots was recorded from the treatment of no salt concentration and the lowest result (79.82 %)

percentage was found from the highest salt concentration (Table 7). The combined effect of variety and different salt concentrations had a significant influence on the percent water content of roots. The maximum water content of roots (86.78 %) was obtained from treatment combination V_2T_0 and the minimum (79.39 %) was obtained from treatment combination V_1T_2 treatment combination (Table 8).

Discussion

Among the growth and yield contributing characters plant height is an important for the yield of carrot. It is evident that the plant height increased gradually with the advancement of time. It is differed significantly with the different variety and different salt treatments. In this study, maximum plant height (33.92 cm) was recorded from *Shundori* at 103 DAS and minimum plant height (33.22 cm) was recorded from *Kuruda*. Results also showed that the tallest plant was recorded in control. On the other hand, the shortest plant was recorded in 150 mM salinity level. Yadav *et al. (*1998) also said that the highest salinity level (16 dS/m) reduced plant height. In chickpea, Garg (2004) also found reduction in shoot length with increase of salinity levels.

The leaf length increased with the increasing time i.e. at different days. The highest length of leaf (14.51 cm) was obtained from *Shundori* and the lowest leaf length (12.66 cm) was found from *Kuruda*. Application of high salt concentration up to 96 DAS produced the lower length of leaf (12.72 cm) whereas lower salt concentration (50 mM NaCl) produced higher length of leaf (14.14 cm). Carrot leaves accumulated high concentrations of Cl^-. For this reason, photosynthesis and stomatal conductance were reduced by 38 and 53 %, respectively and leaf became shorter as also observed by Gibberd *et al.* (2000). Fresh weight of leaves was significantly influenced by the application of different salt concentration. The highest fresh weight of leaves (9.62 g) was obtained from *Shundori* and the lowest fresh weight of leaves (8.16 g) was found from *Kuruda*. Maximum fresh weight of leaves (15.77 g) was recorded from control and lowest fresh weight of leaves (4.77 g) was obtained from the application of high salt concentration (150 mM NaCl).

There was a significant effect of salt concentration on the percent dry matter of leaves. In the treatment applying no salt concentration gave the lowest (18.58 %) percentage of dry matter of leaves and highest (22.91 %) from salt concentration up to 150 mM. The production of the highest dry matter with the maximum application of salt concentration was probably due to the lower amount of water inside the leaves and decreased cell expansion resulting in dense biomass production of the carrot leaves. High salinity caused a decrease in K content and increased Cl content of leaves and plant water consumption and water use efficiency decreased with increasing salinity was stated by Unlukara *et al.* (2010).

Variety and salt concentration had significant effect on the root length of carrot. The higher root length (9.05 cm) was obtained from *Shundori* and the lower root length (9.03 cm) was found from *Kuruda*. The maximum root length (10.12 cm) was obtained from control and minimum root length (7.84 cm) was obtained by maintaining salt concentration up to 100 mM. Akinci *et al.* (2004), Unlukara *et al.* (2010) reported similar results in eggplant. The increased root length due to untreated control condition was possibly due to availability of sufficient moisture which helped in rapid cell elongation leading to longer root formation. Ahmad *et al.* (2005) reported that root length of carrot was higher with higher amount of water level.

The maximum root diameter (13.76cm) was obtained from the treatment of control and (12.66 cm) from the salt concentration up to 50 mM. After that diameter of root reduce and the minimum root diameter (8.09cm) was recorded from the salt concentration up to 150 mM. Ahmed *et al.* (2005) reported that optimum moisture availability to plants lead to higher production of food material in the roots and ultimately resulted in the production of thicker roots of carrot. Although the moisture condition might be optimum with highest level of salt concentration treatment but the absorption ability of the plant were decreased due to high salt concentration which changed the soil p^H. Variety and salt concentration had significant effect on the dry matter of carrot root. The maximum dry matter (18.18 %) was obtained from *Shundori* while the lowest (15.43 %) dry matter of roots was obtained from *Kuruda*. The untreated control treatment gave the lowest (13.87 %) percentage of dry matter of roots and highest (20.19 %) from salt concentration up to 150 mM. The production of the highest dry matter with the maximum application of salt concentration was probably due to the lower amount of water inside the roots and decreased cell expansion resulting in dense biomass production of the carrot roots was stated by Unlukara *et al.* (2010).

The highest root weight (19.56 g) was achieved by application of control and (13.22 g) was from the application of salt concentration up to 50 mM. The lowest root weight (3.93 g) was produced by the application of salt concentration up to 150 mM. It was observed that treatment of control produced longest root having maximum diameter and that might have contributed to the maximum root weight of roots as stated by Ahmad *et al.* (2005). At low concentration (50 mM NaCl) of the salt water, plant growth was not hampered because optimum moisture level was presented in soil. But the weight of root was decreased when treated with highest dose of treatment (150 mM NaCl) because the highest salinity reduced root weight compared with the control. Yadav *et al.* (1998) also agreed with this complement. Variety also had significant effect the highest weight of roots (10.76 g) was obtained from *Kuruda* and the lowest weight of roots (10.18 g) was found from *Shundori*.

Conclusion

The growth and yield contributing traits of carrot irrespective of variety were influenced by different levels of soil salinity. As soil salinity increased all the traits exhibited decreasing trends. The findings of this study postulated that the salinity stress significantly reduced all studied parameters at 100 mM and 150 mM as compared to untreated control as well 50 mM NaCl. It can be summarized that *Kuruda* showed relatively salt tolerant ability as compared to S*hundori*. So, *Kuruda* can be recommend for cultivation in saline prone areas of Bangladesh.

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