Response of *Sophora secundiflora* to Nitrogen Form and Rate

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Abstract. Texas mountain laurel (*Sophora secundiflora*) is a native shrub tolerating drought, heat, windy conditions, and alkaline or wet soils. However, its availability is somewhat low and little information is available on nutrient requirement and other culture information. Two greenhouse experiments were conducted to quantify the responses of Texas mountain laurel to different forms and rates of nitrogen (N) fertilizer. In Expt. 1, 1-year old seedlings were treated for 194 days with three NO₃:NH₄ ratios at 25:75, 50:50, and 75:25 and two rates of N at 100 and 200 mg·L⁻¹ in a factorial design. There was no interaction between the N rate and form on any growth parameters. Nitrogen form did not significantly affect shoot dry weight, root dry weight, root-to-shoot ratio, or the total dry weight. There was no significant difference between N rate of 100 and 200 mg·L⁻¹ on root dry weight, root-to-shoot ratio, or the total dry weight. The shoot dry weight of Texas mountain laurel fertilized with 100 mg·L⁻¹ was higher compared with that of the plants fertilized at 200 mg·L⁻¹. The reduced shoot dry weight at N of 200 mg·L⁻¹ was the result of the higher substrate salinity. In Expt. 2, seedlings were fertilized with five N rates (50, 100, 150, 200, and 250 mg·L⁻¹) for 203 days. Plants watered with 150, 200, and 250 mg·L⁻¹ were taller than those fertilized with 50 mg·L⁻¹. The shoot height of plants watered with 100 mg·L⁻¹ was only significantly different from 50 mg·L⁻¹. For rapid growth of Texas mountain laurel, a N rate range of ≈150 mg·L⁻¹ was recommended supplied with a combination of NO₃-N and NH₄-N in the ratios of 0.3 to 3.0.

Texas mountain laurel (*Sophora secundiflora*), also called mescal bean, is a small evergreen tree native to Texas, New Mexico, and north Mexico. Its ornamental characteristics include terminal racemes of fragrant, violet-blue flowers in the spring followed by bright red seeds. Texas mountain laurel is adapted to xeric conditions (Still and Davies, 1993). Containerized Texas mountain laurel plants watered less frequently maintained similar root dry weight, shoot fresh weight, plant mortality, shoot height, the number of stems, and visual rating as those watered more frequently (Reider, 1987). It is considered an excellent landscape plant for the Southwestern states (Gilman and Watson, 1994; Ruter and Ingram, 1991); however, it has not been widely available from the nursery industry. There is little research-based information for Texas mountain laurel regarding its culture information, especially nutrient requirement.

Nitrogen is a key nutrient in manipulating plant growth and N is normally supplied to plants in the form of urea [CO(NH₂)₂] and two major inorganic forms of N including nitrate (NO₃⁻) and ammonium (NH₄⁺). Studies on many crops indicated that plants fed

with a combination of NO₃-N and NH₄-N had better growth and/or yield responses than plants fed solely on NO₃-N or NH₄-N (Bernardo et al., 1984; Cao and Tibbitts, 1992; Gamiely et al., 1991; Kafkafi, 1990; Santamaria and Elia, 1997). However, some plants have no preference on NO₃-N and NH₄-N. Total dry mass was unaffected when purslane plants were grown in a closed hydroponic system supplied with 200 mg·L⁻¹ N at various NO₃:NH₄ ratios of 1:0, 0.25:0.75, 0.5:0.5, or 0.75:0.25 (Palaniswamy et al., 1997). Some plants have different preferences for NO₃-N and NH₄-N. Bar-Tal et al. (2001a, 2001b) found that the optimum NO₃:NH₄ ratio for maximal stem dry matter production was 3.5 and pepper fruit dry matter production, the total yield, and high quality fruit yield increased with increasing NO₃:NH₄ ratio between 0.25 and 4. On the other hand, a 1:3 ratio yielded the greatest shoot fresh and dry weight, plant diameter, and the number of flower buds per plant in impatiens when N was supplied at a concentration greater than 10.5 mmol·L⁻¹ (Romero et al., 2004). Mesquite seedlings produced the greatest biomass after 120 d fertigation with a solution of 33:67 NO₃:NH₄ compared with NO₃:NH₄ ratios of 100:0, 67:33, or 0:100 (Hahne and Schuch, 2006). The objectives of this study were to investigate the effects of different ratios of NO₃:NH₄ (different N forms) on growth of Texas mountain laurel at two N rates

and to determine the optimal N rate by irrigating them with five levels of N rates.

Materials and Methods

Plant materials. In Expt. 1, seeds of Texas mountain laurel were collected from the trees in the Texas AgriLife Research Center's demonstration garden. Seeds treated with concentrated sulfuric acid for 30 min were sown on 20 Nov. 2006 in plug cells (63 mL) filled with a germination mix of perlite, vermiculite, and peatmoss at 1:1:1 (by vol.). Seedlings were transplanted on 17 Jan. 2007 to 1.8-L pots containing Sunshine mix No. 4 (SunGro Hort., Bellevue, WA) and composted mulch (Western Organics, Inc., Tempe, AZ) at 1:1 (by vol.) amended with 5 kg·m⁻³ dolomitic limestone (Carl Pool Earth-Safe Organics, Gladewater, TX) and 1 kg·m⁻³ Micromax (Scotts, Marysville, OH). From early May to mid-Sept. 2007, plants were grown in a shade-house with 25% light exclusion. On 2 Oct. 2007, plants were transplanted to 2.6-L pots containing the same substrate as that in 1.8-L pots and were grown in the greenhouse. In Expt. 2, seeds of Texas mountain laurel were sowed on 12 Dec. 2007. Germinated seedlings were transplanted to 15-cm pots on 10 Feb. 2008 and then to 2.6-L pots on 21 Sept. 2008. Seedlings were grown in the greenhouse under similar conditions as in Expt. 1.

Experimental design. In Expt. 1, six treatments were created consisting of three ratios of NO₃:NH₄ (25:75, 50:50, 75:25) and two rates of N (100 mg·L⁻¹ and 200 mg·L⁻¹) in a factorial design with 10 replications. The nutrient solutions were prepared by adding fertilizers KH₂PO₄, KNO₃, NH₄NO₃, (NH₄)₂SO₄, and K₂SO₄ to tap water following the composition shown in Table 1. The nutrient solutions had the same level of K⁺ and PO₄³⁻ and different ratios of NO₃:NH₄ at 25:75, 50:50, and 75:25, respectively (Table 1). The major ions in the tap water were Na⁺, Ca²⁺, Mg²⁺, Cl⁻, and SO₄²⁻ at 184, 52.0, 7.5, 223.6, and 105.6 mg·L⁻¹, respectively. The micronutrients were provided through incorporating Micromax into the substrate as described previously. The nutrient solutions were prepared in 100-L tanks and plants were hand-watered at 1 L per pot whenever the substrate surface started to dry to prevent water stress and overwatering. The leaching fraction was initially low (less than 15%) and later increased to ≈25%. Pots were rotated weekly within the greenhouse benches to minimize the differences in environmental conditions. Treatments were initiated on 6 Nov. 2007 and ended on 9 May 2008. The average daily air temperatures in the greenhouse for Expt. 1 were maintained at 23 ± 3 °C (mean ± SD) and the daily light integral [photosynthetically active radiation (PAR)] was 15 ± 5 mol·m⁻²·d⁻¹. A 21× data logger (Campbell Scientific, Logan, UT) was used to measure temperature and light every 10 s and record the hourly and daily average.

In Expt. 2, nutrient solutions with five N rates (50, 100, 150, 200, and 250 mg·L⁻¹) were prepared by adding water-soluble fertilizer 20N–8.6P–16.7K (Peters 20–20–20;

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Table 1. Fertilizer and nutrient composition of irrigation solution of the three nitrogen forms (Expt. 1).

Ratios of NO ₃ :NH ₄	Fertilizer composition (mm)				
	KH ₂ PO ₄	KNO ₃	NH ₄ NO ₃	(NH ₄) ₂ SO ₄	K ₂ SO ₄
25:75	0.25	0.5	0	0.75	0.5
50:50	0.25	1	1	0	0.25
75:25	0.25	1.5	0	0.25	0

	Nutrient composition (mm)				
	NH ₄ ⁺	NO ₃ ⁻	K ⁺	SO ₄ ²⁻	PO ₄ ³⁻
25:75	1.5	0.5	1.75	1.25	0.25
50:50	1	1	1.75	0.25	0.25
75:25	0.5	1.5	1.75	0.25	0.25

Scotts, Allentown, PA) to tap water at 0.25, 0.5, 0.75, 1.0, and 1.25 g·L⁻¹, respectively. The replication number was 10. Solutions were pre-mixed in 100-L tanks and plants were hand-watered as in Expt. 1 but with high leaching fraction from the beginning to prevent salt accumulation. Treatments were initiated on 15 Oct. 2008 and ended 6 May 2009. The greenhouse air temperatures were maintained at 23.5 ± 2.1 °C (mean ± SD) and the daily light integral (PAR) was 13 ± 4.9 mol·m⁻²·d⁻¹.

Measurement. In Expt. 1, on termination, plant height, the number of shoots, and the total length of shoots were recorded. Shoot dry weight (DW) was determined after oven-drying at 70 °C to constant weight. Leachate was collected four times for electrical conductivity (EC) and pH measurement during the course of the experiment. On 28 Apr. [173 d after treatment (DAT)], all containers were flushed with tap water to leach out the accumulated salts in the substrates as reflected by the increasing ECs of the leachate. At the end of the experiment, leaf greenness or relative chlorophyll concentration (measured as the optical density, SPAD reading, an acronym of Soil and Plant Analyzer Development) was recorded on two fully expanded young leaves per plant for all plants in each treatment using a portable SPAD chlorophyll meter (SPAD-502; Minolta Camera Co., Osaka, Japan). Although SPAD readings do not give an absolute measure of chlorophyll concentration, they do provide a useful relative index, which is closely related to leaf chlorophyll concentration (Markwell et al., 1995; Wang et al., 2005).

Leaf net photosynthesis (P_n), transpiration (E), and stomatal conductance (g_s) were measured on four plants per treatment in the final week of the experiment by placing the recently matured leaf in the cuvette of a portable gas exchange system (CIRAS-2; PP Systems, Amesbury, MA). The environmental conditions in the cuvette were controlled at leaf temperature = 25 °C, photosynthetic photon flux = 1000 μmol·m⁻²·s⁻¹, and CO₂ concentration = 400 μmol·mol⁻¹. Data were recorded when the environmental conditions and gas exchange parameters in the cuvette became stable. These measurements were taken between 1000 HR and 1200 HR.

In Expt. 2, plant height was recorded periodically during the course of the experiment. On termination, plants were destructively harvested. Shoots and roots were separated. Dry weights of shoots and roots were deter-

mined by oven-drying at 70 °C to constant weight. One week before ending the experiment, leaf greenness was measured using a SPAD meter as described in Expt. 1. Leaf conductance was measured using a leaf porometer (Decagon Devices, Pullman, WA). Leachate was collected periodically for EC and pH measurement during the course of the experiment. On 3 Mar. (138 DAT) and 15 Apr. (181 DAT), containers with leachate EC higher than 3.0 dS·m⁻¹ were flushed with tap water to leach out the accumulated salts in the substrates to minimize the salinity effect because growth of Texas mountain laurel was reduced at EC of 3.0 dS·m⁻¹ or higher (Niu et al., 2010).

To analyze leaf N concentration for experiments, leaves were separated from stems and four leaf samples were randomly chosen from the 10 plants at the end of the experiment, washed three times with deionized water, and oven-dried at 70 °C. Dried leaves were ground to pass a 40-mesh screen with a stainless steel Wiley mill. Ground samples were submitted to the Soil, Water, and Air Testing Laboratory of New Mexico State University (Las Cruces, NM) for total Kjeldahl N analysis.

Statistical analysis. A two-way analysis of variance using PROC GLM was performed for Expt. 1. When the interaction between the N rate and form was not significant, data were pooled to compare the main factors. For Expt. 2, linear or quadratic regression was performed and the significance was analyzed using PROC REG. To distinguish the differences among the N rates and forms for both experiments, Student-Newman-Keuls multiple comparison was performed. All data were analyzed using SAS software (Version 9.1.3; SAS Institute Inc., Cary, NC).

Results

Plant growth and tissue nitrogen concentration. In Expt. 1, there was no interaction between the N form and rate on any growth parameter and N form did not significantly affect growth either. Therefore, the effect of N rate on shoot dry weight, root dry weight, root-to-shoot ratio, and the total dry weight were pooled from N forms (Table 2). The shoot dry weight of Texas mountain laurel treated with 100 mg·L⁻¹ was higher than that treated with 200 mg·L⁻¹.

Nitrogen rate did not affect the N concentrations in leaves, stems, or roots and therefore the effect of N form was presented (Table 3). The N concentration of stems was 22%

Table 2. Dry weights of shoots, roots and total of Texas mountain laurel as affected by nitrogen (N) rates (Expt. 1).^z

N rate	Shoot (mg·L ⁻¹)	Root (g)	Shoot(g)	Total (g)
N 100	30.7	11.6	0.42	42.3
N 200	24.4	10.6	0.45	35.0
t test	*y	NS	NS	NS

^zData were pooled from three nitrogen forms.

*y indicates significance by t test at P = 0.05.

NS = non-significant.

Table 3. Total nitrogen (N) concentrations of Texas mountain laurel in leaf, stem, and root as affected by N rate and form (Expt. 1).

N form (NO ₃ :NH ₄)	Leaf (%)	Stem (%)	Root (%)
25:75	3.4 a ^z	1.5 b	2.2 a
50:50	2.9 a	1.4 b	2.2 a
75:25	2.8 a	1.8 a	2.0 a

^zMeans with same letters within the same column are not significantly different at P = 0.05 tested by Student-Newman-Keuls multiple comparison.

higher in the NO₃:NH₄ of 75:25 than those in the other two forms. Although not significant, leaf N concentration was numerically lower in the NO₃:NH₄ of 25:75 compared with the other two forms.

In Expt. 2, on 86 DAT, Texas mountain laurels watered with 200 and 250 mg·L⁻¹ N were taller than those watered with 50 and 100 mg·L⁻¹ N (Table 4). Plants watered with 150, 200, and 250 mg·L⁻¹ N were taller on 133, 154, 184, and 205 DAT compared with the plants watered at 50 mg·L⁻¹ N. The shoot height of plants watered with 100 mg·L⁻¹ N was only significantly different from 50 mg·L⁻¹ N on 205 DAT. Although not significant, plants watered with 200 mg·L⁻¹ N had numerically longer shoot heights on 133, 154, 184, and 205 DAT than 250 mg·L⁻¹ N. There were both linear and quadratic relations between plant shoot height and the N rate of the irrigation solution 86, 133, 154, 184, and 205 DAT.

Plants watered with 150 and 200 mg·L⁻¹ N had similar final shoot and root dry weight (Table 5). Plants had lower shoot dry weight but similar root dry weight when watered with 250 mg·L⁻¹ N compared with 200 mg·L⁻¹ N. The root-to-shoot ratio (R/S) was higher in plants watered with 50 mg·L⁻¹ N compared with other N rates. However, leaf N concentration was lower in plants watered with 50 mg·L⁻¹ N compared with other N rates. Shoot DW, root DW, R/S, and leaf N concentration had significant linear and quadratic relationships as N rate increased. Shoot DW started to decrease as N rate increased from 200 to 250 mg·L⁻¹. Although not statistically significantly, leaf N concentration tended to decrease as N rate increased from 100 mg·L⁻¹.

Leachate electrical conductivity and pH. In Expt. 1, plants watered with 200 mg·L⁻¹ N had higher leachate EC than those watered with 100 mg·L⁻¹ N regardless of NO₃:NH₄ ratio from 105 to 184 DAT (Fig. 1A). The leachate EC was 4.2, 3.3, and 3.3 dS·m⁻¹ for

100 mg·L⁻¹ N with NO₃:NH₄ ratios of 25:75, 50:50, and 75:25, respectively, on 105 DAT. Plants in the 200 mg·L⁻¹ N treatments had EC at least 2.0 dS·m⁻¹ higher than their 100 mg·L⁻¹ N counterparts, respectively. All plants had higher EC on 132 DAT, and EC in 200 mg·L⁻¹ N at 50:50 NO₃:NH₄ ratio was 8.4 dS·m⁻¹. After all the containers were flushed with tap water on 174 DAT, all the ECs decreased below their respective level on 105 DAT except 100 mg·L⁻¹ N at 50:50 NO₃:NH₄ ratio. EC values of different treatments on 184 DAT were close to their values on 174 DAT, respectively.

Plants treated with 100 mg·L⁻¹ N with NO₃:NH₄ ratios of 75:25 had the highest leachate pH on 105, 132, 174, and 184 DAT and plants treated with 200 mg·L⁻¹ N with NO₃:NH₄ ratios of 50:50 and 25:75 had the lowest pH on 132, 174, and 184 DAT (Fig. 1B). The pH of the leachate was between 6.5 and 7.5 for all treatments on 105 DAT and 132 DAT. After all the containers were flushed with tap water on 174 DAT, leachate pH of 100 mg·L⁻¹ N at 75:25 NO₃:NH₄ ratio increased to 7.7, whereas 200 mg·L⁻¹ N at 25:75 NO₃:NH₄ and 50:50 NO₃:NH₄ decreased to 5.9 and 6.4, respectively.

In Expt. 2, leachate EC of all treatments was between 1.4 dS·m⁻¹ and 3.1 dS·m⁻¹ from 15 Oct. 2008 (0 DAT) to 9 Feb. 2009 (117 DAT) (Fig. 2). The leachate ECs of all treatments except for 50 mg·L⁻¹ N increased and were in the range between 2.8 dS·m⁻¹ and 5.8 dS·m⁻¹ on 138 DAT, and containers were flushed with tap water on 138 DAT and 151 DAT to lower the EC of all treatments. pH of all treatments was between 6.4 and 7.7 from 0 DAT to 117 DAT (Fig. 2). The pH of all treatments except for 50 mg·L⁻¹ N 50 decreased to below 6.5 on 138 DAT. The pH of all treatments decreased again to a range between 6.0 and 6.7 on 198 DAT.

Gas exchanges and SPAD. There was no interaction between the N rate and form in SPAD readings. The N form only had a significant effect on SPAD reading, so the *t* test was used to separate the difference between the two N rates in all the other measurements. Transpiration, *g*_s, and *P*_n of Texas mountain laurel treated with 100 mg·L⁻¹ N were significantly higher than the ones treated with the 200 mg·L⁻¹ N rate (Table 6).

Both N rate and N form had a significant effect on SPAD reading. The SPAD reading of Texas mountain laurel treated with 100 mg·L⁻¹ N was 66.3, which was significantly higher than those treated with 200 mg·L⁻¹ N (56.2) (Table 7). There was no significant difference on SPAD reading between Texas mountain laurel treated with 25:75 (NO₃:NH₄) and 50:50 (NO₃:NH₄). The SPAD reading was significantly lower in Texas mountain laurel treated with 75:25 (NO₃:NH₄).

Discussion

The effect of NO₃:NH₄ ratio and the N form on plant growth and physiological response depends on species. Growth (shoot dry weight, root dry weight, R/S, and the total

Table 4. Plant shoot height of Texas mountain laurel as affected by nitrogen (N) rates (Expt. 2) on 5, 86, 133, 154, 184, and 205 d after treatment initiation (DAT), respectively.

N rate (mg·L ⁻¹)	Plant shoot ht (cm)					
	5 DAT	86 DAT	133 DAT	154 DAT	184 DAT	205 DAT
50	7.8	7.7 b ²	9.2 b	9.9 b	11.0 c	12.8 c
100	7.7	7.7 b	9.9 b	13.0 ab	16.0 bc	18.3 b
150	7.5	9.2 ab	13.3 a	16.2 a	22.6 a	23.1 ab
200	7.6	11.3 a	16.6 a	17.1 a	26.1 a	28.5 a
250	7.5	11.3 a	15.5 a	16.8 a	21.3 ab	23.0 ab
Significance of regression						
Linear	NS ³	***	***	***	***	***
Quadratic	NS	***	***	***	***	***

²Means with same letters within the same column are not significantly different at *P* = 0.05 tested by Student-Newman-Keuls multiple comparison.

³NS indicates non-significant at *P* = 0.05 and *** indicates significance at *P* = 0.001.

Table 5. Shoot and root dry weight (DW), root-to-shoot ratio (R/S), and the total nitrogen concentration (leaf N) in leaves of Texas mountain laurel watered with different nitrogen rate (Expt. 2).

Nitrogen rate (mg·L ⁻¹)	Shoot DW (g)	Root DW (g)	R/S (%)	Leaf N
50	3.99 d ²	3.26 b	0.85 a	2.11 b
100	7.14 dc	3.27 b	0.47 b	3.24 a
150	11.81 ab	4.33 ab	0.39 b	3.02 a
200	14.90 a	5.28 a	0.38 b	2.94 a
250	10.38 bc	5.13 a	0.56 b	2.76 a
Significance				
Linear	*** ³	***	***	***
Quadratic	***	***	***	***

²Means with same letters within the same column are not significantly different at *P* = 0.05 tested by Student-Newman-Keuls multiple comparison.

³***Significant at *P* = 0.001.

Fig. 1. Leachate electrical conductivity (EC) and pH of Texas mountain laurel measured on 105, 132, 174, and 184 d after treatment (DAT) as affected by nitrogen rate and form (Expt. 1). Vertical bars represent SES (n = 4).

Fig. 2. Time course of leachate electrical conductivity (EC) and pH of Texas mountain laurel plants irrigated at five nitrogen rates (Expt. 2). Containers were flushed with tap water on 3 Mar. [138 d after treatment (DAT)] and 15 Apr. (181 DAT) when leachate EC were higher than 3.0 dS·m⁻¹. Vertical bars represent SES (n = 4).

Table 6. Transpiration (E), stomatal conductance (g_s), and net photosynthesis (P_n) of Texas mountain laurel treated with 100 mg·L⁻¹ (N 100) and 200 mg·L⁻¹ (N 200) nitrogen rates (Expt. 1).

N rate	E	g _s	P _n
N 100	1.77	101.75	8.14
N 200	1.46	76.17	6.88
t test	**	*	*

**Significance by t test at P = 0.05.

Table 7. SPAD readings of Texas mountain laurel as affected by nitrogen (N) rate and form (Expt. 1).

N rate	SPAD
Nitrogen rate	
N 100	66.3 a ^z
N 200	56.2 b
Nitrogen form (NO ₃ :NH ₄)	
25:75	64.9 a
50:50	65.0 a
75:25	54.7 b

^zMeans followed by the same letter within each section are not significantly different at P = 0.05 tested by Student-Newman-Keuls multiple comparison.

dry weight) and gas exchange (E, g_s, and P_n) of Texas mountain laurel were unaffected by the NO₃:NH₄ ratios investigated in the study (25:75, 50:50, and 75:25) when N was applied at 100 mg·L⁻¹ or 200 mg·L⁻¹. The total dry weight of hydroponically grown purslane (Palaniswamy et al., 1997) and growth, flower

yield, and quality of greenhouse-grown 'Royalty' rose (Cabrera et al., 1996) and 'Bridal Pink' rose (Cabrera, 2001) were also unaffected by the ratio of NO₃:NH₄.

The effect of N form on total N concentrations in plant tissue is also species-dependent. Shoot N concentrations of three ornamental woody shrubs, *Cotoneaster dammeri* 'Royal Beauty', *Pyracantha coccinea* 'Wyatti', and *Weigela florida*, were higher when NH₄-N was applied compared with NO₃-N (Guillam et al., 1980). Research on dieffenbachia (Becker et al., 2008), rose (Cabrera et al., 1996), and pepper (Bar-Tal et al., 2001a) found that N uptake was improved and N concentration was higher in plants supplied with NH₄-N. In Texas mountain laurel, although not significant, leaf N concentrations tended to be higher in the NO₃:NH₄ of 25:75, whereas stem N concentration was higher in the NO₃:NH₄ of 75:25. However, the stem N concentrations were ≈50% those in the leaves. The different NO₃:NH₄ also had an effect on SPAD readings with higher SPAD readings correlated with a higher percentage of NH₄-N in the solution.

Irrigating container plants at optimal fertilizer rate is important. Applying a less than optimal amount usually reduces plant growth and affects plant quality, whereas applying higher than the optimal rate is not only a waste of resources, but also leads to the possibility of increased fertilizer runoff and pollution of environment of soil and water.

Wu et al. (2008) reported that the growth of *Sophora davidii* seedlings, a perennial shrub native to China and widely distributed in dry valleys, performed better with a low N rate (92 mg·kg⁻¹) soil compared with no N supply or a high rate of 184 mg·kg⁻¹ irrigated with three water supply regimes (80%, 40%, and 20% field water capacity). Similar to *S. davidii*, Texas mountain laurel is also adapted to dry regions. Cabrera (2003) reported that maximum dry weight yields for *Ilex opaca* 'Hedgeholly' and *Lagerstroemia* × 'Tonto' plants were observed at leaf N concentrations of 2.53% and 2.65%, respectively, and their shoot dry biomass and leaf area increased significantly with applied N concentrations up to 60 mg·L⁻¹, but higher levels caused significant reductions in these parameters. The optimal N rate may be related to growth habit or rapid or slow growth. For *Boronia* (*Boronia megastigma*), an Australian woody shrub, increasing N levels from 0 to 350 mg·L⁻¹ in the nutrient solution increased production of nodes, later shoots from these nodes, and further nodes on these lateral shoots (Reddy and Menary, 1989).

Higher N rate application may cause salt accumulation in the root zone. Plants supplied with 200 mg·L⁻¹ N had leachate EC in the 4.2 dS·m⁻¹ to 8.4 dS·m⁻¹ range, which on average was 2.3 dS·m⁻¹ higher than plants supplied with 100 mg·L⁻¹ N. The leachate EC levels of both 100 mg·L⁻¹ N and 200 mg·L⁻¹ N treatments were substantially higher than the rates recommended for best management practices for container-grown plants (Yeager, 2000). Niu et al. (2010) reported that the growth and gas exchange rates of Texas mountain laurel were reduced when salinity of irrigation water was 3.0 dS·m⁻¹ (with leachate salinity of 4 to 9 dS·m⁻¹) or higher compared with salinity of irrigation water at 1.6 dS·m⁻¹ (control), although no visual foliar salt damage was observed. The lower gas exchange rates, shoot dry weight, and SPAD reading observed in plants watered with 200 mg·L⁻¹ N was obviously the result of higher root zone EC compared 100 mg·L⁻¹ N. The salinity in the root zone in Expt. 2 was closely monitored and controlled and there was significant growth enhancement when N rate was increased from 100 to 200 mg·L⁻¹. The optimal N rate for Texas mountain laurel should be determined primarily based on the results in Expt. 2.

In summary, both N form (NO₃:NH₄ of 25:75, 50:50, 75:25) and rate (100 and 200 mg·L⁻¹) did not interactively affect Texas mountain laurel in any growth parameter, gas exchange and leachate salinity, and pH. Shoot growth was reduced by the higher N rate (200 mg·L⁻¹) compared with 100 mg·L⁻¹, which was the result of the higher substrate salinity as reflected in high leachate salinity. Nitrogen form did not affect any growth parameter. Lower N rate (0 to 100 mg·L⁻¹) resulted in slower growth compared with higher rates. The optimal N rate range is ≈150 mg·L⁻¹ for rapid growth of Texas mountain laurel, which can be supplied by a combination of NO₃-N and NH₄-N.

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