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## NOTE

# VEGETATIVE GROWTH AND CHEMICAL COMPOSITION OF TOMATO PLANTS AS AFFECTED BY DIFFERENT TYPES OF SALT STRESS AND ZINC FERTILIZATION

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## ABSTRACT

The response of tomato (*Lycopersicon esculentum* Mill.) exposed to four Zn rates (0, 5, 10 and 20 mg kg$^{-1}$ soil as Zn $SO_4.7H_2O$), six salinity levels (0, 3, 5, 7, 9, and 11 dS m$^{-1}$) and four salt compositions ($C_1$ =100% NaCl, $C_2$= 60% NaCl+40% $Na_2SO_4$, $C_3$ = 40% NaCl+60% $Na_2SO_4$, and $C_4$ =100% $Na_2SO_4$ on chemical equivalent basis) was studied under greenhouse conditions.Tomato plants treated with the highest salinity level produced significantly less dry matter than those grown without salt addition. Moreover, the NaCl salinity was more toxic to tomato than that of $Na_2SO_4$. Plants supplied with 5 mg Zn kg$^{-1}$ produced more top dry weight than untreated plants; whereas higher rates resulted in less growth. The suppressing effects of soil salinity were alleviated by Zn fertilization and this effect was greater in $C_1$ than $C_4$ treatment. Plant Cl concentration was significantly increased by $C_1$, $C_2$ and $C_3$ treatments and was not affected by $C_4$. On the other hand, increasing salinity resulted in an increase in the Na concentration in tomato top regardless of salt composition. $SO_4$ concentration was high in $C_4$-treated plants, lower in $C_3$ and $C_2$ treatments and unchanged in $C_1$. Zinc application markedly increased Zn concentration in tomato and Zn absorption was enhanced by salinity. It was concluded that when tomato is grown in saline medium, it is advisable that the plant be supplied with adequate Zn.

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**KEY WORDS:** Chloride absorption, Chloride salinity, Sodium concentration, Sulfate salinity, Zinc absorption

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# تاثیر انواع مختلف تنش شوری و کاربرد روی بر رشد سبزینه ای و ترکیب شیمیایی گوجه فرنگی

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## چکیده

پاسخ گوجه فرنگی به چهار سطح روی (صفر، ۵، ۱۰و ۲۰ میلی گرم در یک کیلوگرم خاک به صورت سولفات روی)، شش میزان شوری (صفر، ۳، ۵، ۷، ۹، ۱۱ دسی زیمنس برمتر) و چهار ترکیب نمکی (C1 برابر با ۱۰۰ درصد کلرید سدیم، C2 برابر با ۶۰ درصد کلرید سدیم و ۴۰ درصد سولفات سدیم ، C3 برابر با ۴۰ درصد کلرید سدیم و ۶۰ درصد سولفات سدیم و C4 برابر با ۱۰۰ درصد سولفات سدیم بر مبنای اکی والان شیمیایی) در شرایط گلخانه مطالعه شد. افزودن بالاترین سطح شوری سبب کاهش معنی دار وزن خشک گیاه گوجه فرنگی در مقایسه با شاهد گردید. به علاوه، گوجه فرنگی به کلرید سدیم نسبت به سولفات سدیم حساسیت بیشتری نشان داد. مصرف ۵ میلی گرم روی در کیلو گرم خاک با افزایش قابل توجه وزن خشک گیاه همراه بود. کاربرد بیشتر این عنصر سبب کاهش رشد گوجه فرنگی شد. تاثیر سوء شوری خاک بر رشد گوجه فرنگی با مصرف روی کاهش یافته و در این راستا نقش مفید روی در C1 بیشتر از C4 بود. غلظت کلر در گیاه در تیمارهای C1 ، C2 وC3 افزایش یافت و تحت تاثیرC4 قرار نگرفت. افزایش سطوح شوری بدون توجه به ترکیب نمکی، با افایش غلظت سدیم در اندام هوایی گوجه فرنگی همراه بود. از طرفی حد اکثر میزان سولفات در گیاه تیمار شده با سولفات سدیم مشاهده شد ودرC2 وC3 ، تغییر غلظت این آنیون در گیاه کمتر شده و در تیمار C4 تغییر نکرد. غلظت روی با ازدیاد سطوح روی افزایش محسوسی نشان داده و با شور شدن خاک تشدید شد. به طور کلی توصیه می شود در صورتی که گوجه فرنگی در خاک های شور کشت شود، مقدار کافی روی در اختیار گیاه قرار گیرد.

## INTRODUCTION

Salt accumulation in some soil profiles is a characteristic phenomenon of semiarid and arid regions and limits crop production. Plant growth is usually poor in such soils and this is primarily due to the restricted water uptake by plants, excessive accumulation of certain ions in plant tissues and reduced absorption of some essential plant nutrients.

Soil fertilization has sometimes been advocated to improve the nutritional status under saline conditions so that plant growth might be enhanced. In this regard, the interaction between salinity and macronutrients (5, 17, 18) and micronutrients (6, 7, 16) has been reported. However, the Zn-salinity interaction study on tomato is somewhat scarce (6, 16) and the authors are not aware of any published report about the effect of Zn application on tomato growth in the presence of various combinations of Cl and $SO_4$ salinity. The present study was, therefore, undertaken to evaluate the main and interactive effects of Zn fertilization and salinity level and salinity sources on the growth and chemical composition of tomato seedlings in an arid region calcareous soil.

## MATERIALS AND METHODS

An alluvial calcareous sandy clay loam soil (fine, mixed, mesic, Fluventic Xerochrept) with pH of 7.5 (saturated paste), 0.60% organic matter, 68% CCE, 23 mg $kg^{-1}$ $Na_2HCO_3$-extractable P and 0.35 mg $kg^{-1}$ DTPA-extractable Zn was used in this experiment. Treatments consisted of four Zn rates (0, 5, 10 and 20 mg $kg^{-1}$ soil as $ZnSO_4.7H_2O$), six salinity levels (0, 3, 5, 7, 9 and 11 dS $m^{-1}$) and four salt compositions ($C_1$=100% NaCl, $C_2$ = 60% NaCl + 40% $Na_2SO_4$, $C_3$ = 40% NaCl + 60% $Na_2SO_4$, and $C_4$= 100% $Na_2SO_4$ on chemical equivalent basis). Nitrogen, P and Fe were uniformly applied to each pot at 125, 50 and 5 mg $kg^{-1}$ as $NH_4NO_3$, $Ca(H_2PO_4)_2$, and FeEDDHA, respectively. All nutrients were thoroughly mixed with 3-kg air-dried soil samples.

Fifteen seeds of tomato cv. Red Cloud were planted in each pot and were thinned to three seedlings at 4 wk after emergence. Salinity treatments were imposed by adding aqueous solutions of NaCl and $Na_2SO_4$ when plants were 26 d old. The desired salinity levels were determined according to the procedure given by US Salinity Laboratory (24). It was assumed that the required salinity rates were established in the pots. The experiment was factorially arranged in a completely randomized block design with three replicates. Pots were irrigated with distilled water to the near field capacity by weight as needed without any drainage. The seedlings were grown for 9 wk. At harvest, seedlings were cut at the soil surface, rinsed with distilled water, oven dried at 65°C for 48 h, weighed and ground. A portion of plant material was dry-ashed and analyzed for Zn by atomic absorption and Na by flame photometry. Chloride concentration was determined by the method of Chapman and Pratt (4) and that of $SO_4$ by the procedure of Blanchar *et al.* (3). Data were subjected to the analysis of variance, Duncan's multiple range test and regression analysis.

## RESULTS AND DISCUSSION

The highest salinity level, regardless of salt composition, significantly reduced mean shoot growth when compared with control (Table 1). A suppression in tomato growth by Cl salinity has been reported (1, 14, 19). The poor tomato growth in highly saline media might be due to the suppressing effects of excess soluble salts on photosynthesis, uptake of essential plant nutrients, respiration, protein and nucleic acid synthesis, enzyme activity and soil water availability to plants.

In the present study, the depressing effect of NaCl on the tomato top growth was more severe than of $Na_2SO_4$. This is in agreement with the findings of Hayward and Long (9). In contrast, Joshi and Naik (10) observed that sulfate salinity was more toxic to sugarcane (*Saccharum officinarum* L.) than that of chloride. Lauter and Munns (11) reported that chickpea (*Cicer arietinum* L.) sensitivity to sulfate and chloride was the same provided that Na concentrations in shoots were equal.

Table 1. Effects of Zn fertilization, salinity levels and salt composition on top dry weight of tomato (g $pot^{-1}$).

| Salinity | | Applied Zn (mg $kg^{-1}$ soil) | | | | |
|---|---|---|---|---|---|---|
| Composition† | Level ($dS\ m^{-1}$) | 0 | 5 | 10 | 20 | Mean |
| | 0 | 25.0a§ | 34.7a | 31.5a | 30.5ab | 30.5a |
| | 3 | 27.1a | 34.8a | 33.5a | 31.2a | 31.7a |
| | 5 | 24.5a | 32.7a | 31.4a | 30.4ab | 29.8a |
| $C_1$ | 7 | 24.1a | 33.6a | 29.5a | 29.0ab | 29.1a |
| | 9 | 20.4ab | 29.1ab | 28.1a | 25.4ab | 25.3b |
| | 11 | 15.2b | 24.3b | 24.2a | 23.3b | 21.7c |
| | **Mean** | **22.8C** | **31.5A** | **29.4A** | **28.3B** | |
| | 0 | 24.3ab | 35.1a | 34.0a | 31.4a | 31.2ab |
| | 3 | 28.9a | 37.2a | 34.4a | 31.2a | 32.9a |
| | 5 | 26.5a | 35.1a | 32.0ab | 31.0a | 31.2ab |
| $C_2$ | 7 | 25.2ab | 32.2ab | 31.3ab | 30.0a | 29.7ab |
| | 9 | 22.6ab | 31.8ab | 29.1ab | 27.9a | 27.8bc |
| | 11 | 18.3a | 26.8b | 26.2b | 26.2a | 24.4c |
| | **Mean** | **24.3C** | **33.0A** | **31.2AB** | **29.6B** | |
| | 0 | 25.6a | 36.3ab | 33.1a | 32.3a | 31.8ab |
| | 3 | 29.2a | 39.0a | 32.8a | 33.3a | 33.6a |
| | 5 | 29.9a | 37.1ab | 33.2a | 30.1a | 32.6a |
| $C_3$ | 7 | 25.6a | 33.1abc | 33.3a | 30.2a | 30.8ab |
| | 9 | 25.4a | 30.0bc | 29.9a | 29.9a | 28.8bc |
| | 11 | 24.1a | 27.8c | 26.8a | 27.7a | 26.6c |
| | **Mean** | **26.8C** | **33.9A** | **31.5AB** | **30.6B** | |
| | 0 | 26.3a | 36.6a | 33.7a | 32.5a | 32.3ab |
| | 3 | 30.6a | 36.8a | 34.7a | 34.6a | 34.2a |
| | 5 | 28.3a | 33.4a | 34.0a | 33.5a | 32.3ab |
| $C_4$ | 7 | 27.6a | 33.8a | 33.2a | 30.3a | 31.0abc |
| | 9 | 25.8a | 31.5a | 30.7a | 28.4a | 29.1bc |
| | 11 | 23.9a | 32.2a | 29.7a | 27.3a | 28.3c |
| | **Mean** | **27.2B** | **34.1A** | **32.5A** | **31.1A** | |

† Symbols have been defined in Materials and Methods section.

§ Means followed by the same letter in each column (small letters) and in each row (capital letters) are not significantly different at the 1% level by Duncan's multiple range test.

Application of 5 mg Zn $kg^{-1}$ soil increased top dry weight of tomato (Table 1). Similar results were reported by El-Sherif *et al.* (6). The growth enhancement of tomato by Zn fertilization was anticipated due to low level of DTPA-extractable Zn in the soil used in this study. However, higher rates of Zn generally reduced tomato growth. This is in contrast to the findings by Ravikovitch and Navrot (16) who reported that in Zn-deficient soil, tomato responded positively to 30 mg Zn $kg^{-1}$ soil in both nonsaline and saline soils.

In the present study, the suppressing effects of salinity were alleviated by Zn fertilization (Table 2). These findings are in agreement with other reports (6, 16). However, the enhancing effect of Zn application on tomato growth was greater in $C_1$ than $C_4$ treatment. For instance, with salinity level of 11 dS $m^{-1}$, addition of 5 mg Zn $kg^{-1}$ soil increased top dry weight by 60% in NaCl-treated soil ($C_1$), whereas, for the same Zn and salinity rates, the increase was 35% in $Na_2SO_4$-treated plant ($C_4$). Similar findings were observed by Manchanda *et al.* (12). Highly significant regression equations were obtained between Cl and $SO_4$ concentrations of tomato tops and salinity levels and salt composition, whereas the best predicting equation was observed only between Na concentration and applied salinity:

$$Y_1 = 0.48 + 0.24X_1 - 0.32X_2 - 0.23X_1X_2 \qquad R^2 = 0.95^{**} \qquad [1]$$

$$Y_2 = 0.38 + 0.04X_1 \qquad R^2 = 0.91^{**} \qquad [2]$$

$$Y_3 = 0.17 + 0.25X_1 - 0.1X_1X_2 - 0.004X_1X_2^2 \qquad R^2 = 0.98^{**} \qquad [3]$$

where $Y_1$, $Y_2$ and $Y_3$ are Cl, Na and $SO_4$ concentrations (%), respectively, $X_1$ is salinity levels ($dSm^{-1}$) and $X_2$ is salt composition which takes values of 0, 0.4, 0.6, and 1.0 for $C_1$, $C_2$, $C_3$ and $C_4$, respectively.

The plant Cl and Na concentrations increased significantly by applied salinity and were not affected by Zn fertilization. However, an increase in concentration of Cl became less pronounced in $C_2$ and $C_3$ and was not affected in $Na_2SO_4$-treated plants ($C_4$). A salinity-induced increase in Cl and Na concentrations has been reported by others (1, 15, 20, 21).

Sulfate concentration depended on the principal anion in the medium. If chloride was the principal anion ($C_1$), $SO_4$ concentration was not increased with salinity. However, there was a marked increase in $SO_4$ absorption with the other three salinity treatments. Similar results have been observed for other crops (8, 12). In contrast, Lauter and Munns (11) noted that $SO_4$ concentration in chickpea shoots did not change with different levels of $Na_2SO_4$. In the present experiment, the entry of Na and/or $SO_4$ was considerably lower than that of Cl. This indicates that tomato apparently has no regulatory mechanism to control Cl uptake and this might be responsible for the higher sensitivity of this plant to Cl salinity. Tores and Binghom (22) and Tores *et al.* (23) believe that a Cl-induced nitrogen deficiency may be responsible for the growth suppression of wheat on NaCl-amended soil. Bernstein and Pearson (2) suggested that osmotic effect is a main factor for poor growth of NaCl-treated tomato plants.

Table 2. Effects of Zn fertilization, salinity levels and salt composition on Zn concentration of tomato tops (mg $kg^{-1}$).

| Salinity | | Applied Zn (mg $kg^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| Composition† | Level ($dSm^{-1}$) | 0 | 5 | 10 | 20 | Mean |
| | 0 | 13.9ab§ | 23.8a | 29.4b | 30.9b | 24.4bc |
| | 3 | 13.7b | 22.8ab | 27.0b | 30.7b | 23.6cd |
| | 5 | 13.6b | 20.4b | 26.5b | 30.9b | 22.8d |
| $C_1$ | 7 | 14.1ab | 21.7ab | 27.2b | 31.1b | 23.6cd |
| | 9 | 15.7ab | 22.7ab | 29.2b | 33.5b | 25.3b |
| | 11 | 16.9a | 23.7ab | 34.6a | 38.5a | 28.3a |
| | **Mean** | **14.7D** | **22.5C** | **29.0B** | **32.5A** | |
| | 0 | 13.3a | 22.3bc | 26.3c | 31.2bc | 23.7c |
| | 3 | 13.3a | 21.0c | 26.7c | 30.9bc | 23.0cd |
| | 5 | 13.3a | 20.5c | 24.5c | 28.9c | 21.8d |
| $C_2$ | 7 | 14.1a | 19.4c | 25.0c | 30.3bc | 22.2d |
| | 9 | 14.4a | 24.8ab | 30.0b | 33.3b | 25.6b |
| | 11 | 15.5a | 25.3a | 33.7a | 37.5a | 28.0a |
| | **Mean** | **14.0D** | **22.2C** | **27.7B** | **32.0A** | |
| | 0 | 13.1a | 18.1b | 27.0b | 29.8b | 22.0c |
| | 3 | 13.6a | 18.8b | 26.2b | 30.1b | 22.2c |
| | 5 | 13.9a | 18.7b | 27.7b | 30.0b | 22.6c |
| $C_3$ | 7 | 14.1a | 19.0b | 27.6b | 30.7b | 22.6c |
| | 9 | 14.1a | 20.8ab | 28.6b | 32.6b | 24.0b |
| | 11 | 15.1a | 23.4a | 31.7a | 36.6a | 26.7a |
| | **Mean** | **14.0D** | **19.8C** | **28.1B** | **31.6A** | |
| | 0 | 13.4a | 21.2ab | 25.9b | 29.4b | 22.5c |
| | 3 | 13.5a | 18.6bc | 25.2b | 29.1b | 21.6c |
| | 5 | 14.2a | 17.1c | 24.1b | 28.8b | 21.0c |
| $C_4$ | 7 | 14.6a | 18.6bc | 24.3b | 29.2b | 21.7c |
| | 9 | 14.7a | 19.7bc | 25.9b | 32.3a | 24.2b |
| | 11 | 15.4a | 23.7a | 31.2a | 34.6a | 26.1a |
| | **Mean** | **14.3D** | **19.8C** | **26.1B** | **30.5A** | |

† Symbols have been defined in Materials and Methods section.

§ Means followed by the same letter in each column (small letters) and in each row (capital letters) are not significantly different at the 1% level by Duncan's multiple range test.

Zinc application increased Zn concentration in tomato plants in nonsaline as well as saline soils (Table 2). Similar findings have been reported by others (13, 16). Moreover, Zn absorption was enhanced by salinity both in untreated and in Zn-treated soils. Salinizing the soil apparently caused replacement of exchangeable Zn by Na which then becomes more available. Ravikovitch and Navrot (16) observed that salinity had little effect on Zn concentration in tomato in a clay soil with high native Zn content. However, in the Zn-deficient soil, Zn concentration increased by salinity in Zn -untreated as well as Zn-treated soil.

Regression equations describing the relationships between relative top growth and Cl and Na concentrations in tomato shoots were obtained. Based on these equations, the Cl and Na concentrations required for maximum top growth and for 50% growth decrement were calculated and are shown in Table 3. These data reveal that Cl concentration in tomato shoot associated with maximum growth and 50% reduction in the top dry weight was highest for NaCl-treated plants ($C_1$) and decreased with an increase in the proportion of $Na_2SO_4$ in salt composition (Table 3). On the other hand, Na concentration did not follow a definite pattern in this regard. Lower Cl concentration associated with 50% growth reduction in $C_2$ and $C_3$ might be due to a higher $SO_4$ concentration. In other words, lower Cl accumulation might have been compensated by higher $SO_4$ absorption by tomato seedlings.

In conclusion, it is recommended that tomato plant should be supplied with adequate amount of Zn when grown in saline soils.

Table 3. Top Cl and Na concentrations (%) required for maximum top growth and 50% reduction in top dry weight.

| Salt composition† | Maximum top growth | | 50% Growth reduction | |
|---|---|---|---|---|
| | $Cl^-$ | $Na^+$ | $Cl^-$ | $Na^+$ |
| $C_1$ | 1.03 | - | 3.21 | 0.76 |
| $C_2$ | 0.79 | 0.18 | 2.39 | 0.67 |
| $C_3$ | 0.67 | 0.18 | 1.94 | 0.58 |
| $C_4$ | - | - | | 0.74 |

† Symbols have been defined in Materials and Methods section.

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