Aerial Biomass and Elemental Changes in *Atriplex canescens* and *A. acanthocarpa* as Affected by Salinity and Soil Water Availability

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Abstract—*Atriplex canescens* and *A. acanthocarpa* from the Chihuahuan Desert in México were subjected to different salinity and irrigation treatments in a greenhouse study. Plants were grown in pots containing soil and irrigated with NaCl solutions of 0, 50, and 100 mM at 40 and 80 percent available soil water. Aerial biomass of *A. canescens* declined as NaCl treatments increased. In contrast, the aerial biomass of *A. acanthocarpa* was not negatively affected by the salinity treatments, suggesting a high salt tolerance of this species. Aerial biomass of *A. acanthocarpa* was more reduced by the decrease in irrigation level than that of *A. canescens*. *A. acanthocarpa* had a much higher accumulation of Na in leaf tissues throughout the salinity gradient than *A. canescens*. Tissue concentration of K in both species was minimally affected by the salinity or irrigation treatments. Leaf N concentration increased in both species as plants were subjected to higher salinity treatments. The higher salt tolerance and higher Na absorption of *A. acanthocarpa* favor the use of this plant in reclamation of saline areas, while the low Na accumulation of *A. canescens* makes this species an attractive forage in saline rangelands.

Plants of the genus *Atriplex* are considered xero-halophytes for their ability to grow in dry and saline areas, which allows them to succeed in many disturbed environments (Osmond and others 1980). This characteristic makes *Atriplex* spp. suitable plants for reclamation of highly disturbed areas (Booth 1985). Some species of *Atriplex* are appreciated as forage for livestock and wildlife since their nutritive value is fairly high and their foliage is evergreen (Garza and Fulbright 1988). The high biomass productivity of *Atriplex* has motivated researchers to investigate the feasibility of cultivating some species under seawater irrigation (O'Leary and others 1985).

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A. canescens is the most widely distributed *Atriplex* species in North America and its ecophysiological characteristics, forage potential and genetic diversity have been extensively studied (Glenn and others 1996; Cibils and others 1998). *A. acanthocarpa* is a native shrub to North America, has potential for revegetation in saline rangelands, and is considered a good forage for cattle and deer (Garza and Fulbright 1988). However, this species has received little attention from researchers and very little is known about its salt tolerance and ecophysiological characteristics.

It is important to study the salt tolerance characteristics of halophytes because it could help to understand the potential utilization value of these plants and their ecological adaptations. The present study was an attempt to evaluate the effect of salinity and soil water availability on aerial biomass and leaf concentration of Na, K, and N of *A. canescens* and *A. acanthocarpa*. We hypothesized that increasing salinity levels has a negative effect on aerial biomass production of both species. The second hypothesis was that elemental changes are related to the characteristics of salt tolerance of these species.

Materials and Methods

This study was conducted in a greenhouse located in the Unidad Regional Universitaria de Zonas Aridas, Universidad Autónoma Chapingo, Bermejillo, Durango, México, in 1988. Seeds of *Atriplex canescens* and *A. acanthocarpa* were collected from native populations near San Luis Potosí City and Viesca, Coahuila, respectively. In April, seeds of both species were soaked with distilled water, changing the water daily, during 4 days. Subsequently, seeds were sown in germinating trays filled with a mixture of river sand (60 percent) and soil (40 percent) and irrigated with water from local municipal supply. Seedlings emerged within 3 weeks, and 8 weeks after sowing, one plant of each species was transplanted to 36 pots of approximately 3.5 L volume.

Pots contained a clay loam soil with low electrical conductivity (2 dS m^{-1}) from Rancho El Cono, Salinas de Hidalgo, San Luis Potosí. After plant establishment, plants of both species were watered twice a week with solutions of 0, 50, and 100 mM NaCl and maintained gravimetrically to either 40 or 80 percent available soil water. These treatments were applied during 4 months. In October, the aerial part of the plants were harvested, oven-dried and weighed to measure

dry matter production. The leaves were separated and ground to determine K and Na by flame emission with a Varian AA-1275 atomic absorption spectrophotometer. Total Kjeldahl N was determined in leaves as outlined by Bremner and Mulvaney (1982). The completely randomized design was used in this experiment. The data were subjected to analysis of variance, and mean separation tests at $P < 0.05$ (protected Fisher's LSD) were performed with a Statistical Analysis System (SAS) computer program.

Results

Aerial biomass of *A. canescens* declined as NaCl concentration in the irrigation solution increased (fig. 1). A decrease of 37 percent in dry weight was observed in plants as NaCl concentration increased from 0 to 100 mM. In contrast, *A. acanthocarpa* did not show significant changes in aerial biomass as a result of the salinity treatments (fig. 1). Aerial biomass of *A. acanthocarpa* declined 20 percent in plants irrigated at 40 percent available soil water compared to plants irrigated at 80 percent available soil water (fig. 2). On the other hand, the decrease in water availability did not produce significant changes in the aerial biomass of *A. canescenes* (fig. 2).

A low concentration of Na in leaves of both species was observed in plants irrigated with 0 mM NaCl solutions and increased in plants irrigated with 50 and 100 mM NaCl solutions (fig. 3). A proportion of 1:2.4:2.7 reflected the variation in leaf Na concentration of *A. canescens* irrigated with solutions of 0, 50, and 100 mM NaCl, respectively. In *A. acanthocarpa* the proportion of change was 1:2.1:2.3 (fig. 3). Although leaf Na concentration was similarly affected by salinity in both species, the Na concentration was much higher in *A. acanthocarpa* than in *A. canescens* regardless of the salinity level (fig. 3). The concentration of K was very similar in both species and it was not affected by the salinity treatments (fig. 4). Irrigation treatments did not exert a significant effect on leaf Na and K concentrations in any species.

Salinity and irrigation treatments interacted to determine the variation of N concentration in leaves of *A. canescens*. Plants irrigated at 40 percent available soil water had higher N concentration than plants irrigated at 80 percent available soil water when NaCl concentrations in the irrigation solution were 0 and 50 mM (fig. 5). However, plants irrigated with solutions of 100 mM NaCl did not show variations in N concentration due to changes in available soil water. Regardless of the irrigation treatments, there was a tendency to increase leaf N concentration as salinity levels increased (fig. 5). Leaf N concentration in *A. acanthocarpa* was higher in plants irrigated with solutions of 100 mM NaCl than in plants irrigated with solutions of 0 and 50 mM NaCl (fig. 6). Irrigation treatments did not produce significant changes in leaf N concentration of *A. acanthocarpa*.

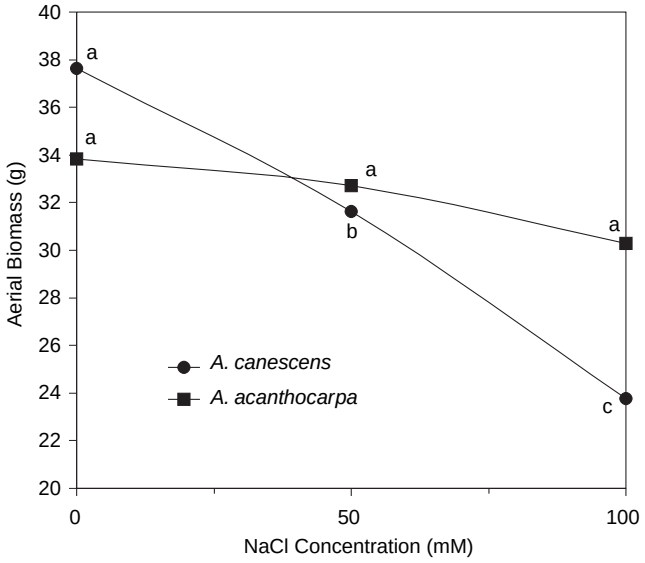

Figure 1—Aerial biomass (g) of *Atriplex canescens* and *Atriplex acanthocarpa* as affected by NaCl concentration in the irrigation solution (means with the same letter are not significantly different at $P > 0.05$).

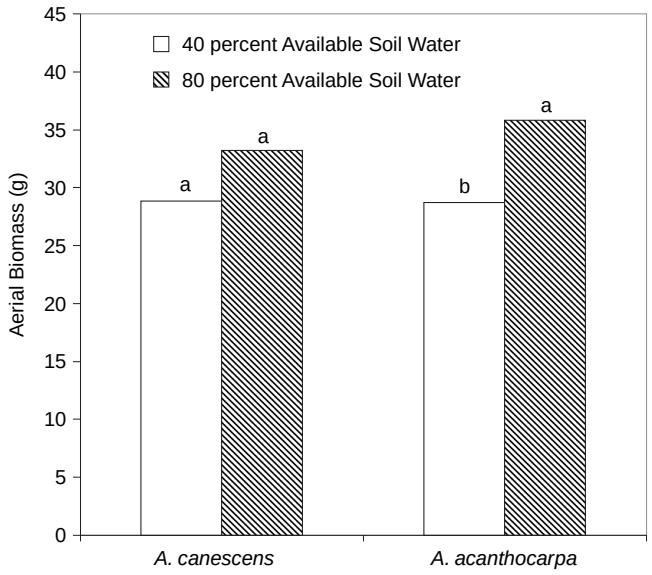

Figure 2—Aerial biomass (g) of *Atriplex canescens* and *Atriplex acanthocarpa* as affected by available soil water (means with the same letter are not significantly different at $P > 0.05$).

Discussion

The decline observed in shoot growth of *A canescens* as salinity levels increased has been previously observed (Glenn and others 1994; Glenn and others 1996). The apparent high salt tolerance of *A. acanthocarpa* has not been previously reported but seems to be similar to that of *Atriplex amnicola*, a halophyte that shows growth reduction only when the salinity of the irrigation solution surpasses 100 mM (El-Haddad and O'Leary 1994). *A. acanthocarpa* seemed to be more tolerant to salinity but less tolerant to drought than *A. canescens*. In agreement with this, Wilkins and Klopateck (1984) found that *A. canescens* had higher drought tolerance than several other native shrubs in Arizona.

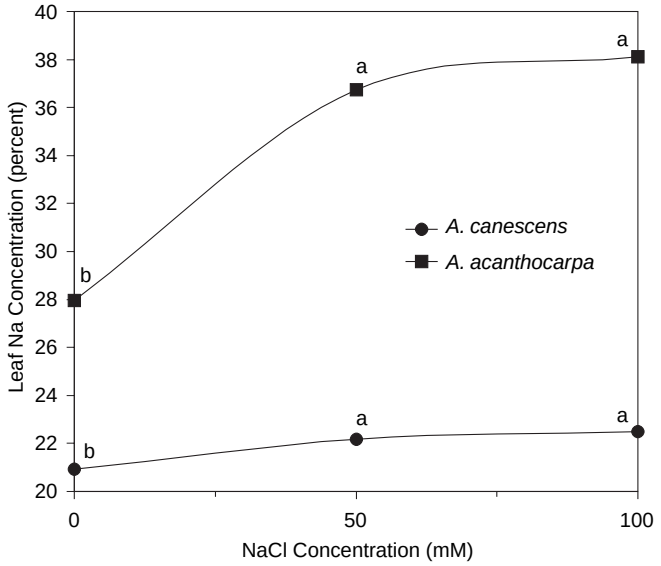

Figure 3—Leaf Na concentration (percent) of *Atriplex canescens* and *Atriplex acanthocarpa* as affected by NaCl concentration in the irrigation solution (means with the same letter are not significantly different at P > 0.05).

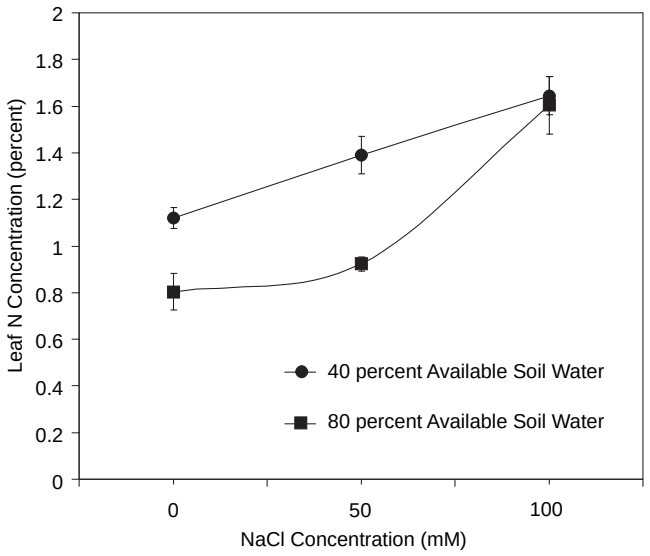

Figure 5—Leaf N concentration (percent) (± 1 SE) of *Atriplex canescens* as affected by NaCl concentration in the irrigation solution and soil water availability.

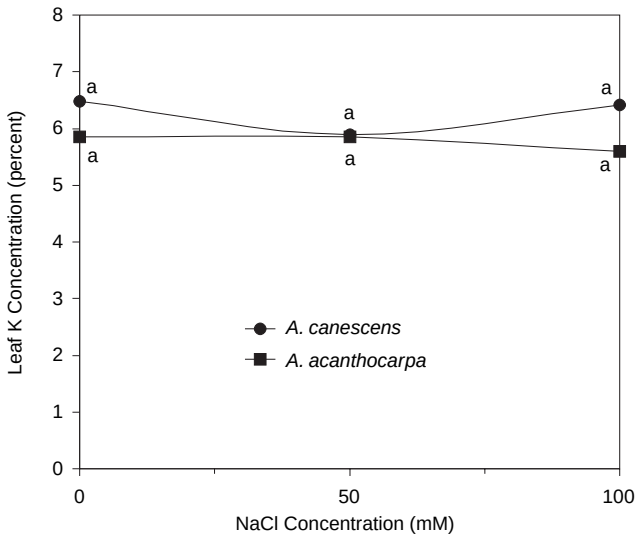

Figure 4—Leaf K concentration (percent) of *Atriplex canescens* and *Atriplex acanthocarpa* as affected by NaCl concentration in the irrigation solution (means with the same letter are not significantly different at P > 0.05).

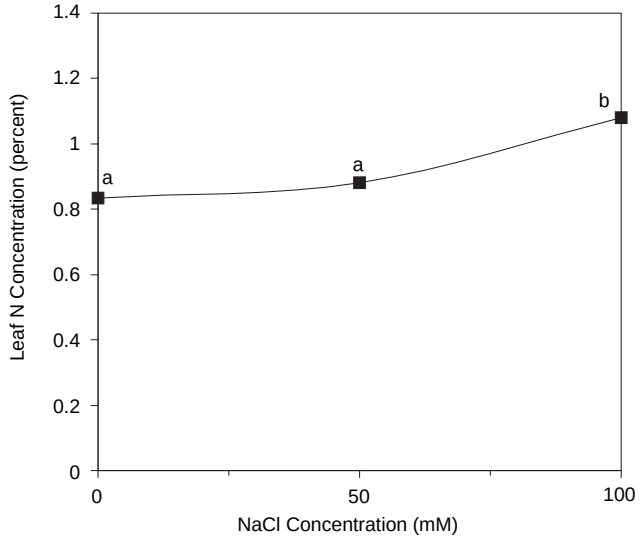

Figure 6—Leaf N concentration (percent) of *Atriplex acanthocarpa* as affected by NaCl concentration in the irrigation solution (means with the same letter are not significantly different at P > 0.05).

Na accumulation increased in *A. canescens* and *A. acanthocarpa* as plants faced increasing salinity levels. This response has been previously reported in *A. canescens* (Glenn and others 1996) and seems to be a typical response in halophytes. Presumably, Na accumulation contributes to decrease leaf osmotic potential in response to salinity increases in the root medium (El-Haddad and O'Leary 1994). However, Na levels in leaves of *A. canescens* were much lower than Na levels in leaves of *A. acanthocarpa* irrespective of the salinity treatments. These results agree with those of Garza and Fulbright (1988). Other studies have shown that under low salinity in the root medium *A. canescens* tends to have lower Na levels in leaves (Wallace and others 1973; Khalil and others 1986), but higher Na levels in roots (Wallace and others 1973) than other *Atriplex* species.

According to Glenn and others (1994) Na is the main cation involved in the osmotic adjustment of *A. canescens*. However, compared to other *Atriplex* species, *A. canescens* seems to exclude Na from the leaves, as many crop plants do to avoid Na damage to leaf tissues (Yeo and Flowers 1986). The low Na accumulation in leaves of *A. canescens* is considered a reason for its high forage value (Wallace and others 1973), but this feature might be also associated with characteristics of low salt tolerance (Glenn and others 1994, 1996). In agreement with this, results of this study showed that *A. canescens* had lower salt tolerance and lower leaf Na levels than *A. acanthocarpa*. The higher salt tolerance and Na uptake of *A. acanthocarpa* make this species a viable candidate for reclamation of disturbed saline areas.

Leaf K concentration in both species remained very stable and was not affected by salinity or irrigation treatments. K is an essential nutrient for plants and its absorption, even under salinity stress, must be maintained under acceptable levels for plant survival (Grattan and Grieve 1992). K and Na uptake by roots are competitive processes, but roots have higher affinity for K than for Na absorption. This characteristic is particularly important in saline soils where Na is much more available than K for plant uptake (Grattan and Grieve 1992).

Leaf N concentration tended to increase in both species as plants faced increasingly high salinity levels, although the effect was more clearly expressed in *A. canescens* than in *A. acanthocarpa*. This result could be partly a consequence of the reduction in aerial biomass caused by salinity stress. Pessarakli and others (1989) reported an increase of N concentration and a dramatic decrease in dry matter yield in salinized corn compared to control plants. Presumably, salinity reduced dry matter yield more than N absorption causing an increase in the concentration of N in leaves. A similar effect was found in red kidney beans subjected to salt and water stresses (Frota and Tucker 1978). In *A. canescens* the low irrigation level also caused increases in N concentration compared to the high irrigation level under low and intermediate salinity treatments. Apparently water stress caused similar effects than salt stress reducing aerial biomass more than N absorption.

Conclusions

Our results supported the hypothesis that increasing salinity levels causes a decline in aerial biomass but only for *A. canescens*. The salinity levels tested in this experiment were not clearly deleterious for *A. acanthocarpa*, which makes it a more salt tolerant species than *A. canescens*. On the other hand, *A. canescens* was more tolerant to drought than *A. acanthocarpa*. The higher salt tolerance of *A. acanthocarpa* corresponded with a high capacity to accumulate Na ions in its leaves compared to *A. canescens*. This supported our second hypothesis. N concentration increased as salinity stress increased in both species, but more evidently in *A. canescens*, perhaps because N absorption was less affected by salinity than plant growth.

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