

Interactive of Calcium, Potassium and Dynamic Unequal Salt Distribution on the Growth of Tomato in Hydroponic System

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Abstract—Due to water shortage, application of saline water for irrigation is an urgent in agriculture. In this study the effect of calcium and potassium application as additive in saline root media for reduce salinity adverse effects was investigated on tomato growth in a hydroponic system with unequal distribution of salts in the root media, which was divided in to two equal parts containing full Johnson nutrient solution and 40 mM NaCl solution, alone or in combination with KCl (6 mM), CaCl₂ (4 mM), K+Ca (3+2 mM) or half-strength Johnson nutrient solution. The root splits were exchanged every 7 days. Results showed that addition of calcium, calcium-potassium and nutrition elements equivalent to half the concentration of Johnson formula to the saline-half of culture media minimized the reduction in plant growth caused by NaCl, although addition of potassium to culture media wasn't effective. The greatest concentration of sodium was observed at the shoot of treatments which had smallest growth. According to the results of this study, in case of dynamic and non-uniform distribution of salts in the root media, by addition of additive to the saline solution, it would be possible to use of saline water with no significant growth reduction.

Keywords—Calcium, Hydroponic, Local salinity, Potassium, Saline water, Tomato.

I. INTRODUCTION

IN recent years due to water shortage, application of saline water is an urgent requirement in agriculture, such as tomato cultivation. Salinity is one of the most serious environmental problems influencing crop growth around the world [1]. Regardless of the cause (ion toxicity, water deficient, and/or nutritional balance), high salinity in the root zone severely impedes normal plant growth and development, resulting in reduced crop productivity or crop failure [2]. The response of tomato to saline media of plant roots has been studied by several researchers [3]–[6]. In addition the response of tomato to unequal distribution of salt in the root zone of plants as an effective method to use of saline water was studied [7]–[12], while the impacts of permanent half root salinity exposing, were one of the problems in this method. Dynamic unequal salt distribution system is a recommended method to dissolve this problem [12].

This technique can be an effective method for using saline water to improve water productivity and plants growth [12]. Although the effect of split-root salinity stress in hydroponic

culture technique has been applied to researches, there is need to improvement in this method for more efficiency, so it seems that present the additive in the root zone of plant such as calcium and potassium can helps to reduce the adverse effects of salinity. In the other hand, calcium and potassium are the effective elements to reduce adverse impacts of salinity in plants [13]–[16]. The addition of calcium and potassium can ameliorate the negative effects of salinity on the growth of tomato [17], [18]. Conversely, tomato yield is improved after K-supplementation when suitable Ca²⁺ amounts are added to the saline nutrient solution [19].

Therefore, the aim of this study was to investigate the effects of Interactive of calcium, potassium and dynamic unequal salt distribution in the root environment on the growth of tomato in a hydroponic system.

II. MATERIALS AND METHODS

A. Plant Material and Culture Conditions

Seeds of tomato (*Lycopersicon esculentum*), which is a commercial cultivar largely cultivated in Iran especially in greenhouses was surface sterilized with 2% (w/v) sodium hypochlorite for 10 min and then were germinated on perlite. The vigorous 5-leaf seedlings were selected and transferred to an aerated half strength Johnson nutrient solution for 9 days. Tomato seedlings were grown in a greenhouse with a temperature of 18-29°C. Therefore, a total of 24 boxes with 6 treatments and four replications were used in this experiment.

B. Treatments

The seedlings were removed from the half strength Johnson nutrient and then the roots of tomato seedlings (one seedling per box) were separated into approximately two equal parts, half was grown in an isolated water black box containing 2.7 l aerated Johnson nutrient solution, and the other half was grown in a similar box containing 2.7 l aerated 40 mM NaCl solution. The full-strength nutrient solution contained the following salts in millimoles per liter: KNO₃, 6; Ca (NO₃)₂, 4; NH₄H₂PO₄, 2; MgSO₄, 1; KCl, 0.50, ZnSO₄, 0.002; H₃BO₃, 0.025; MnSO₄, 0.005; CuSO₄, 0.0005; H₂MoO₃, 0.0001; and Fe-EDTA 0.050. Treatments were distinguished according to the nature of the half saline root zone as: plants supplied with Johnson nutrient solution in one box and 40 mM NaCl in the other box (N), plants supplied with Johnson nutrient solution in one box and 40 mM NaCl + 4mM CaCl₂ in the other box (NC), plants supplied with Johnson nutrient solution in one box and 40 mM NaCl + 6mM KCl in the other box (NK),

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plants supplied with Johnson nutrient solution in one box and 40 mM NaCl + 4mM CaCl₂ + 6mM KCl in the other box (NCK), plants supplied with Johnson nutrient solution in one box and 40 mM NaCl + half Johnson nutrient solution in the other box (NJ) and plants supplied with Johnson nutrient solution in each two parts of box without any salinity stress (J). All solutions in the boxes were renewed weekly. Two parts of roots in each treatment were interchanged every 7 days. The time interval and NaCl level were selected based on the previous experiment [12]. The plants were exposed to salinity in this split-root dynamic hydroponic system for 70 days and then the fruits were collected at the first harvest period.

C. Analyses

At harvest, fresh and dry weight of shoots, plant height, stem diameter, and number of expanded leaves were measured. To measure concentration of mineral elements, 1 g of each sub-sample of plant was placed in an oven at 70°C until reaching a constant weight. Dry samples were combusted at 550°C for 8 hours, and mineral elements in the ash were extracted using HCl 2 M solution. Concentrations of Ca and Mg in the digest solutions were determined by atomic absorption spectrophotometer (Perkin Elmer AA200). Concentration of K and Na was measured by flame photometer (Model410, corning, England), respectively. P concentration was determined by using spectrophotometer (UV- visible 6505). Plant total nitrogen was determined using Kjeldahl procedure.

D. Statistics

The experiment was set up in a completely randomized block design with four replicates. Analysis of variance was carried out using the SAS program. All data were subjected to analysis of variance and means were compared using Fisher's protected Least Significant Difference (LSD) method when the F test indicated significance difference at $P < 0.05$.

III. RESULTS AND DISCUSSION

The greatest number of leaves, stem diameter (15.27 mm) and plant height (80.25 cm) was observed at the treatment which plants supplied with Johnson nutrient solution in each two parts of box without any salinity stress (J), when stem diameter and plant height in treatments supplied with Johnson nutrient solution in one box and 40 mM NaCl with Ca additive and half Johnson nutrient solution additive in the other box (NC and NJ treatments) had not any significant difference with J treatment (Table I). In contrast, the smallest growth of tomato was found at the treatments supplied with Johnson nutrient solution in one box and 40 mM NaCl in the other box without any additive and K additive (N and NK treatments). The treatment which plants supplied with Johnson nutrient solution in each two parts of box without any salinity stress (J) produced the greatest shoot dry (68.99 g) and fresh weight (411.34 g) when the treatment supplied with Johnson nutrient solution in one box and 40 mM NaCl with half Johnson nutrient solution additive in the other box had not any

significant difference ($P < 0.05$) with J treatment (Table I). In contrast, the smallest fresh and dry weight of shoot (52.38 and 8.345 g plant⁻¹, respectively) was produced at the treatment supplied with Johnson nutrient solution in one box and 40 mM NaCl in the other box with K additive (NK) (Table I).

The greatest percentage of nitrogen (2.65), phosphor (55), potassium (6.79), calcium (1.35) and magnesium (0.23) of shoot was observed at the treatment which the two parts of root were immersed in the nutrient solution (J) and the greatest percentage of sodium (0.16) was observed in the shoot of the treatment with Johnson nutrient solution in one media culture and 40 mM NaCl in the other part of media culture (N).

At the N treatment where in a 7-day dynamic split-root system, half of the roots were exposed to the nutrient solution and the other half was immersed in the 40 mM NaCl solution; The use of 40 mM NaCl in one half of the root environment lead to reduction of number of leaf, stem diameter, shoot height, shoot wet and shoot dry weight (42, 29, 58, 85 and 87%, respectively), which was reported by many researchers in equal salt distribution in the root media [20]- [23]. Addition of calcium, calcium-potassium and nutrition elements equivalent to half the concentration of Johnson formula to the saline-half of culture media in NC, NCK, NJ treatments minimized the reduction in plant growth caused by NaCl with significant difference, although addition of potassium to culture media wasn't effective. So the numbers of leaf, stem diameter, shoot height, shoot wet weight and shoot dry weight increased 20, 28, 54, 84 and 86% at the NJ, 29,21, 54, 76 and 78% at the NC and 29, 21, 45, 76 and 81% at the NCK treatment, respectively. In most cases salt tolerance of a crop cultivar can be increased by an increase in the Ca²⁺ concentration in the saline growth medium [24]. In contrast with our results, Khalafalla et al. reported that addition of KNO₃ to growth media significantly ameliorates effect of NaCl on shoots growth of tomato [18]. It seems that the 7 days period of saline and normal condition for each part of root in a dynamic split-root system decreased the impact of saline stress on the root and so plant. The exact effect of calcium to mitigate the adverse effects of salinity on fruit yield and plant growth in equal distribution of salt in root media was reported by many researchers before [25], [26]. Supplemental calcium might have increased Ca²⁺ influx and hence the calcium concentration [27] which was observed in this study (Table II). The protective effect of Ca²⁺ in salinized plants is due to its role in maintaining membrane integrity and suggested that one of the primary effects of salinity is a disruption of membrane integrity caused by displacement of Ca²⁺ from the cell surface by Na⁺ [28]. The significant reduction of sodium concentration in this treatment (Table II) is due to this reason. Application of calcium, together with potassium reduced the adverse effects of NaCl. Tomato yield is improved after K-supplementation when suitable Ca²⁺ amounts are added to the saline nutrient solution [19]. In contrast with the previous studies [18], [29]-[31], extra potassium in the saline root media hadn't significant effects on the plant growth in the present research. In line with our result, Psarras et al. didn't observe any positive effects in the percentage of marketable

fruit; mean fruit yield in the tomato receiving extra K [32]. Sodium to potassium ratio [33] and potassium level in the saline root media [20] are two factors affecting the ability of potassium to reduce adverse effects of salinity. The results showed that the concentration of calcium, sodium and potassium in the shoot is effective on plant growth, where phosphor and nitrogen concentration had not important effect on the plant growth in treatments.

TABLE I

THE EFFECT OF ADDING CALCIUM, POTASSIUM AND HALF-STRENGTH NUTRIENT SOLUTION TO THE HALF PART OF ROOT MEDIA ON THE SHOOT DRY WEIGHT, SHOOT WET WEIGHT, SHOOT HEIGHT, STEM DIAMETER AND NUMBER OF LEAVES

Treatment*	Shoot dry weight (g)	Shoot wet weight (g)	Shoot height (cm)	Stem diameter (mm)	Number of leaves
J	68.99 ^a	411.34 ^a	80.25 ^a	15.27 ^a	16.00 ^a
N	8.62 ^c	63.24 ^c	33.50 ^c	10.87 ^b	9.25 ^c
NJ	61.98 ^a	385.25 ^a	73.00 ^{ab}	15.19 ^a	13.00 ^b
NC	39.02 ^b	257.04 ^b	72.63 ^{ab}	13.80 ^a	13.00 ^b
NK	8.24 ^c	52.38 ^c	43.00 ^c	10.29 ^b	10.50 ^{bc}
NKC	45.10 ^b	263.90 ^b	61.00 ^b	13.16 ^a	13.00 ^b

*N: plants supplied with Johnson nutrient solution in one box and NaCl in the other box, NC: plants supplied with Johnson nutrient solution in one box and NaCl + CaCl₂ in the other box, NK: plants supplied with Johnson nutrient solution in one box and NaCl + KCl in the other box, NCK: plants supplied with Johnson nutrient solution in one box and NaCl + CaCl₂ + KCl in the other box, NJ: plants supplied with Johnson nutrient solution in one box and NaCl + half Johnson nutrient solution in the other box, and J: plants supplied with Johnson nutrient solution in each two parts of box without any salinity stress.

**In each column, means with the same letter are not significantly different

TABLE II

THE EFFECT OF ADDING CALCIUM, POTASSIUM AND HALF-STRENGTH NUTRIENT SOLUTION TO THE HALF PART OF ROOT MEDIA TO THE HALF PART OF ROOT MEDIA ON CONCENTRATION OF NITROGEN, PHOSPHOR, POTASSIUM, SODIUM, CALCIUM AND MAGNESIUM IN THE SHOOT

Treatment	N%	P%	K%	Na%	Ca%	Mg%
J	2.56 ^a	0.55 ^a	6.79 ^a	0.16 ^c	1.35 ^a	0.23 ^a
N	2.53 ^b	0.43 ^a	4.38 ^c	4.29 ^a	0.81 ^{bc}	0.15 ^c
NJ	2.20 ^{ab}	0.53 ^a	5.0 ^{abc}	1.07 ^b	0.92 ^{bc}	0.19 ^b
NC	1.86 ^b	0.51 ^a	4.0 ^c	1.03 ^b	1.18 ^{ab}	0.15 ^c
NK	1.80 ^b	0.39 ^a	6.25 ^{ab}	4.06 ^a	0.68 ^c	0.11 ^d
NKC	2.74 ^a	0.46 ^a	4.90 ^{bc}	1.22 ^b	1.15 ^{ab}	1.15 ^b

*N: plants supplied with Johnson nutrient solution in one box and NaCl in the other box, NC: plants supplied with Johnson nutrient solution in one box and NaCl + CaCl₂ in the other box, NK: plants supplied with Johnson nutrient solution in one box and NaCl + KCl in the other box, NCK: plants supplied with Johnson nutrient solution in one box and NaCl + CaCl₂ + KCl in the other box, NJ: plants supplied with Johnson nutrient solution in one box and NaCl + half Johnson nutrient solution in the other box, and J: plants supplied with Johnson nutrient solution in each two parts of box without any salinity stress.

**In each column, means with the same letter are not significantly different

IV. CONCLUSION

In the present study, the growth of tomato was investigated in the dynamic split-root hydroponic systems where 40 mMNaCl salinity level and various elements were applied at one part of the split roots and the other part was immersed in the nutrient solution. According to the results of the present study, it is concluded that the dynamic split-root hydroponic

system with additive elements is a suitable and applicable technique for using saline waters and improving the plant growth in production of tomato.

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