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Response of Two Jerusalem Artichoke (*Helianthus tuberosus*) Cultivars Differing in Tolerance to Salt Treatment*[1]

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ABSTRACT

To explore genetic variability for two Jerusalem artichoke (*Helianthus tuberosus*) cultivars, N1 (the sixth-generation cultivated with 75% seawater irrigation for six years) and N7 (a general variety), a experiment was conducted to study the changes in physiological attributes under different concentrations (0%, 10% and 25% of seawater concentration in greenhouse and 0%, 30% and 50% of seawater concentration in the field) of seawater salinity stress. In the greenhouse experiment, decreases of dry growth rate, but increases of dry matter percentage and membrane injury occurred in both the genotypes at 10% and 25% seawater treatments, although lesser cell membrane damage was observed in N1 than N7. N1 accumulated greater contents of Na^+, Cl^-, soluble sugar and proline in leaves compared with N7. In the field experiment, the yields of shoot, root and tuber, and the contents of total-sugar and inulin in tubers of N1 were higher than those of N7. Lesser degree of salt injury in N1 indicated that the relatively salt-tolerant cultivar had higher K^+/Na^+ ratio, lower Na^+/Ca^{2+} ratio, and the salt-induced enhancement of osmotic adjustment.

Key Words: cell membrane stability, genetic variabilities, inorganic ions, malondialdehyde, seawater salinity stress

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INTRODUCTION

World faces the progressive depletion of its energetic resources mainly based on non-renewable fuels (Sánchez and Cardona, 2008). The solution to this problem depends on how to develop and implement the technologies based on alternative sources of energy. Ethanol (ethyl alcohol, bioethanol) is the most employed liquid biofuel either as a fuel or as a gasoline enhancer. The fuel ethanol can be obtained from energy crops and lignocellulosic biomass (Dai *et al.*, 2006). As the needs for food of human and animals grow, the crops such as corn, switch grass, sugar cane or sorghum have no prominence for fuel ethanol production (Kim *et al.*, 1998). Jarusalem artichoke (*Helianthus tuberosus*) is a salt- as well as drought-tolerant species that is easily grown in saline and alkaline soils. It is mainly considered as a biomass crop for ethanol production because it commonly yields around 7 and potentially up to 14 t ha^{-1} of carbohydrate (Denoroy, 1996). Other industrial uses of the crop are paper pulp or fuelwood from stems, methane from various parts, acetone-butanol-ethanol production from tubers or whole plant, and hydroxymethylfurfural as a basic molecule for the chemical industry (Hay and Offer, 1992; Denoroy, 1996). It is also used as anti-erosion protection to fix terraces and unstable sand, or as a barrier against fire in large forests (Hay and Offer, 1992; Liu *et al.*, 2008).

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To avoid the competition of biofuel production with nutrition for humans and animals, it is useful to find new sites for the production, such as coastal and semi-arid areas. An estimate shows that about one-thirds of irrigation lands are either saline or alkaline (Jin *et al.*, 2007). The deleterious effects of salinity on plant growth are associated with low osmotic potential of soil solution, nutritional imbalance, specific ion effect, or a combination of these factors (Ashraf and Harris, 2004). At present most of research about salt stress focus on the plants under short-term salt stress. The results showed that membrane disorganization, photosynthetic performance and substantial reduction occur, and activated oxygen species production and metabolic toxicity increase under salt stress (Sudhakar *et al.*, 2001; Yazici *et al.*, 2007; López-Climent *et al.*, 2008; Arfan, 2009). Water and osmotic potential in *Halopyrum mucronatum* increased with the increase of salinity while turgor decreased (Khan *et al.*, 1999). Osmotic adjustment in plants subjected to salt stress can occur by the accumulation of high concentrations of either inorganic ions or low molecular weight organic solutes (Bayuelo-Jiménez *et al.*, 2003). However, there are few reports under short-term salt stress in greenhouse and long-term salt stress in tidal flat, especially about *H. tuberosus*. In this study two *H. tuberosus* cultivars, N1 (the sixth-generation cultivated with 75% seawater irrigation for six years) and N7 (a general variety), were used to explore genetic variability to saline environment both in the greenhouse and field conditions.

MATERIALS AND METHODS

Experimental design

Two *H. tuberosus* cultivars, N1 and N7, were obtained from Shandong Medium Examination Base of Beach Agriculture Academe, Nanjing Agricultural University of China. Tuber slices with buds of N1 and N7 were surface sterilized with 1.0 g L^{-1} $HgCl_2$ for 10 min, rinsed thoroughly with distilled water, and germinated on moist sand in an incubator at 25 °C. Uniformly germinated slices were selected, sown in plastic containers filled with quartz sand, grown in the greenhouse and watered with half-strength Hoagland nutrient solution. After emergence of third leaf, slices of uniform size were planted into plastic pots fitted with insulated covers. Each pot was covered with a polyethylene lid through which plants were supported over the nutrient solution. The pot contained 400 mL of half-strength Hoagland nutrient solution, which was aerated for 8 h daily and renewed every other day. Daily photoperiod was 12 h at photon flux density of 390–410 μmol m^{-2} s^{-1} and maximum/minimum temperature was 25/15 °C. The relative humidity was 60%–70%. Dried seawater salt was added to the half-strength Hoagland's nutrient solution after the sixth leaf emerged out. Three treatments with twelve replicates were established including 0%, 10% and 25% seawater addition. The crude salt was produced by evaporation from seawater in Laizhou Bay. Basic ions in seawater main include HCO_3^- 0.13 g L^{-1}, Cl^- 17.52 g L^{-1}, SO_4^{2-} 3.87 g L^{-1}, Ca^{2+} 0.79 g L^{-1}, Mg^{2+} 1.03 g L^{-1}, K^+ 0.60 g L^{-1}, and Na^+ 9.48 g L^{-1}. The electrical conductivities (EC) of the 0%, 10% and 25% seawater were 0.002, 5.88 and 10.44 dS m^{-1}, respectively. The experiment was performed in two separate sets; one was used to study the growth and ion contents of the plants and second one was analyzed for organic solutes, malondialdehyde (MDA) and electrolytic leakage. All treatments were replicated nine times in each study set. Three replicate plants were harvested 2, 4, and 6 days after treatment for analyses.

The field experiment was carried out at Laizhou Agricultural Research Station, 18 km north to Laizhou City and 3 km from the seashore in Shangdong Province of China (37° 38′ N, 119° 38′ E). Some of the physical and chemical characteristics of the soil are given in Table I. Plot size was 5 m in length and 4 m in width, isolated with thick plastic membranes to avoid saline water seepage during irrigation. The soil was ploughed in winter using a conventional mould board plough, besides, tilled twice more prior to broadcasting *H. tuberosus* tubers. A complete randomized block split plot factorial experiment with six replications was carried out in 2005 growing season using three treatments (irrigation with well water alone, a 7:3 and a 1:1 mixture of well water and seawater, respectively, *i.e.*, 0%, 30% and 50% of seawater concentration). Basic ions in well water mainly include 0.63 g L^{-1} HCO_3^-, 1.21 g L^{-1} SO_4^{2-},