Interaction of Fe and Salinity on Growth and Production of Tomato Plants

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Abstract: In a trial to ameliorate the negative effects of salinity on plant growth and production, this study was conducted during the growing seasons of 2012 and 2013 to investigate the interactive effect of chelated Fe-EDHHA 6% and salinity. Seedlings of tomato plant (Lycopersicon esculentum L.) hybrid Super strain B (salinity sensitive hybrid) were grown in pots and irrigated with saline solution in different concentrations (3000, 4000 and 5000 ppm). Under all salinity concentrations, Plants were supplied an aqueous solution of Fe-EDHHA 6% at four rates i.e. (0.0, 7.14, 9.52 and 11.9 kg/ha) divided into three doses. Data showed that as salinity level increased, all plant growth parameters i.e. plant height, leaf area, chlorophyll content, fresh weight and total yield were negatively and significantly affected. Chemical contents such as N, P and K were significantly reduced as well as plant production. Fe-EDHHA 6% application ameliorated salinity negative effects on plant growth and production as the application rate increased. The highest effect of Fe-EDHHA 6% was recorded with the application rate of 9.52 kg/ha which was not significantly different compared to the highest application rate of 11.9 kg/ha.

Key words: Growth • Fe-EDHHA • Tomato • Salinity • Yield

INTRODUCTION

Worldwide, more than 45 million hectares of irrigated land have been damaged by salt and 1.5 million hectares are taken out of production each year as a result of high salinity levels in the soil [1]. Salinity problem has been reported to affect about 45% of the total Egyptian area (including 26% of water bodies) [2]. Since that report, no further reports have been found about the development of that problem in Egypt although its spreading is noticeable through personal communications with Egyptian growers. The negative effects of salinity have been reported on growth and production of many crops such as mungbean [3], green bean [4]; tomato [5-8] and Sweet pepper [9, 10]. For these reasons different attempts have been tried in order to alleviate the negative effects of salinity on plant performance. For instance, trails for manipulating greenhouse climate [5, 9, 10], application of amino acids and growth regulators [11] and using of environmental friendly materials [4, 12] as well as using physical treatments such as hardening [13,14] and some mineral fertilization [8]. Salama et al. [8] ameliorated the negative effects of salinity by using Zn-EDTA. Other micro nutrients may have similar ameliorating effects on some vegetable crops such as tomato. Tomato is a major vegetable crop in Egypt ranking the first crop in terms of value (2995.412 million dollars) and the third in terms of quantity of production (8105260 metric tons) [15]. According to FAOSTAT [15], Egypt is ranked the fifth on the world in terms of production and value of tomato crop with a total harvested area reached 212446 ha. The cultivation of tomato crop is very favorable by the growers because of its moderate tolerance to salinity which enable the plant to improve its performance by application of some agricultural practices specially those treatments that provide nutrients to the plants.

Therefore, the aim of this study is to investigate the ameliorating effects of Fe on salinity impacts on tomato crop. The effect of Fe supply on pea plant was studied under salinity condition [16] and possible beneficial effects on tomato crop can be found.

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**MATERIALS AND METHODS**

**Plant Material:** Seeds of tomato (*Lycopersicon esculentum* L.) hybrid Super Strain B (salinity sensitive hybrid) [17] were sown in the mid of January of 2012 and 2013 in foam trays under the condition of greenhouse in both seasons of the study. The seedlings of tomato hybrid were transplanted on 27th February 2012 and 2013 at the stage of 5th true leaf in plastic pots in a private farm in New Salhia region, Sharkia governorate, Egypt in both seasons. The pot size was 30 cm in diameter and 50 cm depth. The pots were filled with washed sand. Two uniform seedlings were transplanted in each pot, placed in the open field. Thinning took place after 10 days from transplanting leaving one plant in each pot. Plants were hand-irrigated with fresh water and fertilized with the standard recommendations of the ministry of agriculture in Egypt for two weeks until plant establishment was assured in the growing media then salinity treatments were applied.

**Salinity Treatments:** Three levels of salinity (3000, 4000 and 5000 ppm) were obtained by mixing water from Karoun lake (80 km south west Cairo) with tap water (260 ppm). Plants were divided into groups then irrigated with the targeted salinity level. Irrigation was carried out daily and in each irrigation cycle, enough drain was allowed to ensure adequate leaching until reaching the targeted level of salinity in the drain. Saline irrigation treatments started two weeks after transplanting.

**Fe-EDHHA 6% Treatments:** After the third week of transplanting, plants grown in each salinity level were divided into four groups to be supplied with four rates of Fe-EDHHA 6% namely 0.0 (control); 7.14; 9.52 and 11.9 kg/ha. Plants were supplied an aqueous solution of Fe-EDHHA three times during the growing season after 3, 6 and 9 weeks from transplanting.

**Recorded Data:** At 70 days after transplanting, all the following parameters were measured:

- Total chlorophyll content was measured in the leaves using Minolta SPAD 501 chlorophyll meter [18].
- Macro elements at 70 days after transplanting, sample of fresh leaves (the 4th leaf from the plant top) were taken and considered the most representative ones for plant analysis, according to Ward [19]. The leaves were oven dried at 70°C till a constant weight. The dry matter was finely grounded and wet digested with H₂O₂ and concentrated H₂SO₄ for the determination of nitrogen, phosphorus and potassium according to the following methods:
  - Nitrogen was determined in the digestion product, using the Micro-Kjeldahl method [20].
  - Phosphorus was determined colorimetrically spectrophotometrically according to the method described by King [21].
  - Potassium was determined using the Flame photometer according to the method described by Jackson [22].
- Fruit dry matter content (%) was determined by drying 100g fruit fresh weight for three days on 70°C until reaching a constant dry weight.
- Fruit ascorbic acid content (mg/100g) was determined in fresh weight by using the 2, 6 Dichlorophenol-indolphenol method described in A.O.A.C. [23].
- Average individual fruit weight (g), was taken randomly from the third picking as a representative sample for determining average individual fruit weight (g).
- Total fruit weight (g/plant) was determined as total weight of fruits during the harvesting period.

**Experimental Design and Statistical Analysis:** Treatments were arranged in split plot design with three replicates where salinity was in the main plot and treatments of Fe-EDDHA were in the sub-main. Data were statistically analyzed according to Snedecor and Cochran [24]. Linear regression analysis was carried out using MS-Excel software to calculate all possible relationships between the applied treatments and measured parameters.

**RESULTS**

**Effect of Salinity:** The negative effects of salinity on different plant growth parameters were very clear. Increment in salinity level caused a further decrease in plant height and leaf area (Fig. 1) and these differences
were significant for plant height (LSD 5% = 0.57 and 0.65) and leaf area (LSD 5% = 1.73 and 1.66) for 2012 and 2013, respectively. There were clear negative relationships between salinity levels and each of the parameters for the two growing seasons.

Similarly, chlorophyll content and plant fresh weight showed a negative response to the increment in salinity level (Fig. 2). The differences between the treatments were significant with LSD 5% valuing 1.57 & 1.46 for chlorophyll content and 1.5 & 1.32 for plant fresh weight for the 2012 and 2013 seasons, respectively.

Nutrient contents as represented by N, P (Fig. 3) and K (Fig. 4) responded also negatively to the increasing level of salinity. As the salinity increased, all mentioned nutrient contents decreased with a significant difference at P. 0.05 (LSD= 0.06 & 0.09 for N); (LSD= 0.02 & 0.01 for P) and (LSD= 0.04 & 0.06 for K) for the two growing seasons 2012 and 2013 respectively. The relationships of the effect of salinity levels on the mentioned nutrient contents were negatively clear and presented in Fig. 3 and 4. Only dry matter content of the tomato fruits showed a positive response to the increment in salinity levels. To the contrary of the above observed relationships, there was a positive relationship between increment in salinity levels and the fruit dry matter contents and this relationship is presented in Fig. 4.
Fig. 4: Potassium content in tomato plants and fruit dry matter content in tomato as affected by salinity during the two growing seasons of 2012 and 2013.

Fig. 5: Fruit ascorbic acid content and average individual fruit weight of tomato fruits as affected by salinity levels during the two growing seasons of 2012 and 2013.

Fig. 6: Total fruit weight of tomato plants as affected by salinity levels during the two growing seasons of 2012 and 2013.

Fruit ascorbic acid content showed also a positive response to the increment in salinity level (Fig. 5). The response was significantly affected by salinity treatments (LSD 5% = 1.14 and 1.36 for 2012 and 2013 seasons respectively). The response could be represented by the positive relationship shown by Fig. 5.

Total fruit yield responded negatively to the increment in salinity level (Fig. 6). The response was similar in both growing seasons and LSD 5% values were 3.52 and 5.11 for 2012 and 2013 respectively. The negative relationships in both seasons are represented in Fig. 6.

Effect of Fe Application: Vegetative growth of tomato plants responded positively to the application of Fe as shown in Fig. 7. Plant height and leaf area increased as Fe application rate increased. The differences were significantly higher compared to control treatment. The highest effect was recorded with the rate of 9.52 kg/ha which was not significantly different compared to the highest application rate of 11.9 kg/ha. The positive responses of both plant height and leaf area are shown in Fig. 7.

Plant fresh weight and chlorophyll content showed also positive responses to the increment of Fe application (Fig. 8). The differences in plant fresh weight in response
Fig. 7: Plant height and leaf area of the fifth leaf from the top of tomato plants as affected by different rates of Fe-EDDHA applications.

Fig. 8: Plant fresh weight and chlorophyll content of tomato plants as affected by different rates of Fe-EDDHA application.

Fig. 9: Nitrogen and phosphorus contents of tomato plants as affected by different rates of Fe-EDDHA application.

to Fe application rate were significantly different compared to control treatment. The highest effect was recorded with the Fe application rate of 9.52 kg/ha which was not significantly different compared to the highest application rate 11.9 kg/ha (LSD 5% = 2.43 and 2.27 for the growing seasons 2012 and 2013, respectively). Similarly chlorophyll content showed the same trend with LSD 5% valued 2.11 and 2.07 for the growing seasons 2012 and 2013 respectively. The responses of the two parameters could be represented with the positive regression lines shown in Fig. 8.

Plant nutrients represented by the contents of N, P and K are shown by figures (9 and 10). All those nutrients responded positively and significantly to the increment in the application rate of Fe compared to the control treatment (LSD 5% for 2012 & 2013 seasons are 0.1 & 0.14; 0.04 & 0.03 and 0.1 & 0.09 for N; P and K respectively. The highest response was recorded by the Fe application rate of 9.52 kg/ha which was not significantly different than the highest application rate of 11.9 kg/ha. The positive responses of those nutrients are represented by the positive regression lines shown by Fig. 9 and 10.
Fig. 10: Potassium content in tomato plants and fruit dry matter content as affected by different rates of Fe-EDDHA application.

Fig. 11: Fruit ascorbic acid content and individual fruit weight of tomato plants supplied with different rates of Fe-EDDHA.

Fig. 12: Total fruit weight of tomato plants as affected by different rates of Fe-EDDHA application.

Fruit nutritional and physical qualities in terms of ascorbic acid content and average individual fruit weight respectively responded positively to the application of Fe with a strong responses recorded clearly in fruit ascorbic acid content (Fig.11). The differences were significant compared to control for both parameters and in both seasons. The two parameters showed positive clear relationships between the application rates of Fe and their degree of responses as presented by the regression lines as shown in Fig. 11. Total fruit yield showed also a positive response to the application rate of Fe. As the application rate increased, fruit yield increased in both seasons (Fig. 12). The differences were significantly different compared to control. The positive response could be presented in the regression line shown in Fig.12.

Effect of the Interaction: Fig. 13 shows the effect of interaction between salinity levels and Fe application rates on the vegetative growth of tomato plants represented by plant height. The data show clearly that the effect of salinity dominated the performance of the
Fig. 13: Plant height of tomato plants as affected by the interaction of different salinity levels and application rates of Fe-EDDHA in two growing seasons.

Fig. 14: Leaf area of tomato plants as affected by the interaction of different salinity levels and application rates of Fe-EDDHA in two growing seasons.

Fig. 15: Fresh weight of tomato plants as affected by the interaction of different salinity levels and application rates of Fe-EDDHA in two growing seasons.

plants regarding that parameter however, the Fe treatments alleviated those negative effects compared to non Fe treated plants under all salinity levels. It was also clear that the treatments of Fe did not completely overcome the negative effect of salinity however an alleviating effect of Fe was noticeable with a superior
Fig. 16: Chlorophyll content of tomato plants as affected by the interaction of different salinity levels and application rates of Fe-EDDHA in two growing seasons.

Fig. 17: Nitrogen, phosphorus and potassium contents of tomato plants as affected by the interaction of different salinity levels and application rates of Fe-EDDHA in two growing seasons.
Another parameter of vegetative growth is leaf area which was also negatively affected by the predominant effect of salinity despite the alleviating effect of Fe application rates (Fig.14). Fe application treatments improved plant performance compared to non Fe-treated plants. Because of the predominant effect of salinity, the negative relationships between leaf area of all treatments and salinity levels were still obvious but significantly higher than control. This trend was observed in both growing seasons.

Figure 15 shows also the negative effect of salinity on plant fresh weight although Fe treatments alleviated these negative effects. The degree of response to the interaction effect of salinity levels and Fe application rates was similar for the highest two application rates of Fe (9.52 and 11.9 kg/ha). All treated plants were significantly higher than control treatments regarding plant fresh weight. These trends were true for both growing seasons 2012 and 2013.

Chlorophyll content as shown in Fig. 16 shows also the strong effect of salinity on that parameter and the alleviating effect of Fe on the plants compared to non Fe-treated plants. The differences were strongly
significant particularly at the highest salinity level compared to control. The treatment of 9.52 kg/ha Fe showed the best effect compared to all other treatments but was not significantly different than the higher rate of Fe application (11.9 kg/ha). The trends were the same for the two growing seasons.

Fig. 17 shows the interaction effect on nutrient contents in the plant represented as N, P and K. All nutrient contents improved as Fe rate increased under all salinity levels and were significantly higher compared to control treatments (non Fe treated plants). Only P contents under the highest salinity level were not significantly different than control under the same level of salinity although the contents tended to be higher. All mentioned nutrient contents showed the predominant negative effect of salinity despite the alleviating effect of Fe applications.

A parameter of nutritional quality in the form of ascorbic acid content is shown in Fig. 18 as affected by the interaction effect of salinity levels and Fe application rates. Both factors interacted in the same direction and improved the content of such parameter under all treatments. The highest content was recorded under the highest level of salinity while all Fe treatments showed similar effect but significantly higher than non Fe treated plants.

Similar trend to the ascorbic acid content is the observed trend of fruit dry matter content as shown by figure (19). Although the effect of salinity was very dominant, Fe increased that effect and dry matter content of the fruits increased further compared to non Fe treated plants. The relationships were clearly positive and could be represented by the regression lines as shown in Fig. 19.

![Fig. 20: Average individual fruit weight of tomato plants as affected by the interaction of different salinity levels and application rates of Fe-EDDHA in two growing seasons.](image)

![Fig. 21: Total fruit weight of tomato plants as affected by the interaction of different salinity levels and application rates of Fe-EDDHA in two growing seasons.](image)
The first parameter of physical quality presented as average individual fruit weight is shown by figure (20). The interactive effect of both studied factors showed a negative effect on that parameter although the treatment of Fe alleviated the negative effect of salinity compared to control. The alleviating effect was decreasing as the level of salinity increased but was still significant. The best alleviating effect was recorded with the Fe treatment of 9.5 kg/ha. All treatments showed a negative relationship with increasing salinity levels and could be represented by the regression lines as illustrated in Fig. 20.

Total fruit yield showed also the obvious salinity negative effect despite the effect of Fe application which ameliorated plant production compared to non Fe treatments under the same salinity level (Fig. 21). The difference was significant between all treatments but there was no significant difference among Fe treated plants under the highest salinity level. Fruit yield parameter showed a clear negative relationships with the interactive effects of the two factors as represented by the regression lines as shown in Fig. 21.

**DISCUSSION**

Salinity has ever been known with its negative effects on plant performance. These negative effects come from the osmotic effect on plant water status [5, 9], disturbing the nutritional balance of the plant through the pH of the root zone and/or a specific ion effect of some salts such as sodium chloride. In this study these causes seemed to be present. The osmotic effect was clear on plant water status which was reflected on total plant fresh weight. Fresh weight is a product of water content and assimilates production and both have been reported to be affected negatively by salinity [5, 9]. Water content is a major factor in cell elongation therefore the reduction of the former will reduce cell elongation and that was observed in plant height and leaf area. Many studies reported the same negative effects of salinity on tomato [5, 6, 7, 8, 11, 12, 14], as well as other vegetable crops [3] for mungbean [9] for sweet pepper. Since leaf area was reduced because of salinity, assimilate production must have been reduced due to (at least) the reduction in the intercepted light. Another factor that contributed to the reduction of assimilate production is the reduction in chlorophyll content because of salinity. This may be due to the disturbing effect of salinity on the nutritional balance of the plant which negatively affected the chloroplast structure [25]. This is confirmed by the reduction in nutrient contents recorded in this study.

Chougui et al. [26] found that salinity affected chlorophyll content by affecting negatively the contents of K, Ca and Fe. They also contributed the reduction in assimilate production under saline conditions to the reduction in photosynthesis rate due to reduction in stomatal conductance and internal CO₂ concentration. So, reduction in water status and assimilate production must lead to a reduction in total yield as was recorded in this study. Reduction in yield may come in the form of reduction in total number of fruits [5, 9] and/or a reduction in the average individual fruit weight [11, 17] and/or a reduction in the fruit setting percentage [8] and the latter parameter was observed in this study. The negative effects of salinity on the production of several horticultural crops have been pooled in a study of Sonneveld [27]. Hussein et al. [28] mentioned that salinity affected plant growth through disturbance of mineral uptake and distribution. Indeed the mineral contents of N, P and K were significantly reduced under all salinity levels. On the other hand, the application of Fe improved plant performance in all recorded parameters. The application of Fe especially in a chelated form has been reported to improve growth and production of many crops [29] most likely because of the deficiency of that nutrient in the Egyptian soil and/or its presence in an unavailable form for the plant because of the common high soil pH. Fe is an essential nutrient for many plant physiological processes and its deficiency can significantly reduce plant growth and production.

Plant Fe nutrition, among other nutrients, has been reported to be negatively affected by soil salinity [26] probably due to the high pH which make Fe unavailable for the plant [30]. Therefore the application of Fe in the form of Fe-EDHHA kept the nutrient in an available form for the plant and reduced the effect of salinity on it. This explains the positive effect of Fe-EDHHA application on the plant under saline conditions. The same results were reported by Chougui et al. [26], who used Fe-EDTA with tomato grown under saline conditions. They also reported that photosynthesis; chlorophyll a and b, carotene, Ca⁺⁺, K⁺ and Fe⁺⁺ and total Fe in tomato plants were significantly improved by Fe-EDTA application under saline conditions. Chougui et al. [26] referred the improvement in photosynthesis because of Fe-EDTA application to the improvement in stomatal conductance and increment in internal CO₂ concentration. Fe-EDTA application improved the transfer of Ca⁺⁺ and K⁺ [26] as salinity commonly disturbs this transfer and negatively reduce the content of those nutrients in the cells [31] and this also was observed in this study. In our study the best
Fe treatment was the application rate of 9.5 kg/ha which was not significantly different compared to the highest application rate of 11.9 kg/ha. This probably is due to reaching the full capacity of the roots and/or the effect of Fe at the rate of 9.5 kg/ha has reached its maximum. Although Fe-EDHHA application improved plant performance under saline conditions compared to non Fe treated plants, it was still, to some extent, negatively affected by salinity. This can be explained based on the Blackman’s law that is a limiting factor (Fe) was a determining factor to some extent after which other factor(s) may have become the dominating one(s).

CONCLUSION

It could be concluded that the application of Fe-EDHHA 6% at a rate of 9.5 kg/ha can significantly improve the growth and production of tomato plants grown under saline conditions. However, other factors must be considered which may contribute to a further improvement in plant performance.

REFERENCES