Vol.65: e22210213, 2022
https://doi.org/10.1590/1678-4324-2022210213
ISSN 1678-4324 Online Edition

Article - Agriculture, Agribusiness and Biotechnology

Effect of Salinity Stress on Germination, Seedling Growth, Mineral Uptake and Chlorophyll Contents of Three Cucurbitaceae Species

Muhammad Noman Naseer[1]
https://orcid.org/0000-0001-8502-4500

Faiz Ur Rahman[1,2*]
https://orcid.org/0000-0001-7431-8167

Zahoor Hussain[1]
https://orcid.org/0000-0002-0098-0286

Irshad Ahmad Khan[2]
https://orcid.org/0000-0003-0169-0253

Muhammad Muzammal Aslam[2]
https://orcid.org/0000-0001-9858-1146

Ali Aslam[2,3]
https://orcid.org/0000-0001-7984-4211

Hasnain Waheed[4]
https://orcid.org/0000-0001-8351-1954

Asad Ullah Khan[5]
https://orcid.org/0000-0002-4802-4824

Shahid Iqbal[6]
https://orcid.org/0000-0003-4321-8598

[1]University of Sargodha, College of Agriculture, Department of Horticulture, Sargodha, Pakistan; [2]Chinese Academy of Agricultural Sciences, Zhengzhou Fruit Research Institute, Zhengzhou, P.R. China; [3]Superior University, Faculty of Agriculture and Veterinary Sciences, Raiwind Road Lahore, Pakistan; [4]University of Sargodha, College of Agriculture Department of Agronomy, Sargodha, Pakistan; [5]Zhejiang University, College of Agriculture and Biotechnology, Department of Agronomy, The Key Laboratory for Crop Germplasm Resource of Zhejiang Province, Hangzhou P.R. China; [6]Nanjing Agricultural University, College of Horticulture Nanjing, China.

Editor-in-Chief: Alexandre Rasi Aoki
Associate Editor: Adriel Ferreira da Fonseca

Received: 06-Apr-2021; Accepted: 04-Oct-2021.

*Correspondence: rfaiz36@yahoo.com; Tel.: +92 3090780257 (F.U.R.).

HIGHLIGHTS

- Three species of Cucurbitaceae family are evaluated against the salt stress.
- Higher levels of salinity have more adverse effects on the growth of cucurbits.
- The varieties of bottle gourd performed well against the salt stress.

Abstract: This study was performed to screen out the various species of ‘Cucurbitaceae’ family, musk melon (Kalash and Durga), bottle gourd (Crystal Long and Nuefield) and squash (Green Round, and Squash Malika) against the salt stress. All genotypes were treated with five different levels of NaCl (T0 = control, T1 = 1.5 dS m^{-1}, T2 = 3.0 dS m^{-1}, T3 = 4.5 dS m^{-1} and T4 = 6.0 dS m^{-1}) and half strength of Hoagland’s nutrients solution as the base nutrient solution. Results showed that the bottle gourd varieties “Nuefield” and “Crystal Long” performed best by maintaining the highest germination (93.2% and 85.6%), number of leaves per plant (4.5 and 5.7), shoot length (16.84 cm and 16.14 cm), root length (13.48 cm and 13.00 cm), plant fresh weight (942.2 g and 918.6 g), plant dry weight (118.4 g and 107.5 g), leaf area (171.2 cm^2 and 169.1 cm^2), chlorophyll content (3.5 μg/cm^{-2} and 3.4 μg/cm^{-2}) with low chloride (1.57 ppm and 1.59 ppm) and sodium content (0.47

ppm and 0.51 ppm) under salt stress followed by varieties of Squash (Green Round, and Squash Malika) and musk melon (Kalash and Durga). It was also found that a higher level of salinity (4.5 dS m^{-1} and 6.0 dS m^{-1}) has more adverse effects on the performance of all selected genotypes. Conclusively, it can be recommended that as compared to all tested species, bottle gourd varieties "Nuefield" and "Crystal Long" have the ability to withstand against salinity stress and should be planted under salt stress conditions.

Keywords: Salt stress; Cucurbits; Sodium; Chloride.

INTRODUCTION

Musk melon (*Cucumis melo* L.), bottle gourd (*Lagenaria siceraria* L.) and squash (*Benincasa fistulosa* L.) belong to the family Cucurbitaceae. These family members have crawling vines with round to elliptical-shaped fruits utilized for food either in cooked or raw form. Many biotic and abiotic factors are responsible for cucurbits' short production in Pakistan, but salinity is the major issue for the low production of cucurbits [1,2]. Salinization of soil is widespread worldwide, gradually becoming a serious threat to the world's agriculture and affecting approximately 20% of irrigated land [3]. Salt stress is genuine concerns to the environment, which significantly reduce growth and biomass in plants. Salt stress can significantly inhibit plant growth by decreasing biomass production and reducing net photosynthesis and transpiration [4].

During seed germination water is absorbed by the seed and spindle embryo elongation occurs [5]. Seed germination procedure is exaggerated by different unfavorable factors such as salinity, which is one of the major abiotic stresses disturbing plant growth and development, especially in arid and semi-arid regions [6,7]. It became difficult for seed to germinate during this stress condition because of creation of high osmotic potential, that hinders water absorption (osmotic effect) or produces lethal effects of Na^+ and Cl^- [8].

Salinity causes two types of stress on plants as osmotic stress and ionic stress. In osmotic stress, low water potential in the soil is due to the high amount of sodium ions, while ionic stress is caused by a significant number of lethal ions in the plant root zone area [9]. Salinity affects morphology, anatomy and the entire metabolic system of plants [10]. When salt amount rises in soil solution and water quantity decreases, then the osmotic potential of plant cells also decreases which results in the slow rate of cell division and cell elongation, the photosynthetic process also slows down. Under this type of stress, plants produce reactive oxygen species (ROS). From many pieces of research, it was found that a higher level of ROS) production causes cell death [11,12]. If this condition continues, then the chances of plant death also increase [10,13]. Different plants show different characters in salt stress conditions depending upon their ability to cope with the stress. Initial symptoms of stress condition is the decline in shoot and root growth [10].

Early leaf aging is also observed in saline stress conditions. Leaf aging means low chlorophyll content or protein and a higher rate of cell membrane conductivity. There are also a high amounts of Na^+ and Cl^- ions in leaves and low concentrations of K^+ and Ca^{2+} ions [10,14] and [15]. It has been reported that saline tolerance differs in cucurbits with variables ranging from sensitive to medium tolerance.

It has been reported that saline tolerance differs in cucurbits ranging from sensitive to medium tolerance. Sodium ions have the property to move in both phloem and xylem of a plant [10,16]. It was also studied that salt stress caused ions imbalance in plants and uptake sodium ion in high quantity as compared with other ions resulting in malnutrition. Thus more Na^+ ions may be present in the plant than potassium or any other ions [17,18].

Based on the importance of vegetable family "Cucurbitaceae" and the devastating salinity effects, the current research was performed to screen out cucurbits under saline conditions at seedling stage. Tolerant cucurbits genotypes screened in the current investigation, it can be recommended for cultivation in salt-affected areas. The present study was performed to evaluate the morpho-physiological and ionic attribute performance of musk melon (*Cucumis melo* L.), bottle gourd (*Lagenaria siceraria* L.) and squash (*Benincasa fistulosa* L.) under different levels of salinity.

MATERIAL AND METHODS

Plant material

The place selected for experiments was Horticultural Department Laboratory College of Agriculture, University of Sargodha during summer season of 2016. Seeds of two varieties of musk melon (Kalash and Durga), two varieties of bottle gourd (Crysatl long and Nuefield) and two varieties of squash (Green round and Squash malika) were used in the experiments. In the first part of the experiment, the seeds of selected varieties were disinfected with sodium hypochlorite at 10% concentration, and then they were placed in petri dishes on Whattmann 40 filter paper wetted with desired saline solutions (0, 1.5, 3.0, 4.5 and 6.0 dS m^{-1}). After that, the dishes were placed in a growth chamber at 20 to 22 ˚C in the dark. After seven days, germination was calculated. The germination percentage was calculated by the method of [19]. In the second part of the experiment seeds were sown in controlled conditions of the laboratory. The media used for this experiment was fine river sand; about 500 g sand was filled in each black plastic pot having a size of about 10 inches. Hoagland nutrients solution (half strength) was used as a source of nutrients. Salinity was induced in the form of NaCl in each treatment with two applications. One application was induced before sowing, and a second application was induced 15 days after sowing. Each variety of selected crops was replicated five times.

Morphological Assessment

The number of leaves, root length, and shoot length were measured from every replication in each treatment after 30 days of sowing as described by [20,21]. Plant samples were uprooted carefully after 30 days of sowing washed with distilled water for removal of sand particles. Then these were wrapped with filter paper for removal of any water droplet present on them. For measurement of fresh plant weight, digital balance (Model NBL-823e) was used, and their average was calculated [22]. For dry weight, the sampled plants were taken into paper bags and placed in an oven and dried at 70 ºC for 48 hours [19]. When plants were dried completely, they were removed from the oven and digital balance (Model NBL-823e) was used for the measurement of plant dry weight and then their average was taken [23]. For leaf area, leaves were placed on an electronic leaf area meter (CL-203) for measurement of leaf area and taken as average.

Measurement of Chlorophyll, Sodium (Na^+), and Chloride (Cl^-) content

Chlorophyll content was measured by chlorophyll meter (Hansatech Model Cl-01) by keeping that device on fully expanded leave at three places and then their average was taken as measured by [24].

Sample leaves were collected after 30 days of sowing for calculation of Na^+, which were then digested by concentrated sulfuric acid (0.5 g of leaf material in 5 ml of H_2SO_4). These digested sample leaves were then analyzed by using a Flame photometer (Jenway PFP-7, UK) for sodium content determination. A graded series of the standard of Na^+ was prepared, and a standard curve was drawn. The values of Na^+ obtained from Flame photometer were compared with standard curve and original quantities were calculated.

For chloride ions determination, sampled leaves were collected after 30 days of sowing and dried. Dried leaves were ground first, and then these grinding materials were heated overnight in distilled water in a test tube at 65ºC in an oven. The extract obtained was filtered with Whatmann 40 filter paper. After that, filtered materials were used to determine chloride ions with the help of an analyzer (Corning 920, Germany).

Statistical Analysis

Collected data were analyzed statistically by using the Fisher's analysis of variance technique, and significance of treatments were tested by using Complete Randomized Design (CRD) with two-factor factorial arrangement and means are compared by using least significant difference (LSD) test [25], and graph were prepared using SigmaPlot software

RESULTS

All the cucurbits in our experiment significantly responded against increasing salinity levels (0, 1.5, 3.0, 4.5 and 6.0 dS m^{-1}). It was noticed that the bottle gourd varieties “Nuefield” and “Crystal long” showed the best performance by maintaining the highest germination percentage (93.42% and 85.56%) under salt stress. In comparison, musk melon varieties “Kalash” and “Durga” gave poor performance (58.36% and 54.54%). While the performance of squash varieties “Green round”, “Squash malika” and “Squash long” in that condition was in between bottle gourd and musk melon varieties, as shown in table 1. Data described in table 2 and 3 also showed that the bottle gourd varieties “Nuefield” and “Crystal long” performed best by producing significantly ($P < 0.05$) highest number of leaves (4.5 and 5.7) and leaf area (171.18 cm^2 and 169.08 cm^2) under salt stress, whereas musk melon varieties “Kalash” and “Durga” produced minimum number of leaves (2.92 and 1.64) and leaf area (83.9 cm^2 and 78.38 cm^2).

Table 1. Effect of salinity on germination percentage on varieties of musk melon, bottle gourd and squash under saline condition.

Treatments	Musk melon		Bottle gourd		Squash		Treatment means
	Kalash	Durga	Crystal long	Nuefield	Green round	Squash	
Control	83.20%	83.20%	100%	100%	83.20%	83.20%	88.8% a
1.5 dSm^{-1}	83.20%	83.20%	100%	100%	83.20%	83.20%	88.8% a
3.0 dSm^{-1}	61.40%	42.30%	83.20%	100%	83.20%	83.20%	75.55% b
4.5 dSm^{-1}	42.30%	42.30%	83.20%	83.20%	61.40%	61.40%	62.3% c
6.0 dSm^{-1}	21.70%	21.70%	61.40%	83.20%	42.30%	42.30%	45.43% d
	58.36% d	54.54% d	85.56% b	93.42% a	70.62% c	70.62% c	72.17% b

Table 2. Effect of salinity on number of leaves on varieties of musk melon, bottle gourd and squash under saline condition

Treatments	Musk melon		Bottle gourd		Squash		Treatment means
	Kalash	Durga	Crystal long	Nuefield	Green round	Squash	
Control	3.4±0.45 bc	2.6±0.03c	6.4±0.91 a	5.2±0.23 a	4.2±0.71 ab	4.7±0.45 ab	4.42 a
1.5 dSm^{-1}	3.2±0.34 cd	2±0.10 d	5.8±0.82 a	4.8±0.84 b	4.0±0.81 bc	4.6±0.25 b	4.07 a
3.0 dSm^{-1}	3±0.09b	1.4±0.07 c	5.4±0.57 a	4.6±0.58 ab	3.1±0.07 ab	4.5±0.12 a	3.67 b
4.5 dSm^{-1}	2.8±0.29bc	1.2±0.02 c	5.2±0.35 a	4.16±0.32 a	2.6±0.57 c	4.2±0.09 ab	3.36 b
6.0 dSm^{-1}	2.2±0.18 de	1±0.02e	4.4±0.56 a	4.13±0.5 b	2.6±0.09 cd	3.8±0.19 bc	2.75 c
Varieties mean	2.92 d	1.64 e	5.7 a	4.5 b	3.3 c	4.36 ab	3.75 b

Table 3. Effect of salinity on leaf area on varieties of musk melon, squash and bottle gourd under saline condition

Treatments	Musk melon		Bottle gourd		Squash		Treatment means
	Kalash (cm^2)	Durga (cm^2)	Crystal long (cm^2)	Nuefield (cm^2)	Green round(cm^2)	Squash (cm^2)	
Control	134.4±0.9 d	137.9±0.3 d	229.7±0.45 a	227.2±0.7 a	173±0.21 bc	177.2±0.2b	179.9 a
1.5 dSm^{-1}	120±0.62 d	122.2±0.7d	208.1±0.67 a	204.6±0.4 a	131.1±0.17c	141.1±0.3b	154.52 b
3.0 dSm^{-1}	77.8±0.71 c	78.3±0.63c	186.4±0.44 a	184±0.32 a	91.8±0.51 b	91.8±0.5 b	118.35 ab
4.5 dSm^{-1}	54.4±0.4 c	33±0.3 d	139±0.04 a	136.5±0.3 a	67±0.20 b	69.9±0.1 b	83.3 c
6.0 dSm^{-1}	32.9±0.6 c	20.5±0.6 d	92.7±0.09 a	93.1±0.31a	43.6±0.14 b	46.2±0.2 b	54.83 d
	83.9 c	78.38 c	171.18 a	169.08 a	101.3 ab	105.24 ab	118.18 b

However, with increasing of salinity shoot length and root length decreased in all tested cucurbits as shown in table 4 and 5 but significantly ($P < 0.05$) decrease in shoot and root length (11.8 cm and 11.27 cm), (8.4 cm and 8.3 cm) was recorded in plants having a high dose of salinity like 4.5 and 6.0 dS m^{-1} of NaCl.

Table 4. Effect of salinity on shoot length on varieties of musk melon, squash and bottle gourd under saline condition

Treatments	Musk melon		Bottle gourd		Squash		Treatment means
	Kalash (cm)	Durga (cm)	Crystal long (cm)	Nuefield (cm)	Green round(cm)	Squash (cm)	
Control	8.3±0.93 b	8.3±0.56 b	16.8±0.68 a	17.4±0.68a	10.3±0.30ab	15±0.09 a	12.68 a
1.5 dSm^{-1}	7.7±0.47 b	7.4±0.85 b	16.2±0.67 a	17.2±0.49a	9.9±0.31 b	14.9±0.81a	12.22 a
3.0 dSm^{-1}	7.4±0.75 c	6.8±0.58 c	16.1±0.45 a	17.2±0.70a	9.0±0.10 c	13.5±0.7ab	11.67 b
4.5 dSm^{-1}	7.0±0.83 c	6.7±0.46 c	16±0.60 a	16.8±0.70a	8.8±0.50 c	13±0.51 b	11.38 ab
6.0 dSm^{-1}	6.8±0.34 c	5.4±0.81 c	15.6±0.90 a	15.6±0.1ab	8.5±0.13 c	12.1±0.71b	10.67 c
	7.44 c	6.92 c	16.14 a	16.84 a	9.3 c	13.7 b	11.72 b

Table 5. Effect of salinity on root length on varieties of musk melon, squash and bottle gourd under saline condition

Treatments	Musk melon		Bottle gourd		Squash		Treatment means
	Kalash (cm)	Durga (cm)	Crystal long(cm)	Nuefield (cm)	Green round(cm)	Squash (cm)	
Control	5.4±0.06 cd	4.5±0.23 d	12.4±0.09 a	14.7±0.78 a	7.9±0.39bc	8.7±0.18 b	8.93 a
1.5 dSm^{-1}	5.2±0.01 b	4.6±0.36 b	12.1±0.45 a	14.5±0.01 a	6.8±0.19 b	7.7±0.28 b	8.48 a
3.0 dSm^{-1}	5.0±0.07 b	5.2±0.37b	12.4±0.34 a	13.6±0.30 a	6.7±0.29 b	5.0±0.37 b	7.98 c
4.5 dSm^{-1}	5.1±0.41 c	4.5±0.67 c	15.2±0.56 a	12.6±0.9 ab	6.2±0.37 c	5.0±0.46 c	8.1 b
6.0 dSm^{-1}	4.7±0.08 c	3.2±0.45 c	12.9±0.07 a	12.0±0.3 ab	6.0±0.09 c	9.9±0.05 ab	8.12 b
	5.08 e	4.4 f	13 a	13.48 a	6.72 d	7.26 c	8.32 b

For plant fresh and dry weight the bottle gourd varieties “Nuefield” and “Crystal long” produced highest plant fresh weight (942.2 g and 918.6 g) and plant dry weight (118.4 g and 107.5 g) under salt stress while musk melon varieties “Kalash” and “Durga” produced minimum plant fresh weight and dry weight (Table 6 and 7).

Table 6. Effect of salinity on plant fresh weight on varieties of musk melon, squash, and bottle gourd under saline condition

Treatments	Musk melon		Bottle gourd		Squash		Treatment means
	Kalash (g)	Durga (g)	Crystal long (g)	Nuefield (g)	Green round (g)	Squash (g)	
Control	403.7±0.71d	402.6±0.7d	939.6±1.11a	943.3±2.2a	557.8±0.91c	619.3±0.1b	644.38 a
1.5 dSm^{-1}	397.1±0.82d	392±.09 d	927.8±2.91a	943.2±1.4 a	556.8±1.1c	618.9±0.9b	639.3 a
3.0 dSm^{-1}	387.9±1.63 d	354.4±0.6d	916.5±1.21a	942.9± 2.0a	518±1.3c	608.5±1.0b	621.37 b
4.5 dSm^{-1}	387.4±0.81 d	327.4±0.21e	908.6±1.02a	943.3±3.0a	416.3±0.67d	607.3±1.2b	598.38 bc
6.0 dSm^{-1}	345.3±1.40 c	245.5±0.34d	900.5±1.07a	938.1±1.5a	402.4±0.13c	509.3±0.4b	556.85 c
	384.28 e	344.38 f	918.6 a	942.16 a	490.26 d	592.66 c	612.06 b

Table 7. Effect of salinity on plant dry weight on selected varieties of musk melon, squash and bottle gourd under saline condition.

Treatments	Musk melon		Bottle gourd		Squash		Treatment means
	Kalash (g)	Durga (g)	Crystal long (g)	Nuefield (g)	Green round (g)	Squash (g)	
Control	50.3±0.09 c	47.5±0.34c	109.6±0.82ab	119±0.9ab	107.8±0.62b	127.8±0.3a	93.7 a
1.5 dSm^{-1}	34.7±0.07 c	33.0±0.77 c	108±0.78 ab	118.8±0.6a	107.5±0.55ab	98.4±0.7 b	83.4 b
3.0 dSm^{-1}	34.1±0.12 b	35.8±0.63b	109.1±0.88 a	118.9±0.3a	107.2±0.45 a	109.5±0.8a	85.77 b
4.5 dSm^{-1}	34.2±0.54 b	28.6±0.09b	107.6±0.75 a	118.7±0.6a	106.7±0.71 a	100.5±0.6a	82.72 b
6.0 dSm^{-1}	21.1±0.65 c	17.8±0.18c	102.9±0.38ab	116.5±0.7a	103.2±0.21ab	90.7±0.4 b	75.37 c
	34.88 d	32.54 d	107.44 b	118.42 a	106.48 b	105.38 b	84.19 c

Chlorophyll content (µg cm^{-2})

The chlorophyll contents (µg cm^{-2}) were significantly reduced under salt stress as described in figure 1. It was examined that all the cucurbits in our experiment significantly ($P < 0.05$) responded against increasing salinity levels. It was also observed that as the level of salinity increased the chlorophyll content decreased in all tested cucurbits, but the highest reduction in chlorophyll content was recorded in plants having a high dose of salinity (4.5 and 6.0 dS m^{-1}) (Figure 1).

Among varieties of bottle gourd, squash and musk melon “Nuefield”, “Squash malika” and “Kalash” were produced maximum number of chlorophyll content while “Crystal long”, “Green round”, “Squash long” and “Durga” produced minimum number of chlorophyll content, respectively. Interaction between cucurbits and salinity levels was found to be significant.

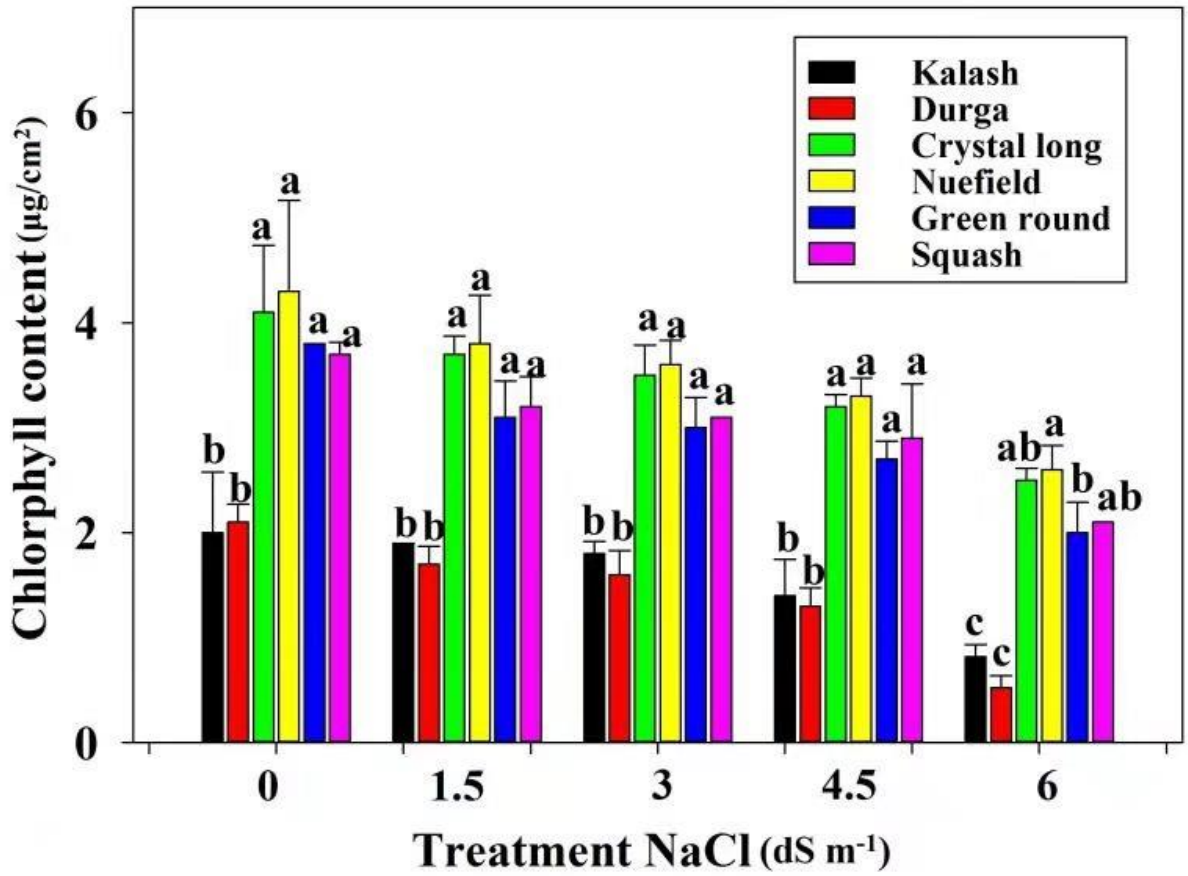

Figure 1. Effect of different levels of salinity on chlorophyll contents in different varieties of musk melon.

Sodium and chloride contents (ppm)

Salt stress significantly ($P < 0.05$) increased leaf Na^+ and Cl^- contents in all tested cucurbits which were grown under saline environment. However, with increasing the salinity level the leaf sodium and chloride contents increased in all tested cucurbits but the highest uptake of Na^+ and Cl^- was observed at 4.5 and 6.0 dS m^{-1} (Figures 2, 3).

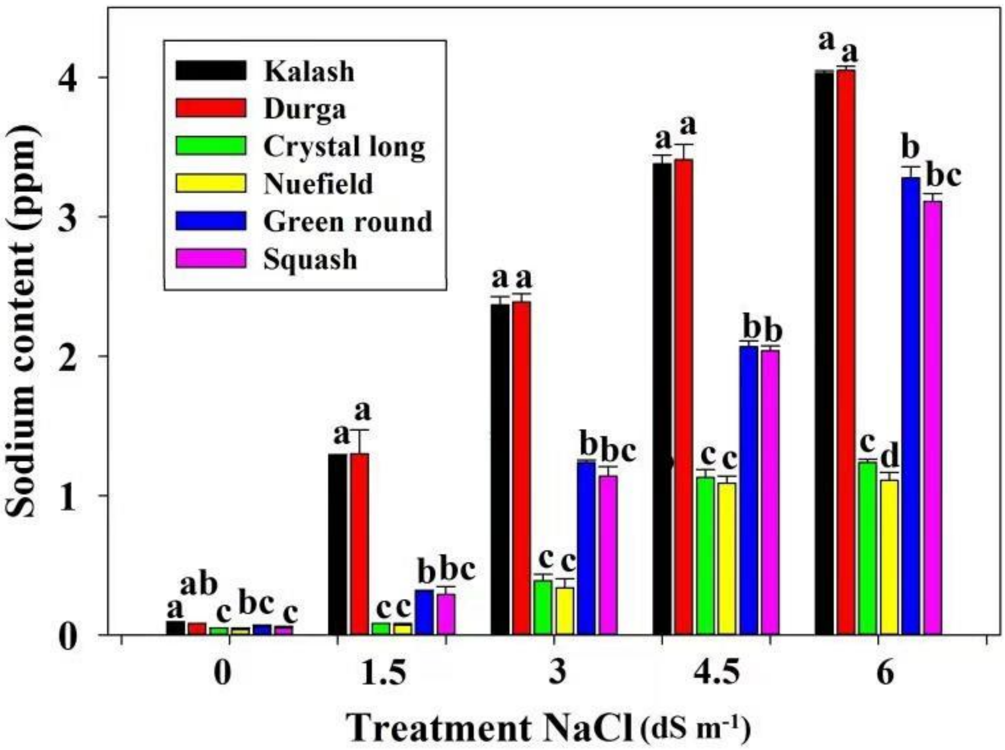

Figure 2. Effect of different levels of salinity on Sodium ions contents in different varieties of musk melon.

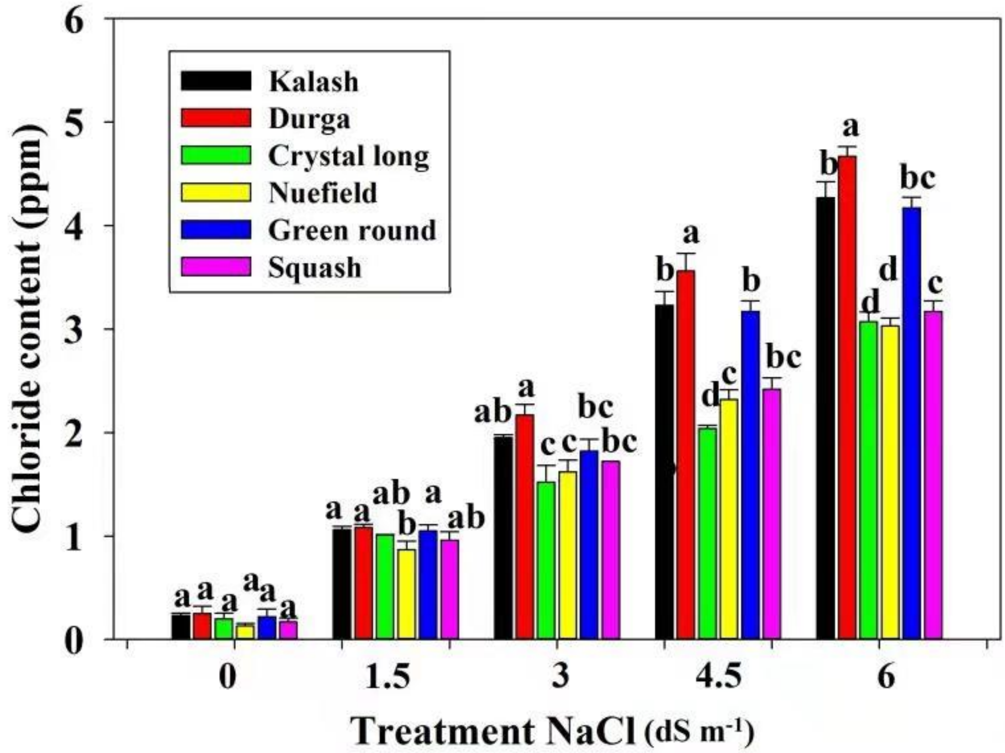

Figure 3. Effect of different levels of salinity on chloride ions contents in different varieties of musk melon.

It was noticed that performance of bottle gourd varieties “Nuefield” and “Crystal long” was best by up taking minimum number of sodium and chloride ions under salt stress while musk melon varieties “Kalash” and “Durga” gave poor performance by absorbing maximum sodium and chloride ions.

DISCUSSION

Salt stress significantly affected the germination and early seedling growth of plants. If the plant shows high germination of seed and healthy growth of seedling under saline conditions, it means these can stand against salinity. Therefore, these plants indirectly play an essential role in better growth and productivity [26]. In the present study, salinity decreased the percentage of germination in all tested cucurbits varieties. The decline in germination percentage is due to too much accumulation of Na^+ and Cl^- in seed tissue. These ions are affecting the movement of organic and mineral reserve along with the respiration process, due to which the germination metabolism is slow down. Many reports indicate that salinity has an inhibitory effect on seedling emergence percentage, germination percentage and growth of seedling [2,27-30]. The salinity affects not only change within genotypes but also change occurs within species. That’s why as compared to other species, the bottle gourd varieties “Nuefield” and “Crystal long” performed best by maintaining highest germination percentage under salt stress.

A negative correlation also existed between the concentration of sodium ions and seedling emergence. In our experiment bottle gourd varieties “Nuefield” and “Crystal long” produced maximum number of leaves, length of shoot, and length of root, plant fresh weight and plant dry weight under salt stress. This might be due to that seedlings stop emerging due to a reduction in the osmotic potential of the root zone under excessive salts effect. Due to these excessive salts, seeds become incapable of taking up moisture which causes expansion of the embryo [31]. Thus, seedling emergence is delayed. Seedling also failed to emerge properly due to presence of lethal ions (Na^+ and Cl^-) which retard the growth of seedling [13,32-36] results indicating that increase in salt stress also has a negative correlation with growth attributes like seedling shoot length, root fresh and dry weight, seedling fresh and dry weight, number of leaves and seedling root length. High salinity causes a reduction in the water potential of the growth medium. Due to this reason, less water is absorbed by the plant which leads to a fall in cell turgor. Thus lower cell turgidity stop division of cell and elongation of cell and plant growth is also slow down.

The maximum chlorophyll contents were recorded in bottle gourd varieties “Nuefield” and “Crystal long” and lowest was observed with musk melon varieties “Kalash” and “Durga” were under salt stress. This can be due to higher salinity levels and resistance against salinity of some species. According to Somayeh, Roghie and Shadi, (2012) total chlorophyll contents decreased under saline conditions with rising salinity. Several studies have been conducted that reduction in chlorophyll content under salinity stress was observed in Zea mays L. [37], Hordeum *vulgare* L. [38], Oriza sativa L. [39] *Gossypium hirsutum* L. [40]. Beinsan et al., described that decline in leaf's chlorophyll content was due to an increase in activity of chlorophyll destroying enzymes that would damage chloroplasts and cause instability of pigments [41].

Plants’ nutritional status is also disturbed significantly by salinity. Salt tolerance potential has closely linked with nutritional regulation. Under saline condition, plant parts have high Na^+, Cl^- and low K+ and Ca^{2+} [42,43]. Many physiological mechanisms occur in plants due to the presence of K^+ and Ca^{2+}. While under salt stress conditions, these ions are replaced by Na^+ which ultimately reduces plant performance. In the current study, all cucurbits exhibited high amount of Na^+ and small amount of K^+ ions as salinity increases. It means there is a negative relationship between Na^+ and K^+ ions and salt resistance depends upon these ions ratio. The difference in Na^+ and K^+ of cucurbits may be owing to their genetic variability and root permeability for these ions. Under a saline environment, salt-tolerant plants send a limited amount of toxic ions like Na^+ to the upper part of plants as they store the maximum amount of these ions in roots.

On the other hand, salt-sensitive plants do not adopt that mechanism. A similar mechanism was also noticed in salinized citrus rootstock [19] in the screening of pea genotypes under saline conditions. In this research, bottle gourd varieties “Nuefield” and “Crystal long” performed best by up-taking a minimum number of Na^+ and Cl^- under salt stress. As the potential of salt tolerance has linked with inorganic osmolytes application (Na^+, Cl^-, K^+, Ca^{2+}) so these can be proficiently used as screening tools for cucurbits. Many reports showed that Na+ and K+ could be used as screening tools under saline regimes [42,43].

CONCLUSION

It is concluded that germination (%), number of leaves per plant, length of shoot, length of root, plant dry weight, fresh plant weight, leaf area, chlorophyll content, sodium content and chloride content are critical screening criteria for salt tolerance in musk melon, bottle gourd and squash selected varieties. From the above results, we also knew that the potential of salt tolerance in musk melon, bottle gourd and squash varieties is associated with the buildup of inorganic osmolytes (Na^+ and Cl^-) in their leaves. As, bottle gourd varieties “Nuefield” and “Crystal long” performance is best due to well maintained the above-mentioned attributes concerning squash varieties “Green round”, and ‘Squash malika” musk melon varieties “Kalash” and “Durga” when salt stress is applied on them. The bottle gourd varieties “Nuefield” and “Crystal long” are more salt-resistant than squash varieties “Green round”, and “Squash malika” and musk melon varieties “Kalash” and “Durga”. In comparison between varieties of bottle gourd, squash and musk melon “Nuefield”, “Squash malika” and “Kalash” performed well while “Crystal long”, “Green round”, and “Durga” had poor performance, respectively.

Funding: This research received no external funding.
Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

1. Cakmak I. Plant nutrition research: Priorities to meet human needs for food in sustainable ways. Plant Soil. 2002 Nov;247(1):3-24.
2. Ahmed MZ, Khan MA. Tolerance and recovery responses of playa halophytes to light, salinity and temperature stresses during seed germination. FLORA. 2010 Nov;205(11):764-71.
3. Latef AAHA, Mostofa MG, Rahman MM, Abdel-Farid IB, Tran L-SP. Extracts from yeast and carrot roots enhance maize performance under seawater-induced salt stress by altering physio-biochemical characteristics of stressed plants. J. Plant Growth Regul. 2019 Sep;38(3):966-79.
4. Chen J, Shang YT, Wang WH, Chen XY, He EM, Zheng HL, et al. Hydrogen sulfide-mediated polyamines and sugar changes are involved in hydrogen sulfide-induced drought tolerance in *Spinacia oleracea* seedlings. Front. Plant Sci. 2016 Aug;7:1173.
5. Bewley J, Black M. 445 Seeds: Physiology of Development and Germination (New York. Plenum Press. 1994.
6. Munns R. tester M., 2008. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 2009 Jun; 2 (59):651-81.
7. Chinnusamy V, Jagendorf A, Zhu JK. Understanding and improving salt tolerance in plants. Crop sci. 2005 Mar; 45(2): 437-48.
8. Cony MA, Trione SO, Guevara JC. Macrophysiological responses of two forage Opuntia species to salt stress. J. Prof. Assoc. Cactus Dev. 2006 Jul; 8(8): 52-62.
9. Okçu G, Kaya MD, Atak M. Effects of salt and drought stresses on germination and seedling growth of pea (*Pisum sativum* L.). Turk J Agric. 2005 Jun; 29(4): 237-42.
10. Kusvuran S, Yasar F, Ellialtioglu S, Abak K. Utilizing some of screening methods in order to determine of tolerance of salt stress in the melon (*Cucumis melo* L.). Res. J. Agric. Biol. Sci. 2007;3(1):40-5.
11. Xia XJ, Wang YJ, Zhou YH, Tao Y, Mao WH, Shi K, et al. Reactive oxygen species are involved in brassinosteroid-induced stress tolerance in cucumber. Plant Physiol. 2009 Jun;150(2):801-14.
12. Yin L, Wang S, Tanaka K, Fujihara S, Itai A, Den X, et al. Silicon mediated changes in polyamines participate in silicon induced salt tolerance in *Sorghum bicolor* L. Plant, Cell Environ. 2016 Feb;39(2):245-58.
13. Ashraf M, Athar H, Harris P, Kwon T. Some prospective strategies for improving crop salt tolerance. Adv. Agron. 2008 Jan;97:45-110.
14. Marschner H. Marschner's mineral nutrition of higher plants: Academic press; 2011 Aug; 8.
15. Bohra J, Doerffling K. Potassium nutrition of rice (*Oryza sativa* L.) varieties under NaCl salinity. Plant Soil. 1993 May;152(2):299-303.
16. Goreta S, Bucevic-Popovic V, Selak GV, Pavela-Vrancic M, Perica S. Vegetative growth, superoxide dismutase activity and ion concentration of salt-stressed watermelon as influenced by rootstock. J. Agric. Sci. 2008 Dec;146(6):695.
17. Shahid M, Pervez M, Balal R, Abbas T, Ayyub C, Mattson N, et al. Screening of pea (*Pisum sativum* L.) genotypes for salt tolerance based on early growth stage attributes and leaf inorganic osmolytes. Aust. J. Crop Sci. 2012 Sep;6(9):1324.
18. Ten Chen C, Kao CH. Senescence of rice leaves XXIX. Ethylene production, polyamine level and polyamine biosynthetic enzyme activity during senescence. Plant Sci. 1991 Jan; 78(2): 193-8.
19. AlKaraki GN. Growth, water use efficiency, and sodium and potassium acquisition by tomato cultivars grown under salt stress. J. Plant Nutr. 2000 Jan;23:1-8.
20. Zhu J, Bie Z, Li Y. Physiological and growth responses of two different salt-sensitive cucumber cultivars to NaCl stress. Soil Sci. Plant Nutr. 2008 Jun;54(3):400-7.

21. Yildirim E, Turan M, Donmez MF. Mitigation of salt stress in radish (*Raphanus sativus* L.) by plant growth promoting rhizobacteria. Roumanian Biotechnol Lett. 2008;13:3933-43.
22. Nasri N, Saïdi I, Kaddour R, Lachaâl M. Effect of salinity on germination, seedling growth and acid phosphatase activity in lettuce. Am. J. Plant Sci. 2015 Jan;6(01):57.
23. GHASSEMI-GOLEZANI K, Esmaeilpour B. The effect of salt priming on the performance of differentially matured cucumber (*Cucumis sativus*) seeds. Not Bot Horti Agrobot Cluj. 2008;36(2):67-70.
24. Lamb JJ, Eaton-Rye JJ, Hohmann-Marriott MF. An LED-based fluorometer for chlorophyll quantification in the laboratory and in the field. Photosynth. Res. 2012 Oct;114(1):59-68.
25. Steel RG. Pinciples and procedures of statistics a biometrical approach. 1997. Report No.: 0070610282.
26. Carpýcý E, Celýk N, Bayram G. Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars. Afr. J. Biotechnol. 2009;8(19).
27. Song J, Fan H, Zhao Y, Jia Y, Du X, Wang B. Effect of salinity on germination, seedling emergence, seedling growth and ion accumulation of a euhalophyte *Suaeda salsa* in an intertidal zone and on saline inland. Aquat. Bot. 2008 May;88(4):331-7.
28. Tlig T, Gorai M, Neffati M. Germination responses of Diplotaxis harra to temperature and salinity. FLORA. 2008 Jul;203(5):421-8.
29. Guan YJ, Hu J, Wang XJ, Shao CX. Seed priming with chitosan improves maize germination and seedling growth in relation to physiological changes under low temperature stress. J. Zhejiang Uni. Sci. B. 2009 Jun;10(6):427-33.
30. Li R, Shi F, Fukuda K. Interactive effects of salt and alkali stresses on seed germination, germination recovery, and seedling growth of a halophyte *Spartina alterniflora* (Poaceae). S. Afr. J. Bot. 2010 Apr;76(2):380-7.
31. Al-Niemi TS, Campbell WF, Rumbaugh MD. Response of alfalfa cultivars to salinity during germination and post-germination growth. Crop Sci. 1992 Jul;32(4):976-80.
32. Malcolm C, Lindley V, O'leary J, Runciman H, Barrett-Lennard E. Halophyte and glycophyte salt tolerance at germination and the establishment of halophyte shrubs in saline environments. Plant Soil. 2003 Jun;253(1):171-85.
33. Qu XX, Huang ZY, Baskin JM, Baskin CC. Effect of temperature, light and salinity on seed germination and radicle growth of the geographically widespread halophyte shrub *Halocnemum strobilaceum*. Ann. Bot. 2008 Jan;101(2):293-9.
34. Cardarelli M, Rouphael Y, Saccardo F, Graifenberg A, Curadi M, Colla G, et al., editors. Evaluation of salt tolerance in rootstocks of Cucurbitaceae. Inter. Sym. Soil Cul. Hydro. 697; 2004 Nov; 669-74.
35. Waheed A, Hafiz IA, Qadir G, Murtaza G, Mahmood T, Ashraf M. Effect of salinity on germination, growth, yield, ionic balance and solute composition of pigeon pea (*Cajanus cajan* (L.) MillSp). Pak. J. Bot. 2006 Dec;38(4):1103.
36. Taffouo VD, Djiotie NL, Kenné M, Din N, Priso R, Dibong S, et al. Effects of salt stress on physiological and agronomic characteristics of three tropical cucurbit species. J Appl Biosci. 2008;10:434-41.
37. Cha-Um S, Kirdmanee C. Effect of salt stress on proline accumulation, photosynthetic ability and growth characters in two maize cultivars. Pak J Bot. 2009 Feb;41(1):87-98.
38. Grewal HS. Water uptake, water use efficiency, plant growth and ionic balance of wheat, barley, canola and chickpea plants on a sodic vertosol with variable subsoil NaCl salinity. Agric Water Manag. 2010 Jan;97(1):148-56.
39. Amirjani MR. Effect of NaCl on some physiological parameters of rice. EJBS. 2010;3(1):6-16.
40. Desingh R, Kanagaraj G. Influence of salinity stress on photosynthesis and antioxidative systems in two cotton varieties. Gen. Appl. Plant Physiol. 2007;33(3-4):221-34.
41. Beinsan C, Camen D, Sumalan R, Babau M, editors. Study concerning salt stress effect on leaf area dynamics and chlorophyll content in four bean local landraces from Banat area. 44th Croatian & 4th International Symposium on Agriculture, Opatija, Bosnia and Herzegovina; 2009 Feb; 16.
42. Faheed FA, Hassanein A, Azooz M. Gradual increase in NaCl concentration overcomes inhibition of seed germination due to salinity stress in *Sorghum bicolor* L.). Acta agron. Hung. 2005 Aug;53(2):229-39.
43. Dasgan HY, Aktas H, Abak K, Cakmak I. Determination of screening techniques to salinity tolerance in tomatoes and investigation of genotype responses. Plant Sci. 2002 Oct;163(4):695-703.