

# Assessment of Cucumber Genotypes for Salt Tolerance Based on Germination and Physiological Indices

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## Abstract

Soil salinity is one of the primary problem for agricultural crops which causes a great loss in crop production in Pakistan and worldwide. Various approaches have been implemented to overcome salinity problem. Assembly of crops for the enhancement of salt tolerance is a good strategy to achieve cost-effective yields. Cucumber is considered as one of the leading vegetable crop around the world for the nourishment of human being as source of nutrients, minerals, and vitamins. Screening of 12 cucumber genotypes using some physiological indices, that is, seedling germination stress tolerance index, plant height stress tolerance index, root length stress tolerance index, shoot and root dry weight stress tolerance index, and shoot and root fresh weight stress tolerance index were performed for the identification of salt tolerance. Using the above characteristics genotypes, Valley and HC-999 were categorized as tolerant, Safaa and Debra as medium tolerant, while Thamin-II identified as medium sensitive and NSC-CM1 and Akbar are classified as sensitive genotypes of cucumber. According to the current study findings, the screened cucumber genotypes for salinity tolerance can also be suggested to farmers for the improved production and yield of crop at saline soil.

## Keywords

cucumber, salt tolerance, physiological indices

## Introduction

Saline soil is an important problem of agricultural lands which causes a great loss in crop productivity all over the world.<sup>1</sup> Soluble salts accumulated in soil at harmful levels adversely affects development and productivity of plants in many areas of the world with low rainfall because of improper precipitation for leaching<sup>2</sup> and as a result of severe loss in crop production which leads to low economic returns and soil erosions at large scale. High levels of salts affects approximately 6% (400 million hectares) of world's land, which cover almost half of the irrigated land and 40% of the cultivated area.<sup>3</sup> Several factors such as deficiency in rainfall, increased rate of surface evaporation, weathering of soil, irrigation with water containing high salt contents, and poor cultural practices are considered the fundamental factors causing 10% annual increase in saline soil.<sup>4</sup> For the retrieval of saline soil, billions are consumed annually.<sup>5</sup>

Salinity generally disrupts the photosynthetic mechanism inside the plants in several aspects.<sup>6</sup> The damaging and inhibitory effect of salinity varies from species to species.<sup>7</sup> The salt

stress severely caused the reduction in biomass and overall plant productivity due to osmotic stress and ion toxicity. As a consequence, reduction in reproductive development of plants, nutrients uptake, and reactive oxygen species production in plants<sup>8,9</sup> reduced activity of photosynthetic process, antioxidant production, ionic homeostasis,<sup>7</sup> osmotic stress, and

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nutrient imbalance including the sodium and chloride toxicity,<sup>10</sup> membrane injury,<sup>11</sup> anxious leaf water relations,<sup>12</sup> and disturbance in hormonal balance.<sup>13</sup> Plant species differ in their salt tolerance depending on their genetic makeup ranging from high to low levels of salts in the soil. Increased salinity causes osmotic effect, which slow down the seed germination and emergence of roots leading to improper management of nutritional requirements of plants for their vigorous growth.<sup>14</sup> In conclusion, agronomical and several physiological attributes are highly affected by the salinity, ultimately resulting in reduced plant growth and productivity.<sup>14</sup> It is therefore necessary either to renovate such soils into useable land or either economically use that saline area by growing salt tolerant plants for the better production of crops in salt-hit areas.<sup>15</sup>

Vegetables are essential for numerous metabolic processes in the human body due to the presence of phytochemicals and nutrients.<sup>16</sup> High level of salinity threatened the crops productivity, primarily in irrigated crop lands which produce 40% of the world's food.<sup>17</sup> Cucumber is considered as one of the leading vegetable crop throughout the world for the nourishment of human being and considered as salt-sensitive crop.<sup>18</sup> Salinity level more than 1.3 dS·m<sup>-1</sup> significantly influenced the growth of cucumber, and with the increase in each unit of EC decreases the crop productivity by 15.9% (Chartzoulakis, 1992).<sup>19</sup> Cucumber yield is highly affected by salt stress, which is one of the most destructive abiotic stress resulting in the reduction of farmers' income.<sup>20</sup>

There is dire need to identify the salt tolerant genotypes of plants, so that better production can be achieved even under saline irrigated lands. Salinity tolerance can be enhanced by effective screening techniques that might be constructive in evolving the salt-tolerant genotypes with increased productivity. Many experiments have been done to study the physiological responses of cucumber for the production of salt-tolerant cucumber varieties. The physiological indices have been used as screening tools for the identification of salt-tolerant plant species in many crops.<sup>21,22</sup>

The main aim of the present study was the assessment of salt-tolerant cucumber genotypes through effective screening tools under salt stress which in future may be helpful for breeding programs and also to calculate the negative impacts of various levels of salinity on cucumber.

## Materials and Methods

The screening of 12 genotypes of cucumber (*Cucumis sativus* L) in Petri plates with varying levels of NaCl like 0, 50, 100, 150, and 200 mM for salt tolerance was done using physiological indices as screening tool. The seeds were obtained from AARI (Ayub Agricultural Research Institute, Faisalabad, Pakistan). The experiment was conducted at Plant Stress Physiology Lab, GCWUF (Government College Women University Faisalabad). Cucumber seeds were surface sterilized with 10% sodium hypochlorite solution for 5 minutes, then washed with distilled water 3 times. Fifteen seeds per cucumber genotype were allowed to mature in Petri dishes containing

filter paper and shifted them to growth chamber (Sanyo-Gallenkamp, Loughborough, United Kingdom) running at 28°C ± 2°C. The experiment was designed in growth chamber sustained at 10-hour photoperiod with 80 μM·s<sup>-1</sup>·m<sup>-2</sup> light strength for 15 days. The germination was noted on a daily basis and their stress tolerance indices were calculated using given formula. After 2 weeks of germination, several morphological attributes like plant shoot and root lengths and plant biomass were examined. For the determination of dry weight, the seedlings were dried at 70 C for 48 hours.

## Physiological Indices

Germination stress tolerance index (GSI) is calculated by determining the promptness index by means of following formula<sup>23</sup>:

$$PI = nd1 (1.00) + nd2 (0.75) + nd3 (0.50) + nd4 (0.25),$$

where nd1, nd2, nd3 and nd4 = number of seeds germinated on the first, second, third, and fourth day, respectively. GSI, physiological index of plant height (PHSI), root length stress tolerance index (RLSI), shoot fresh weight stress tolerance index (SFSI), RFSI, shoot dry weight stress tolerance index (SDSI), root dry weight stress tolerance index (RDSI) were found using following formula:

$$\begin{aligned} GSTI &= (PI \text{ of stressed seeds} / PI \text{ of control seeds}) \times 100 \\ PHSI &= (\text{Plant height of stressed plants} \\ &\quad / \text{Plant height of control plants}) \times 100 \\ RLSI &= (\text{Root length of stressed plants} \\ &\quad / \text{Root length of control plants}) \times 100 \\ SFSI &= (\text{Shoot fresh weights of stressed plants} \\ &\quad / \text{Shoot fresh weights of control plants}) \times 100 \\ RFSI &= (\text{Root fresh weights of stressed plants} \\ &\quad / \text{Root fresh weights of control plants}) \times 100 \\ SDSI &= (\text{Shoot dry weights of stressed plants} \\ &\quad / \text{Shoot dry weights of control plants}) \times 100 \\ RDSI &= (\text{Root dry weights of stressed plants} \\ &\quad / \text{Root dry weights of control plants}) \times 100 \end{aligned}$$

## Statistical Analysis

Averages and standard deviation (SD) values of obtained data have been computed on Microsoft Excel 2007 for Microsoft Windows 2007. The obtained data have been subjected to statistical analysis by applying analysis of variance test followed by multiple comparison tests to evaluate the significance of the data using statistical software Minitab version 19.0. The *P* values less than .05 (*P* < .05) are considered statistically significant.

## Results

Increased salt concentration in soil showed the negative effects on germination rate of cucumber and its GSI was highly deteriorated under the influence of salt stress. All the salinity treatments differ significantly, Valley, HC-999, Safaa, and Debra showed maximum values of GSI at 50 mM NaCl, whereas

**Table 1.** Germination Stress Tolerance Index (GSI) of 12 Genotypes of Cucumber.

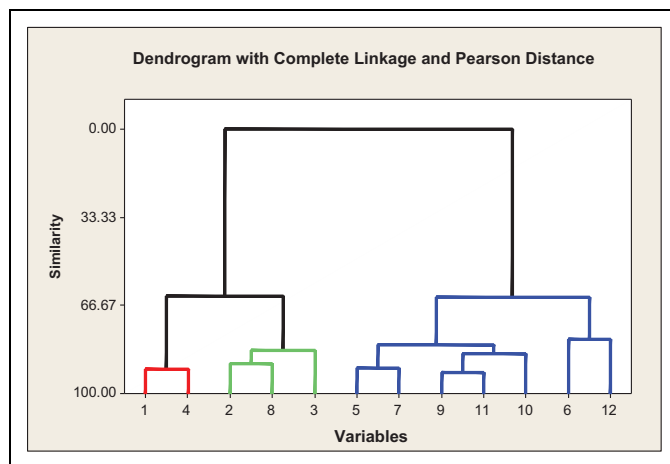
No.	Cucumber Varieties	NaCl Levels (mmol)				Means	Ranking
		50	100	150	200		
1	Valley	100 <sup>a</sup>	92.7 <sup>a</sup>	85.6 <sup>a</sup>	82.1 <sup>a</sup>	90.1 <sup>a</sup>	1
2	Safaa	98.2 <sup>ab</sup>	84.2 <sup>c</sup>	73.2 <sup>c</sup>	57 <sup>c</sup>	78.1 <sup>d</sup>	4
3	Debra	100 <sup>a</sup>	87 <sup>b</sup>	78.4 <sup>b</sup>	65.3 <sup>b</sup>	82.6 <sup>c</sup>	3
4	HC-999	100 <sup>a</sup>	88.2 <sup>b</sup>	83 <sup>a</sup>	76.4 <sup>a</sup>	86.9 <sup>b</sup>	2
5	Alfa prime	87 <sup>c</sup>	76.7 <sup>e</sup>	63.2 <sup>e</sup>	0	56.7 <sup>h</sup>	8
6	NSC-CMI	70 <sup>f</sup>	62 <sup>h</sup>	49.6 <sup>h</sup>	0	45.4 <sup>i</sup>	12
7	Thamin-II	83.2 <sup>d</sup>	73.1 <sup>f</sup>	60 <sup>f</sup>	0	54 <sup>i</sup>	9
8	Akad	95.2 <sup>b</sup>	78.4 <sup>d</sup>	69.3 <sup>d</sup>	55 <sup>c</sup>	74.4 <sup>e</sup>	5
9	HCU-171C	76.6 <sup>e</sup>	70 <sup>f</sup>	57 <sup>f</sup>	50 <sup>d</sup>	63.4 <sup>f</sup>	6
10	Cucumber Kalam	90 <sup>b</sup>	80 <sup>d</sup>	65 <sup>e</sup>	0	58.7 <sup>g</sup>	7
11	Early king	80 <sup>e</sup>	75 <sup>e</sup>	55.2 <sup>g</sup>	0	52.5 <sup>j</sup>	10
12	Akbar	72 <sup>f</sup>	67.4 <sup>g</sup>	51	0	47.6 <sup>k</sup>	11
	Mean	87.6 <sup>A</sup>	77.8 <sup>B</sup>	65.8 <sup>C</sup>	32.15 <sup>D</sup>		

Note: The values bearing the same small letters in columns and same capital letters in rows as superscript differ nonsignificantly at  $P > .05$ .

**Table 2.** Plant Height Stress Tolerance Index (PHSI) in 12 Genotypes of Cucumber.

No	Cucumber Varieties	NaCl Levels (mmol)				Means	Ranking
		50	100	150	200		
1	Valley	93 <sup>a</sup>	86 <sup>a</sup>	81.1 <sup>a</sup>	67.1 <sup>a</sup>	81.8 <sup>a</sup>	1
2	Safaa	87.6 <sup>c</sup>	75.2 <sup>c</sup>	61 <sup>c</sup>	42.4 <sup>c</sup>	66.3 <sup>c</sup>	4
3	Debra	88 <sup>b</sup>	78.5 <sup>c</sup>	66.6 <sup>c</sup>	47.6 <sup>c</sup>	70.1 <sup>c</sup>	3
4	HC-999	89.7 <sup>b</sup>	81.6 <sup>b</sup>	71.4 <sup>b</sup>	59.1 <sup>b</sup>	75.4 <sup>b</sup>	2
5	Alfa prime	82.1 <sup>d</sup>	63.1 <sup>e</sup>	53.6 <sup>d</sup>	0	49.7 <sup>e</sup>	7
6	NSC-CMI	72.8 <sup>g</sup>	47.1 <sup>h</sup>	27.1	0	36.7 <sup>f</sup>	12
7	Thamin-II	81.4 <sup>e</sup>	69.4 <sup>d</sup>	44.3 <sup>e</sup>	0	48.6 <sup>e</sup>	8
8	Akad	81.5 <sup>e</sup>	66.9 <sup>d</sup>	55.3 <sup>d</sup>	34.9 <sup>d</sup>	59.6 <sup>d</sup>	5
9	HCU-171C	76.6 <sup>f</sup>	51.1 <sup>g</sup>	35.5 <sup>f</sup>	15.5 <sup>e</sup>	44.6	10
10	Cucumber Kalam	84.5 <sup>c</sup>	76.1 <sup>c</sup>	46.4 <sup>e</sup>	0	51.7 <sup>e</sup>	6
11	Early king	83.6 <sup>d</sup>	59.1 <sup>f</sup>	42.8 <sup>e</sup>	0	46.3 <sup>e</sup>	9
12	Akbar	77.1 <sup>f</sup>	52.8 <sup>g</sup>	22.8 <sup>g</sup>	0	38.1 <sup>f</sup>	11
	Mean	83.1 <sup>A</sup>	67.1 <sup>B</sup>	50.5 <sup>C</sup>	22.2 <sup>D</sup>		

Note: The values bearing the same small letters in columns and same capital letters in rows as superscript differ nonsignificantly at  $P > .05$ .



**Figure 1.** Dandrogram from cluster analysis for salt tolerance in different cucumber genotypes based on physiological indices: a screening tool. Clusters detail; Cluster: 1, 1-Valley, 4-HC-999, 2-Safaa, 8-Akad, 3-Debra; Cluster 2: 5-Alfa prime, 7-Thamin-II, 9-HCU-171C, 11-Early king, 10-Cucumber Kalam, 6-NSC-CMI, 12-Akbar.

minimum GSI was noted in NSC-CMI (Table 1). At 100 mM NaCl level, the highest germination (GSI) was noted in Valley followed by HC-999 and the lower most was observed in Akbar. The genotypes valley and HC-999 were again maintained the highest GSI at 150 mM NaCl level, with the least performance shown by Akbar. At 200 mM NaCl level, few genotypes showed good performance in which Valley and HC-999 were at the highest number and Akbar remained at the lowest position in the list. Cluster analysis for salt tolerance in different cucumber genotypes based on physiological indices is shown as dandrogram in Figure 1.

For plant height stress tolerance index, Valley and HC-999 gave maximum values at 50 mM salinity level followed by

**Table 3.** Roots Lengths Stress Tolerance Index (RLSI) in 12 Genotypes of Cucumber.

No.	Cucumber Varieties	NaCl Levels (mmol)				Means	Ranking
		50	100	150	200		
1	Valley	94.3 <sup>a</sup>	87 <sup>a</sup>	77.7 <sup>a</sup>	66.8 <sup>a</sup>	81.4	1
2	Safaa	89.7 <sup>c</sup>	82.3 <sup>c</sup>	75.5 <sup>b</sup>	65.3 <sup>b</sup>	78.2	3
3	Debra	89.6 <sup>c</sup>	81 <sup>c</sup>	70.6 <sup>c</sup>	58.6 <sup>d</sup>	74.9	4
4	HC-999	91.3 <sup>b</sup>	84.7 <sup>b</sup>	76.6 <sup>a</sup>	61.9 <sup>c</sup>	78.6	2
5	Alfa prime	78.1 <sup>e</sup>	56.3	34.4 <sup>f</sup>	0	42.2	9
6	NSC-CMI	75 <sup>f</sup>	53.5 <sup>h</sup>	33.3 <sup>h</sup>	0	40.4	11
7	Thamin-II	79.8	55.8 <sup>g</sup>	35.6 <sup>h</sup>	0	42.8	8
8	Akad	85.1 <sup>d</sup>	76.5 <sup>d</sup>	63.8 <sup>d</sup>	51 <sup>e</sup>	69.1	5
9	HCU-171C	75.7 <sup>f</sup>	56 <sup>g</sup>	42 <sup>f</sup>	14 <sup>f</sup>	46.9	7
10	Cucumber Kalam	75.4 <sup>f</sup>	58.4 <sup>f</sup>	37.7 <sup>g</sup>	0	41	10
11	Early king	85.4 <sup>d</sup>	69.4 <sup>e</sup>	54.9 <sup>e</sup>	0	52.4	6
12	Akbar	72 <sup>g</sup>	57.3 <sup>f</sup>	29.3 <sup>j</sup>	0	39.6	12
	Mean	82.6 <sup>A</sup>	68.1 <sup>B</sup>	52.6 <sup>C</sup>	26.4 <sup>D</sup>		

Note: The values bearing the same small letters in columns and same capital letters in rows as superscript differ nonsignificantly at  $P > .05$ .

Debra and Safaa, while Akbar and NSC-CMI showed minimum values (Table 2). Under increased level of salinity, as 100 mM NaCl, the genotypes Valley and HC-999 showed higher values, whereas Akbar and NSC-CMI showed minimum values. Similarly, at salt stress levels 150 and 200 mM, only Valley and HC-999 achieved the maximum plant height and Akbar and NSC-CMI has the minimum height.

For root length index, all the abovementioned concentrations of NaCl significantly affected all the cucumber genotypes. Root length index was reduced with the increased level of salt stress, the genotype Valley and then HC-999 achieved good length of plant root as compared to rest of all

**Table 4.** Shoot Fresh Weight Stress Tolerance Index (SFSI) in 12 Genotypes of Cucumber.

No.	Cucumber Varieties	NaCl Levels (mmol)				Means	Ranking
		50	100	150	200		
1	Valley	87.7 <sup>a</sup>	74.8 <sup>a</sup>	57.8 <sup>a</sup>	46.5 <sup>a</sup>	66.7	1
2	Safaa	78.5 <sup>d</sup>	65.7 <sup>d</sup>	50 <sup>c</sup>	26.4 <sup>e</sup>	55.1	4
3	Debra	81.1 <sup>c</sup>	62.4 <sup>e</sup>	46.4 <sup>d</sup>	32.9 <sup>c</sup>	55.7	3
4	HC-999	86.2 <sup>a</sup>	72.4 <sup>b</sup>	52.1 <sup>b</sup>	42.8 <sup>b</sup>	63.3	2
5	Alfa prime	74.4 <sup>f</sup>	49.7 <sup>g</sup>	34.5 <sup>g</sup>	0	39.6	10
6	NSC-CM1	77.7 <sup>e</sup>	42.8 <sup>h</sup>	26.5 <sup>h</sup>	0	36.7	11
7	Thamin-II	68.1 <sup>g</sup>	57.2 <sup>f</sup>	49.6 <sup>c</sup>	0	43.7	9
8	Akad	77 <sup>e</sup>	62.5 <sup>e</sup>	47.2 <sup>d</sup>	29.7 <sup>d</sup>	54	5
9	HCU-171C	71.9	46.7 <sup>g</sup>	41.9 <sup>f</sup>	15.4 <sup>f</sup>	43.9	8
10	Cucumber Kalam	85.7 <sup>b</sup>	67.4 <sup>c</sup>	42.3 <sup>e</sup>	0	48.8	6
11	Early king	79.4 <sup>d</sup>	63.6 <sup>e</sup>	43.6 <sup>e</sup>	0	46.6	7
12	Akbar	67.9 <sup>g</sup>	42.5 <sup>h</sup>	22.9 <sup>i</sup>	0	33.3	12
	Mean	77.9 <sup>A</sup>	58.9 <sup>B</sup>	42.9 <sup>C</sup>	16.1 <sup>D</sup>		

Note: The values bearing the same small letters in columns and same capital letters in rows in superscript differ nonsignificantly at  $P > .05$ .

**Table 5.** Root Fresh Weight Stress Tolerance Index (RFSI) in 12 Genotypes of Cucumber.

No.	Cucumber Varieties	NaCl Levels (mmol)				Means	Ranking
		50	100	150	200		
1	Valley	95.8 <sup>a</sup>	87.5 <sup>a</sup>	65.2 <sup>b</sup>	79 <sup>a</sup>	81.8	1
2	Safaa	85.2 <sup>c</sup>	74.9 <sup>d</sup>	46.3 <sup>e</sup>	67.1 <sup>c</sup>	68.3	4
3	Debra	87.2 <sup>c</sup>	77.1 <sup>c</sup>	69.6 <sup>a</sup>	51 <sup>d</sup>	71.2	3
4	HC-999	91.4 <sup>b</sup>	85.5 <sup>b</sup>	62.4 <sup>b</sup>	74.5 <sup>b</sup>	78.5	2
5	Alfa prime	69.6 <sup>g</sup>	52.5 <sup>g</sup>	35.6 <sup>f</sup>	0	39.3	10
6	NSC-CM1	72 <sup>f</sup>	46.1 <sup>h</sup>	26.2 <sup>g</sup>	0	36	11
7	Thamin-II	77.7 <sup>e</sup>	60.4 <sup>f</sup>	40.8 <sup>f</sup>	0	44.7	9
8	Akad	82 <sup>d</sup>	69 <sup>e</sup>	60 <sup>c</sup>	43.8 <sup>e</sup>	63.6	5
9	HCU-171C	74.5 <sup>f</sup>	51.4 <sup>g</sup>	36.4 <sup>f</sup>	18.7 <sup>f</sup>	45.2	8
10	Cucumber Kalam	78.6 <sup>e</sup>	68.1 <sup>e</sup>	50.6 <sup>d</sup>	0	49.1	6
11	Early king	76.8 <sup>e</sup>	66 <sup>e</sup>	46.2 <sup>e</sup>		47.2	7
12	Akbar	68 <sup>g</sup>	47.6 <sup>h</sup>	23.6 <sup>h</sup>	0	34.8	12
	Mean	79.8 <sup>A</sup>	65.5 <sup>B</sup>	50.7 <sup>C</sup>	23.9 <sup>D</sup>		

Note: The values bearing the same small letters in columns and same capital letters in rows as superscript differ nonsignificantly at  $P > .05$ .

(Table 3). However, at 50 and 100 mM salinity levels, minimum values were observed in NSC-CM1 and Akbar, while at 200 mM NaCl, only few genotypes, that is, Valley, HC-999, Safaa, showed maximum results.

Shoot fresh weight of all cucumber genotypes was highly affected by the high level 150 and 200 mM of salinity. With the increased level of salinity, SFSI of all genotypes was reduced significantly. The maximum reduction was noted in Akbar and then in Thamin-II at 50 mM NaCl, while Valley followed by HC-999 showed maximum results. Under 100 mM NaCl, maximum shoot fresh weight stress index was observed again in Valley and HC-999 and maximum reduction was noted in

**Table 6.** Shoot Dry Weight Stress Tolerance Index (SDSI) in 12 Genotypes of Cucumber.

No.	Cucumber Varieties	NaCl Levels (mmol)				Means	Ranking
		50	100	150	200		
1	Valley	84.3 <sup>b</sup>	71.8 <sup>b</sup>	55.1 <sup>b</sup>	39.6 <sup>a</sup>	62.7	2
2	Safaa	77.7 <sup>d</sup>	58.4 <sup>e</sup>	43.1 <sup>e</sup>	33.7 <sup>c</sup>	53.3	5
3	Debra	83.4 <sup>b</sup>	70.4 <sup>b</sup>	52 <sup>c</sup>	37.3 <sup>b</sup>	60.7	3
4	HC-999	87.6 <sup>a</sup>	73.2 <sup>a</sup>	57 <sup>a</sup>	37.3 <sup>b</sup>	63.7	1
5	Alfa prime	78.7 <sup>d</sup>	62.5 <sup>d</sup>	41.5 <sup>e</sup>	0	45.6	7
6	NSC-CM1	76.4 <sup>e</sup>	51.6 <sup>g</sup>	31.5 <sup>g</sup>	0	39.8	10
7	Thamin-II	76.4 <sup>e</sup>	57.9 <sup>e</sup>	35.5 <sup>f</sup>	0	42.5	9
8	Akad	83.6 <sup>b</sup>	68.8 <sup>c</sup>	41.5 <sup>e</sup>	25.7 <sup>d</sup>	54.8	4
9	HCU-171C	79.6 <sup>c</sup>	56.6 <sup>f</sup>	34.6	14.1 <sup>e</sup>	46.2	6
10	Cucumber Kalam	80.5 <sup>c</sup>	58.5 <sup>e</sup>	37.5 <sup>f</sup>	0	44.1	8
11	Early king	80.6 <sup>c</sup>	63.9 <sup>d</sup>	49.5 <sup>d</sup>	0	48.4	5
12	Akbar	74.3 <sup>f</sup>	47.1 <sup>h</sup>	31.6 <sup>g</sup>	0	38.2	11
	Mean	79.8 <sup>A</sup>	61.1 <sup>B</sup>	42.5 <sup>C</sup>	15.6 <sup>D</sup>		

Note: The values bearing the same small letters in columns and same capital letters in rows as superscript differ nonsignificantly at  $P > .05$ .

**Table 7.** Root Dry Weight Stress Tolerance Index (RDSI) in 12 Genotypes of Cucumber.

No.	Cucumber Varieties	NaCl Levels (mmol)				Means	Ranking
		50	100	150	200		
1	Valley	90.3 <sup>a</sup>	78.9 <sup>a</sup>	71.7 <sup>a</sup>	58.5 <sup>a</sup>	74.8	1
2	Safaa	84.6 <sup>c</sup>	71.2 <sup>c</sup>	62.4 <sup>b</sup>	44.3 <sup>d</sup>	65.6	4
3	Debra	88.6 <sup>b</sup>	74.2 <sup>b</sup>	64.3 <sup>b</sup>	49.2 <sup>c</sup>	69	3
4	HC-999	89.4 <sup>b</sup>	76.4 <sup>a</sup>	71 <sup>a</sup>	52.3 <sup>b</sup>	72.3	2
5	Alfa prime	76.1 <sup>e</sup>	56.9 <sup>f</sup>	39.1 <sup>d</sup>	0	43	8
6	NSC-CM1	71.8 <sup>f</sup>	38.2 <sup>h</sup>	20.6 <sup>g</sup>	0	32.6	11
7	Thamin-II	70.7 <sup>f</sup>	51.9 <sup>g</sup>	33.2 <sup>e</sup>	0	38.9	10
8	Akad	87.5 <sup>c</sup>	72 <sup>c</sup>	60.8 <sup>c</sup>	40.2 <sup>e</sup>	65.1	5
9	HCU-171C	80.3 <sup>d</sup>	59.2 <sup>e</sup>	38.7 <sup>d</sup>	8.3 <sup>f</sup>	46.6	7
10	Cucumber Kalam	84.8 <sup>c</sup>	68.4 <sup>d</sup>	58.4 <sup>c</sup>	0	52.9	6
11	Early king	73.6 <sup>e</sup>	60.6 <sup>e</sup>	36.7 <sup>e</sup>	0	42.8	9
12	Akbar	65.6 <sup>f</sup>	35.1 <sup>i</sup>	21.7 <sup>f</sup>	0	30.6	12
	Mean	80.2 <sup>A</sup>	61.9 <sup>B</sup>	48.2 <sup>C</sup>	21 <sup>D</sup>		

Note: The values bearing the same small letters in columns and same capital letters in rows as superscript differ nonsignificantly at  $P > .05$ .

Akbar followed by NSC-CM1 (Table 4). Under the observation of SFSI results, Valley and HC-999 genotypes behaved well in all the salinity levels as compared to others, whereas Akbar and NSC-CM1 presented the least values under salt stress.

Same trend was observed in SDSI, which was gradually decreased with the increased level of NaCl (Table 5). Maximum value of shoot dry weight stress tolerance index at 50 mM salt stress was presented by HC-999, Valley, and Akad, whereas the minimum was in Thamin-II, NSC-CM1, and Akbar. Under 100 mM NaCl level, genotype Akbar followed by NSC-CM1 exhibited poor values and increased shoot dry weight was recorded in Valley, HC-999, Debra, and Akad.

With the increasing level of salinity at 150 and 200 mM NaCl, HCU-171C, Akbar, and NSC-CM1 exhibited low values and HC-999, Valley, Debra, and early king showed maximum, and at 200 mM NaCl level, few genotypes presented good values including Valley, HC-999, Debra, and Safaa.

The influence of salinity on the index value of plant root fresh weights represented the same trend as in SFSI, and maximum results were recorded on the genotypes Valley and HC-999, while Alfa-Prime and Akbar listed in the last at salt stress level of 50 mM. Same results were observed at 100 mM, 150 mM, 200 mM NaCl, according to which Valley and HC-999 followed by Debra and Safaa achieved maximum weights while HCU-171C, Akbar, and NSC-CM1 showed minimum values (Table 6). Plant root dry weight value considerably decreased with the increased concentration of salinity.

Plant root dry weight was increased by decreasing the salinity level. Maximum values of RDSI were attained at 50 mM in genotypes Valley, HC-999 followed by Debra, Akad, and cucumber Kalam, while minimum values were observed in Akbar and Thamin-II (Table 7). Whereas at increased salt level 100 mM, the Valley, HC-999, Debra, and Akad exhibited good values, while NSC-CM1 and Akbar showed poor results. The genotypes Valley, HC-999, and Safaa accomplished maximum values of RDSI at 150 mM and 200 mM of NaCl, followed by Akbar and NSC-CM1 which were remained at the lowest rank. Mean square values of data for plant Germination, Shoot length, Root length, Shoot fresh weight, Root fresh weight, Shoot dry weight, Root dry weight stress tolerance indices are given in Table 8.

## Discussion

The main purpose of the study was to identify salt-tolerant genotypes in cucumber germplasm in relation to biomass production at early vegetative growth stages under different levels of salinity. Results showed that germination percentages were reduced in all genotypes of cucumber at all salt levels. However, saline solution with the range of 50 to 100 mM NaCl level, the genotypes valley, HC-999, Debra, Akad, and cucumber Kalam showed better results as compared to other genotypes (Table 1). Likewise, at 150 to 200 mM NaCl, Valley, HC-999, Debra, and Safaa exhibited better performance as compared to other cucumber genotypes. It is well-documented that under the influence of salt stress, genotypes with greater germination produced significant morphological traits with high yield,<sup>7,24</sup> whereas through GSI, salt-tolerant cultivars can be recognized and salinity affects the seed potency and seed storage conditions during germination. In this experiment, strong and vigorous seeds with good capability were sown. So, plant germination rate may have been reduced because of the negative effect of increased levels of salt stress. The present findings are in agreement with the studies of Hamid et al.<sup>14</sup> Increased salt stress can reduce seed germination as well as root emergence because of the osmotic effect which inhibits the plants for retaining their appropriate nutritional requirements essential for better plant growth.<sup>24</sup> However, in

the present experiment, healthy seeds with similar size and good capability were used. So, in this case, the reduction in GSI might be due to the effect of salinity. Results of Hamid et al.<sup>14</sup> also confirmed the present findings in which germination of cucumber genotypes may have been reduced under the influence of salt stress.

Physiological index of plant height data demonstrated that genotypes Valley and HC-999 are considered as salt tolerant, whereas Nsc\_m1 and Akbar as salt sensitive. The differences between genotypes might be due to the genetic variations.<sup>24</sup> The overall trend of the experiment was that with the increasing level of salinity, plant height stress tolerance index was decreased. Among various crops, salt stress plays negative effects resulting in the reduction of plant growth.<sup>25,26</sup> Present study elaborated the results of root length index, which revealed that Valley and HC-999 could be grown up to 200 mM NaCl of salt stress as they showed higher values up to this salt level (Table 3) because maximum value of biomass has been recorded and several studies demonstrated that tolerant varieties enhance the yield and biomass under salinity as compared to the sensitive lines.<sup>23</sup>

Root growth was highly decreased in cucumber from Kalam, NSC-CM1, and Akbar at decreased levels of NaCl as 50 mM and 100 mM (Table 3). Plants vary in their tolerance to salinity that depends on their efficiency of root system with regard to nutrient absorption and K, Na uptake discrimination.<sup>27</sup> At lower levels of salinity (50 mM, 100 mM NaCl) according to the results of SFSI, the genotypes Valley, HC-999, Debra, and cucumber Kalam exhibited good results than that of the others, whereas Thamin-II followed by Akbar showed minimum values (Table 4). However, salinity levels 150 mM and 200 mM, Valley, HC-999, Safaa, and Debra showed highest values and categorized as the most salt-tolerant genotypes and Akbar, NSC-CM1, HCU-171C, and Akad as sensitive ones. These findings are in accordance with the results of previous studies.<sup>21,23</sup> Saline soil with the salt level from 100 mM to 200 mM, Valley, and HC-999 can be recommended to farmers for better results.

The results of root fresh weight stress tolerance index clearly revealed that genotypes Valley and HC-999 achieved highest biomass at all applied NaCl levels followed by Debra, Safaa, and Akhad, whereas NSC-CM1 and Akbar showed lowest values and can be categorized as the salt-sensitive genotypes (Table 5). These results are consistent with the studies of Hasegawa et al.<sup>26</sup> Similarly Akram et al.<sup>28</sup> and Hamid et al.,<sup>14</sup> revealed that root fresh and dry weights and shoot length decrease with increasing levels of salinity in several crops like all hybrids of maize (*Zea mays* L.), sugarcane, and wheat, respectively. Genotypes HC-999, Valley, Debra, and Akad at all salinity levels behave positively and showed maximum biomass production for shoot dry weight tolerance index and can be considered as salt tolerant for cultivation, and cucumber Kalam, Thamin-II, NSC-CM1, and Akbar produced minimum biomass and behave as sensitive genotypes (Table 6). These results showed reduced biomass by shoot under the saline stress.

**Table 8.** Mean Square Values of Data for Plant Germination, Shoot Length, Root Length, Shoot Fresh Weight, Root Fresh Weight, Shoot dry Weight, Root Dry Weight Stress Tolerance Indices.

Techniques	DF	GSI	SLSI	RLSI	SFWSI	RFWSI	SDWSI	RDWSI
V	11		869.51 <sup>a</sup>	1199.90 <sup>a</sup>	370.00 <sup>a</sup>	1124.60 <sup>a</sup>	316.56 <sup>a</sup>	1008.28 <sup>a</sup>
T	3		8136.59 <sup>a</sup>	6933.29 <sup>a</sup>	7962.69 <sup>a</sup>	6852.50 <sup>a</sup>	9164.12 <sup>a</sup>	7466.73 <sup>a</sup>
Error	33		110.27	115.40	82.04	88.53	52.59	81.51
Total	47							

Abbreviations: GSI, Germination stress tolerance index; RDWSI = Root dry weight stress tolerance indices; RLSI, Root length stress tolerance index; RFWSI = Root fresh weight stress tolerance index; SLSI, Shoot length stress tolerance index; SFWSI = Shoot fresh weight stress tolerance index; SDWSI = Shoot dry weight stress tolerance index.

<sup>a</sup>Significant ( $P < .01$ ).

It is documented that increased salinity enhances the stunted plant growth.<sup>29</sup> In cucumber, enhanced concentration of sodium ions are accumulated in the leaves resulting in the reduction in dry mass of both roots and shoots.<sup>27</sup> However, the finding of Ashraf et al<sup>23</sup> described that Na<sup>+</sup> uptake is less in salt-tolerant varieties.<sup>23</sup> Roots are the primary organ which showed sensitivity under all levels of salinity.<sup>28</sup> Under saline condition, oxygen deficiency removes the plants from energy sources, resulting in the accretion of high concentration of ethylene which constrains the growth of plant root.<sup>28</sup> Salinity affects the root dry weights stress tolerance index (Table 7); it was clear from the results of RDSI that growth of roots was decreased under all recommended salinity. Maximum root biomass was attained in Valley followed by HC-999 and Debra; however, NSC-CM1 and Akbar continued with the lowest position and behave as salt-sensitive genotypes. These results are confirmed by the finding of a previous study.<sup>23</sup> According to the mentioned results, it is concluded that all levels of salinity pay negative impacts on all agronomical traits. Salinity causes nutrient imbalance like lower transport of essential ions as NO<sub>3</sub>, which causes reduction in nitrogen compounds, which may be the basic reason of reduction in plants growth.<sup>14,30</sup> Biomass production was deteriorating at 50 and 100 mM salt stress by 48% and 59% in beans and by 14% in cotton.<sup>31</sup>

The relative shoot length of seedlings in salt tolerance enhances the biomass production and plant and also increase the absorption of K<sup>+</sup> ions while lower the shoot Na<sup>+</sup> ions resulting in an increase of K<sup>+</sup> and Ca<sup>2+</sup> ions in plants,<sup>24</sup> whereas by increasing salinity levels, biomass production was decreased. The results of present experiment as regard to the biomass decreased due to the effect of NaCl stress as justified by the previous findings.<sup>24,32,33</sup> Various studies demonstrated the negative effects of salinity on several plant morphological traits, hence reducing the leaf surface expansion and biomass of plant by increased level of salinity<sup>19,25,34</sup>; however, other researchers described the same results under salt stress.<sup>24,29,35</sup> Plants are specific in their behavior toward the stress and can be improved through genetic variability.<sup>36</sup> Crops with good genetic variability can tolerate to salt stress, that is, sorghum has great potential of variability.<sup>33</sup> These genetic modifications among cucumber genotypes provide good information through which these genotypes could be grown in saline areas to enhance the productivity of crop, and also with the help of

these information, salt-tolerant species can be identified for further utilization in breeding program.

Cluster analysis is used to group different cucumber genotypes based on various characteristics, and the genotypes which are related to one another are placed in one cluster. The cluster 1 comprised of 5 genotypes and these have similarities with each other and consider as salt-tolerant one, whereas cluster 2 consisted of 5 genotypes and showed less similarities with the genotypes present in cluster 1 and considered as medium salt-tolerant genotypes, and in cluster 3, 2 genotypes are present and they also show less similarities with other genotypes for the characters under study and not performed well so they are categorized as sensitive one. Literature emphasizes on the use of cluster analysis to screen the crop germplasm for stress tolerance.<sup>37-39</sup> Selected genotypes could be used in further breeding programs for salt tolerance.

## Conclusion

The outcomes of this experiment showed that physiological indices can be used for the screening of cucumber genotypes for salinity stress, and the genotypes Valley and HC-999 are tolerant and can be further utilized in saline areas to increase the development and yield of cucumber genotypes in salt hit areas of the world.


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