تأثير التغذية النتراتية والأمونياكية في تحمل البندورة (*Lycopersicon esculentum* cv. Shanon) لملوحة NaCl في الزراعة المائية

The Effect of Nitrate and Ammonium Nutrition on Tomato (*Lycopersicon esculentum* cv. Shanon) Tolerance to NaCl Salinity in Hydroponic Culture

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الملخص

الملوحة مشكلة رئيسية في البيوت المحمية عند زراعة محاصيل الخضر في المحاليل الغذائية. غالباً ما يلاحظ زيادة قيم الناقلية الكهربائية (EC) في وسط الجذور نتيجة امتصاص الماء والبخر/نتح مما ينتج عن ذلك تراكم للأملاح في المحاليل الغذائية. ولذلك تم إجراء تجربة في البيت البلاستيكي على نبات البندورة (صنف شانون) باستخدام المحاليل الغذائية لتقصي تأثير ملوحة NaCl بتركيزين (0 و 75 ميليمول) والشكل الآزوتي (نترات/أمونيوم، 0:100، 25:75، 50:50، 75:25، 100:0) في النمو وامتصاص العناصر الغذائية الكبرى. حصدت النباتات بعد 24 يوم من النمو، جففت في الفرن وسجلت الأوزان الجافة للمجموعين الخضري والجذري، وتم إجراء التحاليل الكيميائية عليها لتقدير محتواها من العناصر الغذائية (Cl, Na, Mg, Ca, K, P, N). أدت الملوحة إلى انخفاض نمو المجموعين الخضري والجذري، وخفف وجود الأمونيوم في المحلول الغذائي حتى نسبة 50% (نترات/أمونيوم = 50:50) من وطأة الملوحة، كما انخفض أيضاً طول المجموع الجذري بتأثير الملوحة والأمونيوم بتراكيزه العالية (75 و 100%) من الآزوت في المحلول الغذائي. لم يتأثر معدل امتصاص الجذور للآزوت بالملوحة (التدفق، مغ/م جذور/يوم)، وزاد بوجود كلا الشكلين من الآزوت (نترات/أمونيوم بمعدل 50:50). انخفض معدل تدفق K+ و Ca+2 و الـ Mg2+ بوجود الملوحة، وللأمونيوم تأثير سلبي على كفاءة امتصاصها خاصة عند التراكيز العالية 75 و 100%. أدى وجود الأمونيوم في المحلول إلى زيادة معدل تراكم N في المجموع الخضري (مغ/غ مادة جافة/يوم) في المعاملات غير المالحة، ولكن لم يتأثر معدل تراكم الآزوت كثيراً بزيادة الأمونيوم في الوسط بوجود الملوحة. أدت الملوحة وتزايد تراكيز الأمونيوم إلى محدودية نقل العناصر K+ و Ca+2 و الـ Mg2+ إلى المجموع الخضري وتراكمها فيه. بينت النباتات التي تلقت تركيز ملحية من NaCl معدلات تدفق وتراكم في المجموع الخضري

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عالية لكل من الصوديوم والكلور، وتكون قيم الـ Na+ أعلى بكثير من الـ Cl-. لقد تم الاستنتاج أنه يمكن تخفيف وطأة الأثر السلبي للملوحة في النمو وامتصاص العناصر الغذائية بوجود تغذية مختلطة NH4/NO3 بنسبة 50:50 في المحلول الغذائية.

الكلمات المفتاحية: البندورة، الزراعة المائية، NaCl، الملوحة، امتصاص العناصر الغذائية.

Abstract

A greenhouse experiment was conducted growing tomato (cv. Shanon) in nutrient culture to investigate the effect of NaCl salinity (0 and 75 *mM*) and N form (NO_3:NH_4 ratios 100:0, 75:25, 50:50, 25:75, 0:100) on growth and macronutrient uptake. Plants were harvested after 24 days and were oven-dried. Weights were recorded and analyzed for nutrient contents (N, P, K, Ca, Mg, Na, and Cl) both in shoots and roots. Salinity decreased growth of shoots and roots which was partly restored by the presence of NH_4^+ in the nutrient solution up to 50:50 NO_3:NH_4. Root length was reduced by salinity and by high NH_4^+ at 75 and 100 % NO_3:NH_4 ratios. The uptake efficiency of N and P (Inflow, mg/m RTL/day) was not affected by salinity, but increased by mixed NO_3:NH_4 solutions. Inflow values for K^+, Ca^{2+}, and Mg^{2+} decreased with salinity and NH_4^+ had a negative effect especially at high concentrations. Specific accumulation rates in the shoots (SAcR, mg/g DM/day) increased for N in none-saline tomato with increasing NH_4^+ in the nutrient solution, while was not affected in saline plants with varying NH_4^+ concentrations. There was a limitation in the transport of K^+, Ca^{2+}, and Mg^{2+} to the shoots due to salinity and NH_4^+ in the nutrient solution. Saline plants exhibited very high inflow and SAcR values for Na^+ and Cl^-, which were much higher in Na^+ than for Cl^-. It was concluded that the deleterious effects of salinity on biomass production and nutrient uptake can be minimized by using the mixed of N nutrition (50:50 of NO_3:NH_4) in the nutrient solution.

Key words: Tomato, hydroponic, NaCl, Salinity, Nitrogen, Nutrient uptake.

Introduction

Plants grown in hydroponic system often experience constraints on growth, development, and nutrients disorder, mostly resulting from salinity in the root media. This is the result of high evaporation/transpiration that increases salt concentration in the nutrient solution (Fan *et al*., 2012). Consequently, growth and fruit production is reduced (Magan, *et al*., 2008). The deleterious effects of salinity on plant growth are associated with (i) reduction of water potential in the root zone that causes water deficit, (ii) toxicity of ions such as Na^+ and Cl^-, (iii) nutrient deficiencies or imbalance by depression in uptake and /or shoot transport, or (iv) a combination of all these factors (Ashraf, 1994, Gama *et al*., 2007).

Salinity reduces fresh and dry weight of shoots of tomato in soilless culture at relatively low salinity range (0-2.15 DS m^{-1}). Kamrani, *et al*., (2013) concluded that salinity should reach 20 m*M* to show an effect on tomato shoot development. The reduction in shoot growth was attributed to the reduction in photosynthesis that led to reduction in expansion of tissue and disturbance in mineral supply either in excess or deficiency (Zhang *et al*., 2016). Salinity was also reported to negatively affect tomato root growth under soilless cultivation where salinity decreased root elongation rates by about 26% when plants were subjected to 1% NaCl (Zhang *et al*., 2016), length density in the late growing season after 67 days of growing (Snapp *et al*., 1991), and reduced root fresh weight by 30% after 3 weeks of growth in 100 m*M* NaCl (Albacete, *et al*., 2008). Root DM was also shown to be reduced under

salinity (10 ds m^{-1}) together with increased root:shoot ratio (Lovelli *et al*., 2011), which usually coincided with reduction in root length and surface area (Evlagon *et al*., 1992).

The other negative effects of salinity are the results of competition between the ions at the root level, which may lead to alterations in the ionic balance inside the plant tissue, in the functionality of the membrane, and in transport and enzymatic activities (Flagella et al., 2002). Sodium was reported to interfere with the absorption of K^+ and Ca^{2+} and/or increase the requirement of a particular nutrient element such as P in tomato (Grattan, and Grieve, 1999). Antagonism effects in mineral uptake have also been observed as a result of the effect of chloride with respect to nitrate ion as well as phosphate and sulfate (Papadopoulos and Rending, 1983). The salinity-N results contrast markedly in which the N uptake or accumulation in the shoot may be reduced under salinity conditions, although there are studies that found the opposite or no effect (Feigin, 1985). In these studies where NaCl-treated plants contained less N than un-saline plants, there is no evidence to support the fact that the effect is growth-limiting (Munns and Termaat, 1986). A more recent review refers to more than antagonism. Salinity can also impair N in plants by reducing plant water absorption due to changes in soil water potential. Many studies have reported that osmotic effects of salt ions in soil solution decreased water absorption and mass flow of nutrients including N to the roots, and subsequently, caused a marked reduction in the uptake by plants (Zakery-Asl *et al*., 2014). Besides limiting the N uptake via ionic antagonism and reducing water availability and absorption, salinity can also restrict N uptake by reducing plant N demand due to a marked relative growth rate (Kafkafi and Bernstein, 1996).

The form in which N is supplied to salt-stressed plants can influence salinity-N relations, as well as affect salinity's relation with other nutrients (Grattan and Grevie, 1999). Na^+ was shown to have an antagonistic effect with NH_4^+ and could cause a significant reduction in NH_4^+ uptake under salinity condition (Dluzniewska *et a*l., 2007). Reduction in NH_4^+ uptake with increasing Na^+ concentration in soil solution has been observed in many plant species (Ashraf *et al*., 2018). Lewis *et al*., (1989) reported that NH_4^+ nutrition of maize became more sensitive to salinity and that addition of Ca^{2+} increased the tolerance of NO_3-fed plants to salinity compared to NH_4-fed plants. The mixed nutrition of maize NO_3/NH_4 in saline condition decreased K^+ uptake compared to saline NO_3-fed plants (Martinez and Creda, 1989). This study has also shown that NH_4 present in the nutrient solution led to an increase in Na^+ and Cl^- concentrations in the shoots, while the concentrations of K^+ and Ca^{2+} were decreased. The mixed NO_3/NH_4 nutrition of tomato improved plant growth and reduced salinity's negative effect on growth (Flores, *et al*., 2001; Drihem and Pilbeam, 2002; Ben-Oliel *et al*., 2005), and on fruit production and quality (Ben-Oliel *et al*., 2005). Bialczyk *et al*., (2007) reported an increased biomass production of tomato by about 180% when NH_4^+ was supplied at a rate of 50% of the total concentration of N in the nutrient solution.

Objectives

In our previous research, tomato plants (cv. Shanon) were shown to tolerate NaCl salinity level of 75 *mM* in the nutrient solution (Yousif *et al*. 2021) at which a little less than 50% of plant growth was reduced. According to Grattan and Grieve (1999), this level of growth reduction is the critical salinity tolerance of tomato (cv. Shanon). This raises the question of the possible enhancement of salt tolerance of this tomato hybrid by inducing different ratios of nitrogen forms in the nutrient solution. Tomato plants were here grown in nutrient solutions containing increasing NH_4 concentration percentage of 0, 25, 50, 75 and 100% of NO_3:NH_4.

Materials and Methods

Plant Cultivation:

Commercially available tomato seedlings (100 seedlings) (*Lycopersicon esculentum* cv. Shanon) were transferred into 16-L^{-1} buckets (ten seedlings per bucket 30x25x25 cm) containing complete half-strength nutrient solutions (pH 6.0) for a 7 d pre-culture period in a greenhouse on the University of Tishreen campus. Seedlings were supported by polystyrene sheets with holes allowing roots to immerse in the nutrient solution. After pre-culturing, seedlings of similar mass were selected (4.71±0.5 g) and treatments (NO_3:NH_4 100:0, 75:25, 50:50, 25:75, 0:100) were imposed in full-strength nutrient solution. Salinity was induced at 75 m*M* as NaCl which led to increase EC from 1.83 in the control treatments to 7.58 ds m^{-1}. Five seedlings remained in each treatment bucket, and removed seedlings were taken for measurements as zero time. The solution consisted of: 1.5 *mM* $Ca(NO_3)_2$; 1.0 *mM* K_2HPO_4; 0.5 *mM* $MgSO_4$; and micronutrients were supplied according to Long Ashton formula (Hewitt, 1966). Ammonium was supplied as $(NH_4)_2SO_4$ and Ca was compensated in ammonium- containing treatments as $CaSO_4$. All treatments contained N and Ca concentrations at 42 and 60 mg L^{-1}. The pH of all solutions was adjusted to 6.0 using 1*M* H_2SO_4 or NaOH, and aerated continuously throughout the experiment. Nutrient solutions were renewed every other day.

Harvest Procedure:

Plants were harvested after 24 d of growth, shoots were separated from roots and fresh weights recorded. Subsamples of 1 cm roots fragments (1 g) were taken for the measurement of root length (Tennant, 1975). Shoots and roots of each individual plant were oven-dried at 70 ◦C for 48 h and dry weights were calculated.

Chemical analysis:

Shoots and roots dry matter were grounded to pass a 0.5 mm screen and kept in sealed plastic bags prior to analysis. Subsamples of shoots and roots (0.1 g DM) were extracted in 10 ml of hot water (45 ◦C) for 1 hour, filtered and Cl^- concentrations were determined in the filtrate (Ryan *et al*., 2001). Total nitrogen was determined by Kjeldahl procedure, while nutrients P, K, Ca, Mg, and Na were determined in plant tissues after dry digestion (Ryan *et al*., 2001).

Calculations:

Data of nutrients concentrations in DM of shoots and roots were used to calculate total nutrient uptake by the whole tomato plants.

To further investigate the effect of ammonium presence in the nutrient solution on the tolerance to salinity, inflow rates (I, mg of nutrient uptake/meter root length/day) were calculated using the equation of Williams (1946):

$$I = [(N2 - N1) / (T2-T1)] \times [Ln(L2/L1) / (L2-L1)]$$

Where: N1 and N2 are the nutrient content of plant at 0 and 24 day; L1 and L2 are the total root length at 0 and 24 day; T1 and T2 are the time between the two harvests (period of growth).

The same equation was also used to calculate specific accumulation rates of nutrients in the shoots (SAcR, mg of nutrient/g shoot DM/day), which provide an insight to translocation of nutrients to the shoots:

$$SAcR = [(N2 – N1) / (T2-T1)] \times [Ln(W2/W1) / (W2-W1)]$$

Where: N1 and N2 are the nutrient content of shoots at 0 and 24 day; L1 and L2 are shoot DM at 0 and 24 day; T1 and T2 are the time between the two harvests (period of growth).

Statistics:

The experiment was a complete randomized designed with three replicates. All data were statistically analyzed using the ANOVA procedure considering the sources of differences are the percentage of N form (N), Salinity (SAL) and their interaction (NxSAL). Mean separation was calculated using the LSD procedure at 0.05% level of significance (SAS, 1999).

Results

Plant growth:

Tomato plants responded differently to allocation of dry matter accumulation between shoots and roots according to the form of nitrogen nutrition and salinity in the growth medium. Salinity had a significant effect on shoot dry matter whereas it was not the case for root growth (Fig. 1). There was a significant difference in both shoots and roots related to the NO_3:NH_4 ratios ($P \leq 0.0001$), and in interaction with the level of NaCl salinity (75 *mM*) in the nutrient solution ($P \leq 0.0001$). Tomato plants grew well and similarly in non-saline nutrients with increasing NH_4^+ in the nutrient solution up to 50% NH_4^+ (NO_3:NH_4 = 50:50), after which shoot growth decreased rapidly by about 37 and 65%. In the presence of salinity, shoot growth decreased by 36% in the 100% NO3 treatment, and to a lesser extent with increasing NH_4 in the nutrient solution to (NO_3:NH_4=75:25) and (NO_3:NH_4=50:50) by 11 and 18% (Fig. 1). Thereafter, saline plant had higher shoot DM in the NO_3:NH_4 25:75 and 0:100 treatments compared to non-saline treatment of the same N form ratios.

Root growth increased with increasing NH_4^+ in the nutrient solution up to (NO_3:NH_4= 50:50) in non-NaCl treatments and thereafter, decreased gradually (Fig. 1). In NaCl treatments, root DM increased in the presence of 25% NH_4, almost unchanged in the 50% treatment and thereafter, started to decrease with 75 and 100% NH_4 in the nutrient solution. It is only in the 100% NH_4 treatment where root weight became less than the 100% NO_3^- in the saline treatments.

The different effect of N form ($P \leq 0.0001$) and interaction with salinity ($P \leq 0.0422$) and the magnitude of effects has led to higher shoot:root ratios in the non-saline 100% and 75% NO_3^- percentage to total N compared to the same treatment in which NaCl is present. Therefore shoot:root ratios decreased in the non-saline treatment whereas remained almost the same in saline treatments (Fig. 2).

Total root length was not affected by increasing NH_4^+ % in the nutrient solution up to treatment (NO_3:NH_4 = 50:50) in the non-NaCl treatments, while increased slightly, but not significantly, in the presence of NaCl (Fig. 3). In this range of NO_3:NH_4 ratios (up to 50:50), NaCl decreased total root length by about 20, 10 and 15 % compared to non-NaCl treatments. Thereafter, total root length decreased sharply with increasing NH_4^+ in the nutrient solution up to 75 and 100% both in saline and non-saline treatments which, however, were not significantly different.

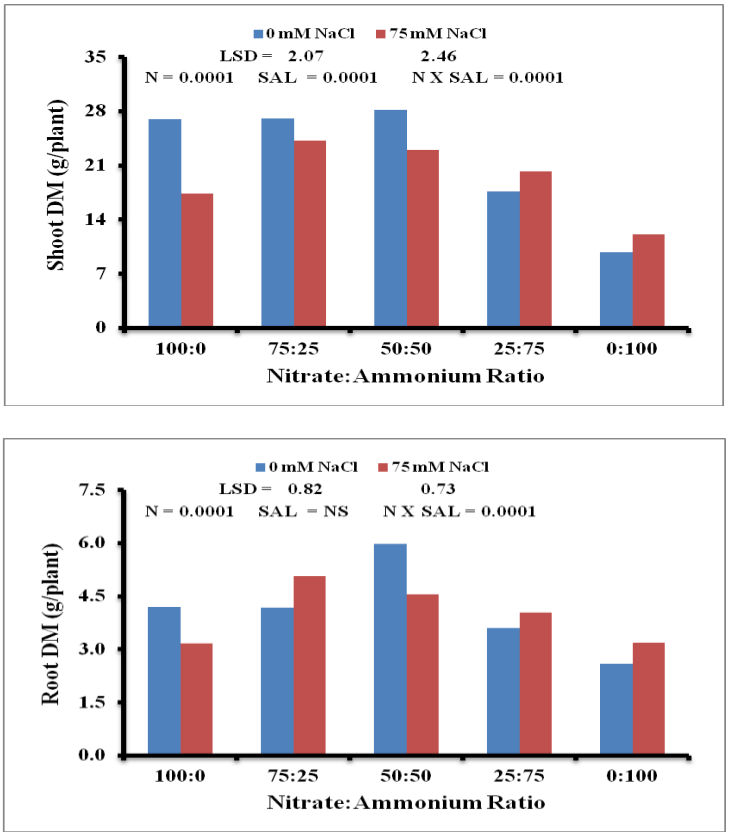

Figure 1: The effect of NO_3:NH_4 nutrition on shoot and root growth of tomato grown under salinity NaCl stress (75 *mM*) for 24 days.

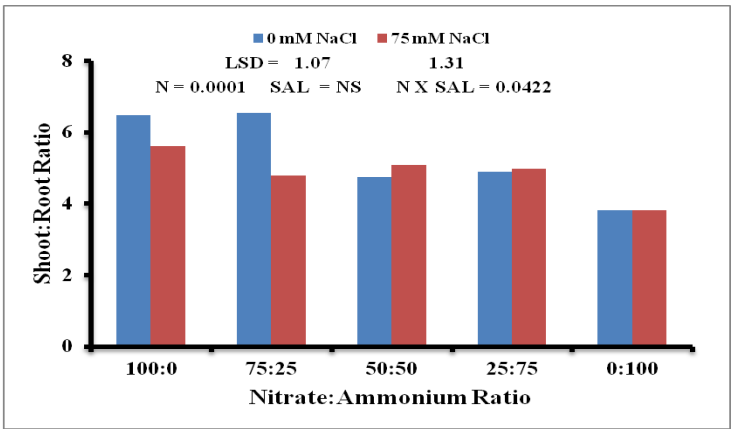

Figure 2: The effect of NO_3:NH_4 nutrition on shoot/root ratio in tomato grown under salinity NaCl stress (75 *mM*) for 24 days.

Nutrients uptake:

The uptake of macro-nutrients was significantly affected by the form and ratio of NO_3/NH_4 (N), salinity (SAL, with the exception of N uptake), and their interaction (NxSAL) and *Pr* values were less than 0.0039 (Fig. 4). While the uptake of N and P increased, they took similar trend in which salinity increased their uptake by the whole tomato plants in treatments (NO_3:NH_4= 100:0 and 75:25). The uptake of N and P reached the highest uptake values in the NO_3:NH_4= 50:50 ratio, but in non-saline treatment became higher than in saline treatments. N and P plant uptakes in non-saline NO_3:NH_4= 50:50 treatments were 833 and 42 mg/plant , an increased rate of 85 and 77 % compared to 100% NO_3^- treatment. For saline treatments rates of increased N and P were 34 and 49% compared to 100%

NO_3^- saline treatment. Thereafter, uptake of both nutrients (N and P) decreased slowly up to increased NH_4^+ ratio to 100% in the nutrient solution. Values remained, however, close to treatments NO_3:NH_4 100:0 (Fig. 4).

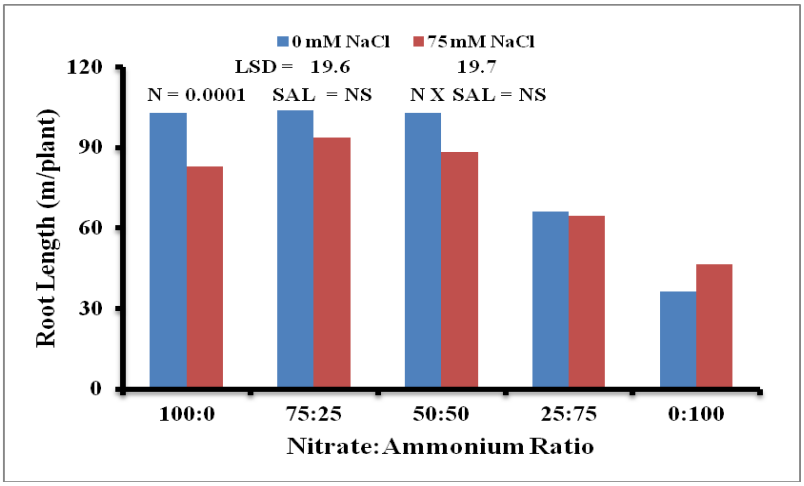

Figure 3: The effect of NO_3:NH_4 nutrition on total root length of tomato grown under salinity NaCl stress (75 *mM*) for 24 days.

Magnesium and K^+ also had a similar uptake pattern, increasing uptake with increasing % NH_4^+ in the nutrient solution up to NO_3:NH_4 (50:50), non-saline being higher than saline treatments. Uptake values reached the highest of (285 and 223 for Mg) and values of 521 and 439 for K^+ in control and saline treatments, respectively. The average percent increase was 20-28% compared to when NO_3^- was the only form of nitrogen in the solution. Thereafter, uptake decreased gradually with increasing NH_4^+ concentration to 75:25 and 100:0 (NO_3:NH_4) in both saline and non-saline treatments.

NaCl stress decreased Ca^{2+} uptake at all percent ratio of NO_3:NH_4 in the nutrient solution (Fig. 4).The highest value of uptake by tomato plants was in the control non-saline treatment (NO_3:NH_4= 100:0) which was 589 mg/plant, decreased by 23% to 453 mg/plant in saline treatment. The sharp decrease in Ca^{2+} uptake occurred when N ratio was 25:75 NO_3:NH_4 in both saline and non-saline treatments.

As for Na^+ uptake, it increased significantly in saline treatments with increasing NH_4^+ in the nutrient solution from 0 to 25% of total N concentration to reach a value of 2255 mg/plant, and thereafter, decreased gradually with decreasing growth to 941 mg Na^+/plant (Fig. 4). Non-saline plant contained a small amount of Na due to salt contamination used for the preparation of the nutrient solution and adjustment of pH using NaOH. Cl^-, uptake in non-saline treatments decreased gradually, but slowly, with increasing NH_4^+ concentrations from 0 to 100% of total N supply. Cl^- uptake increased in saline treatment up to NO_3:NH_4 (50:50) and then decreased significantly toward NO_3:NH_4 0:100 ratio (Fig. 4). Obviously, saline plants contained higher quantities of both Na and Cl^- than those of non-saline tomato plants at all ratio rates of NO_3:NH_4.

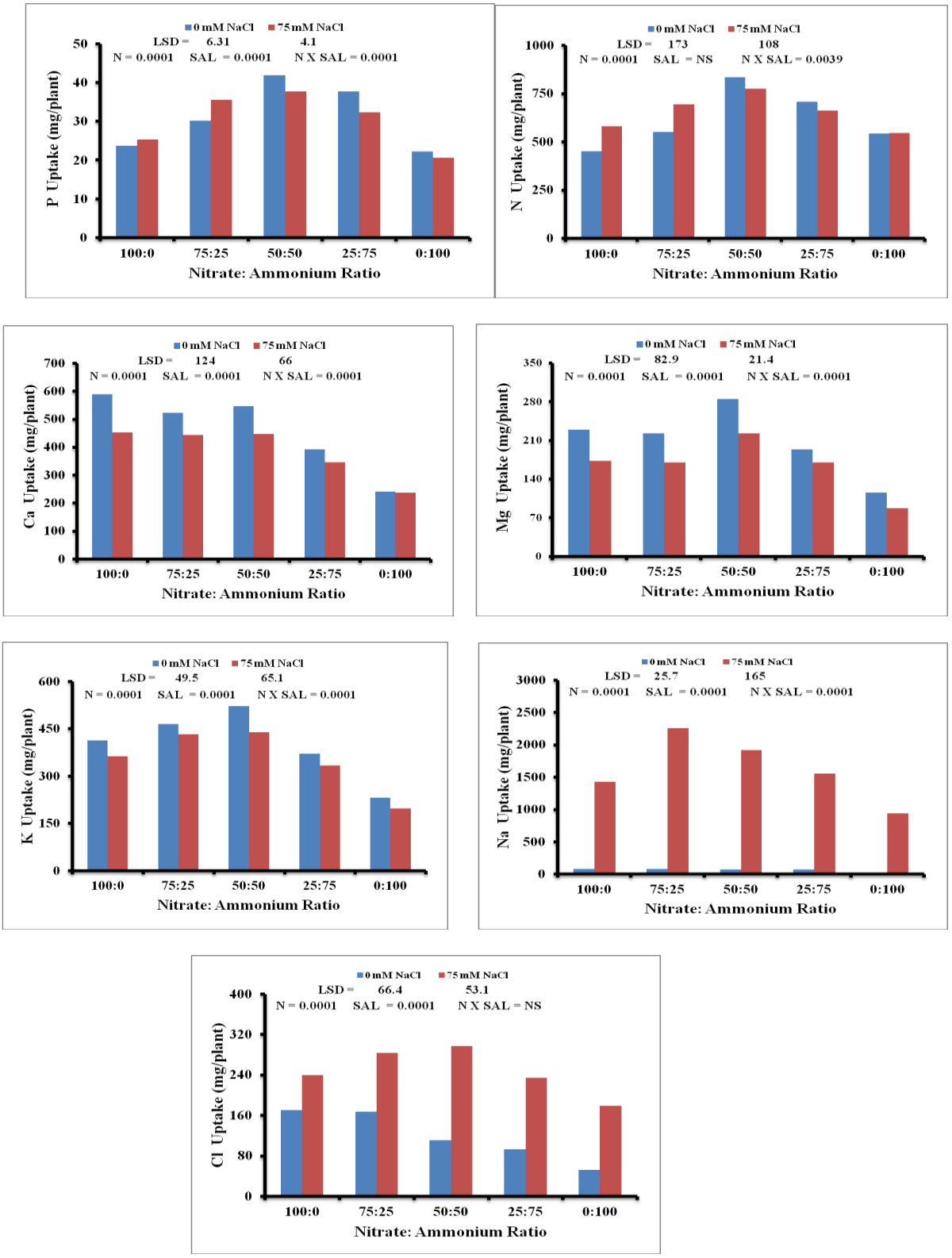

Figure 4: The effect of NO_3:NH_4 nutrition on total uptake of nutrients by whole plant of tomato grown under salinity NaCl stress (75 m*M*) for 24 days.

Discussion

The observed reduction in shoot growth under salinity (Fig. 1) is common, and seems to relate to the rate of photosynthesis that leads to reduction in expansion of tissue and disturbance in mineral supply (Zhang *et al*., 2016). It was also reported that under salinity, a reduced cell enlargement could result from reduction in water tension in the leaves (Sacher and Staples, 1985). Alarcon *et al*., (1994) illustrated that water tension in saline soil seems to be the main reason for restricted tissue growth. Shimul *et al*., (2014) reported that total tomato leaf chlorophyll content, stomatal resistance and photosynthetic activity are significantly reduced with increasing salinity. The effect of salinity on dry matter production and partitioning between shoots and roots of tomato has been documented (Ashraf *et al*., 2018; Mavrogiano-Poulos *et al*., 2002). Our results show that the presence of NH_4 in the nutrient solution (25 and 50% of the nitrogen dose) seems to improve shoots and roots growth under salinity (Fig. 1). This finding coincided with the results of several researchers (Flores *et al*., 2001; Drihem and Pilbeam, 2002; Ben-Oliel *et al*., 2005; Bialczyk *et al*., 2007). Lovelli *et al*. (2011) reported that both shoots and roots dry matter of tomato was reduced under salinity (10 ds m^{-1}), the effect being more pronounced on shoots, so the shoot:root ratio was decreased. The addition of 14 mg/l^{-1} of NH_4^+ (in our case it constitutes one-third of total N concentration in the nutrient solution) improved shoot growth (Ben-Oliel *et al*., 2005). The effect of NH_4 and salinity was more pronounced on shoots compared to roots, consequently, shoot:root ratios were decreased (Fig. 2) (Zhang *et al*., 2016).

Salinity reduced tomato roots (Fig. 1) as the result of reduced root elongation rate and lateral root growth due to restriction in root cell growth and increased root lesion (Zhang *et al*., 2016). The root length of tomato plants was reduced by 54% after 4 days exposure to Hoagland's solution salinized with 100 *mM* NaCl (Evlagon *et al*., 1992). Fresh and dry weights of tomato roots, total root length, number of adventitious, tap root, and lateral root decreased with increasing EC range (1.5-10 ds m^{-1}) in the nutrient solution (Schwarz and Grosch, 2003). Our visual observation probably attributes the decrease RL (Fig. 2) to reduced branching of lateral roots, short and stunted lateral roots with increasing NH_4 concentrations in the nutrient solution (Le Bot *et al*., 1990), and due to salinity which also caused a severe phytophthora root rot (Snapp *et al*., 1991).

The process of nutrients uptake by plants is mostly affected in saline environment, probably due to the antagonistic effect of salt ions especially NO_3^- and NH_4^+, disturbance of N ions loading into root xylem, reduced water absorption due to osmotic changes in the root zone, reduction in transpiration rate, damage of root membrane structure, and/or lower N demand due to the reduced growth rate (Ashraf *et al*., 2018). Most previous studies have reported a decrease in N uptake in saline NO_3^-Fed tomato plants (Ashraf *et al*., 2018). The absorption of NO_3^- my be closely linked to reduced water uptake rather than to antagonism with Cl^- present in the root media (Abdelgadir *et al*., 2005). The limitation in plant growth is propably due to reduced NO_3^- uptake or/and linitation in NO_3^- movement from vacoual to the cytoplasm for reduction resulted from high Cl^- concentration in the plant tissue (Martinez and Cerda, 1989). Kafkafi *et al*., (1982) concluded that NO_3^- uptake decreased under NaCl salinity is not because of Cl^- concentration in the external solution but rather due to internal tissue Cl^- concentration. This was not the case in this study in which saline plants absorbrd greater amount of N (Fig. 4) regardless of the relatively smaller saline plants compared to none-saline plants (Fig. 1). Similar results were obtained for saline tomato plant (Giuffrida *et al*., 2009), in which N concentrations were within the sufficiency range (Above 26 mg/g shoot DM). The concentrations of

N in the shoots were higher in saline plants in the 100:0 and 75:25 NO_3:NH_4 treatments, and hence concentations, while increasing, were similar between saline and non-saline plant shoots (data not shown). The presence of NH_4^+ in the nutrient solution increased the total uptake of N (Fig. 4). It was obseved that N uptake increased by 35% under field condition when 25% of the N required dose was applied as NH_4^+ (Raun and Johnson, 1999). Assimilation of NO_3^- requires the energy equivalent to 20 ATP/mol, whereas NH_4^+ assimilation requires only 5 ATP/mol (Ashraf *et al*., 2018). This energy saving could be invested in growth and nutrients uptake.

Calculations of effeciency in which nutrients are taken up (Inflow, I: mg of nutrients/meter root length/day) and specific accumulation rates in the shoots (mg of nutrients/g DM/day) are presented in table 1 and 2. These calculations discard differences between treatment plants related to sizes, weights, and presents the core effeciency in which nutrients are absorbed, translocated, and accumulated in the shoots. These data indicate that in the 100% NO_3^--fed plants, salinity increased the uptake effeciency of N (Inflow) by about 10% and increased translocation and accumulation in the shoots by 25% (Table 1 and 2). Inflow rates of N increased signifcantly with increasing NH_4^+ concentration ratio in the nutrient solution in both saline and non-saline plants by about 20-31 % (Table 1). Translocation of NO_3^-/NH_4^+ from the roots to the shoots (SAcR) also increased in none-saline treatments by about 8-30%, while in saline treatments SAcR did not significantly change up to 100% NH_4^+-Fed plants after which it increased by 15% (Table 2).

Numerous studies on tomato as well as other crops have shown that K^+ accumulated in plant tissue is reduced as Na^+ increased in the growth media (Grattan and Grieve , 1999; Zhang *et al*., 2016). The mechanism involoved may be related to the competition between Na^+ and K^+ for the absorption sites on the plasmalemma (Maathuis and Amtmann, 1999). In this study, although salinity decreased the accumulation of K^+ in the shoots, no K defeciency symptoms were obseved and seem to agree with other researcher findings (Hu and Schmidhalter, 1997; Qaryouti and Suwwan, 2006). Concentrations of K^+ in the shoots were 20.2 mg/g DM in the 100% NO_3-fed none-saline plants and were reduced to 13 mg/g DM under salinity (data not presented). K uptake effeciency (inflow) decreased in none-saline treatments when NH_4^+ was supplied at a 75% of the total N concentation in the nutrient solution. While K^+ inflow rates were lower in saline treatments compared to none-saline, they remained almost unaffcted with increasing NH_4^+ ratios in the nutrient solution. The same trend was true for K^+ SAcR in the shoots.

As for P, there was no clear effect of NaCl salinity on its concentrations in the shoots which was also confirmed by calculations Inflow and SAcR rates (Table 1 and 2). This is consistent with the previous results on tomato (Giuffrida *et al*., 2009; Mavrogiano-Poulos *et al*., 2002). Intersingly, the inflow values for P into tomato roots (mg/meter RTL/day) were increased significantly by NH_4^+ in the nutrient solution of non-saline plants (increased from 0.083 in the 100:0 NO_3:NH_4 treatment to 0.114 and 0.132 in 50:50 and 25:75 NO_3:NH_4 treatments, respectively). In saline plants, the increase in P inflow values was from the first level of NH_4^+ induced into the nutrient solution (Treatment 75:25 NO_3:NH_4) (Table 1). Similar trends for SAcR rates in the shoots were observed (Table 2).

Table 1: The effect of NO_3:NH_4 nutrition on inflow rates of mineral nutrients (I, mg/m/day) into the roots of tomato plants during 24 days of salinity stress.

NO_3:NH_4	NaCl *mM*	Inflow (mg/m/day)						
		N	P	Ca	Mg	K	Na	Cl
100:0	**0**	1.53^{B}	0.083^{C}	2.27^{A}	0.88^{A}	1.54^{A}	0.20^{A}	0.42^{A}
75:25		1.83^{B}	0.086^{C}	1.57^{B}	0.89^{A}	1.44^{A}	0.20^{A}	0.42^{A}
50:50		2.22^{A}	0.114^{B}	1.56^{B}	0.92^{A}	1.48^{A}	0.18^{AB}	0.27^{A}
25:75		2.19^{A}	0.132^{A}	1.26^{B}	0.67^{B}	1.19^{B}	0.24^{A}	0.31^{A}
0:100		2.16^{A}	0.081^{C}	0.79^{C}	0.44^{C}	0.79^{C}	0.11^{C}	0.27^{A}
100:0	**75**	1.69^{B}	0.067^{B}	0.83^{B}	0.29^{C}	0.75^{B}	4.22^{BC}	0.71^{A}
75:25		2.02^{AB}	0.098^{A}	0.99^{AB}	0.38^{BC}	0.98^{AB}	6.08^{A}	0.76^{A}
50:50		2.01^{AB}	0.094^{A}	0.98^{AB}	0.42^{B}	0.99^{AB}	5.36^{AB}	0.82^{A}
25:75		2.26^{AB}	0.102^{A}	1.12^{A}	0.52^{A}	1.11^{A}	5.41^{A}	0.81^{A}
0:100		2.46^{A}	0.093^{A}	1.07^{A}	0.31^{C}	0.84^{AB}	4.16^{C}	0.77^{A}
$LSD_{0.05}$		0.49	0.016	0.32	0.13	0.25	0.74	0.19
Effect of		$Pr \leq F$						
NO_3:NH_4		***	***	***	***	***	**	NS
SAL		NS	*	***	***	***	***	***
NO_3:NH_4 x SAL		NS	**	***	***	***	**	NS

Means with the same letter within each salinity group treatments are not significantly different; LSD values are to compare all treatments; NS not significant.

Table 2: The effect of NO_3:NH_4 nutrition of specific accumulation rates of mineral nutrients (SAcR, mg/g DM/day) in the shoots of tomato plants during 24 days of salinity stress.

NO_3:NH_4	NaCl *mM*	SAcR (mg/g DM/day)						
		N	P	Ca	Mg	K	Na	Cl
100:0	**0**	7.58^{B}	0.357^{C}	11.95^{A}	4.56^{A}	7.80^{A}	1.08^{A}	2.10^{A}
75:25		8.27^{AB}	0.374^{C}	7.93^{B}	4.41^{A}	7.39^{AB}	1.08^{A}	2.10^{A}
50:50		9.96^{A}	0.475^{B}	7.03^{BC}	4.24^{A}	6.88^{B}	0.96^{AB}	1.27^{A}
25:75		10.78^{A}	0.690^{A}	5.88^{C}	3.26^{B}	5.99^{C}	1.35^{A}	1.53^{A}
0:100		10.44^{A}	0.388^{C}	3.59^{D}	2.20^{C}	3.74^{D}	0.63^{B}	1.30^{A}
100:0	**75**	10.16^{B}	0.399^{C}	4.68^{A}	1.67^{B}	4.50^{AB}	27.31^{C}	4.20^{A}
75:25		9.98^{B}	0.473^{A}	4.53^{A}	1.80^{B}	4.92^{A}	32.49^{A}	3.71^{A}
50:50		9.83^{B}	0.429^{BC}	4.60^{A}	1.83^{B}	4.99^{AB}	28.58^{B}	4.08^{A}
25:75		9.48^{B}	0.425^{BC}	4.85^{A}	2.24^{A}	5.07^{AB}	25.5^{D}	3.56^{A}
0:100		11.91^{A}	0.455^{AB}	5.17^{A}	1.51^{B}	4.19^{B}	22.70^{E}	3.85^{A}
***$LSD_{0.05}$**		1.73	0.055	1.05	0.92	0.67	0.80	0.95
Effect of		$Pr \leq F$						
NO_3:NH_4		***	***	***	**	***	***	NS#
SAL		**	NS#	***	***	***	***	***
NO_3:NH_4 x SAL		**	***	***	*	***	***	NS#

Means with the same letter within each salinity group treatment are not significantly different; *LSD values are to compare all treatments; #NS not significant

The uptake effeciency of the roots to absorb Ca^{2+} (Table 1) was greatly reduced under salinity in the 100:0 NO_3:NH_4 treatment (from 2.27 in non-saline to 0.83 mg/meter RTL/day in saline treatment). There was a sharp decrease (69%) by the presence of 25% NH_4 in the nutrient solution (dropped from 2.27 to 1.57), thereafter, inflow rates decreased slowly to 0.79 with NH_4^+ concentrations reaching100% in the nutrient solution. This was not the case in saline treatments in which the increased concentration of NH_4^+ in the nutriet solution did not lead to decrease inflow of Ca^{2+}, but rather a slight increase in inflow rates (Table 1). The accumulation rates (SAcR, Table 2) of Ca^{2+} in the shoots took the same trend as inflow indicating probably that there was no limitation to Ca^{2+} loading into the xylem sap and transport up to the shoots (Caravajal *et al*., 1999; Giuffrida *et al*., 2009). The effect of salinity or/and NH_4^+ in the nutrient solution on the inflow and SAcR rates of Mg^{2+} was similar to those stated for Ca^{2+} (Tables 1 and 2). However, concentrations of both cations (data not shown) decreased in the shoots with NaCl salinity, and decreased gradually with increasing the concentration of NH_4^+ in the nutrient solution. Concentrations of both ions remained in all treatments in the range of sufficiency. The decrease of macronutrients is probably not related to antagonistic effect of NaCl or/and NH_4^+ in the growth media as it was proportional to decrease in dry matter production (Magan *et al*., 2005).

Obviously, saline tomato plants accumulated high quantities of Na^+ and Cl^- in the shoots as the nutrient solution contained 75 *mM* of NaCl salt, which correspond to 1725 and 2662.5 mg/$l^{-1}$of Na^+ and Cl^- respectively (Table 1 and 2). Interstingly, values of inflow rates and SAcR in the shoots were much higher for Na^+ compared to Cl^- by a factor of 6 to 7 times. This probably indicates that the uptake mechansim for Na^+ was not inhibted by K^+, Ca^{2+} and Mg^{2+} presence in the nutrient solution. The presence of NaCl in the nutrient solution determined a remarkable accumulation of Na^+ and Cl^- in tomato plants (Giuffrida *et al*., 2009). This was attriputed by other researcher in case of Na^+ to water transpired by the leaves because Na^+ is transported to shoots in the transpiration stream in the exylem (Munns and Tester, 2008; Tester and Davenport, 2003). This certainly was not the case for Cl^- as tomato plant aquired nuch less quantities of Cl^- compared to Na^+ (Fig. 4). This is because of the different transport mechanisms of ions and the patterns of accumulation (White and Broadley, 2001). It seems that the presence of NH_4^+ in the nutrient solution increses Na^+ and Cl^- uptake up to 50:50 NO_3:NH_4, and thereafter, has a negative effect on their uptake by tomato plants. Calculted inflow and SAcR (Table 1 and 2) indicate that only when NH_4^+ concentration reaches 100% of the N dose in the nutrient solution, the effeciency in which Na^+ absorption and accumulation by the roots was reduced. This is probably due to the small competition resulting from the cation NH_4^+ (Drihem and Pilbeam, 2002).

Conclussion

1. Salinity reduces tomato shoots and roots growth when nitrate is the only form of nitrogen, but the presence of NH_4^+ in ratios up to 50:50 NO_3:NH_4 reduces the the negative effect of salinity up to the salt level 75 *mM*.
2. Salinity has a marked effect on the uptake effeciency of K^+, Ca^{2+}, and Mg^{2+} by the roots and the presence of NH_4^+ in the growth solution up to 25:75 NO_3:NH_4 ratio seems to enhance their uptake.
3. The uptake effeciency of N and P was not affected by salinity and NH_4^+ ehanced their uptake both in saline and non-saline conditions.

4. It was concluded that the deleterious effects of salinity on biomass production and nutrient uptake can be minimized by the use of NH_4^+ at a rate of 50% in the nutrient solution.

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References

- Abdelgadir, E.M., M. Oka and H. Fujiyama. 2005. Characteristics of nitrate uptake by plants under salinity. J. Plant Nutr. 28 (1):33-46.
- Alarcon, J.J., M.J. Sanchez-Blanco, M.C. Bolarin and A. Torrecillas. 1994. Growth and osmotic adjustment of two tomato cultivars during and after saline stress. Plant Soil, 166:75-82.
- Albacete, A., M.E. Ghanem, C. Martinez-Andujar, M. Acosta and J. Sanchez-Bravo. 2008. Hormonal changes in relation to biomass partitioning and shoot growth impairment in salinized tomato (*Solamum lycopersicum* L.) plants. J. Exp. Bot. 59:4119-4131.
- Ashraf, M. 1994. Breeding for salinity tolerance in plants. Crit. Rev. Plant Sci., 13:17-42.
- Ashraf, M., S.M. Shahzad, M. Imtiaz and M.S. Rizwan. 2018. Salinity effects on nitrogen metabolism in plants-focusing on the activities of nitrogen metabolizing enzymes: a review. J. Plant Nutr. DOI: 10.1080/01904167.2018.1431670.
- Bialczyk, J., Z. Lechowski, D. Dziga and E. Mej. 2007. Fruit yield of tomato cultivated on media with bicarbonate and nitrate/ammonium as the nitrogen source. J. Plant Nutr. 30 (1):149-161.
- Ben-Oliel, G., S. Kant, M. Naim, H.D. Rabinowitch, G.R. Takeoka, R.G. Buttery and U. Kafkafi. 2005. Effects of ammonium to nitrate ratio and salinity on yield and fruit quality of large and small tomato fruit hybrids. J. Plant Nutr. 27 (10):1795-1812.
- Carvajal, M., V. Martinez and A. Cerda. 1999. Influence of magnesium and salinity on tomato plants grown in hydroponic culture. J. Plant Nutr. 22:177-190.
- Dluzniewska, P., A. Gessler, H. Dietrich, J.P. Schnitzler, M. Teuber and H. Rennenberg. 2007. N uptake and its metabolism in *Populus canescens* upon salinity. New Phytologist 173:279-293.
- Drihem, K. and D.J. Pilbeam. 2002. Effects of salinity on accumulation of mineral nutrients in wheat grown with nitrate-nitrogen or mixed ammonium: nitrate-nitrogen. J. Plant Nutr. 25 (10):2091-2002.
- Evlagon, D., I. Ravina andP.M. Neumann. 1992. Effects of salinity stress and calcium on hydraulic conductivity and growth in maize seedling roots. J. plant Nutr. 15:795-803.
- Fan, R.Q., X.M. Yang, H.T. Xie and M. Reeb. 2012. Determination of nutrients in hydroponic solutions using mid-infrared spectroscopy. Sci. Hortic. 144:48-54.
- Feigin, A. 1985. Fertilization management of crops irrigated with saline water. Plant Soil 89:285-299.
- Flagella, Z., V. Cantore, M.M. Giuliani, E. Tarantino and A. De Caro. 2002. Crop salt tolerance: physiological, yield and quality aspects. Recent Res. Devel. Plant Biol. 2:155-186.
- Flores, P., M. Carvajal, A. Cerda and V. Martnez. 2001. Salinity and ammonium/nitrate interactions on tomato plant development, nutrition, and metabolites. J. Plant Nutr. 24 (10):1561-1573.
- Gama, P.B., S. Inanaga, K. Tanaka and R. Nakazawa. 2007. Physiological response of common bean (*Phaseolus vulgaris*) seedlings to salinity stress. Afr. J. Biotechnol. 6 (2):79-88.

- Grattan, S.R. and C.M. Grieve. 1999. Salinity - Mineral nutrient relations in horticultural crops. Sci. Hort. 78:127-157.
- Giuffrida, F., M. Martorana and C. Leonardi. 2009. How sodium chloride concentration in the nutrient solution influences the mineral composition of tomato leaves and fruits. Hort. Sci. 44 (3):707-711.
- Hewitt, E.J 1966. Sand and water culture methods used in study of plant nutrition. Eastern Press, London, pp. 547.
- Hu, Y. and U. Schmidhalter. 1997. Interactive effects of salinity and macronutrient level on wheat. 2. Composition. J. Plant Nutr. 20:1169-1182.
- Kafkafi, U., N. Valoras and J. Letey. 1982. Chloride interaction with nitrate and phosphorus nutrition in tomato (*Lycopersicon esculentum* L.). J. Plant Nutr. 5 (12):1369-1385.
- Kafkafi, U. and N. Bernstein. 1996. Root growth under salinity stress. In "Plant Root, The Hidden Half", eds. Y. Waisel, A. Eshel, and Kifkafi, U. pp. 435-451, NY, USA: Dekker.
- Kamrani, M.H., H. Khoshvaghti and H. Hosseinniya. 2013. Effects of salinity and hydroponic growth media on growth parameters in tomato (*Lycopersicon esculentum Mill*). Int. J. Agron. Plant Prod. 4 (10):2694-2698.
- Le Bot, J. G.A. Alloush and E.A. Kirkby. 1990. Mineral nutrition of chickpea plants supplied with NO_3 or NH_4-N. II. Ionic balance in relation to phosphorus stress. J. Plant Nutr. 13:1591-1605.
- Lewis, O.A.M., E.O. Leidi and S.H. Lips. 1989. Effect of nitrogen source on growth and response to salinity stress in maize and wheat. New Phyto. 111:155-160.
- Lovelli, S., A. Scopa, M. Perniola, T. Di Tommaso and A. Sofo. 2011. Abscise acid root and leaf concentration in relation to biomass partitioning in salinized tomato plants. J. Plant Physiol. 169:226-233.
- Maathuis, F.J.M. and A. Amtmann. 1999. K^+ nutrition and Na^+ toxicity: the basis of cellular K^+/Na^+ ratios. Ann. Bot., 84:123-133.
- Magan, J.J., E. Casas, M. Gallardo, R,B. Thompson and P. Lorenzo. 2005. Uptake concentrations of tomato crop in different salinity conditions. In: "Proc. IS on Soil Cult. And Hydroponics", Ed: Urrestarazu, M. Acta Hort. 697 ISHS: 365-369.Manag. 95:1041-1055.
- Magan, J.H., M. Gallardo, R.B. Thompson and P. Lorenzo. 2008. Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic condition. Agric. Water Manag. 95:1041-1055.
- Martinez, V. and A. Cerda. 1989. Nitrate reductase activity in tomato and cucumber leaves as influenced by NaCl and N source. J. Plant Nutr. 12 (11):1335-1350.
- Mavrogiano-Poulos, G., D. Savvas and V. Vogli. 2002. Influence of NaCl-salinity imposed on half of the root system of hydroponically grown tomato on growth, yield, and tissue mineral composition. J. Hort. Biotechnol. 77:557-564.
- Munns, R. and A. Termaat. 1986. Whole-plant response to salinity. Aust. J. Plant Physiol. 13:143-160.
- Munns, R. and M. Tester. 2008. Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 59:651-681.
- Papadopoulos, I. and V.V. Rending. 1983. Interactive effects of salinity and nitrogen on growth and yield of tomato plants. Plant Soil 73:47-57.
- Qaryouti, M.M. and M.A. Suwwan. 2006. Influence of NaCl salinity on vegetative growth, nutrient uptake and proline content in two tomato cultivars grown under greenhouse condition. Dirasat, Agricultural Sci. 33 (1):47-58.

- Raun, W.R. and G. Jhonson. 1999. Improving nitrogen use efficiency for cereal production. Agron. J. 91 (5):357-363.
- Ryan, J., G. Estefan and A. Rashid. 2001. Soil and plant analysis: Laboratory Manual. ICARDA, NARC, 172 pp.
- Sacher, R.F. and R.C. Staples. 1985. Inositol and sugars in adaptation of tomato to salt. Plant Physiol. 77:206-210.
- SAS Institute. *SAS user's guide: Statistics*. SAS Inst., Cary, NC.1999.
- Schwarz, D. and R. Grosch. 2003. Influences of nutrient solution concentration and root pathogen (*Pythium aphanidermatum*) on tomato root growth and morphology. Sci. Hortic. 97:109-120.
- Shimul, M.A.H., I. Sic, Sadia, M.Z.K. Roni, U. Jamal and A.F.M. Ddin. 2014. Response of Tomato (*lycopersicon esculentum*) to salinity in hydroponic study. Bangladesh Res. Pub. J. 10(3):249-254.
- Snapp, S., C. Shennan and A.H.C. Van Bruggen. 1991. Salinity effects on severity of phytophthora parasitica Dast. Infection, inorganic ion relations and growth of *Lycopersicon esculentum* Mill. 'UC82B' New Phytol. 119:275-284.
- Tennant, D. 1975. A test of a modified line intersect method of estimating root length. J. Ecol. 63:995-1001.
- Tester, M. and R. Davenport. 2003. Na^+ tolerance and Na^+ transport in higher Plants. Ann. Bot. 91:503-527.
- White, P.J. and M.R. Broadley. 2001. Chloride in soils and its uptake and movement within the plant: A review. Ann. Bot. 88:967-988.
- Williams, R.F. 1946. The physiology of plant growth with special reference to the concept of net assimilation rate. *Ann. Bot*. 10:41-72.
- Yousif, A., G.A Alloush and A. Jaloul. 2021. Response of Some Tomato Hybrid (*Lycopersicon esculentum* L.) in Green Houses to Induced NaCl Salinity in Nutrient Solutions. Syrian J. Agri. Res. 9(1): in press.
- Zakery-Asl, M.A., S. Bolandnazara and S. Qustan. 2014. Effect of salinity and nitrogen on growth, sodium, potassium accumulation, and osmotic adjustment of halophyte *Suaeda aegyptiaca* (Hasselq.). Zoh. Archives of Agron. and Soil Sci. 60: 785-792.
- Zhang, P., M. Senge and Y. Dai. 2016. Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system. Reviews in Agri. Sci. 4:46-55.

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