

Impact of salinity on tolerance, vigor, and seedling relative water content of haricot bean (*Phaseolus vulgaris* L.) cultivars

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Abstract: A laboratory experiment was undertaken to evaluate the impact of salinity on seedling tolerance and vigor indices, phytotoxicity, and relative water content of haricot bean cultivars. Two haricot bean cultivars (Lehade and Chercher) and five salinity levels (0, 2, 4, 8, and 16mM) were factorially arranged in Completely Randomized Design with three replications. The result of the study revealed that no significant interaction effect between cultivars vs salinity treatments ($p < 0.05$). However, cultivars differ significantly ($p < 0.05$) on seedling and root vigor indices, shoot phytotoxicity, and relative water content of shoot and root. Lehade gave higher seedling, shoot and root vigor indices; whereas, Chercher gave relatively higher seedling tolerance index, and lower shoot and root phytotoxicity. The highest relative shoot and root water contents were recorded on Chercher compared to Lehade. The increase in NaCl concentrations significantly ($p < 0.05$) decreased seedling, shoot, and root vigor indices; and the lowest vigor indices were observed on 16mM NaCl concentration. However, the phytotoxicity of shoot and root increased as the concentrations of NaCl increased; and the lowest value of phytotoxicity observed at control treatment and 2 mM, while the highest on 16mM. Significant negative relationships were observed between relative shoot ($R^2 = 0.896$) and root ($R^2 = 0.904$) water contents, and salinity concentrations. In conclusion, cultivars varied genetically for their tolerance, and relative water content. The increase in salinity decreased vigor and tolerance indices, and relative water content; however increased phytotoxicity percentage of root and shoot of haricot bean.

Key words: NaCl, *Phaseolus Vulgaris*, Phytotoxicity, Relative Water Content, Tolerance, Vigor

1. Introduction

In Africa, 1,899 million hectares (Mha) of land is affected by salinity [8]. In Ethiopia 44 Mha (36% of the country's total land areas) are potentially susceptible to salinity problems [33]. According to [33] out of the 44 Mha, 33 Mha have dominantly salinity problems, 8 Mha have combined salinity and alkalinity problems, and 3 Mha have dominantly alkalinity problems.

The semi-arid and arid lowlands and valleys in Ethiopia have major problems of salinity and alkalinity [10, 25]. About 9% of the population lives in the areas affected by salinity [31]. Salt affected soils increased from 6% to 16% of the total land area of Ethiopia [31]. Many authors [22, 34, 9, 32, 12] also reported the rapid increase of salinity problems in many parts of the country including; Melkassa, Melka Sadi, Melka Werer, Abaya State Farm, and Dams in

Mekelle Plateau. At present, the Ethiopian government has a great tendency to introduce and implement large-scale irrigation agriculture to increase agricultural productivity [24]. Hence, unless proper management strategies designed, the prevailing salinity problem in the country is expected to be severe in years to come [22].

Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil [13]. Some salts are toxic to plants when present in high concentration. According to [5], the highly tolerant crops can withstand a salt concentration of saturation extract up to 10 gL⁻¹, the moderately tolerant crops up to 5 gL⁻¹, and the sensitive group up to about 2.5 gL⁻¹.

Seed germination, seedling emergence, and early survival are particularly sensitive to substrate salinity [19,

35]. Salt stress affect physiological processes [29], and exerts undesirable effects through osmotic inhibition and ionic toxicity [27]. In general, germination and seedling growth parameters are the most viable criteria used for selecting salt tolerance in crop plants; hence, percentage of germination and seedling growth are important growth parameters to be studied for cultivar selection [26]. Although, there are many studies on the effect of salinity on percentage and rates of germination on various crops [1-3, 24, 26], there is limited information on tolerance, phytotoxicity, and relative water contents effect of salinity. Therefore, the present study was performed in order to investigate the effects of different salt concentrations on the tolerance, vigor, and seedling relative water content of haricot bean cultivars.

2. Materials and Methods

A laboratory experiment was conducted in May, 2013 at the Department of Plant Sciences and Horticulture, Ambo University, to study the effect of salinity on seedling tolerance, vigor, and seedling relative water content of haricot bean cultivars. The experiment was arranged in factorial and laid out in completely randomized design with three replications. Factors included were two cultivars (Lahede and Chercher), and salinity in five levels (0, 2, 4, 8, and 16mM), deionized water was used for the control

treatment. NaCl was used as sources of salinity as described by [21]. Seed were surface sterilized with 5% Sodium hypochlorite solution for 5 min, and rinsed with distilled water. Ten uniform seeds of the two haricot bean cultivars, were placed in a Petri plate (9.5 cm diameter) using a forceps. Filter papers were well soaked by adding 10ml with the respective solution (4 treatment solutions and the control) at an interval of 48hrs as described by [28]. All the Petri plates were covered with lids and kept at a room temperature ($24 \pm 2^\circ\text{C}$). Germination was continued for 12 days and germinated seeds were counted daily. The seeds were considered germinated when radicles appeared and are visible with a length reached 2mm. After 12 days parameter such as percent of germination were calculated according to [17]; and root and shoot lengths of seedling were measured using a centimeter scale. Root and shoot dry weights were measured after oven-drying for 72 h at 60°C . Seedling vigor index (SVI) was determined as per [14]:

Seedling Vigor Index = % of Germination \times Seedling dry weight

Seedling Tolerance index (STI) were determined by [15] method:

STI = (Mean root length in NaCl solution / Mean root length in distilled water) \times 100

Percentage of phytotoxicity for shoot and root of seedlings were calculated using the formula given by [7]:

$$\text{Phytotoxicity of Shoot (\%)} = \frac{\text{Shoot length of control} - \text{Shoot length of treatment}}{\text{Shoot length of control}} \times 100$$

$$\text{Phytotoxicity of Root (\%)} = \frac{\text{Root length of control} - \text{Root length of treatment}}{\text{Root length of control}} \times 100$$

Relative seedling water content (RSWC) was calculated as per the formula used by [30]:

$$\text{RSWC} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Statistical analysis was performed using one-way ANOVA using SAS statistical software (Version 9). Based on the ANOVA results mean separations were performed by Duncan's multiple range test (DMRT) at 5% level.

3. Results and Discussion

Analysis of variance showed that there is no significant difference for interaction effects between sodium chloride concentrations and cultivars ($p < 0.05$) for all investigated traits.

3.1. Salinity Effect on Seedling Tolerance, Vigor, and Relative Water Content of Haricot Bean Cultivars

Analysis of variance showed that cultivars varied significantly ($p < 0.05$) on seedling and root vigor indices, shoot phytotoxicity, and relative water content of shoot and root. The maximum value for seedling, shoot and root vigor indices were recorded on Lahede cultivar (55.7%, 37.2%,

and 18.5%) compared to Chercher (50.8%, 36.2%, and 14.5%), respectively (Table 1). This was due to the difference in their germination percentage, where 100 % and 91.5% germination were recorded on Lahede and Chercher, respectively. This implies Lahede gave similar germination percentage in all conditions, like controls; although it developed lower root and shoot lengths. Crop cultivar may germinate effectively under salt stress; nevertheless, its seedling growth may be salt affected [4]. Similar to this findings different authors [11, 1] confirmed that some cultivars had initial high germination percentage even at high salinity (16 ds/M) but their vigor decline in the subsequent seedling growth parameters.

Cultivar Chercher gave relatively high seedling tolerance index, and low shoot and root phytotoxicity (Table 1). The phytotoxicity of shoot varied significantly ($p < 0.05$) with cultivars, and the highest (33.03%) was recorded on Lahede, and the lowest on Chercher (23.97%) (Table 1). Nevertheless, there was no significant difference ($p < 0.05$) between cultivars for root phytotoxicity. However,

Chercher had relatively low phytotoxicity of roots that indicates, it was better in tolerating higher NaCl concentration, than Lehide. This elucidates the presence of genetical variability between cultivars for tolerance and phytotoxicity effect of NaCl. The result of this study is in agreement with other authors [22, 26], who reported the presence of genetic variability on haricot bean and chickpea cultivars to salinity tolerance, respectively.

Table 1: Salinity effect on vigor, tolerance, and seedling relative water content of haricot bean

Cultivars	SVI	SHVI	RVI	STI	SHPT	RPT	RSWC	RRWC
Lehide	55.7 a	37.2 a	18.5 a	71.6 a	33.0 a	28.4 a	45.8 b	42.7 b
Chercher	50.8 b	36.2 a	14.5 b	73.3 a	24.0 b	26.7 a	52.1 a	55.8 a
SE(m)	2.12	1.69	0.95	3.99	3.94	3.99	3.67	2.79
CV (%)	6.7	7.7	9.9	9.5	23.9	25.1	13	9.8

Means with similar letters in each column are not significant at 5% level of probability.

SVI: Seedling vigor index; SHVI: Shoot vigor index; RVI: Root vigor index; STI: Seedling tolerance index; SHPT: Shoot phytotoxicity; RPT: Root phytotoxicity; RSWC= Relative shoot water content; RRWC: Relative root water content

The analysis of the data also indicated that statistically

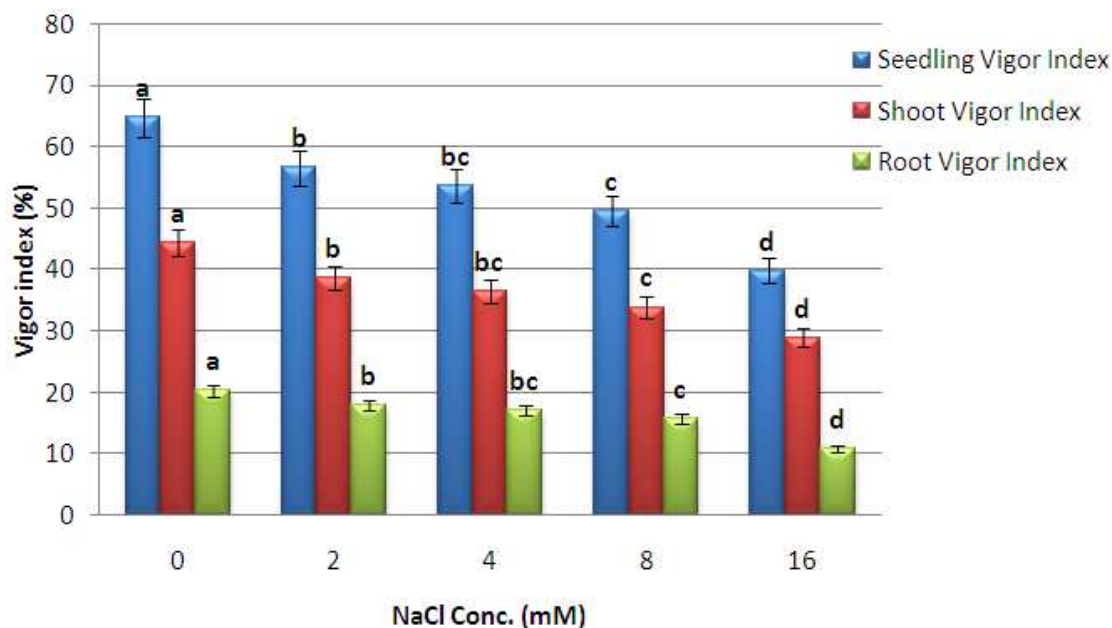


Figure 1. Effect of NaCl on seedling vigor indices averaged over cultivars

3.3. Phytotoxicity of Salinity on Shoot and Root of Haricot Bean

The phytotoxicity of shoot and root increased as the concentration of salinity increased (Figure 2). The lowest shoot and root phytotoxicity of NaCl were observed at control treatment, and 2mM concentrations; however the highest phytotoxicity was recorded at 16mM concentrations. The highest phytotoxicity of shoot (57.04%) and root

significant differences ($p < 0.05$) observed between Lehide and Chercher for relative water contents of shoot and root. The highest relative shoot (52.12%) and root (55.77%) water contents were recorded on Chercher compared to Lehide (Table 1). Earlier study proved that [23] cultivars, which possess the highest seedling relative water content, are having better tolerance to toxic effects of salts through dilution. Hence, Chercher showed a better tolerance to NaCl toxicity.

3.2. Salinity Effect on Seedling Vigor Indices of Haricot Bean

The analysis of variance indicated that increase in salinity significantly ($p < 0.05$) decreased seedling, shoot, and root vigor indices. The highest vigor indices of seedling (64.9%), shoot (44.5 %), and root (20.4%) were recorded on control treatment; and the lowest vigor indices 39.9%, 29% and 11% were observed on 16mM NaCl concentration for seedling, shoot and root, respectively (Figure 1). The result of this study showed that salinity has negative effects on haricot bean vigor indices. This could be due to the inability of bean seedlings to adjust osmotically to the toxic effects of Cl^- and/or Na^+ . Different authors [21, 18] also reported similar results in diverse crop species.

(58.74 %) were observed at 16mM (Figure 2). Recently, [16] reported that root and shoot phytotoxicity reduced at lower concentration, and increased at higher concentration on wheat. An increase in NaCl concentration resulted inhibitory or toxic effect of salinity, which is usually observed only after the start of elongation of radicle [20].

The analysis of variance showed that seedling tolerance index decreased significantly ($p < 0.05$) with increase in NaCl concentration (Figure 3). The regression analysis also

indicated that there was a negative relationship ($y = -3.356x + 92.61$; $R^2 = 0.94$) between tolerance index of seedling and NaCl concentrations. The tolerance index showed that, haricot bean has low tolerance to NaCl concentrations, especially at 8 and 16 mM as compared to control treatment (Figure 3). The reason for low tolerance against NaCl might be due to changes in the physiological mechanism

during seed germination and seedling growth of haricot bean. Other authors [22] and [2] reported similar results on low tolerance of some haricot bean and sorghum cultivars seedlings at 16 ds/m salinity levels compared to control, respectively; however, there is variability among species and cultivars for tolerances level..

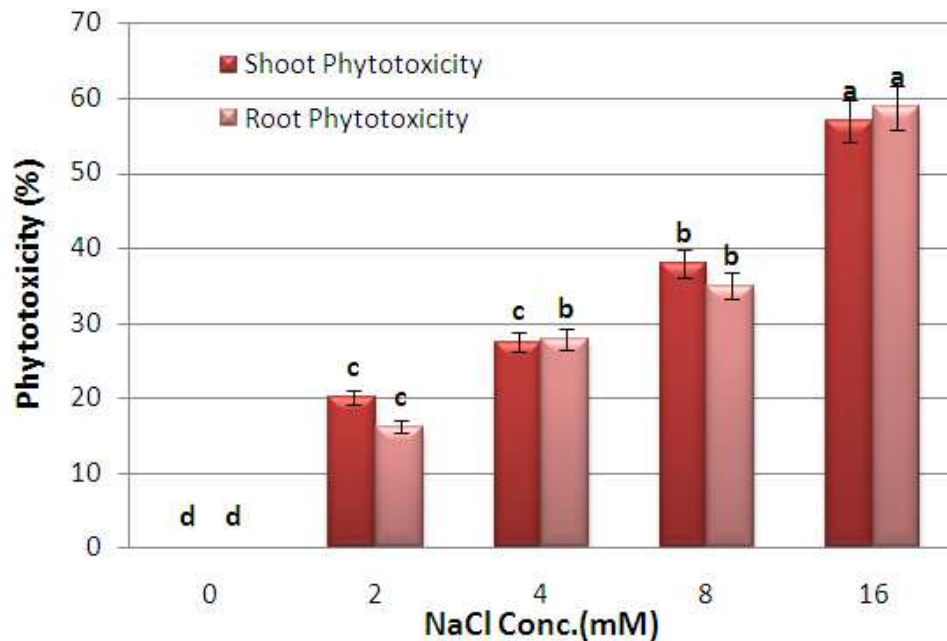


Figure 2. Phytotoxicity effect of NaCl on shoot and root averaged over cultivars

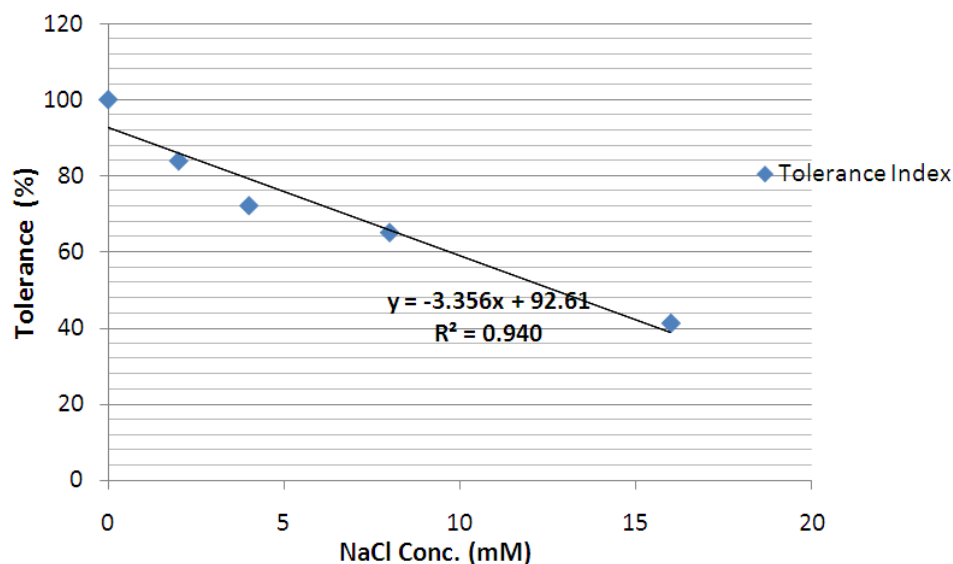


Figure 3. Effect of NaCl on seedling tolerance index averaged over cultivars

3.4. Salinity Effect on Relative Water Content of Shoot and Root of Haricot Bean Seedling

The result of this study indicated that an increase in salt concentration decreased significantly ($p < 0.05$) seedling shoot and root relative water content (Figure 4). The regression analysis showed that there was a strong negative

relationship ($Y = -0.700x + 49.43$; $R^2 = 0.896$) between the relative shoot water content (RSWC), and salinity concentrations (Fig. 4). Linear regression analysis results also showed a strong negative relation ($y = -0.764x + 53.51$; $R^2 = 0.904$) between relative root water content, and increase in salinity. Root and shoot relative water content of haricot bean seedling showed a decreasing trend with

increasing in NaCl concentrations (Figure 4). With increased in salinity, relative shoot and root water content decreased from 52.63 to 40.01%, and 49.67 to 37.26%, respectively. The highest values of relative water content of shoot and root were observed on the control, while the lowest on 16mM salt concentration. This result was in

agreement with [22] who found a drastic decrease in seedling shoot and root relative water content at higher salinity level. However, the impact salinity was notable on shoot relative water content (SRWC) compared to the root relative water content (RRWC). This is in agreement with previous reports in sorghum [2], lentil [3], and Maize [6].

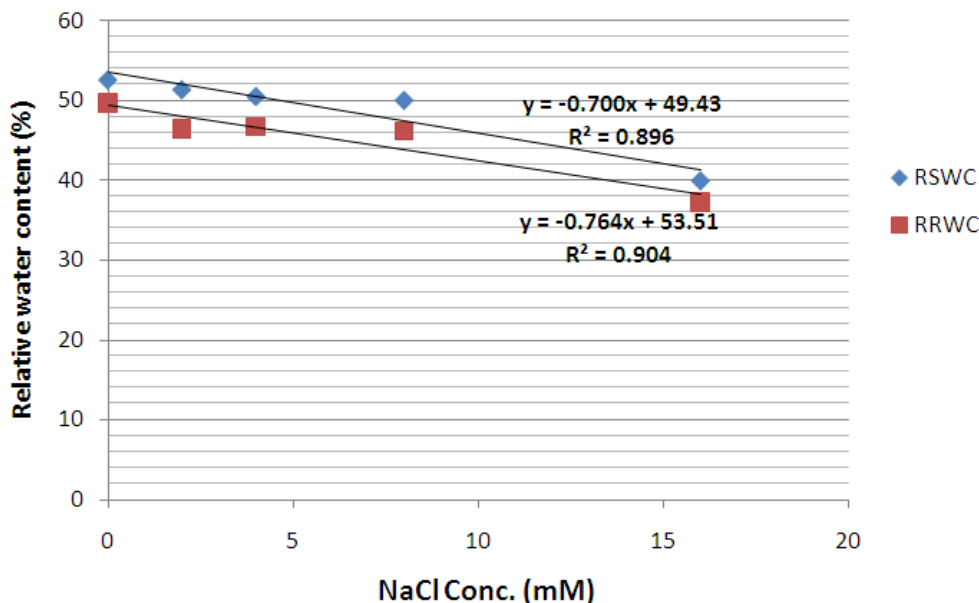


Figure 4. Effect of NaCl on shoot and root moisture content averaged over cultivars

4. Conclusion

The results of this study confirmed that cultivars vary in their vigor and tolerance indices, phytotoxicity, and relative water content. Chercher cultivar gave high seedling tolerance index, and relative shoot and root water contents; but low in shoot and root phytotoxicity. Hence, Chercher cultivar gave higher tolerance to salinity than Lehade cultivar. The increase in salinity concentration decreased vigor and tolerance indices, and relative shoot and root water contents; and increase in shoot and root phytotoxicity of haricot bean.

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