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Research Article

Effect of Zinc Treatment on the Alleviation of Sodium and Chloride Injury in Tomato (*Lycopersicum esculentum* (L.) Mill. cv. Lale) Grown Under Salinity

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Abstract: Nonsaline and saline (30 mM NaCl), Zn (10, 20, 40 mg kg^{-1}) and without Zn treatment and factorial combinations of NaCl and Zn on the fresh and dry weights of the plants, and sodium (Na), chloride (Cl) and zinc (Zn) contents of both young and old leaves were determined and the effects of Zn on the Na and Cl translocation within the plants were investigated. Salinity decreased the fresh and dry weights of the plants while this effect of salinity diminished with increasing Zn levels. Na and Cl concentrations of both young and old leaf tissues decreased with increasing levels of Zn treatment and these decreases were more pronounced in the presence of salinity. Zn treatment also decreased Na and Cl translocation from old leaves to young leaves. Zinc content of the leaf tissues increased in both saline and nonsaline conditions with Zn treatment. From the result of the present study, it was concluded that in the salt affected areas, zinc application could alleviate possible Na and Cl injury in plants.

Key Words: Tomato, (*Lycopersicon esculentum* (L.) Mill. cv. Lale), Salinity, Zinc, Sodium, Chloride.

Tuzlu Koşullarda Yetiştirilen Domates (*Lycopersicum esculentum* (L.) Mill. Lale) Bitkisinde Sodyum ve Klor Zararının Giderilmesinde Çinko Uygulamasının Etkisi

Özet: Bu çalışmada, tuzsuz ve tuzlu (30 mM NaCl), çinkosuz ve çinkolu (10, 20, 40 mg kg^{-1}) ve tuz ve çinkonun faktoriyel kombinasyonlu koşullarda yetiştirilen domates (*Lycopersicon esculentum* (L.) Mill. Lale) bitkisinin taze ve kuru ağırlıkları saptanmış, yaşlı ve genç yapraklarda sodyum (Na), klor (Cl) ve çinko (Zn) içeriği belirlenmiş ve çinkonun bitkide sodyum ve klor taşınımına etkisi araştırılmıştır. Tuzluluk bitkinin taze ve kuru ağırlığını azaltmış, tuzluluğun bu zararı Zn uygulamasıyla giderilmiştir. Yaşlı ve genç yaprakların Na ve Cl içerikeri Zn artışına bağlı olarak azalmıştır ve bu azalış tuzlu koşullarda daha belirgin olmuştur. Zn uygulaması Na ve Cl'un yaşlı yapraklardan genç yapraklara taşınımını da azaltmıştır. Tuzlu ve tuzsuz her iki koşulda da Zn uygulaması yaprakların Zn kapsamını artırmıştır. Bu çalışmadan elde edilen sonuçlara göre, tuzlu alanlarda Zn uygulaması bitkilerde Na ve Cl zararını önleyebilmektedir.

Anahtar Sözcükler: Domates (*Lycopersicon esculentum* (L.) Mill. cv. Lale), Tuzluluk, Çinko, Sodyum, Klor.

Introduction

Plant growth and yield are reduced by salinity, and the ionic composition of the salts in the soil solution and within plant tissues (1). The tomato, one of the most important and widespread vegetable crop in the world, is considered to be moderately salt tolerant (2) and salt stress results in a limitation in plant growth by water deficit, ion toxicity (such as Cl^- and Na^+), ionic imbalance (e.g., a high Na/Ca ratio), or a combination of any of these factors (1, 3, 4).

Salt exclusion minimizes ion toxicity but accelerates water dificit in plants, whereas salt absorption facilitates osmotic adjustment but can lead to ion toxicity and nutritional imbalance (3, 5).

Adaptation to salinity can be achieved by Na and Cl exclusion which requires either high tissue tolerance to Na and Cl, or avoidance of high tissue concentrations of these ions. As suggested by Parker et al., (6) and Marschner and Cakmak (7) root cell membrane permeability is increased under Zn deficiency which might be related to the functions of Zn in cell membranes. As reported by Welch et al., (8) Zn is necessary for root cell membrane integrity, and in this function, it prevents excessive P uptake by roots and the translocation of P from roots to leaves. From this point of view, external Zn concentrations could mitigate the adverse effect of NaCl by inhibiting Na and/or Cl uptake or translocation.

The objective of this study was to examine the possible protective role of Zn agaiinst salinity by restricting excessive uptake and translocation of Na and Cl in tomatoes grown under salinity.

Materials and Methods

Tomato (*Lycopersicum esculentum* (L.) Mill. Lale) plants were grown in a glasshouse under natural light conditions (approximate day conditions during the period of time: 18-22°C air temperature, 200-250 µmol/m^2/s light intensity and 60% relative humidity. Tomato seeds were surface sterilized in 0.07 M NaOCl for 5 min, rinsed thoroughly, and germinated and grown in polyethylene tubes containing peat: perlite (1:1) mixture. Three-week-old seedlings were transplanted at a rate of one plant per pot filled with 4000 g of air dried soil. Some characteristics of the soil were as follows: texture loamy clay, $CaCO_3$ 5.75%, pH (1:2.5 water) 7.61, EC 0.56 dS m^{-1}, organic matter 1.07%, total N 0.15%. The concentrations of NH_4OAc-extractable K, Ca and Na wereas follows (mg kg^{-1}): 450, 4800 and 60 respectively. $NaHCO_3$-available P was 10.70 mg kg^{-1} and DTPA-extractable Zn was 0.57 mg kg^{-1}.

The soil was salinized by adding 30 mM NaCl (1.75 g kg^{-1} soil) levels. Zinc was applied at the rates of 0, 10, 20 and 40 mg kg^{-1} as $ZnSO_4.7H_2O$. Nitrogen, K and P were applied all the pots 300, 278 and 200 mg kg^{-1} rates as $(NH_4)_2SO_4$, KNO_3 and H_3PO_4.

The plants were harvested 14 weeks after transplantation and the fresh weights were recorded. Old and young leaf samples were taken from each plant for mineral element determination. After sampling, plant materials were washed with deionized water, then dried at 70°C and ground for analysis.

Sodium and Zn concentrations were assayed in concentrated HNO_3 and $HClO_4$ (4:1) digested samples. Sodium was measured with a flame photometer and Zn with a Atomic Abrosption Spectrophotometer (AAS). Water extractable Cl was determined by potentiometric titration with $AgNO_3$ as described by Lambert and DuBois (9).

The experimental design was completely randomized with four replicates. The data were analyzed with ANOVA and the differences were compared with the LSD test (Duncan's multiple range test, $_{p<0.05}$).

Results

The results of the interactions between salinity and Zn are shown in Figures 1-4 and the summaries of variance (P values) of the experimental data are given in Table 1.

Fresh and dry weights of the plants

The fresh and dry weights of the plants increased as the Zn concentration in the soil was increased (Figure 1). At concentrations of 10 mg Zn kg^{-1} soil or higher, the fresh and dry weights of the plants were about the same. The fresh and dry weights of the plants decreased at the given salinity (30 mM NaCl) level.

Sodium concentrations in the plants

Sodium concentrations in old leaf tissues were found to be higher than in young leaves. The concentration of Na increased in both young and old leaves of the plants with the NaCl treatment and increases were more pronounced in older leaves. However, it decreased with

Table 1. Summaries of analysis of variance (P values) of experimental data as affected by the interaction between salinity and zinc.

		P values of the experimental data							
Source	Df	Fresh Weight	Dry Weight	Na Conc. (young leaf)	Na Conc. (old leaf)	Cl conc. (young leaf)	Cl Conc. (old leaf)	Zn Conc. (young leaf)	Zn Conc. (old leaf)
Zn	3	0.019*	0.022*	0.000***	0.000***	0.020*	0.001***	0.000***	0.000***
Salinty	1	0.000**	0.000***	0.000***	0.000****	0.000***	0.000***	0.514ns	0.101ns
ZnxSal.	3	0.139ns	0.088ns	0.002***	0.00***	0.022*	0.001***	0.125ns	0.632ns

*: p<0.05, **: p<0.01; ***: p<0.001; ns: non significant

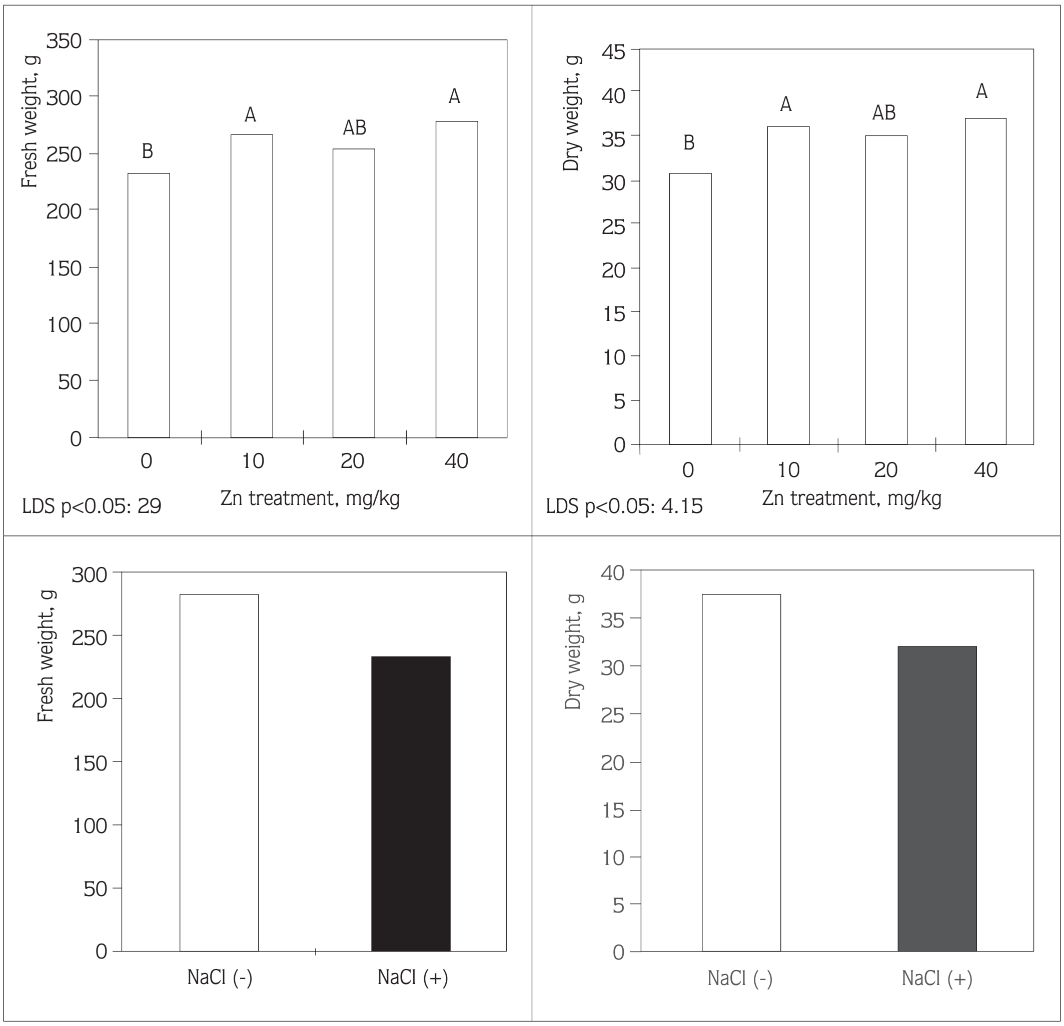

Figure 1. Effect of salinity and Zn treatment on the fresh and dry matter yield of tomatoes under saline conditions. Means followed by same letters are not significantly different (Duncan's multiple range test, $p<0.05$).

increasing Zn treatments. In fact, Na concentrations in both young and old leaves were higher with 0 mg kg^{-1} Zn than with higher levels of Zn, and the differences between nonsaline and saline conditions decreased relatively with increasing Zn treatments. From these results it can be concluded that translocation of Na from old leaves to the young leaves is reduced by applying Zn (Figure 2).

Chloride concentrations in the plants

Increasing levels of Zn decreased Cl concentrations in young and old leaves of the plant in the presence of salinity similar to Na concentration while the differences recorded with levels of Zn higher than 10 mg kg^{-1} were the same as fresh and dry weights. However, this response was not obtained in the absence of salinity. Chloride concentrations in leaves increased significantly with external NaCl and was more pronounced in the old leaves than the young leaves. The translocation of Cl from old leaves to the young leaves was inhibited by Zn treatment (Figure 3).

Zinc concentrations in the plants

Zinc concentrations in both old and young leaves increased with increasing Zn levels in saline and nonsaline conditions. In contrast to Cl and Na concentrations, young leaves contained greater amounts of Zn than old leaves did (Figure 4).

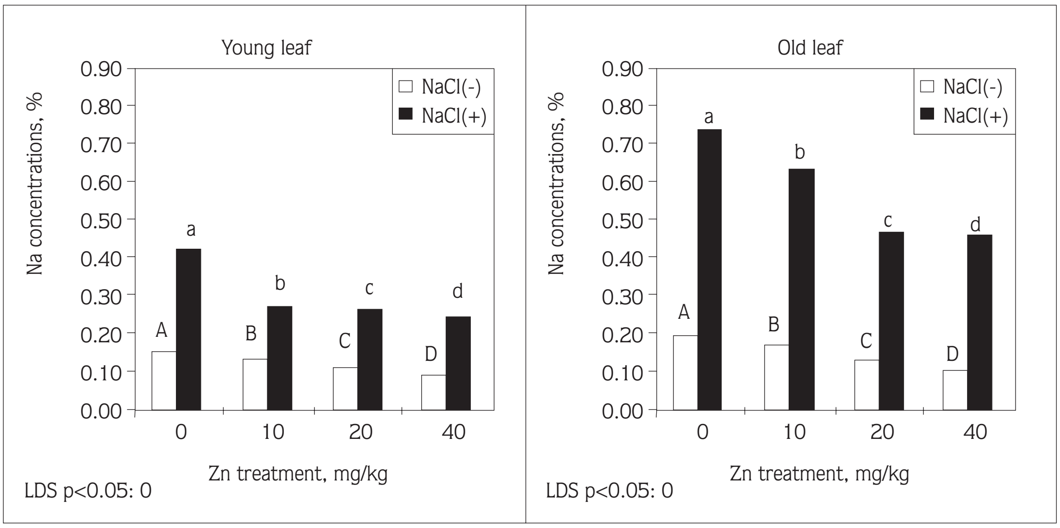

Figure 2. Sodium concentrations (in dry weights) of young and old leaves of tomato plants as affected by Zn treatment in the absence and presence of NaCl salinity. Means followed by same letters are not significantly different (Duncan's multiple range test, p<0.05). Capital letters for the comparisons of NaCl(-) and small letters for the comparisons of NaCl(+).

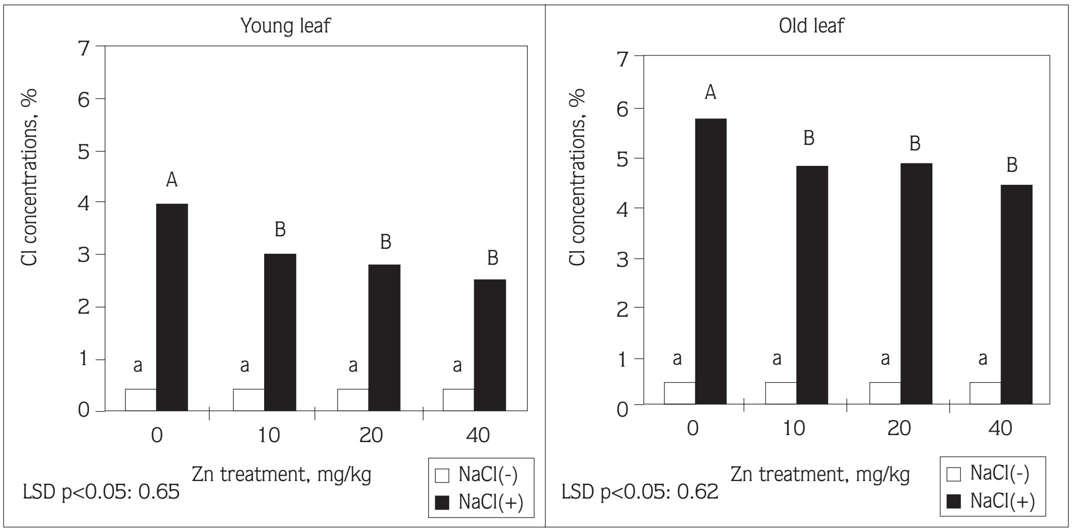

Figure 3. Cloride concentrations (in dry weights) of young and old leaves of tomato plants as affected by Zn treatment in the absence and presence of NaCl salinity. Means followed by same letters are not significantly different (Duncan's multiple range test, p<0.05). Capital letters for the comparisons of NaCl(-) and small letters for the comparisons of NaCl(+).

Discussion

Lower fresh and dry weight due to salinity is attributed to water stress, Na and Cl toxicity and ionic imbalance (4, 10, 11). In fact, the plants' Na and Cl concentrations were found to be much higher than the toxic levels. According to Finck (12) sodium levels of 0.80% in barley, which is a salt tolerant crop, are considered toxic and according to Bartolomaeus et al., (13) the tomato is more sensitive than barley to salinity. Chloride in excess of 0.5-1.5% can cause toxic effects in some plants and chloride tolerant plants are said to withstand up to 4.0% (14). In the present study, Cl concentrations in the young and old leaves of tomato

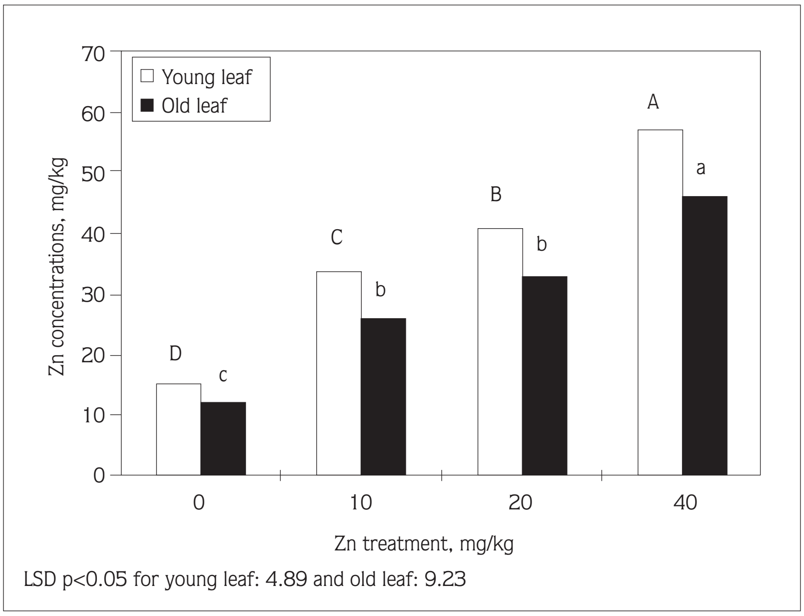

Figure 4. Effect of Zn treatment on the Zn concentrations (in dry weights) of young and old leaf tissues of tomato plants grown under salinity. Means followed by same letters are not significantly different (Duncan's multiple range test, $p<0.05$).

plants were found to be higher than 2% and 4% respectively.

The positive effect of Zn treatment of the fresh and dry weights of the tomato plants grown under salinity could be explained by the decreases in uptake of Na and Cl concentrations and translocations from the old leaves to young leaves as a results of increasing membrane integrity with Zn treatment. As reported by Welch et al., (8) root cell membranes of Zn-deficient plants lose integrity and P accumulates due to nonselective absorption. Marschner and Cakmak (7) ascribed loss of membrane integrity to peroxidative attack of membrane lipids by free oxygen radicals and they speculated that there is a physiological link between increased membrane permeability and hyperaccumulation of P. These mechanisms of Zn on the P uptake and translocation could also be valid in Na and Cl uptake.

The results suggest that Zn has a control mechanism and/or a regulatory function on the Na and Cl uptake and translocation rate. The role of Zn in this mechanism is not explained clearly hence, Zn might possibly be involved in the integrity and function of the biomembranes of plants. The results of this experiment lead to the conclusion that possible Na and Cl toxicity, especially in Zn deficient areas, could be alleviated by Zn treatment.

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