Leaching Fraction and Fertilization Effects on Growth of Three Woody Legumes Inoculated with Rhizobia

William R. Graves, Sandra R. Anfinson, and Kathryn K. Lappegard
Department of Horticulture, Iowa State University, Ames, IA 50011-1100

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Abstract. Scotch laburnum [*Laburnum alpinum* (Mill.) Bercht.], Amur maackia [*Maackia amurensis* Rupr. & Maxim.], and Chinese wisteria [*Wisteria sinensis* (Sims) Sweet] were inoculated with compatible rhizobia and treated with leaching fractions (LF) of 0, 0.2, and 0.4 using fertilizer solutions with 3.6 and 10.7 mol N/m³ for 10 weeks. LF did not affect plant dry mass, leaf area, or stem length. Growth was higher among plants provided 10.7 mol N/m³, but only plants provided 3.6 mol N/m³ formed root nodules. We conclude that growth is not reduced by eliminating leaching during the first 10 weeks of seedling development, and that application of 10.7 mol N/m³ prevents nodulation of these species.

Reducing leaching fractions (LF) minimizes irrigation runoff but may curtail growth of salt-sensitive plants, particularly if high fertilizer concentrations are applied (Ku and Hershey, 1992; Yelanich and Biernbaum, 1990, 1993). Inoculation with rhizobia might substitute for N applied during production of some crops, but effects of LF and N on root nodulation of many nursery crops are not known. Our objective was to determine the effect of 0, 0.2, and 0.4 LF imposed using solutions containing 3.6 and 10.7 mol N/m³ on growth of Scotch laburnum, Amur maackia, and Chinese wisteria inoculated with rhizobia.

Materials and Methods

Scarified seeds of Scotch laburnum and Amur maackia were sown on 18 May 1993, and unscarified seeds of Chinese wisteria on 21 May, in flats with 1 perlite : 1 sphagnum peat (v/v). Flats were kept in a glasshouse with natural radiation and irrigated daily with tap water.

Twenty-four seedlings of each species were planted singly in 1840-ml plastic pots (15 cm in diameter) (Belden Plastics, St. Paul, Minn.) on 14 June (block 1) and 15 June (block 2) using a commercial medium (Fisons Special Blend #1 Mix; Fisons, Warwick, N.Y.) of 5 sphagnum peat : 4 composted pine bark : 1 perlite (by volume). Plastic screen was placed over drainage holes to prevent loss of medium. Before planting, 550 ml distilled water was

applied to each pot three times, decreasing the electrical conductivity (EC) of leachate from ≈ 2.7 to ≈ 0.7 dS·m⁻¹. While planting, 1.5 ml of liquid rhizobial culture with $\approx 10^8$ cells/ml (Batzli et al., 1992) was placed in each planting hole. For Amur maackia, USDA 4349 (*Rhizobium* Culture Collection, Beltsville, Md.) was used. Equal volumes of USDA 3104 and 3105 were used for Chinese wisteria. TAL 1262 (NifTAL, Univ. of Hawaii, Paia) was used for Scotch laburnum.

Pots were arranged on a glasshouse bench in a randomized complete-block design. Within both blocks, four pots with each species were assigned to a 3 × 2 factorial of treatments. There were three LF treatments (0, 0.2, and 0.4) and two fertilizer solution treatments (3.6 and 10.7 mol N/m³) prepared with tap water (pH = 9.1, EC = 0.4 dS·m⁻¹, alkalinity = 58 mg·liter⁻¹) and a commercial 21N–2.2P–16.6K fertilizer (Peters Excel All Purpose; Grace-Sierra, Milpitas, Calif.). Solution pH was adjusted to between 6.0 and 6.6 by adding sulfuric acid. After planting, pots were brought to container capacity by irrigating with 300 ml of

the appropriate solution. Initial mass of pots at container capacity was determined after they drained for 1 h.

Irrigations were performed each Monday and Thursday (block 1) or Tuesday and Friday (block 2). The volume of solution to apply to achieve the proper LF was determined for each pot as described by Ku and Hershey (1992). Treatments were maintained for 10 weeks. Maximum radiation intensity during treatments was 510 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (400–700 nm), and the air ranged from 18 to 34°C.

Plants were harvested on 23 (block 1) or 24 (block 2) Aug. Length of stems ≥ 3 cm long was measured. Leaf surface area was determined using a LI-COR 3100 area meter (LI-COR, Lincoln, Neb.). EC of a complete vertical core sample of medium from pots with Chinese wisteria, the species that received the most irrigation solution, was estimated (Bunt, 1988). Roots were separated from the medium and assessed visually for nodulation. Dry mass of shoots and roots was determined after tissues were held at 67°C for 2 days. The influence of LF, fertilizer, and their interaction on the dependent variables was evaluated by using analysis of variance. In no case was the interaction significant ($P \leq 0.05$), so only means of main effects will be presented.

Results and Discussion

The total volume of solution applied to the three species to provide 3.6 mol N/m³ ranged from (milliliters) 19,970 to 21,410; 27,160 to 29,730; and 35,650 to 42,050 for plants in the 0, 0.2, and 0.4 LF treatments, respectively. For plants given 10.7 mol N/m³, 26,040 to 28,340 ml; 32,900 to 34,390 ml; and 46,010 to 49,580 ml were applied to plants in the 0, 0.2, and 0.4 LF treatments, respectively. The actual LF (total volume of leachate/total volume applied) averaged over species and N treatments for plants in LF 0.2 and 0.4 was 0.12 and 0.33, respectively. Using similar methods with florist crops, Ku and Hershey (1991, 1992) also found actual LF to be less than predicted LF. Differences between actual and predicted LF might be minimized by considering plant mass

Table 1. Influence of leaching fractions (LF) and rate of applied N on growth of containerized seedlings of Amur maackia, Scotch laburnum, and Chinese wisteria. LF values are means of 16 replicate plants at both N rates. Nitrogen rate values are means of 24 replications at three LF. LSD values are for the $P = 0.05$ level.

Species and dependent variable	Leaching fraction				N rate applied (mol·m ⁻³)		
	0	0.2	0.4	LSD	3.6	10.7	LSD
Amur maackia							
Root dry mass (g)	0.9	0.8	0.9	0.2	0.6	1.2	0.2
Shoot dry mass (g)	2.4	2.4	2.6	0.6	1.3	3.6	0.5
Leaf area (cm ²)	416	478	499	132	253	676	108
Stem length (cm)	23.6	24.3	24.5	5.8	17.9	30.4	4.7
Scotch laburnum							
Root dry mass (g)	0.8	0.9	1.0	0.3	0.7	1.1	0.2
Shoot dry mass (g)	2.0	2.4	2.5	0.8	1.2	3.3	0.7
Leaf area (cm ²)	288	319	352	135	201	438	110
Stem length (cm)	29.0	32.1	30.1	9.7	19.8	41.0	7.9
Chinese wisteria							
Root dry mass (g)	1.3	1.4	1.6	0.4	1.0	1.9	0.4
Shoot dry mass (g)	3.9	3.8	4.2	1.1	1.7	6.1	0.9
Leaf area (cm ²)	770	732	908	214	247	1359	175
Stem length (cm)	33.7	31.6	31.6	12.4	22.7	41.9	10.1

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when determining the volume of solution to apply at each irrigation (Ku and Hershey, 1991).

LF did not affect growth of the three species (Table 1). Dry mass, leaf area, and stem length for plants given 10.7 mol N/m³ exceeded those for plants given 3.6 mol N/m³ (Table 1). Mean ($\pm$ SE) EC of the medium was 1.2 (0.2), 1.2 (0.1), and 1.1 (0.2) dS·m⁻¹ in the 0, 0.2, and 0.4 LF treatments, respectively, when maintained with solution containing 3.6 mol N/m³. Mean ($\pm$ SE) EC was 2.6 (0.1), 2.2 (0.2), and 1.4 (0.2) dS·m⁻¹ at LF0, 0.2, and 0.4, respectively, using solution with 10.7 mol N/m³. Plants given 3.6 mol N/m³ nodulated profusely, and LF did not appear to influence nodule quantity or size. Plants given 10.7 mol N/m³ lacked nodules.

Leaching can be eliminated for 10 weeks without affecting growth of Amur maackia, Scotch laburnum, and Chinese wisteria. As expected, medium EC was highest with the higher fertilizer rate and with decreasing LF. However, the highest EC we found, 2.6

dS·m⁻¹, was considerably less than the EC of the medium of florist crops treated with 0 LF and 21.4 mol N/m³ ($\approx$ 7 dS·m⁻¹) (Ku and Hershey, 1991, 1992). Maintaining a low LF with a fertilizer solution containing >10.7 mol N/m³ might have reduced growth of the species we studied by increasing the EC of the medium above a critical level. However, plants treated with 10.7 mol N/m³ appeared vigorous and healthy, and the absence of nodules suggests these plants were not deficient in N. Therefore, applying solutions with >10.7 mol N/m³ might decrease growth at a low LF but not increase growth at a high LF beyond what we achieved. Future studies should define optimal N levels for these species at varying LF. Among plants provided 3.6 mol N/m³, the similarity of the EC of the medium at the different LF suggests the plants acquired as much N from the medium as possible. The small size and extensive root nodulation of these plants indicate they were deficient in N, which may explain the lack of an LF effect on growth.

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