

Effects of Salinity on Seedling Biomass Production and Relative Water Content of Some Haricot Bean (*Phaseolus vulgaris*) Varieties

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Abstract: The aim of this research was to study the effects of salinity on 14 haricot bean (*Phaseolus vulgaris*) varieties at 0, 2, 4, 8 and 16 dS m⁻¹. Data analysis was carried out using jmp 5 (version 5.0) and SPSS (version 12) statistical softwares. Seedling Shoot Fresh Weight (SSFW), Seedling Shoot Dry Weight (SSDW), Seedling Root Fresh Weight (SRFW) and Seedling Root Dry Weight (SRDW) were measured and seedling Shoot Relative Water Content (SRWC) and seedling Root Relative Water Content (RRWC) were calculated. The two ways ANOVA for varieties found statistically insignificant with respect to Seedling Root Fresh Weight (SRFW), seedling Shoot Relative Water Content (SRWC) and seedling Root Relative Water Content (RRWC) ($p > 0.05$) but it was significant with respect to Seedling Shoot Fresh Weight (SSFW), Seedling Shoot Dry Weight (SSDW) and Seedling Root Dry Weight (SRDW) ($p < 0.05$). On the other hand, the two ways ANOVA for treatments displayed statistical significance for all the above parameters at ($p < 0.0001$). However, it was insignificant for variety treatment interaction ($p > 0.05$) with respect to the entire parameters. Varieties such as Awash-1, Argene, Chore, Mexican 142 and Awash Melka were found to be salt tolerant during seedling biomass production and in Relative Water Content (RWC). On the other hand, varieties Red Kidney (DRK), Dimtu, Gofta, Cranscope and Sinkinesh were found to be salt sensitive during seedling biomass production and in RWC. The rest haricot bean varieties were intermediate in their salt tolerance. The study affirmed the presence of broad intraspecific genetic variation in haricot bean varieties for salt stress with respect to their early biomass production and Relative Water Content (RWC).

Key words: Dry matter, haricot bean, relative water content, salinity, varieties, biomass

INTRODUCTION

Salt-affected soils are distributed throughout the world and no continent is free from the problem (Brady and Weil, 2002). Salinization of soil is one of the major factors limiting crop production particularly in arid and semi-arid regions of the world (Ahmed, 2009). Globally, a total land area of 831 million ha is salt affected. African countries like Kenya (8.2 Mha), Nigeria (5.6 Mha), Sudan (4.8 Mha), Tunisia (1.8 Mha), Tanzania (1.7 Mha) and Ghana (0.79) are salt affected to various degrees (FAO, 2000). Salt stress is known to perturb a multitude of physiological processes (Noreen and Ashraf, 2008). It exerts its undesirable effects through osmotic inhibition and ionic toxicity (Munns *et al.*, 2006). Increased salinity caused a significant reduction in germination percentage, germination rate and root and shoots length and fresh root and shoots weights (Jamil and Lee, 2006).

In Ethiopia, salt-affected soils are prevalent in the Rift valley and the lowlands. The Awash valley in general and the lower plains in particular are dominated by salt affected soils (Gebreselassie, 1993). A significant

abandonment of banana plantation and a dramatic spread to the adjacent cotton plantation of Melka Sadi farm was reported (Abegaz, 1995). Moreover, of the 4000 ha irrigated land of the above farm 57% has been salt-affected (Taddese and Bekele, 1996). Similarly, the occurrence of salinity problem in Melka Werer Research farm was reported (Haider *et al.*, 1988). Another study also depicted that of the entire Abaya State farm, 30% has already been salt-affected (Tsige *et al.*, 2000).

This problem is expected to be severe in years to come. Because under the prevailing situation of the country; there is a tendency to introduce and implement large-scale irrigation agriculture so as to increase productivity (Mamo *et al.*, 1996). In the absence of efficient ways of irrigation water management, salt-build up is an inevitable problem. To alleviate the problem, we need to look for a solution (Gebre and Georgis, 1988). It can be done either using physical or biological practice (Gupta and Minhas, 1993; Marler and Mickelbart, 1993). Since, environmental management (physical approach) is not economically feasible (El-Khashab *et al.*, 1997), there is a need to concentrate on the biological approach or

crop management (Ashraf and McNeilly, 1988, Ashraf *et al.*, 2008; Ashraf, 2009). Nevertheless to proceed with this approach, affirming the presence of genetically based variation for salt-tolerance in a particular crop is a prerequisite (Verma and Yadava, 1986; Marler and Mickelbart, 1993; Mahmood *et al.*, 2009). This could be done at different crop growth stages such as crop establishment (germination, emergence and seedling growth). There are reasonably adequate information on the effects of salinity on crops germination and emergence (Maas, 1986). However, there is only a little information on the impacts of salinity on crops biomass production during seedling growth (Katerji *et al.*, 1994).

Therefore, this research attempted to investigate the effect of salinity on fourteen haricot bean (*Phaseolus vulgaris*) varieties with respect to seedling biomass production and Relative Water Content (RWC).

MATERIALS AND METHODS

This study was conducted in Ethiopia from March 2008 to April 2009 at Mekelle University in the Laboratory of Biology Department. Seeds of 14 haricot bean (*Phaseolus vulgaris*) varieties were obtained from Melkassa Agricultural Research Center (MARC). The specific haricot bean varieties used in the research were Roba-1, Gofta, Chore, Awash-1, Awash Melka, Sinkinesh, Dimtu, Red Kidney (DRK), Tabor, Nassier, Zebra, Cranscope, Mexican 142 and Argene. Moreover, the NaCl concentrations used were 2, 4, 8 and 16 dS m⁻¹. These salinity levels were obtained by dissolving 1.12, 2.10, 4.95 and 9.9 g NaCl in 1 L of distilled water, respectively. Distilled water (0 dS m⁻¹) was served as a control.

Germination experiment was conducted in a laboratory at room temperature using the procedures followed by Verma and Yadava (1986) and Mamo *et al.* (1996). Petri dishes with a diameter of 10 cm that have been lined with whatman no. 3 filter study were supplied with 10 mL of each treatment solution (4 treatment solutions and the control). Following this, 8 uniform seeds of haricot bean varieties were placed on each petri dish and the petri dishes were arranged in a Randomized Complete Block Design (RCBD) with 4 replications. Eventually, the petri dishes were covered with a polyethylene sheet to avoid the loss of moisture through evaporation. Treatment application continued every other day and germination count was started after 48 h of sowing and continued until the 14th day. The seed was considered to have germinated when both the plumule and radicle had emerged ≥ 0.5 cm. After the 14 days, seedling shoot and root fresh weights were recorded and finally oven dried at 70°C for 48 h and the seedling shoot

and root dry weight were measured using sensitive balance. Relative seedling water content was calculated: fresh weight-dry weight/fresh weight $\times 100$ (Shalaby *et al.*, 1993).

RESULTS AND DISCUSSION

Seedling Shoot Fresh Weight (SSFW): The two ways ANOVA for variety ($p < 0.05$) and treatment ($p < 0.0001$) was significant. However, it was statistically insignificant for variety treatment interaction ($p > 0.05$) with regard to Seedling Shoot Fresh Weight (SSFW). Seedling Shoot Fresh Weight (SSFW) was facilitated at 2 dS m⁻¹ in all varieties and also at both 2 and 4 dS m⁻¹ in varieties Awash-1, Chore, Dimtu, Red Kidney (DRK), Gofta, Nassier, Roba-1, Awash Melka and Zebra as compared to the control. Varieties Red Kidney (DRK), Gofta, Cranscope and Dimtu were more salt-affected but varieties Awash-1, Argene, Chore, Awash Melka and Mexican 142 were least salt-affected at both 8 and 16 dS m⁻¹ salt concentrations (Fig. 1).

Seedling Root Fresh Weight (SRFW): The two ways ANOVA for variety treatment interaction and variety was insignificant ($p > 0.05$) however, it was significant for treatment ($p < 0.001$) with respect to Seedling Root Fresh Weight (SRFW). Seedling Root Fresh Weight (SRFW) was enhanced at 2 dS m⁻¹ in varieties Awash-1, Chore, Nassier, Cranscope and Roba-1 and also at both 2 and 4 dS m⁻¹ in variety Gofta as compared to the control. Varieties Dimtu, Red Kidney (DRK), Cranscope and Sinkinesh were most salt-affected but varieties Awash-1, Argene, Chore, Mexican 142 and Awash Melka were found to be least salt-affected at 8 and 16 dS m⁻¹ salinity levels (Fig. 2).

Seedling Shoot Dry Weight (SSDW): The two ways ANOVA showed statistical significance for treatment and variety ($p < 0.05$) but it was insignificant for variety treatment interaction ($p > 0.05$) with regard to Seedling Shoot Dry Weight (SSDW). Seedling Shoot Dry Weight (SSDW) was enhanced in all varieties at 2 dS m⁻¹ as compared to the control. Varieties Dimtu, Red Kidney (DRK), Cranscope and Gofta were the most salt-affected however, varieties Awash-1, Argene, Chore, Mexican 142 and Awash Melka were least salt-affected at 8 and 16 dS m⁻¹ salinity levels.

Seedling Root Dry Weight (SRDW): The 2 ways ANOVA for variety treatment interaction was found statistically insignificant ($p > 0.05$). However, it was significant for variety ($p < 0.05$) and for treatment

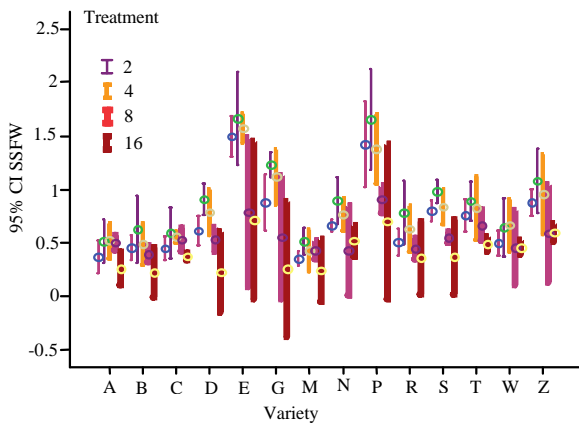


Fig. 1: Effects of different salinity levels (0, 2, 4, 8 and 16 dS m^{-1}) on Seedling Shoot Fresh Weight (SSFW) of *Phaselolus vulgaris* varieties. (Key to Varieties: R = Roba-1, G = Gofta, C = Chore, A = Awash-1, W = Awash Melka, S = Sinkinesh, D = Dimtu, E = Red Kidney (DRK), T = Tabor, N = Nassier, Z = Zebra, P = Cranscope, M = Mexican 142 and B = Argene)

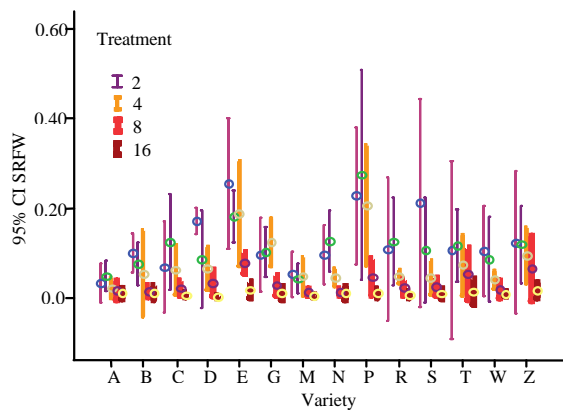


Fig. 2: Effects of different salinity levels (0, 2, 4, 8 and 16 dS m^{-1}) on Seedling Root Fresh Weight (SRFW) of *Phaselolus vulgaris* varieties (in centimeter). (Key to Varieties: R = Roba-1, G = Gofta, C = Chore, A = Awash-1, W = Awash Melka, S = Sinkinesh, D = Dimtu, E = Red Kidney (DRK), T = Tabor, N = Nassier, Z = Zebra, P = Cranscope, M = Mexican 142 and B = Argene)

($p < 0.0001$) with respect to Seedling Root Dry Weight (SRDW). As compared to the control, Seedling Root Dry Weight (SRDW) was enhanced at 2 dS m^{-1} in varieties Awash-1, Dimtu, Red Kidney (DRK), Gofta, Mexican 142, Nassier, Cranscope, Roba-1 and Tabor. It was also stimulated at 4 dS m^{-1} in varieties Red Kidney (DRK) and

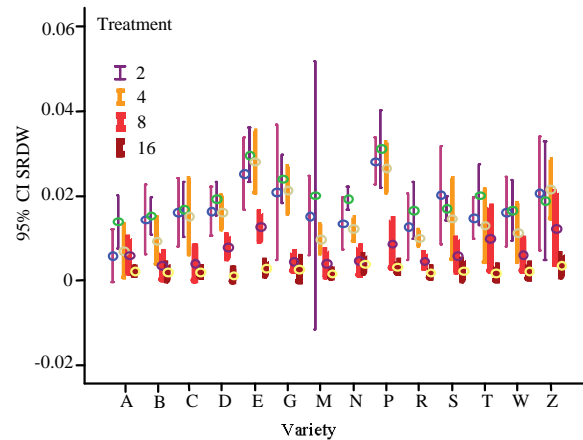


Fig. 3: Effects of different salinity levels (0, 2, 4, 8 and 16 dS m^{-1}) on Seedling Root Dry Weight (SRDW) of *Phaselolus vulgaris* varieties. (Key to Varieties: R = Roba-1, G = Gofta, C = Chore, A = Awash-1, W = Awash Melka, S = Sinkinesh, D = Dimtu, E = Red Kidney (DRK), T = Tabor, N = Nassier, Z = Zebra, P = Cranscope, M = Mexican 142 and B = Argene)

Zebra as compared to the control. At 8 and 16 dS m^{-1} varieties Dimtu, Red Kidney (DRK), Gofta, Cranscope, Sinkinesh and Zebra were more salt affected however, varieties Awash-1, Argene, Mexican 142, Nassier and Roba-1 were least salt-affected (Fig. 3).

Seedling Shoots Relative Water Content (SRWC): The two ways ANOVA showed statistical significance for treatment ($p < 0.0001$). However, it was insignificant for both variety and variety treatment interaction ($p > 0.05$) with regard to Seedling Shoots Relative Water Content (SRWC). Seedling Shoot Relative Water Content (SRWC) was facilitated in all varieties as compared to the control. Moreover, it was stimulated both at 2 and 4 dS m^{-1} in varieties Awash-1, Chore, Dimtu, Red Kidney (DRK), Gofta, Nassier, Cranscope, Roba-1, Tabor, Awash Melka and Zebra. Varieties Red Kidney (DRK), Gofta, Cranscope, Sinkinesh and Zebra had the lowest SRWC and but varieties Awash-1, Argene, Chore, Mexican 142 and Awash Melka possessed the highest Shoot Relative Water Content (SRWC) (Fig. 4).

Seedling Roots Relative Water Content (RRWC): The 2 way ANOVA for treatments was statistically significant ($p < 0.0001$) but it was insignificant for variety and variety treatment interaction ($p > 0.05$) with respect to seedling Root Relative Water Content (RRWC). seedling Root Relative Water Content (RRWC) was stimulated at 2 dS m^{-1} in varieties Chore, Nassier, Cranscope, Roba-1

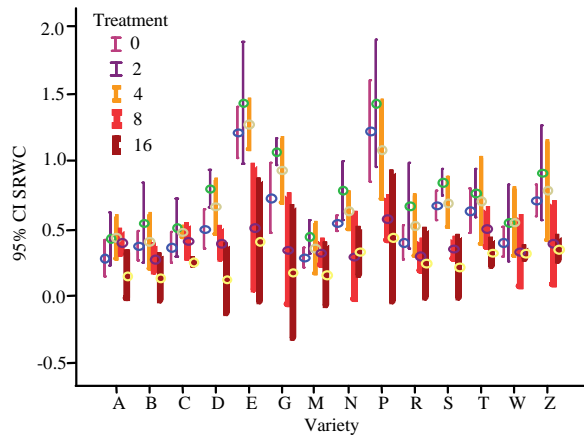


Fig. 4: Effects of different salinity levels (0, 2, 4, 8 and 16 dS m^{-1}) on Seedling Shoot Relative Water Content (SRWC) of *Phaselolus vulgaris* varieties (Key to Varieties: R = Roba-1, G = Gofta, C = Chore, A = Awash-1, W = Awash Melka, S = Sinkinesh, D = Dimtu, E = Red Kidney (DRK), T = Tabor, N = Nassier, Z = Zebra, P = Cranscope, M = Mexican 142 and B = Argene)

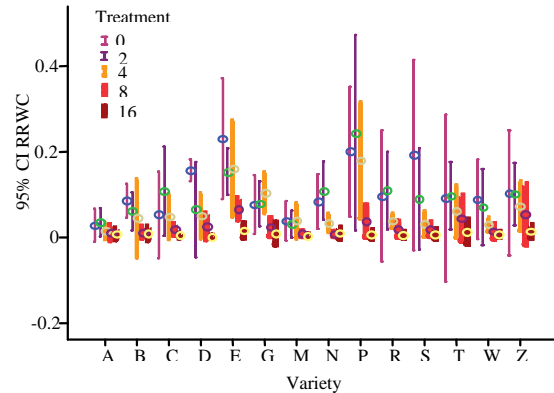


Fig. 5: Effects of different salinity levels (0, 2, 4, 8 and 16 dS m^{-1}) on Seedling Root Relative Water Content (RRWC) of *Phaselolus vulgaris* varieties (Key to Varieties: R = Roba-1, G = Gofta, C = Chore, A = Awash-1, W = Awash Melka, S = Sinkinesh, D = Dimtu, E = Red Kidney (DRK), T = Tabor, N = Nassier, Z = Zebra, P = Cranscope, M = Mexican 142 and B = Argene)

and Awash-1 and both at 2 and 4 dS m^{-1} in variety Gofta as compared to the control. Varieties Dimtu, Red Kidney (DRK), Cranscope and Sinkinesh had the least seedling Root Relative Water Content (RRWC). However, varieties such as Awash-1, Chore, Gofta, Mexican 142, Nassier and Awash Melka had the highest seedling Root Relative Water Content (RRWC). The remaining varieties had intermediate seedling Root Relative Water Content (RRWC) (Fig. 5).

In varieties Dimtu, Red Kidney (DRK), Gofta, Cranscope, Sinkinesh, Tabor and Zebra Seedling Shoot Fresh Weight (SSFW) decreased as the salinity level increased. This does agree with previous studies conducted in durum wheat and tef (Mamo *et al.*, 1996) and phaseolus species (Bayuelo-Jimenez *et al.*, 2002). Increased salinity level caused simultaneous reduction of seedling shoot and root fresh weights in varieties Red Kidney (DRK), Dimtu and Cranscope. This is in line with previous reports in wheat (Afzal *et al.*, 2005) and sugar beat, cabbage, amaranth and pak-choi (Jamil and Lee, 2006).

In general, Seedling Shoot Fresh Weight (SSFW) was more salt affected than Seedling Root Fresh Weight (SRFW). This is in accord with previous research reports in wheat and triticale genotypes (Shalaby *et al.*, 1993), phaseolus species (Bayuelo-Jimenez *et al.*, 2002) and sugar beat, cabbage, amaranth and pak-choi (Jamil and Lee, 2006). Increased salinity level caused simultaneous reduction in seedling root and shoot dry matter

production (SSDW and SRDW) in varieties Dimtu, Red Kidney (DRK), Cranscope and Gofta. Similar, research results were reported in sorghum (Boursier and Lauchli, 1990), wheat and triticale genotypes (Shalaby *et al.*, 1993), barely (Cho and Kim, 1998) and *prosopis alba* (Meloni *et al.*, 2004). On the other hand, both seedling fresh and dry biomass production (SSFW, SRFW, SSDW and SRDW) were concurrently reduced as a result of increased salinity level in varieties Gofta, Cranscope and Red Kidney (DRK). This does agree with previous research findings in rice (Shannon *et al.*, 1998), Phaseolus species (Bayuelo-Jimenez *et al.*, 2002), wheat (Afzal *et al.*, 2005) and catharanthus roseus (Abdul-Jaleel *et al.*, 2008). Seedling Relative Water Content (RWC) was drastically decreased at higher salinity level, 16 dS m^{-1} . However, the impact was remarkable on Shoot Relative Water Content (SRWC) compared to the Root Relative Water Content (RRWC). This is in agreement with previous reports in lentil (Ashraf and Waheed, 1993), Maize (Cicek and Cakirlar, 2002), *Prosopis alba* (Meloni *et al.*, 2004).

The two ways ANOVA for treatments was significant with regard to all parameters considered. On the one hand, the ANOVA for varieties was insignificant with respect to SRFW, RRWC and SRWC. This implies that there were no significant varietal differences among haricot bean varieties in relation to the parameters considered above. However, it was significant with respect to SSFW, SSDW and SRDW. This reveals the presence of considerable

varietal differences among haricot bean varieties in respect to SSFW, SSDW and SRDW. Accession treatment interaction was insignificant for Seedling Shoot Fresh Weight (SSFW), Seedling Shoot Dry Weight (SSDW), Seedling Root Fresh Weight (SRFW), Seedling Root Dry Weight (SRDW) and seedling Root Relative Water Content (RRWC) and seedling Shoot Relative Water Content (SRWC); reflecting that all accessions responded similarly to salt stress with respect to these parameters. In general, salt stress at 2 dS m^{-1} stimulated SSFW, SRFW, SSDW, SRDW, RRWC and SRWC in some varieties. The impact of 2 and 4 dS m^{-1} salinity levels was not profound with respect to all parameters considered. Nevertheless, most varieties were profoundly affected at 8 and 16 dS m^{-1} salinity levels.

Crop cultivar may germinate effectively under salt stress; nevertheless, its seedling growth may be salt-affected (Azhar and McNeilly, 1987).

In line with this, varieties Roba-1, Red Kidney (DRK), Tabor and Zebra were less salt-affected during germination (in another study) than subsequent growth (had inadequate seedling biomass production and relative water content).

This implies that these accessions are salt tolerant during germination than subsequent growth like seedling biomass production and relative water content. On the other hand, crop genotype may be salt sensitive during both germination and seedling growth. This has already been reported in rice (Shannon *et al.*, 1998) and cowpea (Murillo-Amador and Troyo-Diequez, 2000). Similarly in this research, variety Red Kidney (DRK) and Dimtu were found salt sensitive at higher salinity levels during germination and seedling biomass production and through their relative water content.

Thus these haricot bean variety could not be directly cultivated even on slightly saline soils. On the other hand, varieties Awash-1, Argene, Chore, Mexican 142 and Awash Melka were found salt tolerant with respect to seedling biomass production and Relative Water Content (RWC). These accessions also had the lowest germination rate (rapid emergence and facilitated seedling growth) (in another study).

Their salt tolerance capability might emanate from their faster germination which allowed the emerging seedlings to accumulate more biomass relative to the control (Bayuelo-Jimenez *et al.*, 2002). Thus due to the facilitated seedling root and shoot characteristics, these genotypes were enabled to possess the highest seedling Relative Water Content (RWC) which in turn enabled them to tolerate the toxic effects of salts through dilution (Lee and Senadhira, 1998). Since, these 5 haricot bean varieties had rapid emergence, facilitated seedling growth,

highest seedling biomass production and Relative Water Content (RWC); they could effectively establish themselves on moderately saline soils.

CONCLUSION

The study revealed the presence of broad intraspecific variation among haricot bean (*Phaseolus vulgaris*) varieties in response to salt stress during seedling biomass production and Relative Water Content (RWC). Specifically, the study proved that varieties Awash-1, Argene, Chore, Mexican 142 and Awash Melka were the most salt tolerant of all haricot bean varieties studied. Thus these 5 varieties could be cultivated on slightly saline soils directly. Because, owing to their rapid emergence, facilitated growth, highest biomass production and relative water content they could establish themselves effectively on such soils. However, this could not be a guarantee for them to be salt tolerant in later growth stages. Thus to recommend the cultivation of these 5 haricot bean varieties in the field, there must be further profound greenhouse and field investigation at the whole plant growth level.

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