Journal of Horticultural Science and Technology 4(2): 62-67 (2021)
ISSN: 2617-3220 (Print), 2664-9489 (Online)
https://doi.org/10.46653/jhst2142062

Original Research

Evaluation of *Capsicum annum* L. Genotypes Against Salinity Induced by NaCl

Muhammad Zohaib Nasir[a], Mujahid Ali[b]*, Saqib Ayyub[a], Bilal Akram[a], Rashid Hussain[c], Zaid Mustafa[d] and Hafiz Muhammad Tayyab Khan[e]

[a] Institute of Horticultural Sciences, University of Agriculture, Faisalabad-38000, Pakistan
[b] Water Management Research Farm, Renala Khurd-56150, Okara, Punjab, Pakistan
[c] Department of Horticultural Sciences, Faculty of Agriculture and Environment, The Islamia University of Bahawalpur-63100, Punjab, Pakistan
[d] Department of Agricultural Sciences, Allama Iqbal Open University Islamabad, Pakistan
[e] Department of Horticulture, College of Agriculture, University of Sargodha, Sargodha, Pakistan

ABSTRACT

Soil salinity harmfully effect bell pepper production being salt sensitive crop. The aim of this study was to compare capsicum (bell-pepper) cultivars for their ability to tolerate salt stress. Electrical conductivity of different levels *i.e.,* control (no sodium chloride), 1.5, 3.0, 4.5, and 6.0 dS m^{-1}, was developed by using NaCl, after 30 days of seedling emergence of six cultivars (Yolo Wonder, California Wonder, Cop-amber Hybrid, F1 Pangs No. 206, Sweet Pepper F1, Kaka F1). These cultivars were evaluated based on morphological (shoot and root length, plant fresh and dry biomass), physiological (chlorophyll content) and biochemical attributes (nitrogen concentration, and protein contents). Minimum chlorophyll contents (SPAD units) in Kaka F1 (16.77 SPAD units) at 1.5 dSm^{-1}. However, maximum value of chlorophyll contents was observed in Sweet Pepper F1 (49.23 SPAD units) at control followed by "Yolo Wonder" (41.53 SPAD units) at control. Maximum dry biomass was found in California Wonder (0.468 g) at 1.5 dSm^{-1}, while minimum value of dry biomass (g) was observed in Kaka F1 (0.095 g) at 4.5 dSm^{-1}. Six cultivars of capsicum were categorized into three groups. Salt tolerant cultivars included "California Wonder" followed by "Yolo Wonder". "Kaka F1" was proved most salt sensitive and all others were moderately salt tolerant.

Keywords: *Bell-pepper, cultivars, electrical conductivity, saline soil, chlorophyll contents.*

Article History: *Received 12 April 2021; Revised 19 June 2021; Accepted 23 June 2021; Published 30 June 2021.*

INTRODUCTION

Bell-pepper, *Capsicum annuum*, also known as" Sweet Pepper", locally known as "Shimla ki Mirch" is probably of American origin. Bell pepper can be grown best in sandy loam and silt loam soils. It is much sensitive to salt stress (Hussein et al., 2012). Total world production of world bell pepper is 38.01MMT. China (18.98 MMT), Mexico (3.24 MMT), Turkey (2.63 MMT), Indonesia (2.59 MMT), Spain (1.40 MMT), and Egypt 764.29 KMT are its leading producing countries. However, Pakistan has very less per acre production of bell-pepper (Statista, 2019).

Salinity in major problem which is growing day by day. It is of immense important because of its significant impact on yield and quality. Pakistan is an agriculture-based country so this issue must be addressed. Various types of salts are present in soils. In one of previous study plant growth and development was significantly decreased by salinity in bell pepper (Rubio et al., 2011). Various biochemical and physiological process are affected by salinity which lead to damaging carbohydrate manufacturing and its consumption (Arif et al., 2020). This is due to reactive oxygen species production and their detrimental effects on metabolism (Kamran et al., 2020). Sodium accumulation alters photosynthetic rate which can lead to lessening plant biomass production (Azuma et al., 2010).

Sodium content in soil significantly reduce yield in various crops. Due to increase in salinity, millions of acres' agricultural productive lands are becoming baron each year (Velmurugan et al., 2020). Marketable fruit yield and quality was highly reduced by the use of saline water in capsicum (Semiz et al., 2014). This might be due to the fact that water use efficiency was affected (Patil et al., 2014). Plant adopt mechanism of defensive against these detrimental changes by developing various enzymatic and non-enzymatic antioxidant (Ramanjulu and Sudhakar, 2001).

Most of the vegetables are drastically affected by soil salinity. So, management and different techniques are required to cope with this issue (Machado and Serralheiro, 2017; Selim et al., 2017).

* Corresponding author
Email: mujahidali2263@gmail.com (M. Ali)

Screening of vegetables against salt stress is of vital important and feasible method to cope with this situation (Shaheen et al., 2013). The aim of study was to evaluate bell-pepper cultivars for their salt tolerance potential and to find cultivar suitable for cultivation in saline conditions.

MATERIAL AND METHODS

The pot study was conducted at Horticultural Research Area, University of Agriculture Faisalabad. Four salinity levels having EC i.e., 1.5, 3, 4.5, and 6 dS m^{-1} NaCl) and six cultivars namely ("Yolo Wonder", "California Wonder", "Cop-amber Hybrid", "F1 Pangs No. 206", "Sweet Pepper F1", "Kaka F1") was arranged from reliable research stations and tested for screening and results compared with control (1.0 dS m^{-1} NaCl) (without additional NaCl application). Each treatment was replicated thrice. The experiment was layout under completely randomized design (CRD). EC of the medium was noted daily. Hoagland's solution was used as nutrient medium. Seeds were sown in plastic pots containing 7 Kg sand. Pots were kept in the open field. The number of seedlings per pot was adjusted to four and the seeds were watered according to the need of plant by observing the moisture of sand. Nutrient composition of the solution having pH of 6-6.5 kept maintained (Model Genway, 3510) USA. After every week Hoagland solution (Table 1) was applied for nourishment of seedlings.

After two weeks of salt application data were collected. To evaluate the impact of different EC levels, various attributes were studied *i.e.,* mortality (%), shoot length (cm), root length (cm), total length (cm), total fresh mass (g), total dry mass (g) were measured. Chlorophyll contents (CCI) were found out by chlorophyll meter (CCM-200plus Bio- Scientific USA).

Measurement of leaf nitrogen content

Leaf nitrogen contents and protein were measured by following procedure already reported by Ataulkarim et al. (2016). Fresh leaf samples were washed with detergent for surface disinfection then rinsed, dried, and then ground into fine powder by an electric grinder for further process. So, determination of the leaf N concentration (LNC) using the micro-Kjeldahl method and was expressed as mg g^{-1} DW.

Table 1: Composition of Hoagland nutrient solutions.

Reagent	Stock (g/L)	Stock sol. for 10L ½ conc. (ml)	Stock sol. for 200L ½ conc. (ml)
Macro-nutrients			
KH_2PO_4	136	5	100
KNO_3	101	25	500
$Ca(NO_3)_2.4H_2O$	236	25	500
$MgSO_4.7H_2O$	246	10	200
Micro-nutrients			
H_3BO_3	2.86	5	100
$MnCl_2.4H_2O$	1.81	5	100
$ZnSO_4.7H_2O$	0.22	5	100
$CuSO_4.5H_2O$	0.08	5	100
$H_2MoO_4.H_2O$	0.02	5	100
Fe-EDTA	37.33	5	100

Analysis of leaf protein content

The total protein contents (%) were determined by multiplying leaf nitrogen amount by factor depending on the protein types. This value is called the 'crude protein' content. The leaf protein determination formula (AOAC, 2000) was as follow:

$$\text{Crude protein} = N \times 6.25$$

Statistical analysis

Means were compared by Least Significant Difference (LSD) test and analysis of variance was performed by using Statistix 8.1 software package.

RESULTS

It was revealed that there was significant difference among selected bell-pepper genotypes against different selected levels of salinity. Complete mortality (100 %) was observed in "Pangs No. 206" and Kaka F1 at highest level of salt application (6 dS m^{-1}). At control minimum mortality (5.3 %) was found in sweet pepper F1 at par with Yolo Wonder (5.6 %) (Table 2).

Data regarding shoot length showed that there was significant difference among cultivars against salt stress. Maximum shoot length was found in Yolo Wonder (6.19 cm) at control followed by Yolo Wonder (6.08 cm) at 1.5 dSm^{-1} of salt application was observed. At control minimum value regarding shoot length was observed in Kaka F1 (2.69 cm) at 4.5 dSm^{-1} followed by Cop-amber hybrid (2.82 cm) at 4.5 dSm^{-1} (Table 3).

Data regarding root length showed that there was significant difference among cultivars against salt stress. Maximum root length was found in California Wonder (11.46 cm) at 6.0 dSm^{-1} followed by Cope-amber F1 (9.21 cm) at 6.0 dSm^{-1}. While minimum (5.64 cm) root length was seen in California Wonder at 4.5 dSm^{-1} of salt application at par with Kaka F1 (5.72 cm) at control (Table 4).

It was observed that total plant length showed that there was significant difference among cultivars against salt stress. Maximum total plant length in California Wonder (14.42 cm) at 6.0 dSm^{-1} followed by was observed in Yolo Wonder (13.28 cm) at 1.5 dSm^{-1}. Minimum value of total plant length was observed in Cop-amber hybrid F1 (7.87 cm) at 3.0 dSm^{-1} followed by Sweet Pepper F1 (8.53 cm) 6.0 dSm^{-1} (Table 5).

Fresh biomass (g) showed that there was significant difference among cultivars against salt stress. Maximum fresh biomass in California Wonder (1.07 g) at 3.0 dSm^{-1} followed by (0.73 g) at control and by Cope-amber F1 (0.66 g) at 1.5 dSm^{-1} was observed. Minimum value of fresh biomass (g) was observed in Kaka F1 (0.23 g) at 4.5 dSm^{-1} followed by Sweet Pepper F1 (0.23 g) 6.0 dSm^{-1} (Table 6).

Dry biomass showed that there was significant difference among cultivars against salt stress. It was seen that maximum in California Wonder (0.468 g) at 1.5 dSm^{-1} followed by Pangs No. 206 (0.365 g) was observed at 4.5 dSm^{-1}. Minimum value of dry biomass was observed in Kaka F1 (0.095 g) at 4.5 dSm^{-1} followed by Sweet Pepper F1 (0.110 g) at 6.0 dSm^{-1} (Table 7).

Number of leaves showed that there was significant difference among cultivars against salt stress. Maximum number of leaves were observed in California Wonder (5.89) at 3.0 dSm^{-1} followed same cultivar (5.33) at 1.5 dSm^{-1}. At control minimum value of number of leaves was observed in Sweet Pepper F1 (3.89) at both 3.5 dSm^{-1} and 6.0 dSm^{-1} (Table 8).

It was depicted that chlorophyll contents showed that there was significant difference among cultivars against salt stress. It was seen that minimum chlorophyll contents (SPAD units) in Kaka

Table 2: Response of different cultivars of bell-pepper for mortality percentage (%) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	5.6 m	20.6 i-l	19.7 i-l	32.4 f-i	5.3 m	9.6 lm	15.56 D
1.5	13.9 klm	23.6 f-l	22.7 g-l	15.7 j-m	24.1 f-k	15.6 j-m	19.28 D
3.0	35.7 efg	37.0 ef	52.5 cd	21.4 h-l	34.1.7 e-h	28.5 f-j	35.00 C
4.5	21.8 g-l	53.6 cd	73.8 b	46.5 de	59.8 bcd	26.8 f-k	47.07 B
6.0	59.6 cd	65.7 bc	36.9 ef	100.0 a	56.9 cd	100.0 a	69.86 A
Mean	27.34 C	40.12AB	41.16AB	43.22 A	36.16 B	36.12 B	

Figures sharing same letters do not differ from each other at P ≤0.05 according to LSD test.

Table 3: Response of different cultivars of bell-pepper for shoot length (cm) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	6.19 a	4.05 b-d	3.07 d-f	3.28 d-f	3.39 d-f	3.12 d-f	3.851 A
1.5	6.08 a	3.37 d-f	3.58 c-f	3.43 c-f	3.28 d-f	3.76 c-e	3.915 A
3.0	4.42 bc	3.19 d-f	3.10 d-f	2.97 ef	2.75 f	3.68 c-f	3.351 B
4.5	4.81 b	3.32 d-f	2.82 ef	3.08 d-f	3.21 d-f	2.69 f	3.322 B
6.0	3.81 c-e	2.97 ef	3.32 d-f	*Mortality*	3.19 d-f	*Mortality*	2.214 C
Mean	5.064 A	3.380 B	3.180 B	2.550 C	3.162 B	2.650 C	

Figures sharing same letters do not differ from each other at P ≤ 0.05 according to LSD test.

Table 4: Response of different cultivars of bell-pepper for root length (cm) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	6.86 b-d	8.51 a-c	7.31 b-d	8.11 a-d	5.80 b-d	5.72 b-d	7.051 A
1.5	7.20 b-d	7.94 a-d	7.00 b-d	6.80 b-d	6.98 b-d	5.91 b-d	6.971 A
3.0	7.51 b-d	8.08 a-d	4.77 d	7.88 a-d	7.92 a-d	6.98 b-d	7.188 A
4.5	7.79 b-d	5.64 b-d	6.24 b-d	7.99 a-d	6.90 b-d	7.63 b-d	7.035 A
6.0	6.48 b-d	11.46 a	9.21 ab	*Mortality*	5.34 cd	*Mortality*	5.416 B
Mean	7.168 AB	8.325 A	6.906 AB	6.157 BC	6.590 BC	5.247 C	

Figures sharing same letters do not differ from each other at P ≤ 0.05 according to LSD test.

Table 5: Response of different cultivars of bell-pepper for plant length (cm) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	13.05 ab	12.56 a-d	10.38 b-f	11.38 a-f	9.19 c-f	8.84 d-f	10.90 A
1.5	13.28 ab	11.31 a-f	10.58 b-f	10.23 b-f	10.25 b-f	9.66 b-f	10.88 A
3.0	11.93 a-e	11.26 a-f	7.87 f	10.84 a-f	10.67 b-f	10.65 b-f	10.54 A
4.5	12.60 a-c	8.96 c-f	9.07 c-f	11.07 a-f	10.11 b-f	10.32 b-f	10.35 A
6.0	10.29 b-f	14.42 a	12.53 a-d	*Mortality*	8.53 ef	*Mortality*	7.63 B
Mean	12.232 A	11.705 AB	10.087 BC	8.708 CD	9.752 C	7.897 D	

Figures sharing same letters do not differ from each other at P ≤0.05 according to LSD test.

Table 6: Response of different cultivars of bell-pepper for fresh biomass (g) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	0.42 b-f	0.73 b	0.43 b-f	0.24 e-g	0.26 e-g	0.31 d-g	0.403AB
1.5	0.62 b-d	0.64 bc	0.66 bc	0.30 d-g	0.31 d-g	0.27 e-g	0.472AB
3.0	0.55 b-e	1.07a	0.45 b-f	0.34 c-f	0.22 fg	0.29 d-g	0.489A
4.5	0.51 b-f	0.46 b-f	0.41 b-f	0.23 e-g	0.25 e-g	0.23 e-g	0.353 BC
6.0	0.47 b-f	0.49 b-f	0.29 d-g	*Mortality*	0.23 e-g	*Mortality*	0.250 C
Mean	0.516 B	0.682A	0.454 B	0.225 C	0.259 C	0.225 C	

Figures sharing same letters do not differ from each other at P ≤0.05 according to LSD test.

F1 (16.77 SPAD units) at 1.5 dSm^{-1} followed by California Wonder (17.23 SPAD units) at the same level of salinity. At control maximum value of chlorophyll contents was observed in Sweet Pepper F1 (49.23 SPAD units) at control followed by Yolo Wonder (41.53 SPAD units) at control (Table 9).

Data regarding nitrogen content showed that there was significant difference among cultivars against salt stress. Maximum nitrogen content in Pangs No. 206 (0.517 mg g^{-1} DW) at control followed by (0.450 mg g^{-1} DW) was observed in Sweet Pepper F1 at control and at 1.5 dSm^{-1} of salt application at par

Table 7: Response of different cultivars of bell-pepper for plant dry biomass (g) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	0.111 d-f	0.243 b-e	0.176 b-f	0.133 c-f	0.132 c-f	0.166 b-f	0.1606 A
1.5	0.186 b-f	0.468 a	0.161 b-f	0.136 c-f	0.151 b-f	0.139 c-f	0.2072 A
3.0	0.171 b-f	0.344 a-c	0.109 d-f	0.173 b-f	0.134 c-f	0.148 c-f	0.1801 A
4.5	0.263 a-e	0.212 b-f	0.140 c-f	0.365 ab	0.103 ef	0.095 ef	0.1967 A
6.0	0.171 b-f	0.199 b-f	0.322 a-d	*Mortality*	0.110 d-f	*Mortality*	0.1338 A
Mean	0.180 B	0.293 A	0.181 B	0.161 B	0.126 B	0.109 B	

Figures sharing same letters do not differ from each other at P ≤0.05 according to LSD test.

Table 8: Response of different cultivars of bell-pepper for number of leaves to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	4.10 e-h	4.78 b-e	4.33 d-g	4.33 d-g	4.33 d-g	4.67 b-f	4.423 AB
1.5	4.40 c-g	5.33 b	4.11 e-h	4.33 d-g	4.67 b-f	4.33 d-g	4.529 A
3.0	4.32 d-g	5.89 a	4.11 e-h	5.00 b-d	3.89 gh	4.33 d-g	4.591 A
4.5	4.11 e-h	5.06 bc	4.33 d-g	4.22 e-g	3.44 h	4.00 f-h	4.194 B
6.0	4.33 d-g	4.33 d-g	4.10 e-h	*Mortality*	3.89 gh	*Mortality*	2.776 C
Mean	4.253 B	5.078 A	4.196 B	3.578 C	4.044 B	3.467 C	

Figures sharing same letters do not differ from each other at P ≤ 0.05 according to LSD test.

Table 9: Response of different cultivars of bell-pepper for chlorophyll contents (SPAD units) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	41.53 ab	26.87 b-e	21.57 c-e	20.57 de	49.23 a	35.17 a-d	32.48 A
1.5	27.47 b-e	17.23 e	24.12 c-e	33.03 b-d	29.07 b-e	16.77 e	24.63 B
3.0	36.30 a-c	23.30 c-e	22.17 c-e	33.50 b-d	31.13 b-e	27.40 b-e	28.96 AB
4.5	32.33 b-d	23.83 c-e	26.60 b-e	28.47 b-e	23.83 c-e	20.43 de	25.91 B
6.0	20.93 de	23.63 c-e	21.00 de	*Mortality*	22.60 c-e	*Mortality*	14.69 C
Mean	31.71A	22.97 B	23.11 B	23.11 B	31.17A	19.95 B	

Figures sharing same letters do not differ from each other at P ≤0.05 according to LSD test.

Table 10: Response of different cultivars of bell-pepper for leaf nitrogen contents (mg g^{-1} DW) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	0.417 bc	0.450 b	0.417 bc	0.517 a	0.450 b	0.350 d	0.433 A
1.5	0.283 e	0.283 e	0.383 cd	0.450 b	0.450 b	0.250 e	0.350 BC
3.0	0.350 d	0.350 d	0.450 b	0.383 cd	0.383 cd	0.250 e	0.361 B
4.5	0.283 e	0.350 d	0.450 b	0.350 d	0.250 e	0.283 e	0.327 C
6.0	0.250 e	0.250 e	0.350 d	*Mortality* f	0.250 e	*Mortality* f	0.183 D
Mean	0.316 C	0.336 BC	0.410 A	0.340 BC	0.356 B	0.226 D	

Figures sharing same letters do not differ from each other at P ≤ 0.05 according to LSD test.

Table 11: Response of different cultivars of bell-pepper for leaf crude protein contents (%) to different levels of salinity.

NaCl conc.	Cultivars						Mean
(dS m^{-1})	Yolo Wonder	California Wonder	Cop-amber hybrid F_1	Pangs No. 206	Sweet pepper F1	Kaka F1	
Control	2.60 bc	2.81 b	2.60 bc	3.23 a	2.81 b	2.19 d	2.7083 A
1.5	1.77 e	1.77 e	2.39 cd	2.81 b	2.81 b	1.56 e	2.1875 BC
3.0	2.19 d	2.18 d	2.81 b	2.39 cd	2.39 cd	1.56 e	2.2569 B
4.5	1.77 e	2.19 d	2.81 b	2.19 d	1.56 e	1.77 e	2.0486 C
6.0	1.56 e	1.56 e	2.19 d	*Mortality*	1.56 e	*Mortality*	1.1458 D
Mean	1.979 C	2.104 BC	2.562 A	2.125 BC	2.229 B	1.416 D	

Figures sharing same letters do not differ from each other at P ≤0.05 according to LSD test.

with Pangs No. 206 (0.450 mg g^{-1} DW) at 1.5 dSm^{-1} and Cop-amber hybrid F1 (0.450 mg g^{-1} DW) at 3.0 and 4.5 dSm^{-1}. At control minimum value regarding nitrogen content was observed in Kaka F1 (2.50 mg g^{-1} DW) at 1.5 dSm^{-1} and 3.0 dSm^{-1}, similarly same value was observed in Yolo Wonder 2.50 mg g^{-1} DW) and California Wonder 2.50 mg g^{-1} DW) at 6.0 dSm^{-1} (Table 10).

Data regarding leaf crude protein content showed that there was significant difference among cultivars against salt stress. Maximum leaf protein was found in Pangs No. 206 (3.23 %) at control followed by (2.81 %) in Sweet Pepper F1 at control and at 1.5 dSm^{-1} of salt application at par with Pangs No. 206 (2.81 %) at 1.5 dSm^{-1} and Cop-amber hybrid F1 (2.81 %) at 3.0 and 4.5 dSm^{-1}. At control minimum value was observed in Sweet Pepper F1 (1.56 %) at 4.5 dSm^{-1} and 6.0 dSm^{-1} at par with Yolo Wonder and California Wonder (1.56 cm) at 6.0 dSm^{-1}, similarly in Kaka F1 (1.5 %) showed same value at 1.5 dSm^{-1} and 3.0 dSm^{-1} (Table 11).

DISCUSSION

Gradual increase in salt stress level in the growing medium enhanced damaging impacts on all bell pepper cultivars. Various cultivars under study showed varied response to different salinity levels. Some cultivars tolerated to highest salinity levels, but a few couldn't as high salt content in soil hinder uptake of nutrients in plants (Tanaka et al., 2018). Ai et al. (2021) reported about four genotypes of chili behaved differently against different salinity levels produced by NaCl or $CaCl_2$. Some cultivars adopt defensive mechanisms by improving enzymatic and non-enzymatic antioxidants during salt stress (Bano et al., 2014). Various types of cultivars of vegetables could be screened out based on their physiological and biochemical characteristics (Tahira et al., 2014). Present study depicted that some cultivars completely died at its highest level of salt stress. This fact was previously observed when salinity induced harmful changes which lead to complete death of plants with increase in its level and with the passage of time (Meng at el., 2011).

Bell pepper plants were severely affected in this study due to hindrance in nutrient uptake and low chlorophyll pigment production under high salt contents in soil. Such changes were previously reported by Ashraf and Harris (2004). Such results were seen when shoot length was deceased due to salt stress because of accumulation and sodium ions (Janagard et al., 2008). Hamayun et al. (2010) found out the reason of low height was due to gibberellic acid production.

Taïbi et al. (2016) confirmed the correlation of chlorophyll content with height. A similar effect was observed when "Cop-amber Hybrid" F_1 had gained more height and chlorophyll content (SPAD value) and hence photosynthetic apparatus is significantly impaired (Pessarkali et al., 2004; Ashraf et al., 2005; Brown et al., 2006). Root length was also prominently reduced by increasing salt stress doses; this was initially reported by Maiti et al. (2010). Plant biomass decreased due to injury of sodium and chloride ions (Amirjani, 2010). Potassium has very important role in stomatal opening and closing but due to high Na^+ replaces or disturbs its proper functioning ultimately transpiration effects and nutrient absorption hinders (Pakniyat and Armion, 2007; Yasar et al., 2008). Protein was higher in amount in salt tolerant cultivars as proteins play an imminent role in plant stress response since, they are directly involved in the acquisition of an enhanced stress tolerance (Kosová et al., 2011).

CONCLUSION

It was concluded that plant damage was increased with enhancement of salt concentration in nutrient medium. Outcomes showed that some cultivars of bell-pepper were more tolerant to salt stress than others. Salt tolerant cultivars included "California" Wonder followed by "Yolo Wonder". "Kaka F1" was salt sensitive and "Cop-amber Hybrid", "F1 Pangs No. 206" along with "Sweet Pepper F1", were moderately salt tolerant.

DECLARATION OF COMPETING INTERESTS

All authors declare no conflict of interest for this publication.

AUTHOR CONTRIBUTION STATEMENT

Muhammad Zohaib Nasir: Conceptualized idea and conducted this research work and collected data. **Mujahid Ali:** Conceptualized idea and designed this research work and collected data. **Saqib Ayyub and Saqib Ayyub:** Assisted in methodology, validation, editing, reviewing. **Rashid Hussain:** Assisted in laboratory analysis; **Zaid Mustafa:** Editing, reviewing, software analysis and improving of the manuscript. **Hafiz Muhammad Tayyab Khan:** Assisted in methodology, validation, editing and reviewing.

REFERENCES

Abbas, T., Pervez, M.A., Ayyub, C.M., Shaheen, M.R., Tahseen, S., Shahid, M.A., Bilal, R.M. Ana Manan, A. 2014. Evaluation of different okra cultivars for salt tolerance. *International Journal of Plant, Animal and Environmental Sciences*, 4(3): 23-30.

Ai, T.N., Tran, T.N.B., Lam, N.H., Nguyen, M.H. and Phan, C.H. 2021. Assessment of Salinity Tolerance of 4 Chili Pepper Genotypes in Vietnam. *Journal of Southwest Jiaotong University*, 56(2):94-110. https://doi.org/10.35741/issn.0258-2724.56.2.9

Alwi, N.A. and Ali, A. 2014. Reduction of *Escherichia coli* O157, *Listeria monocytogenes* and *Salmonella enterica* sv. Typhimurium populations on fresh-cut bell pepper using gaseous ozone. *Food Control*, 46: 304-311. https://doi.org/10.1016/j.foodcont.2014.05.037

Amirjani, M.R. 2010. Effect of NaCl on some physiological parameters of rice. *European Journal of Biological Sciences*, 3(1):6-16.

AOAC. 2000. Official Methods of Analysis. 17th Edition, Association of Official Analytical Chemists, Arlington, VA.

Arif, Y., Singh, P., Siddiqui, H., Bajguz, A. and Hayat, S. 2020. Salinity induced physiological and biochemical changes in plants: An omic approach towards salt stress tolerance. *Plant Physiology and Biochemistry*, 156, 64-77. https://doi.org/10.1016/j.plaphy.2020.08.042

Ashraf, M. and Harris, P.J.C. 2004. Potential biochemical indicators of salinity tolerance in plants. *Plant Science*, 166(1): 3-16. https://doi.org/10.1016/j.plantsci.2003.10.024

Ashraf, M., Ali, Q. and Rha, E.S. 2005. The effect of applied nitrogen on the growth and nutrient concentration of kalonji (*Nigella sativa*). *Australian Journal of Experimental Agriculture*, 45: 459–463. https://doi.org/10.1071/EA03261

Ataulkarim, S.T., Liu, X., Lu, Z., Yuan, Z., Yan, Z. and Cao, W. 2016. In-season estimation of rice grain yield using critical nitrogen dilution curve. *Field Crop Research,* 195: 1–8. https://doi.org/10.1016/j.fcr.2016.04.027

Azuma, R., Ito, N., Nakayama, N., Suwa, R., Nguyen, N.T., Larrinaga-Mayoral, J.Á. and Saneoka, H. 2010. Fruits are more sensitive to salinity than leaves and stems in pepper plants (*Capsicum annuum* L.). *Scientia Horticulturae*, 125(3): 171-178. https://doi.org/10.1016/j.scienta.2010.04.006

Bano, S., Ashraf, M. and Akram, N.A. 2014. Salt stress regulates enzymatic and nonenzymatic antioxidative defense system in the edible part of carrot (*Daucus carota* L.). *Journal of Plant Interactions*, 9:(1) 324-329. https://doi.org/10.1080/17429145.2013.832426

Brown, C.E., Pezeshki, S.R. and DeLaune, R.D. 2006. The effects of salinity and soil drying on nutrient uptake and growth of *Spartina alterniflora* in a simulated tidal system. *Environmental and Experimental Botany*, 58(1-3): 140-148. https://doi.org/10.1016/j.envexpbot.2005.07.006

Hamayun, M., Khan, S.A., Khan, A.L., Shinwariz, K., Hussain, J., Sohn, E., Kang, S., Kim, Y., Khan, M.A. and Lee, I. 2010. Effect of salt stress on growth attributes and endogenous growth hormones of soybean cultivar. *Pakistan Journal of Botany*, 42(5): 3103-3112.

Hussein, M.M., El-Faham, S.Y. and Alva, A.K. 2012. Pepper plants growth, yield, photosynthetic pigments, and total phenols as affected by foliar application of potassium under different salinity irrigation water. *Agricultural Sciences*, 3: 241-248. http://dx.doi.org/10.4236/as.2012.32028

Janagard, M.S., Tobeh, A. and Esmailpour, B. 2008. Evaluation of salinity tolerance of three canola genotyps at germination and early seedling growth stage. *Journal of Food Agriculture and Environment*, 6(2): 272.

Kamran, M., Parveen, A., Ahmar, S., Malik, Z., Hussain, S., Chattha, M.S. and Chen, J.T. 2020. An overview of hazardous impacts of soil salinity in crops, tolerance mechanisms, and amelioration through selenium supplementation. *International Journal of Molecular Science*, 21(1): 148. https://doi.org/10.3390/ijms21010148

Kosová, K., Vítámvás, P., Prášil, I.T. and Renaut J. 2011. Plant proteome changes under abiotic stress contribution of proteomics studies to understanding plant stress response. *Journal of Proteomics*, 74: 1301–1322. https://doi.org/10.1016/j.jprot.2011.02.006

Machado, R.M.A. and Serralheiro, R.P. 2017. Soil salinity: effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. *Horticulturae*, 3(2): 30.

Maiti, R. 2010. A novel technique for evaluating and selecting crop genotypes for salinity tolerance: its progress. *International Journal of Bio-resource and Stress Management*, 1(1): 51-53. https://www.ikprress.org/index.php/PCBMB/article/view/6455

Meng, X.L., Dong, Y.W., Dong, S.L., Yu, S.S., and Zhou, X. 2011. Mortality of the sea cucumber, *Apostichopus japonicus* Selenka, exposed to acute salinity decrease and related physiological responses: osmoregulation and heat shock protein expression. *Aquaculture*, 316(1-4): 88-92. https://doi.org/10.1016/j.aquaculture.2011.03.003

Pakniyat, H. and Armion, M. 2007. Sodium and proline accumulation as osmoregulators in tolerance of sugar beet cultivars to salinity. *Pakistan Journal of Biological Sciences*, 10(22): 4081-4086. https://doi.org/10.3923/pjbs.2007.4081.4086

Patil, V.C., Al-Gaadi, K.A., Wahb-Allah, M.A., Saleh, A.M., Marey, S.A., Samdani, M.S. and Abbas, M.E. 2014. Use of saline water for greenhouse bell pepper (*Capsicum annuum*) production. *American Journal of Agricultural and Biological Sciences*, 9(2): 208-217. https://doi.org/10.3844/ajabssp.2014.208.217

Pessarakli, M. and Kopec, D.M. 2004. Growth responses of bermudagrass and seashore Paspalum to different levels of FerroGrow multi-nutrient fertilizer. *Journal of Food, Agriculture & Environment (JFAE)*, 2: 284-286.

Ramanjulu, S. and Sudhakar, C. 2001. Alleviation of NaCl salinity stress by calcium is partly related to the increased proline accumulation in mulberry (*Morus alba* L.) callus. *Journal of Plant Biology*, 28: 203–206.

Rubio, J.S., Pereira, W.E. Garcia-Sanchez, F., Murillo, L. and Garcia, A.L. 2011. Sweet pepper production in substrate in response to salinity, nutrient solution management and training system. *Horticultura Brasileira*, 29: 275-281. https://doi.org/10.1590/S01020536201100030003

Selim, S.M., Abdella, E.M., Badwy, A.I. and Al-Elwany, O.A. 2017. Mitigate the effects of soil-salt stress on chili pepper (*Capsicum frutescens* L.) plants by foliar application of salicylic acid. *Egyptian Journal of Applied Science*, 32 (9): 234-253.

Semiz, G.D., Suarez, D.L., Ünlükara, A. and Yurtseven, E. 2014. Interactive effects of salinity and N on pepper (*Capsicum annuum* L.) yield, water use efficiency and root zone and drainage salinity. *Journal of Plant Nutrition*, 37(4): 595-610. https://doi.org/10.1080/01904167.2013.867985

Shaheen, S., Naseer, S., Ashraf, M. and Akram, N.A. 2013. Salt stress affects water relations, photosynthesis, and oxidative defense mechanisms in *Solanum melongena* L. *Journal of Plant Interactions*, 8(1): 85-96. https://doi.org/10.1080/17429145.2012.718376

Statista. 2019. Global production of vegetables in 2019. Agriculture, Farming. https://www.statista.com/statistics/264065/global-production-of-vegetables-by-type/

Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of Statistics: A biometrical approach. 3rd ed. McGraw Hill Co., New York, USA.

Tahira, A., Pervez, M.A., Ayyub, C.M., Shaheen, M.R., Sana, T., Shahid, M.A., Bilal, R.A. and Abdul, M. 2014. Evaluation of different okra cultivars for salt tolerance. International *Journal of Plant, Animal and Environmental Sciences*, 4(3): 23-30.

Taïbi, K., Taïbi, F., Abderrahim, L.A., Ennajah, A., Belkhodja, M. and Mulet, J.M. 2016. Effect of salt stress on growth, chlorophyll content, lipid peroxidation and antioxidant defense systems in *Phaseolus vulgaris* L. *South African Journal of Botany*, 105: 306-312. https://doi.org/10.1016/j.sajb.2016.03.011

Tanaka, H., Yamada, S., Masunaga, T., Yamamoto, S., Tsuji, W. and Murillo-Amador, B. 2018. Comparison of nutrient uptake and antioxidative response among four Labiatae herb species under salt stress condition. *Soil Science and Plant Nutrition*, 64(5): 589-597. https://doi.org/10.1080/00380768.2018.1492334

Velmurugan, A., Swarnam, P., Subramani, T., Meena, B., Kaledhonkar, M. 2020. Water demand and salinity. Farhani, M. H. D. A., Vatanpu, V. and Taheri, A. H. (Eds). Desalination-challenges and opportunities. Book on Demand BOD Publisher, UK, 130.

Yasar, F., Ellialtioglu, S. and Yildiz, K. 2008. Effect of salt stress on antioxidant defense systems, lipid peroxidation, and chlorophyll content in green bean. *Russian Journal of Plant Physiology*, *55*(6): 782-786. https://doi.org/10.1134/S1021443708060071