Salinity Tolerance of *Lupinus havardii* and *Lupinus texensis*

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**Abstract.** Use of recycled water to irrigate urban landscapes and nursery plants may be inevitable as fresh water supplies diminish and populations continue to grow in the arid and semiarid southwestern United States. *Lupinus havardii* Wats. (Big Bend bluebonnet) has potential as a cut flower and *Lupinus texensis* Hook. (Texas bluebonnet) as a bedding plant, but little information is available on salt tolerance of these species. A greenhouse study was conducted to characterize the growth in response to various salinity levels. Plants were grown in 10-L containers and drip-irrigated with synthesized saline solutions at electrical conductivity levels of 1.6, 3.7, 5.7, 7.6, or 9.4 dS m\(^{-1}\). Although shoot growth of *L. texensis* was reduced as salinity levels increased, it was visually acceptable (without any visual injury) when irrigated with salinity levels of less than 7.6 dS m\(^{-1}\). All plants survived at 7.6 dS m\(^{-1}\), whereas only 15% died at 9.4 dS m\(^{-1}\). In contrast, *L. havardii* had leaf injury at 5.7 dS m\(^{-1}\). No plants survived at 9.4 dS m\(^{-1}\), and only 7% plants survived at 7.6 dS m\(^{-1}\). In addition, growth of *L. havardii* was significantly reduced and plants were shorter at elevated salinity levels. Cut raceme yield of *L. havardii* decreased at salinity levels greater than 3.7 dS m\(^{-1}\). However, no difference in cut raceme yield was observed between the control and 3.7 dS m\(^{-1}\), although shoot growth was reduced. Overall, *L. texensis* was more salt-tolerant than *L. havardii*.

Because fresh water supplies are limited in many parts of the world, using alternative water sources for irrigating horticultural crops may become necessary. Alternative water sources (hereafter called nonpotable water) include recycled water, treated municipal effluent (reclaimed water) and brackish ground water, which generally contain higher levels of salts compared with potable water. Previous research has demonstrated the possibility of using nonpotable water for irrigating high-value horticultural crops (Grieve et al., 2005, 2006; Shannon et al., 2000; Shillo et al., 2002) and for landscape irrigation (Devitt et al., 2005; Marosz, 2004; Niu and Rodriguez, 2006a, 2006b; Wu et al., 2001). For landscape plants, maximizing growth is not essential and indeed, excessive shoot vigor is often undesirable. To maintain a compact growth habit, ornamental plants traditionally have either been pruned or treated with growth regulators (Cameron et al., 2004). Therefore, nonpotable water may play an important role for landscape irrigation where potable water supply is limited. Salinity stress in some instances has positive effects on crop yield and quality in some floricultural crops (Grieve et al., 2006). For example, number of flowers, stem weight, and stem diameter of lisanthuses were increased when salinity stress was imposed during the final stage of vegetative growth compared with the control (Shillo et al., 2002). Salinity stress during early reproductive stage resulted in shorter, more robust pedunules with larger inflorescences in carnation (Baas et al., 1995).

*Lupinus havardii* is an annual native to a narrow geographic range along the Rio Grande River in southwest Texas and has shown potential to be grown as a specialty cut flower (Davis et al., 1994; Piccioni et al., 2001). It has fragrant and attractive blue racemes with a length of 40 to 55 cm supporting 25 to 30 fully opened flowers (Mackay and Davis, 1998). In Texas, *L. texensis* is a hardy winter annual and is the best-known, most widely distributed member of the *Lupinus* genus (Davis et al., 1994). Transplants of *L. texensis* are produced for spring and fall sales, but those grown during late summer and early fall are the best for garden performance in warmer regions in the United States (Davis et al., 1994). There is no information available on the impact of saline irrigation on the growth and development of these two species. The objectives of this study were to determine the salinity threshold for marketable production of *L. havardii* and *L. texensis* and assess the effects of increasing levels of salinity on growth of these species.

Materials and Methods

**Plant materials and cultural conditions.** Seeds of *L. havardii* and *L. texensis* were obtained from a nursery (Plants of the Southwest, Albuquerque, N.M.), scarified with concentrated sulfuric acid for 90 min for *L. havardii* and 45 min for *L. texensis*, and sowed in a greenhouse on 10 Jan. in plug trays (85 cm\(^2\) per cell) filled with a mix consisting of equal parts of vermiculite, peat, and perlite on a volume basis. Seedlings were transplanted on 1 Mar. to 10-L containers filled with Metromix 200 (Scotts Co., Marysville, Ohio). Plants were drip-irrigated as needed, based on container weight, with a nutrient solution containing 0.5 g L\(^{-1}\) of 20N–8.6P–16.7K (Peters 20–20–20; Scotts, Allentown, PA). The air temperature in the greenhouse was 18 to 24 °C during the day and 12 to 14 °C at night during the experimental period. The daily light integral (photosynthetically active radiation) was 10 to 20 mol m\(^{-2}\)d\(^{-1}\) measured by a quantum sensor (Model Q50-SUN; Apogee Instruments, Logan, Utah). A 21X datalogger (Campbell Scientific, Logan, Utah) was used to measure temperature and light at 10-s intervals and the hourly averages were recorded.

**Treatments.** Saline solutions were prepared by adding sodium chloride (NaCl), magnesium sulfate (MgSO\(_4\)·7H\(_2\)O), and calcium chloride (CaCl\(_2\)) at 87%, 8%, and 5% (by weight), respectively, to the nutrient solution mentioned previously to simulate the salt composition in reclaimed municipal effluent discharged by the local water utility. Five salinity levels of 1.6 (nutrient solution, control), 3.7, 5.7, 7.6, or 9.4 dS m\(^{-1}\) electrical conductivity (EC) were created, and saline irrigation was initiated on 9 Mar. and ended on 24 May (11 weeks). There were 15 plants per treatment for each species, which were randomly placed on greenhouse benches. Five magnetic drive pumps (Model 3-MD-MT-HIC: Little Giant Co., Oklahoma City, Okla.) were used to pump the nutrient or saline solutions to each container through a...
Results

After 11 weeks of treatment, *L. havardii* had leaf injuries at salinity levels 5.7 dS·m⁻¹ or greater. The 7.6 dS·m⁻¹ and 9.4 dS·m⁻¹ salinity treatments had 7% and 0% survival rates, respectively. Plants had similar visual appearance and no differences were found in cut raceme yield between the control (1.6 dS·m⁻¹) and 3.7 dS·m⁻¹ (Fig. 1). In contrast, *L. texensis* were visually acceptable (without any injuries) when irrigated at salinity up to 7.6 dS·m⁻¹ with a 100% survival rate at 7.6 dS·m⁻¹ and 15% at 9.4 dS·m⁻¹. Shoot growth of both species decreased as salinity levels increased, but the reduction at 5.7 dS·m⁻¹ and 7.6 dS·m⁻¹ was more severe in *L. havardii* than *L. texensis*. Similar observations were noted as growth index decreased with increasing salinity levels for both species. Number of flowers and visual quality in *L. texensis* were similar at salinity up to 5.7 dS·m⁻¹.

Shoot Na concentrations in *L. havardii* were significantly higher in salinity treatments 3.7 dS·m⁻¹ or greater compared with the control (Fig. 2). Shoot Cl concentrations in *L. havardii* was similar among 3.7, 5.7, and 7.6 dS·m⁻¹ and was ≈5 times higher than in the control. In *L. texensis*, shoot Na concentration was higher at 7.6 dS·m⁻¹ than the control, but there were no differences among 1.6, 3.7, and 5.7 dS·m⁻¹ or among 3.7, 5.7, and 7.6 dS·m⁻¹. Shoot Cl concentrations in *L. texensis* at 3.7 dS·m⁻¹ and 5.7 dS·m⁻¹ were different from the control and 7.6 dS·m⁻¹. Shoot Na and Cl increased to their maximum level at 3.7 dS·m⁻¹ for *L. havardii* but increased incrementally for *L. texensis* with increasing salinity. Decrease in ψₛ followed the same trend. Species main effect was not significant for shoot Na or Cl concentrations or ψₛ.

Discussion

For cut flower growers, producing high-quality flowers with an adequate cut length is important. In this study, we found that flower yield and quality (quantified by raceme length) were similar when irrigated with nutrient solution at 1.6 dS·m⁻¹ (control) and 3.7 dS·m⁻¹. The average EC of municipal reclaimed water is ≈2.0 dS·m⁻¹ depending on region or water source (Khurram and Miyamoto, 2005; Wu et al., 2001). This may indicate the possibility of using reclaimed water or other saline water to produce *L. havardii* cut flowers with little or no reduction in yield and quality as long as...
The salinity of irrigation water is below 3.7 dS m⁻¹ and well-drained medium is used. Carter et al. (2005) found that saline waters dominated by sulfate and chloride salts at salinity up to 8 dS m⁻¹ or higher may be used commercially to produce cut flowers of Celosia argentea (L.) Kuntze. Beneficial effects of using saline water for irrigation were also reported in lisianthus (Shillo et al., 2002) and carnation (Baas et al., 1995). Salt tolerance and threshold for producing quality cut flowers varied with plant species (Shillo et al., 2002). The slight reduction in shoot growth incited by elevated salinity at 3.7 dS m⁻¹ did not have a significant impact on yield.

Because L. texensis is used as a bedding plant, both growth rate and aesthetic appearance are important for bedding plant growers. Any delay in growth or visual damage may affect profit. Because the reduction in shoot growth is not commercially significant, this species can be produced using saline water at EC of up to 5.7 dS m⁻¹. After installation in the landscape, visual appearance is more important than growth rate. In fact, for landscape use, a smaller or compact container plant is more preferred than a larger one if attractiveness is similar. In a landscape environment, slower growth is more desirable from a ground maintenance point of view. Therefore, non-potable water at moderate salinity levels may be used as natural growth regulators to control the excessive growth or elongation.

Some species tolerate salt stress by avoiding taking up certain types of ions or by tolerating high ion concentrations in the tissue. Wu et al. (2001) found that salt-tolerant plants tended to accumulate less salt in leaf tissue than less salt-tolerant plants, and a wide range of salt tolerance was found among the 10 landscape plant species examined. The small differences in salt tolerance between the two species in this study may be attributable to their uptake of Na and Cl ions. For example, shoot Na and Cl concentrations at 3.7 dS m⁻¹ and 5.7 dS m⁻¹ were higher in L. havardii than L. texensis. This may be why the ψₚ were lower in L. havardii than L. texensis at 3.7 and 5.7 dS m⁻¹.

In summary, shoot growth in both species were reduced at elevated salinity levels. The threshold of salinity for producing marketable flowers of L. havardii is 3.7 dS m⁻¹ with slight reduction in shoot growth and no visual injury. Although shoot growth in L. texensis was also reduced, there was no visible injury at salinity up to 5.7 dS m⁻¹, and more plants in L. texensis survived at higher salinity (7.6 dS m⁻¹ and 9.4 dS m⁻¹) than L. havardii. Therefore, L. texensis was more salt-tolerant than L. havardii and the threshold for irrigation may be up to 5.7 dS m⁻¹ with no visual injury.

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