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Irrigation water salinity influences at various growth stages of *Capsicum annuum*

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ABSTRACT

Availability of fresh surface water for irrigation is declining in southern New Mexico, and saline groundwater is increasingly used for irrigation. This study evaluates the effects of irrigation using saline water on the chile pepper plants. The chile pepper (*Capsicum annuum* L.) cultivars selected include, AZ 1904, NuMex Joe E. Parker, NuMex Sandia Select, LB 25, and 3441. Salt tolerance of these five cultivars was studied at various growth stages including germination, emergence, vegetative growth, flowering and fruiting stages in a greenhouse set up. The five saline treatments included for germination were tap water of EC 0.6 (control), well water of EC 3 and 6, and RO concentrate of EC 8 and 10 dS/m. During plant emergence and growth, natural water ECs for irrigation were 0.6 (control), 3, 5 and 8 dS/m. Increasing irrigation water salinity increased mean germination time but did not affect the final germination percentage. Increasing irrigation water salinity increased mean emergence time but the final percentage emergence was affected significantly only after EC ≥3 dS/m. Plant growth was significantly affected after several weeks of continuous exposure to saline water application (EC ≥3 dS/m). Increasing salinity decreased days to flowering, photosynthesis, stomatal conductance, relative fresh shoot and fruit weights, and water use efficiency. Results show that the selected chile pepper cultivars can be irrigated up to an irrigation water salinity level of ≤3 ds/m. Among all the cultivars, 3441 was found to be the most tolerant to salinity. Environmentally sound reuse of RO concentrate will encourage desalination in water scarce areas and greenhouse chile cultivation.

1. Introduction

Salinity and drought are two of the major abiotic stresses for crop production in many parts of the world including the southwestern United States. These regions are predominantly arid to semiarid and are affected by salinity due to low rainfall, high evapotranspiration and saline groundwater (Niu et al., 2010b). With the persistent drought in these regions, the surface water availability for irrigation has declined and groundwater is increasingly used by farmers for irrigation. About 75% of the available groundwater is saline, with an electrical conductivity >3 dS/m (Lansford et al., 1990; WRRI, 1997). Continuous application of saline water can lead to the buildup of salts near the soil surface. Consequently, osmotic potential and nutritional imbalance induce stress in plants and consequently adversely impact growth and yield (Ashraf and Wu, 1994; Singh et al., 2014); however, effects of salinity could be a function of the growth stages, species and variety of the plant (Botía et al., 1998).

The responses of crops to salinity often change from one development stage of growth to the next. Most crops show tolerance to salinity during germination with a delay in days to germination (Maas and Poss, 1989). Unlike germination however, most crops are susceptible during emergence and vegetative development as seedlings are subjected to water stress, varying salinities due to capillary rise and evaporation near the soil surface (Katerji et al., 1994; Pasternak et al., 1979). Plants become progressively more tolerant to salinity with maturity, especially at later stages of development (Lauchli and Epstein, 1990; Ashraf and Foolad,

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2007). However, the growth responses to salinity can differ within species. Like sugarbeet (*Beta vulgaris* L.), a crop known to be salt tolerant during later growth stages is fairly sensitive at germination stage (Jamil and Rha, 2004); and turnip (*Brassica campestris* L.) has salt tolerance at germination, but is more susceptible to salts at seedling growth (Francois, 1984). In addition, salinity induces early flowering in onion (*Allium cepa* L.), but it delays flowering of tomato (*Lycopersicon esculentum* L.) (Shannon and Grieve, 1998). Thus, there is variability of growth responses to salt stress within species and quantitative information available on salt tolerance at different growth stages for many of the species is meager.

Chile pepper is an important cash crop of Southwestern United States, with nearly 8000 to 10,000 acres harvested annually in New Mexico with a processed value estimated to be $500 million (Bosland and Walker, 2014). It has been classified as moderately sensitive to salinity with a threshold level of 1.5 dS/m, above which yield begins to decline (Maas and Hoffman, 1977). Some studies have reported that the seedling stage of chile pepper is more sensitive to salinity than germination (Chartzoulakis and Klapaki, 2000; Niu et al., 2010b). Introduction of salt tolerant genotypes could be an effective way to eliminate salinity effects for all crops including chile pepper. Limited studies have reported that some chile pepper genotypes are more salt tolerant than others (Aktas et al., 2006; Chartzoulakis and Klapaki, 2000; Niu et al., 2010a). Thus, it is necessary to examine the stress response of different varieties of chile pepper at various growth stages for sustaining crop production.

Salt components in the irrigation water can have a large variability across the globe. However, Na^+, Ca^{2+} and Mg^{2+} are dominant cations, and Cl^-, $SO_4{}^{2-}$ and $HCO_3{}^-$ are the dominant anions in most of the groundwater (Grattan and Grieve, 1998). To our knowledge, most of the saline studies conducted so far on peppers used NaCl either as sole or as dominant salinizing agent (Aktas et al., 2006; Chartzoulakis and Klapaki, 2000; Demir and Mavi, 2008; Niu et al., 2010a; Yildirim and Güvenç, 2006). Therefore, research on the use of natural brackish groundwater for irrigation is needed for sustaining chile pepper production in arid areas including the southwestern USA. Objectives of the study were to assess (1) the effect of saline groundwater irrigation at various growth stages of chile peppers; and (2) the relative salt tolerance of five chile peppers cultivars. This study was conducted in a greenhouse environment because there is a potential of greenhouse chile pepper production in New Mexico and New Mexico Department of Agriculture does not allow land application of water with EC >4 dS/m.

2. Materials and methods

This study was carried out in a greenhouse located at the Fabian Garcia Science Center of New Mexico State University (NMSU), Las Cruces, New Mexico (32.2805°N latitude and 106.770°W longitude at an elevation of 1186 m above sea level). The average air temperature in the greenhouse recorded during the entire experiment was 32.44 ± 0.16 °C during day and 24.22 ± 0.12 °C during night. Five chile pepper cultivars were selected for this study. NuMex Joe E. Parker and NuMex Sandia Select are NMSU cultivars. Seeds of the remaining three cultivars were obtained from various seed suppliers (AZ 1904 from Curry Chile and Seed, Pearce, AZ; LB25 from Biad Chile, Leasburg, NM; and 3441 from Olam, Las Cruces, NM). Natural saline well water and concentrate coming out of the reverse osmosis (RO) system were used for irrigation. Both well water and RO concentrate were provided by the Brackish Groundwater National Desalination Research Facility (BGRNDRF), Alamogordo, NM.

2.1. Germination experiment

A replicated germination experiment was conducted in petri dishes (100 mm diameter, 16 mm height). The salinity treatments consisted of five levels including tap water of EC 0.6 (control), well water of EC 3 and 6 and RO concentrate of EC 8 and 10 dS/m. In each petri dish four filter papers were placed and moistened with different levels of saline water, and excess water was drained. For each chile pepper cultivar, 25 seeds were placed on the moistened filter paper. Petri dishes were tightly sealed using parafilm to avoid evaporation. The experiment was conducted on a greenhouse bench and petri dishes were protected from direct sunlight by black shade cloth placed above the dishes so that air movement was not restricted. Based on the reduction in weight of petri dish, about 1 ml of tap water was added to each petri dish once every week to replenish the lost moisture. Seeds were considered germinated and removed once the length of the radicle surpassed the length of the seed. Ungerminated seeds remained in the dish until the conclusion of the study and their viability was determined using the imbibed crush test. The number of seeds germinated was counted daily and final germination was determined after 28 days. The experiment was a completely randomized design with four replications of each combination of treatments.

2.2. Emergence experiments

Replicated emergence experiments were conducted in the soil collected from the Fabian Garcia Science Center of NMSU (Table 1). Irrigation waters including, brackish well waters and RO concentrate, were collected once a month from BGNDRF and chemical analysis was performed (Table 2). Additionally greenhouse environmental parameters varied, therefore, two experiments for emergence were conducted simultaneously side by side in the greenhouse.

Soil was air dried, gently crushed, and sieved through a 4 mm sieve. Soil, sand, and organic peat were mixed thoroughly in the ratio 8:1:1 on a volume basis. Soil mix was sterilized in an oven at a temperature of 180° F for 30 min. Cylindrical pots of 6.5 cm diameter and 25 cm length were used in the experiment. The perforated bottom of each pot was covered with cheese cloth to prevent soil loss and gravel were placed on the bottom to allow free drainage. Packing of the soil was done in 5 cm depth increments to obtain a homogenous profile. Soil was washed three times with tap water to leach any pre-existing salts. Four natural water treatments selected for irrigation were: tap water of EC 0.6, well water of EC 3 and 5 and RO concentrate of EC 8 dS/m. Before sowing seeds, soil was irrigated twice with each of the water treatment to raise the soil salinity to the water treatment level. Sowing was done by placing four seeds of each chile pepper within a soil depth of 1–2 cm. Emergence was recorded at a two day intervals and final emergence was determined 35 days after sowing. Irrigation water treatments were

Table 1
Mean ± SE (standard error) for some of the physiochemical properties of soil used for experiments.

Sand (%)	Silt (%)	Clay (%)	BD (g/cm^3)	Cations (meq/L)			SAR	pH	EC (dS/m)
				Mg	Ca	Na			
78.70 ± 0.09	11.00 ± 0.12	10.30 ± 0.03	1.36 ± 0.01	1.38 ± 0.22	2.75 ± 0.09	4.88 ± 0.19	3.41 ± 0.01	7.80 ± 0.03	0.87 ± 0.02

BD: Bulk Density, SAR: sodium adsorption ratio, EC: electrical conductivity.