

How Salinity Affect Germination and Emergence of Tomato Lines

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ABSTRACT

High salt concentrations in soil and irrigation water restrict establishment and growth of tomato (*Solanum lycopersicum*). Correcting saline condition in field and greenhouse would be expensive and temporary while selection and breeding for salt tolerance can be a wise solution to minimize salinity effects as well as improve production efficiency. In order to find any kind of tolerance to saline condition, effects of four salinity levels in irrigation water (0.5, 2.5, 5, and 10 $\text{ds}\cdot\text{m}^{-1}$) on seed germination and seedling emergence, and growth of tomato lines LA₃₇₇₀, R₂₀₅, CT₆, Fla, and ME were investigated in a greenhouse. Germination percentage and rate, emergence percentage and rate of all tomato lines were delayed and decreased by salinity increasing from 2.5 $\text{ds}\cdot\text{m}^{-1}$ to 10 $\text{ds}\cdot\text{m}^{-1}$. All seedling growth characters, except seedling height, were decreased with increasingly salinity levels. At germination and emergence stage, LA₃₇₇₀ were more tolerant to salinity than others.

Keywords: *Solanum lycopersicum*, Salinity, seedling tolerance, germination, genetic tolerance

INTRODUCTION

It is well documented that the amount and quality of irrigation water available in many of the arid and semiarid regions of the world are the main limiting factors to the extension of agriculture (Beck, 1984; Munns, 2002). Saline-sodic irrigation water, coupled with the low annual rainfall and high evaporation and transpiration in the arid and semi-arid regions, resulted in accumulation of soluble salts in the soil solution and of cations (especially sodium ions) on exchange sites, which can alter the structure and, consequently, affect the soil hydraulic conductivity (Sameni and Morshedi, 2000 and Parida, 2005). High Soil salinity level can be a major environmental constraint to crop productivity. Most crops are susceptible to salt stress and either die or have a yield reduction (Scholberg and Loccascio, 1999). In many crops, seed germination and early seedling growth are most sensitive stages to environmental stresses (Jones, 1986). In tomato (*Solanum lycopersicum*), high concentrations of salt (150 mM NaCl and 15 mM CaCl₂) in the germination media significantly delays onset and reduces the rate of germination (Foolad and Lin, 1997, 1998; Jones, 1986). Investigation of salinity and Wheat (*Triticum vulgare* L.) indicated that there is a significant positive correlation between seedling and mature plant response to salt stress (Al Harbi et al, 2008), however Foolad reported Absence of a genetic relationship between salt tolerance during seed germination and vegetative growth in tomato (Foolad and Lin, 1997). Although, screening of tomato seedlings for salt tolerance may not be reliable to distinguish a mature plant as tolerant or sensitive but it is necessary to test them in all growth stages to know if they have any genetic tolerance to saline condition.

“Plants exposed to salt stress undergo changes in their environment. The ability of plants to tolerate salt is determined by multiple biochemical pathways that facilitate retention and/or acquisition of water, protect chloroplast functions, and maintain ion homeostasis. Essential pathways include those that lead to synthesis of osmotically active metabolites, specific proteins, and certain free radical scavenging enzymes that control ion and water flux and support scavenging of oxygen radicals or chaperones. The ability of plants to detoxify radicals under conditions of salt stress is probably the most critical requirement. Many salt-tolerant species accumulate methylated metabolites, which play crucial dual roles as osmoprotectants and as radical scavengers. Their synthesis is correlated with stress-induced enhancement of photorespiration” (Parida, 2005).

Large genetic variation of tolerance to salt level exists among tomato genotypes. However, salt tolerance breeding programs had been restricted by the complexity of the trait, insufficient genetic and physiological knowledge of tolerance-related traits, and lack of efficient selection domain (Foolad and Lin, 1998). Most commercial cultivars of tomato are sensitive to moderate levels of salinity up to 2.5 $\text{ds}\cdot\text{m}^{-1}$, without significant yield reduction (Hartz, 1990).

Correcting saline condition in field and greenhouse would be expensive and temporary while selection and breeding for salt tolerance can be a wise solution to minimize salinity effects (Foolad, 1996) as well as improve production efficiency. So breeding tolerant cultivars of tomato under saline conditions is needed. Genetic characterization of useful germplasm is the first step toward releasing tolerant cultivars. This study tried to find any level of tolerance to saline conditions in 5 tomato inbred lines.

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MATERIALS AND METHODS

The study was carried out at the Faculty of Agriculture, Ferdowsi University of Mashhad, IRAN.

Germination

Sterile germination media (0.8 % w:v agar) containing 0.5, 2.5, 5, and 10 $\text{ds}\cdot\text{m}^{-1}$ of NaCl used to simulate salinity. Seeds were surface-sterilized with 1 % NaOCl solution for 12 minutes and rinsed with sterile distilled water several times then blotted using sterile paper towels. Seeds were plated onto Petri dishes under aseptic conditions. Each Petri dish contained 8 seeds of one inbred-line. Petri dishes were placed in a controlled-environment growth chamber at 25 °C and 80% relative humidity.

Seeds were considered germinated when the radical was at least 2 mm long (Al Harbi et al., 2008). Number of germinated seeds was recorded daily (germination rate), and the final germination percentage was determined after 10 days. There were 20 combinations of treatments (five tomato lines and four salinity levels). The experiment was a factorial, in a completely randomized design, with three replications.

Data analysis indicated that there were significant differences among inbred-lines in the germination percentage and germination rate in all treatments.

Emergence and Seedling Growth

Emergence tests were carried out in seedling trays with 190 cells (4 × 4 × 6 cm), which were filled with sterilized coco peat[†] and sand 1:1 v/v and placed in a greenhouse at 25 ± 3°C 60% ± 15% relative humidity. Seeds of the tomato Inbred-lines were sown one seed per cell. Then, Irrigation was begun immediately after by adding 200 mL of NaCl (0.5, 2.5, 5, and 10 $\text{ds}\cdot\text{m}^{-1}$) solutions daily. Irrigation with distilled water repeated every 2 days to avoid aggregation of salt in the medium. A seedling was considered emerged when the hypocotyls hook was visible above the media surface. Number of emerged seeds was recorded daily (emergence rate), and the final emerged seedling percentage determined after 10 days. The experiment was factorial, in a completely randomized design, with four replications.

Seedling height, number of leaves, leaf area, and total fresh and dry weights of seedling recorded at 40 days after sowing.

RESULTS AND DISCUSSION

Germination

ANOVA for germination percentage and rate indicated significant differences among lines, salinity levels, and their interactions (Table 1). The correlation between rate and percentage of germination was significantly negative ($r = -0.92$, $P < 0.01$) showing germination rate was delayed while germination percentage was decreased (Figure, 1).

Table 1. Germination rate and percentage analysis

source of variance	df	Mean squares	
		Germination percentage	Germination rate
Lines (L)	4	33794.2000**	21.17800**
Salinity levels (S)	3	3111.0000**	100.04000**
S × L	12	915.2000**	0.69900**
Error	19	184.35	0.5772

[†] Coir, coconut husks.

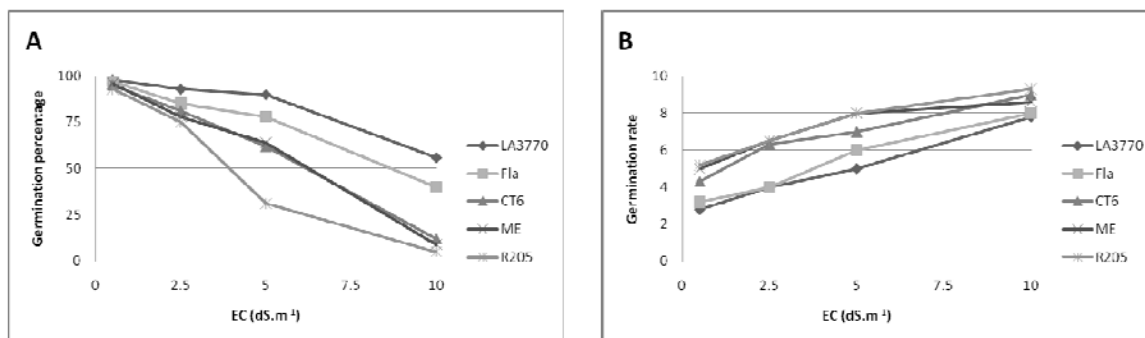


Figure 1. Effect of salinity level on germination percentage (A) and germination rate (B) of tomato Lines.

For all lines, germination percentage was higher at the lowest level of salinity ($0.5 \text{ ds} \cdot \text{m}^{-1}$) while having the fastest germination rate in the same level. Final germination percentage decreased and germination rate was delayed as salinity increased (Figure,1). The results indicated that LA₃₇₇₀ and Fla had acceptable germination percentages and rates when they were irrigated with $5.0 \text{ ds} \cdot \text{m}^{-1}$ of NaCl. It indicates that these two lines are more tolerant to salinity at germination stage compared to the other studied lines.

Salinity may affect germination by facilitating intake of toxic ions, which may change certain enzymatic or hormonal activities. Also salinity may affect seed germination by decreasing absorption of water, because activities and events normally associated with germination, can be either delayed and/or proceed at reduced rates. Cuartero and Fernandez-Munoz (1999) reported that seeds need 50% more days to germinate at 80 mM NaCl ($\text{EC} = 1.4$) than in a medium without salt and almost 100% more days at 190 mM NaCl ($\text{EC} = 3.4$). Neamatollahi et al, (2009) also report that increasing of NaCl concentration in priming treatments may reduce germination percentage due to higher osmotic pressures.

Emergence and Seedling Growth

Results analysis indicated significant differences between lines in different salinity levels for all emergence and seedling growth characters, except seedling Length (Data not show). Salinity and water deficiency led to decrease plant metabolic activities and finally decrease plant growth (hussein et al., 2007). It may occur due to the mechanism of dry matter partitioning in stress conditions. Seedling send more assimilates to roots to improve uptake ability and so the seedling above ground growth may be declined. Interactions between lines \times salinity levels were significant for emergence percentage, emergence rate, and seedling fresh and dry weight. LA₃₇₇₀ had the highest value of all characters followed by Fla (Figure 2). The comparison indicated that successive increase in salinity levels were associated with significant decrease of emergence percentage, emergence rate, and seedling fresh and dry weight in all lines.

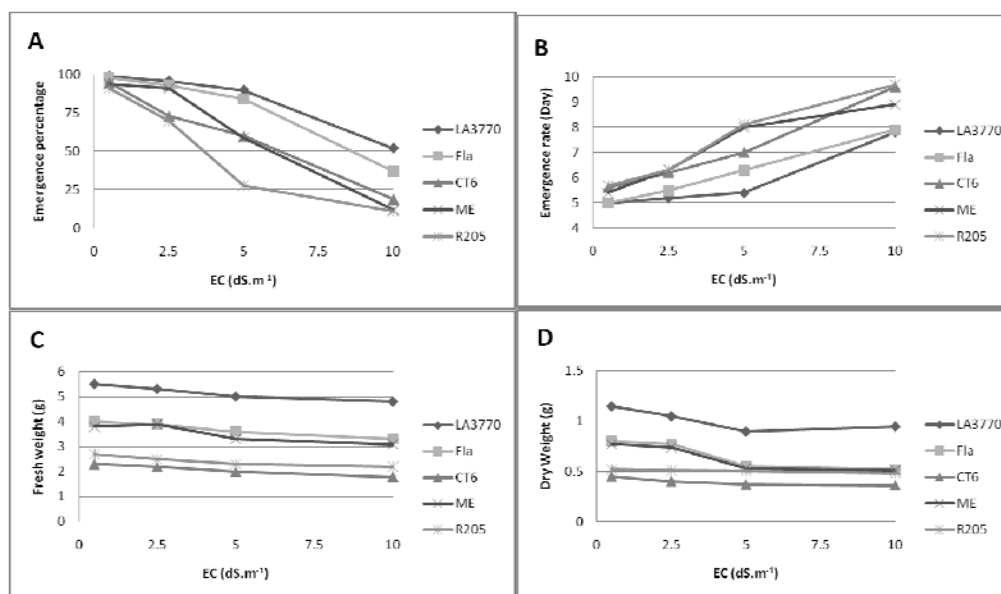


Figure 2. Effect of salinity level on emergence percentage (A), emergence rate (B), fresh weight (C), and dry weight (D) of tomato Lines.

LA₃₇₇₀ ($2.5 \text{ ds}\cdot\text{m}^{-1}$) had the highest value of these characters and R₂₀₅ ($10 \text{ ds}\cdot\text{m}^{-1}$) had the lowest values in emergence percentage (Figure 2A), and emergency rate (Figure 2B). CT₆ had the lowest value of both fresh and dry weight (Figure 2C, D). Increasing salinity was associated with significant decrease in emergence percentage, emergence rate, and seedling fresh and dry weights in all lines. LA₃₇₇₀ had higher tolerance to salinity in compare to the other cultivars. However, CT₆ was susceptible to salinity levels. Why plant growth reduces under salinity is a matter of controversy. It has been related to salt-induced disturbance of water balance and, in the extreme, to a loss of leaf turgor, which can reduce leaf expansion and photosynthetic leaf area (Erdei and Taleisnik, 1993; Huang and Redmann, 1995). Water uptake by tomato plants declines as salt concentration in irrigation water increases (Soria and Cuartero, 1997). Reduction of plant water uptake under saline conditions could be related to reductions in morphological and physiological parameters like leaf area, stomatal density, and stomatal closure (stomata conductance and transpiration).

The salt sensitivity of some tomato cultivars to salinity could be due to both the toxic effect of Na and Cl ions and nutritional imbalance induced by salinity, as plant growth was inversely correlated with Na and Cl contents and directly correlated with K and Ca contents (Alfocea, 1993).

The role of plant hormones under saline stress is critical in modulating physiological responses that will eventually lead to adaptation to an unfavorable environment. Nevertheless, the functional level of plant hormones, and their relative tissue concentration, may have a different impact on plant growth and stress tolerance at increasing salinity of the root environment. Vigorous plant growth may counteract the negative effects of salinization. In contrast, low gibberellins (GA) levels have been associated with reduced growth in response to salinity (Maggio, 2010). Based on these facts and maggio et al., report, exogenous applications of the plant hormone GA₃ may compensate for the salt-induced growth deficiency and consequently facilitate tomato plant adaptation to a saline environment. So tomato lines which genetically have an ability to produce more GA₃ in its seedling stage may be tolerant to saline conditions. DiLeo et al, discussed how salinity promote abscisic acid (ABA) production. He also described how ABA can influence disease response pathways in plants and mentioned that ABA has been associated with susceptibility of plants (Including tomato) to bacteria, fungi, and oomycetes (dileo, 2010). It is known that tomato susceptibility to damping-off in seedling stage is high and salinity may increase it. Tomato lines which are resistant to fungal and bacterial diseases may be more tolerant to salinity. It may happen because of less ABA production (should be measured in tolerant tomato seedlings) or the total plant health. In this study Fla and LA₃₇₇₀ lines which have high resistant level to fungal diseases, showed more tolerance to saline conditions.

CONCLUSIONS

Genetic variability offers a valuable tool for studying mechanisms of salt tolerance in tomato, and it will be appreciated to find tomato line(s) with genetic tolerance to saline conditions.

It may be useful to employ LA₃₇₇₀ and Fla as donor plants in tomato breeding programs for increasing seedling tolerance to saline conditions although it is not clear that tolerance in seedling stage have same result in other critical stages of tomato growth.

It should be mentioned that the concentration used for inducing salinity conditions in a limited time of exposure may improve the germination percentage and rate as a seed priming treatment. So appropriate concentrations and exposure time is needed to simulate saline conditions.

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