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Does water salinity affect pepper plant response to nitrogen fertigation?

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ABSTRACT

Recent increase in demand for agricultural products combined with scarcity of fresh water has motivated increased use of non-conventional water sources for irrigation. Application of water varying in quality dictates adjustment of nitrogen (N) management. The response of bell pepper to a range of different concentrations of N and salinity (NaCl) was evaluated in soilless and field experiments under greenhouse conditions. Pepper plant biomass and yield increased with N and decreased with salinity. Chloride accumulated mainly in the stems and the fraction of Cl in leaves increased as a function of increased exposure to salinity. Increasing N application resulted in reduced Cl uptake and accumulation in pepper organs, including leaves and petioles. Although N significantly reduced Cl content and concentration in leaves and petioles it did not compensate for the negative effects of increasing salinity. This indicates that salinity itself and not Cl − N competition was the limiting factor affecting growth and yield.

1. Introduction

Recent increase in demand for agricultural products, combined with scarcity of fresh water has provided incentive for utilization of non-conventional water sources for irrigation (Yeo, 1999). Irrigation managers can alternatively utilize water containing high concentrations of salts (Beltrán, 1999) or desalinated water devoid of dissolved minerals (Yermiyahu et al., 2007). Both extremes are most likely to occur in water-scarce arid and semi-arid regions and both require specific management. Irrigation with water high in salts requires an increase in the irrigation volume in order to reduce the salt concentration from the active root zone (Ben-Gal et al., 2009). Desalinated water, whether used directly or incidentally, requires consideration of return of minerals that may otherwise not have needed to be fertilized (Yermiyahu et al., 2007).

Irrigation with desalinated water instead of water containing high concentrations of salts has economic and environmental beneficial aspects. Irrigation with desalinated water was found to increase maximum yields of bell peppers by 50% and allowed a reduction in irrigation water application rate by half compared to irrigation with local brackish groundwater (electrical conductivity ($EC = 3.2\ dS\ m^{-1}$) (Ben-Gal et al., 2009). The reduction in the required leaching fraction with the reduction in water salinity, is anticipated to reduce N leaching and enhance efficiency of N fertilization (Yasuor et al., 2013). Optimal N application strategies are expected to vary according to crop water requirements, water quality and irrigation method.

The interaction of N nutrition and salinity on plant development is still unclear. Shenker et al. (2003) reported that in sweet corn plants grown in lysimeters under low salinity ($EC = 0.5\ dS\ m^{-1}$) levels, leaf N concentration, N uptake, and yield increased with increased N fertilization. However, as salinity increased (EC from 2.5 to $7.5\ dS\ m^{-1}$) the uptake of N and its effect on corn plants decreased. Min et al. (2014) reported that cotton biomass, yield, evapotranspiration and water use efficiency decreased significantly when the salinity of irrigation water increased. This in spite of the fact that, regardless of irrigation salinity, the measured parameters increased as N application rate increased. The relative positive effects of N were reduced when the EC of the irrigation water was

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8.0 dS m^{-1} (Min et al., 2014). Chen et al. (2010) reported that, under low soil salinity (2.4 dS m^{-1} in saturated-paste extract), increasing the rate of N application significantly enhanced the N uptake of cotton plants grown in pots. However, under moderate and high soil salinity levels (7.7, 12.5, 17.1 dS m^{-1} in saturated-paste extract) total N uptake was not correlated with the N application treatment.

One of the ways that salinity affects plant response is due to the competition between specific ions resulting in differential uptake and possibly leading to mineral imbalances or deficiencies which might reduce crop growth (Bernstein et al., 1974; Grattan and Grieve 1992). Under conditions of salinity, N concentration in plant leaves has been shown to decrease due to increasing chloride (Cl) concentration in pepper (Cohen et al., 2003; De Pascale et al., 2003; Rubio et al., 2010), tomato (Kafkafi et al., 1982), lettuce and Chinese cabbage (Feigin et al., 1991). The repercussions of this competition are stronger in salt susceptible plants as compared to tolerant plants (Xu et al., 2000). Kafkafi et al. (1982) and Feigin et al. (1991) showed that increasing the nitrate (NO_3) concentration in the root medium led to a decrease of Cl uptake in tomato, lettuce, and Chinese cabbage plants.

Sweet bell pepper (*Capsicum annum* L.) production is commercially important in various regions of the world including Israel, Southern Europe and North Africa where the crop is grown from autumn to spring in greenhouses and net-houses. Such production in protective structures commonly yields seasonally more than 100 ton·ha^{-1} of high quality fruit (Bar-Tal et al., 2001; Ben-Gal et al., 2008; Yasuor et al., 2013). Peppers are considered to be sensitive to salinity (Maas, 1990), with a response function described by a threshold of saturated paste soil extract electrical conductivity (ECe) of 1.5 dS m^{-1} and a 14% decrease in biomass production for every additional 1 dS m^{-1} increase in ECe (Ben-Gal et al., 2008). Semiz et al. (2014) demonstrated that increasing irrigation water EC reduced pepper yield under both optimal (270 kg ha^{-1}) and sub-optimal N application (135 kg ha^{-1}). However, when plants were grown under sub-optimal N, pepper fruit was not affected by increased salinity levels up to 3.4 dS m^{-1}. These observations clearly demonstrate that when pepper plants face more than one stress causing factor, plant response is mainly affected by the most limiting factor (Shani et al., 2005; Yermiyahu et al., 2008).

Our driving hypothesis was that low salinity (desalinated) irrigation water would improve N uptake by crops leading to increased and improved yield. Contrarily, irrigation with water high in salts would reduce N uptake and decrease yield relative to low salinity irrigation water. Therefore, under high salinity plant response to N concentration in the irrigation water would be stronger than under low salinity.

The objectives of this study were to: 1) evaluate pepper response to different N levels under varied water salinity and 2) study the interactions between N and Cl uptake, accumulation and distribution in pepper plants.

2. Materials and methods

2.1. Description of study sites

Experiments on bell peppers (*Capsicum annum* L.) grown in containers in 2011 (Soilless 1 experiment) and 2012 (Soilless 2 experiment) were conducted in a 50-mesh screen house at the Gilat Research Center (31°20′N, 34°39′E), in Israel. A third experiment (field experiment), in a 25-mesh screen house, also investigating bell peppers, was conducted in soil during 2012 at the Central Arava R&D experimental station (30°46′N, 35°14′E), Israel. Soilless 1 and 2 experiments involved a summer cropping season while the field experiment was conducted in autumn-winter. In all three cases, the experimental design was complete randomized block, with nine treatments of three salinity levels (low, medium and high) and three N application levels (low, medium and high), replicated 5 times (Table 1). In all three experiments, irrigation water was applied at a rate designed to achieve a leaching fraction (drainage/irrigation) of 0.23. The rate of applied water therefore changed during the growing season according to plant development and weather conditions.

2.2. Description of the soilless experiments

Bell pepper plants (Rita, 7199, Zeraim Gedera, Israel) were grown over two seasons in 90 L styrofoam containers (18 cm high, 100 cm length and 50 cm width) filled with Perlite-206 (mean particle size 0.8 mm) (Agrikal Industries, Habonim, Israel). New perlite was used in both years. In the first experiment (Soilless 1), 30 day old seedlings were transplanted on May 29, 2011, grown for 165 days, and irrigated with desalinated water with uniform fertilization concentration for the following two weeks. Each of the 5 blocks contained three rows of containers. Initially, the plants were fertilized with liquid fertilizer (Shafir Gat fertilizers Ltd, Israel) in which N, K_2O, and P_2O_5 concentration was 6, 6, and 6%, respectively. This fertilizer was provided at a rate of 0.75 L m^{-3} in order to deliver N, K and P concentrations in irrigation water of 4.3, 1.2 and 0.84 mM, respectively. The fertilizer contained microelements (Gat fertilizers Ltd, Israel). After the first two weeks the N and salinity treatments were initiated. In second experiment (Soilless 2), the seedlings were transplanted on May 28, 2012 and grown for 142 days, the water quality treatments were initiated immediately thereafter with fertilizer concentration identical to that described for the Soilless 1 experiment. In both Soilless 1 and 2 experiments, the area of each plot was 3.4 m^2, replicated area was 10.2 m^2 and treatment area was 51 m^2. There were 6 plants per container in Soilless 1 and 5 in Soilless 2. The irrigation water for each treatment was prepared in a 1.5 m^3 tank and pumped daily to the containers via a drip irrigation system with inline 1.6 L h^{-1} drippers (Netafim, Tel-Aviv, Israel) spaced every 20 cm. Target salinity levels were reached by adding NaCl. Salts used to prepare the irrigation solutions were: KNO_3, $Ca(NO_3)_2$, KH_2PO_4, $MgSO_4$, $Mg(NO_3)_2$, and K_2SO_4. Microelements, Fe, Mn, Zn and Cu were given at concentrations of 0.02, 0.01, 0.004 and 0.0009 mM, respectively. The ratio of N—NH_4 to total N was 20, 10 and 5%, in the low, medium and high N treatments, respectively. The average concentrations in irrigation water of P, Ca, K, S and B were 0.42 ± 0.04, 1.30 ± 0.01, 4.1 ± 0.3, 0.86 ± 0.08 and 0.30 ± 0.05 mM, respectively. The pH of the fertigated water ranged between 6.0 and 6.5 in all treatments. Average and standard deviation of EC, and of N, Na, and Cl concentration in irrigation water over time are detailed in Table 1.

2.3. Description of the field experiment

Bell pepper seedlings (Canon, 7158, Zeraim Gedera, Israel) were planted on September 15, 2012, grown for 220 days in a sandy soil (93% sand, 3% silt and 4% clay) and irrigated with either desalinated water (EC ~ 1.0 dS m^{-1}, P, K, Ca, S and Mg concentrations were <0.03, <0.15, 1.57, 1.83, and 1.09 mM, respectively), local brackish water (~2.5 dS m^{-1}, P, K, Ca, S and Mg concentrations were <0.03, 0.37, 4.86, 6.49, and 4.44 mM, respectively), or local brackish water with addition of NaCl (~4.0 dS m^{-1}). Salts used to prepare the solutions were: NH_4NO_3, KNO_3, KH_2PO_4, $MgSO_4$, $NaNO_3$, and KCl. Micro-elements were added similarly to the soilless experiments. The N—NH_4 to total N ratio was 30% in all N treatments. The pH of the irrigation solutions ranged from 6.0 to 6.5 in all treatments. The average and standard deviation of EC and N, Na, and Cl concentration in irrigation water are detailed in Table 1. Plants were irrigated using a drip system consisting of laterals adjacent to each pepper row, with inline 1.6 L^{-1} h^{-1} drippers spaced every