Nitrogen Nutrition of Containerized *Cryptomeria japonica* 'Elegans Aurea'[1]

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Abstract

Containerized, rooted stem cuttings of 'Elegans Aurea' Japanese cedar [*Cryptomeria japonica* (L.f.) D. Don 'Elegans Aurea'] grown in calcined clay, were fertilized three times weekly for 14 weeks with a complete nutrient solution containing 0, 25, 50, 100, or 200 mg N/liter supplied as ammonium nitrate. Top and root dry weights were not affected by N rate suggesting that 25 mg N/liter was adequate for maximizing growth. Nitrogen fertilization increased top and root dry weights by 149% and 20%, respectively, compared to the nontreated controls (0 mg N/liter). As N concentrations increased, root area and total root length decreased linearly. Nitrogen fertilization decreased root:top ratio by 50% compared to the nontreated controls. However, the root:top ratio was not affected by N rate. Percent top N concentration was increased by N compared to the nontreated control. Percent top K, Ca, and Mg decreased linearly with increasing N rates. There was a quadratic response in percent top P with a maximum at 50 mg N/liter.

Index words: Japanese cedar, fertilization, conifer, foliar analysis, arcillite, container production.

Significance to the Nursery Industry

Recent introduction of various cultivars of Japanese cedar [*Cryptomeria japonica* (L. f.) D. Don] has stimulated interest in the commercial potential of this attractive evergreen tree and also created a need for production information. One popular cultivar, 'Elegans Aurea' can be used in the landscape or as a containerized Christmas tree. Maximum overall top and root growth of containerized 'Elegans Aurea' cryptomeria was realized by applying a solution containing 25 mg N/liter three times weekly. Higher rates of N significantly decreased root area, total root length, and percent top P, Ca, and Mg concentrations.

Introduction

Japanese cedar [*Cryptomeria japonica* (L. f.) D. Don], a coniferous evergreen indigenous to Japan and southern China (4), is a widely used timber species in the Orient. This species is also considered a sacred tree in Japan with great landscape value (3). Japanese cedar (cryptomeria) is currently gaining popularity in the eastern United States as an excellent evergreen screen. The species does best in a fertile, deep, acidic, moist soil, but will tolerate clay both during dry and wet periods (4, 17). There are many cultivars of cryptomeria with smaller cultivars being more desirable than others for residential landscaping. One such cultivar is 'Elegans Aurea' which has soft, feathery, bright green foliage and normally reaches a height of 3–5 m (9–15 ft) in most landscapes, but can grow taller (4). 'Elegans Aurea' cryptomeria has a yellow-green fall color that persists throughout the winter before becoming green in the spring.

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Since the commercial value of woody landscape species is generally based on height and cross sectional area, growers attempt to maximize growth by supplying optimum quantities of water and nutrients. An optimal nutrient regime maximizes growth with a minimum amount of fertilizer, which reduces nutrient losses and potential environmental pollution.

Nitrogen is the mineral nutrient that promotes the greatest top (aerial tissue) growth in conifers (10). Growth is asymptotic with increasing substrate N with the optimal N concentration often dependent upon the reported growth measurements (11). Henry et al. (6) reported 230 mg N/liter maximized top growth of eastern redcedar (*Juniperus virginiana* L.) in a pine bark substrate while root growth was maximized at 105 mg N/liter. Ingestad (9), working with Scotch pine (*Pinus sylvestris* L.), found that nutrient solutions containing 50 and 5 mg N/liter were optimal for top and root growth, respectively. In contrast, Ingestad (8) reported a nutrient solution with 50 mg N/liter produced maximum top and root growth of Norway spruce [*Picea abies* (L.) Karst.]. For most conifers in container culture, 100 to 150 mg N/liter appears optimal (10). However, little is known about the N requirements of cryptomeria. Tsutsumi (18) demonstrated in a hydroponic experiment that ammonium nitrate was the best N source for cryptomeria; however, no N rate recommendations were given. Therefore, the objective of this study was to determine the influence of N fertilization on growth and mineral nutrient status of 'Elegans Aurea' cryptomeria.

Materials and Methods

On February 12, 1993, uniform, rooted single-stem cuttings of 'Elegans Aurea' cryptomeria with a mean height of 22 cm (8.8 in) and stem diameter mean of 4.4 mm (0.25 in) were potted in 3.8 liter (#1) black plastic containers in arcillite, a calcined montmorillonite and illite clay. Arcillite was selected as the substrate because it allows recovery of intact root systems at harvest (7).

Plants were grown in a greenhouse under natural irradiance (8:00 AM to 5:00 PM) with day/night temperatures of 24 ± 4°C (75 ± 7°F) /16 ± 4°C (60 ± 7°F). From 11:00 PM

Table 1. Source and concentration of mineral nutrients in the nutrient solution.

Mineral nutrient	Source	Concn. (mg/l)
N	NH_4NO_3	0 to 200
P	H_3PO_4	30
K	K_2SO_4	50
Ca	Ca acetate	50
Mg	$MgSO_4$	25
Fe	Iron chelate	5
B	H_3BO_3	0.5
Cu	$CuSO_4$	0.02
Mn	$MnCl_2$	0.5
Mo	$NaMoO_4$	0.1
Zn	$ZnSO_4$	0.05

Table 2. Initial mean values of selected measurements of 'Elegans Aurea' cryptomeria.[z]

Parameter	Top	Root	R:T[y]
Dry weight (g)	2.16	1.06	0.49
Nutrient concentration (%)[x]			
N	1.22		
P	0.55		
K	1.15		
Ca	1.51		
Mg	0.40		
Nutrient content (mg)[x]			
N	26.4		
P	11.9		
K	24.8		
Ca	32.6		
Mg	8.6		

[z]Height = 22 cm, stem diameter = 4.4 mm.
[y]R:T = root dry weight:top dry weight.
[x]Mean of five plants on a dry weight basis.

to 2:00 AM daily, plants received a night interruption from incandescent bulbs that provided a photosynthetic photon flux of 3.6 μmol/m^2/s plus photomorphogenic radiation of 0.7 W/m^2 as measured at the top of the containers with a cosine corrected LI-COR LI-185 quantum/radiometer/photometer (LI-COR, Lincoln, NB).

The experiment, a randomized complete block design with 9 single plant replications, consisted of five concentrations of N (0, 25, 50, 100, or 200 mg N/liter) supplied as ammonium nitrate. Three weeks after potting, fertilization was initiated with one liter of nutrient solution (Table 1) applied to each plant on Monday, Wednesday, and Friday. Before application, the nutrient solution was adjusted to pH 6.0 using 1N NaOH. Tap water containing 0.10, 0.0, 0.5, 4.0, 20.0 and 2.0 mg/liter NO_3, NH_4, P, K, Ca, and Mg, respectively, with a pH of 7.0 was applied on remaining days.

At treatment initiation, plant height and stem diameter measurements were taken from the surface of the substrate. In addition, five plants were harvested to determine initial top and root dry weights, and top nutrient concentrations. Initial nutrient content of tops was calculated from the nutrient concentration and top dry weight. Initial mean values of selected measurements are presented in Table 2. After 14 weeks, plant heights and stem diameters were measured, roots were washed free of arcillite and each plant separated into tops (stems and needles) and roots. All tissue was dried at 70°C (158°F) for 72 hr. Before drying, total root length and root area of four replications per treatment were measured utilizing a Monochrome Agvision System 286 Image Analyzer (Decagon Devices, Inc., Pullman, WA). Height, stem diameter, top and root dry weights, total root length, and root area were used to calculate the following: root:top ratio (root dry weight / top dry weight), percent increase for height and stem diameter [(final measurement – initial measurement) / initial measurement], root length:top ratio (total root length / top dry weight), root area:top ratio (root area / top dry weight), and relative growth rates for height and stem diameter [$(\ln W_2 - \ln W_1) / (t_2 - t_1)$ where W_1 and W_2 are measurements at t_1 and t_2].

After drying, tops of five replications per treatment were ground in a Wiley mill to pass a 40-mesh (0.425 mm) screen. Tissue samples, [1.25 g (0.04 oz)] were combusted at 490°C (914°F) for 6 hr. The resulting ash was dissolved in 10 ml 6 N HCl and adjusted to 50 ml with distilled deionized water. Phosphorus, K, Ca, and Mg concentrations were determined by inductively coupled plasma emission spectroscopy. Nitrogen was determined using 10 mg (0.00035 oz) samples in a Perkin Elmer 2400 CHN elemental analyzer (Perkin Elmer Corp., Norwalk, CT). All tissue analyses were conducted at the Analytical Service Laboratory, Department of Soil Science, North Carolina State University.

Data were subjected to regression analyses. The analyses showed significance for most measurements only if the nontreated control (0 mg N/liter) was included in the analyses. Therefore, the nontreated control was excluded from the regression analyses and a linear contrast was utilized to test for differences between a pooled N treatment effect and nontreated control (15).

Results and Discussion

Height, stem diameter, height and stem diameter relative growth rate, percent height and stem diameter increase, and top dry weight responded similarly. Therefore, of these data, only top dry weight data are presented.

Top dry weight was not affected by N rate suggesting that 25 mg/liter was adequate for maximizing growth (Table 3). This is similar to data reported for Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] (19), sitka spruce [*Picea sitchensis* (Bong.) Carr.] (19), Formosa pine (*Pinus taiwanensis* Hayata) (2), and Taiwan Douglas fir (*Pseudotsuga wilsoniana* Hayata) (2) as the optimum N concentration ranged between 25 and 50 mg/liter. However, this is a low N concentration compared to many woody landscape species where 100 to 300 mg N/liter were required to maximize growth (12, 13, 22). Obtaining maximum growth with 25 mg N/liter was initially thought to be an artifact of the arcillite substrate. However, a preliminary study demonstrated that 'Elegans Aurea' cryptomeria responded similarly when grown in milled pine bark [(<13 mm) (0.5 in)], a common container substrate in the southeastern United States, or arcillite (data not presented). In addition, Warren and Bilderback (21) showed that arcillite does not release measurable amounts of NO_3, NH_4, P, K, Ca, or Mg. Arcillite also has a pH between 5.9–6.1, thus not requiring adjustment. Nitrogen fertilization increased top dry weight by 149% compared to the nontreated controls (0 mg N/liter) (11.7 to 4.7 g, respectively). Plants not receiving N (0 mg N/liter) exhibited symp-

Table 3. Effect of nitrogen rate on various growth measurements and ratios of 'Elegans Aurea' cryptomeria.

Nitrogen rate	Top dry wt.	Root dry wt.	Root area	Total root length	RA:RL[z]	R:T[y]	RL:T[x]	RA:T[w]
(mg N/l)	(g)	(g)	(cm^2)	(cm)				
0	4.7	1.8	113	1124	0.10	0.39	256.8	25.9
25	12.1	2.3	164	1439	0.11	0.19	112.3	12.8
50	11.9	2.2	154	1295	0.12	0.19	104.7	12.5
100	11.7	2.2	115	857	0.14	0.19	71.3	9.6
200	11.2	1.9	102	776	0.13	0.18	63.8	8.3
Significance[v]								
Linear	NS	NS	**	**	*	NS	***	***
Quadratic	NS	NS	NS	NS	*	NS	**	NS
N rate vs. control[u]	***	**	NS	NS	**	***	***	***

[z]RA:RL = root area:total root length.

[y]R:T = root dry weight:top dry weight.

[x]RL:T = total root length:top dry weight.

[w]RA:T = root area:top dry weight.

[v]NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, $P \leq 0.01$, or $P \leq 0.001$, respectively. Zero rate not included in the regression analysis.

[u]Linear contrast. N rate = pooled nitrogen treatment. Control = 0 mg N/liter.

toms characteristic of N deficiency, (e.g., chlorosis and stunting).

Similarly, root dry weight was not affected by N rate (Table 3). This is in contrast to previous reports where increasing N concentration reduced root dry weight (1, 20, 23). Nitrogen increased root dry weight 20% compared to the nontreated controls (2.1 to 1.8 g, respectively). Root response to N is usually reduced compared to top response (14). Even though root dry weight was not affected by N rate, root area and total root length decreased linearly with increasing N rate (Table 3). Chiang et al. (2), working with Formosa pine and Taiwan Douglas fir, also reported that total root length decreased with increasing N concentration. Although total root length was reduced by increasing N rate, it had no apparent affect on top growth. However, root length may be important when transplanting into the landscape because the plant is dependent upon existing roots for water and nutrient absorption. Even though total root length and root area responded similarly to N rate, there was a proportionally greater change in root length compared to root area.

Table 4. Effect of nitrogen rate on percent nutrient concentration in tops of 'Elegans Aurea' cryptomeria.

Nitrogen rate	Percent dry weight				
(mg N/l)	N	P	K	Ca	Mg
0	0.81	0.57	1.58	1.55	0.33
25	1.89	0.37	1.69	1.18	0.24
50	2.29	0.39	1.84	1.16	0.24
100	1.97	0.25	1.70	0.91	0.20
200	2.20	0.21	1.58	0.89	0.19
Significance[z]					
Linear	NS	***	**	***	**
Quadratic	NS	*	NS	NS	NS
N rate vs. control[y]	***	***	*	***	***

[z]NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, $P \leq 0.01$, or $P \leq 0.001$, respectively. Zero rate not included in the regression analysis.

[y]Linear contrast. N rate = pooled N treatment. Control = 0 mg N/liter.

This is illustrated by the quadratic response of the root area:total root length ratio with increasing N rate (Table 3).

The root:top ratio was not affected by N rate (Table 3), illustrating further that top and root dry weight responded similarly to N concentration. However, root:top ratio was decreased by 50% compared to the nontreated controls (0.19 vs. 0.39, respectively). Root dry weight relative to top dry weight is commonly reduced when the external supply of N is increased (5, 11, 20, 24). Even though the root to top relationship was not affected by N rate, root length:top and root area:top ratios decreased linearly with increasing N rate (Table 3) suggesting N rate affected root growth more than that suggested by root dry weight. Since total root length or area should more accurately reflect the volume of soil which is potentially accessible to the plant compared to root dry weight, the root length:top ratio or root area:top ratio may be a better indicator of future landscape performance (14). Thus, higher N rates during production may produce a lower quality plant since total root length and area are reduced.

Top nutrient concentration and nutrient content were similar. Thus, only nutrient concentration data are presented. Percent top N was not affected by N levels suggesting that similar quantities of N were absorbed regardless of external N rate (Table 4). This is in contrast to other conifers where percent N increased linearly or quadratically with increasing external N rates (6, 19, 22); however, this response was not surprising since Ingestad (9) reported there are great differences between tree species in their ability to absorb nutrients supplied at different concentrations in the substrate.

Top percent N increased compared to the nontreated control plants (2.09% compared to 0.81%, respectively). This value (2.09% N) is within the reported range of foliar percent N (1.5 to 2.8% N) reported for other conifers (6, 8, 9). Percent K, Ca, and Mg decreased linearly with increasing N rates (Table 4). This is in agreement with other reports that increased N supply results in relatively low foliar K, Ca, and Mg (5, 11, 20, 22). Reduced K, Ca, and Mg results from competition with cations that are taken up more readily by roots (11). Increased N supply reportedly suppresses foliar P (16). However, results herein demonstrated there was a quadratic response in percent P with a maximum at 50 mg N/liter. Henry et al. (6) reported a similar response for eastern red cedar.

Root and top growth of 'Elegans Aurea' cryptomeria were maximized at a relatively low rate of N (25 mg/liter). Higher rates of N could potentially produce a lower quality plant by decreasing total root length and root area. In addition, since the cultivar did not absorb more N as the external N rate increased, this additional N could be lost by leaching, contributing to environmental pollution.

Literature Cited

1. Brouwer, R. 1962. Nutritive influences on the distribution of dry matter in the plant. Netherlands. J. Agr. Sci. 10:399–408.

2. Chiang, C.H., Y.N. Wang, S.T. Lin, S.H. Wu, S.H. Sheu, and K.C. Chang. 1989. Water culture study on *Pinus taiwanensis* and *Pseudotsuga wilsoniana* (II). Growth characteristics of four-month-old seedlings. J. Expt. For. Natl. Taiwan Univ. 3(1):21. (Abstr.)

3. Creech, J.L. 1984. Cryptomeria has many landscape uses. Amer. Nurseryman 159(5):47.

4. Dirr, M.A. 1990. Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation, and Uses. 4th ed. Stipes Publishing Co. Champaign, IL.

5. Fowells, H.A. and R.W. Krauss. 1959. The inorganic nutrition of loblolly pine with special reference to N and P. Forest Sci. 5:95–112.

6. Henry, P.H., F.A. Blazich, and L.E. Hinesley. 1992. Nitrogen nutrition of containerized eastern redcedar. I. Growth, mineral nutrient concentrations, and carbohydrate status. J. Amer. Soc. Hort. Sci. 117:563–567.

7. Hiller, L.K. and D.C. Koller. 1979. Potato growth responses in arcillite and sand. HortScience 14:534–536.

8. Ingestad, T. 1959. Studies on the nutrition of forest tree seedlings. II. Mineral nutrition of spruce. Physiol. Plant. 12:568–593.

9. Ingestad, T. 1960. Studies on the nutrition of forest tree seedlings. III. Mineral nutrition of pine. Physiol. Plant. 13:513–533.

10. Landis, T.D., R.W. Tinus, S.E. McDonald, and J.P. Barnett. 1989. The Container Tree Nursery Manual. vol. 4. Seedling Nutrition and Irrigation. U. S. Dept. Agr. Forest Serv., Agr. Hdbk. 674.

11. Mengel, K. and E. A. Kirkby. 1987. Principles of Plant Nutrition. 4th ed. Intern. Potash Inst., Worblaufen-Bern, Switzerland.

12. Niemiera, A.X. and R.D. Wright. 1982. Growth of *Ilex crenata* Thunb. 'Helleri' at different substrate nitrogen levels. HortScience 17:354–355.

13. Phillion, B.J., and M. Libby. 1984. Growth of potted black spruce seedlings at a range of fertilizer levels. The Plant Propagator 30(2):10-11.

14. Russell, R.S. 1977. Plant Root Systems. McGraw-Hill, London.

15. SAS Institute, Inc. 1990. SAS/STAT User's Guide. vol. 2. SAS Institute, Inc., Cary, NC.

16. Smith, P.F. 1962. Mineral analysis of plant tissue. Annu. Rev. Plant Physiol. 13:81–108.

17. Tripp, K.E. 1993. 'Sugi': An ancient word for Japanese cedar, a modern name for an outstanding conifer. Amer. Nurseryman 178(7):26–39.

18. Tsutsumi, T. 1962. Studies on nutrition and fertilization of some important Japanese conifers. Bull. Govt. Forest Expt. Sta. (Tokyo) 137:1–158.

19. van den Driessche, R. 1968. A comparison of growth responses of Douglas fir and Sitka spruce to different nitrogen, phosphorus, and potassium levels in sand culture. Can. J. Bot. 46:531–537.

20. Warren, S.L. 1993. Growth and nutrient concentrations in flowering dogwood after nitrogen fertilization and dormant root pruning. J. Arboriculture 19:57–63.

21. Warren, S.L. and T.E. Bilderback. 1992. Arcillite: Effect on chemical and physical properties of pine bark substrate and plant growth. J. Environ. Hort. 10:63–69.

22. Warren, S.L., W.A. Skroch, and L.E. Hinesley. 1987. Effect of root competition and nitrogen on growth and mineral content of *Abies fraseri*. Can. J. Forest Res. 17:1092–1099.

23. Wright, R.D. and A.X. Niemiera. 1985. Influence of N, P, and K fertilizer interactions on growth of *Ilex crenata* Thunb. 'Helleri'. J. Environ. Hort. 3:8–10.

24. Yeager, T.H. and R.D. Wright. 1981. Influence of nitrogen and phosphorus on shoot : root ratio of *Ilex crenata* 'Helleri'. HortScience 16:564–565.