Nitrogen Nutrition of Containerized *Thuja* x 'Green Giant'[1]

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Abstract

Rooted stem cuttings of 'Green Giant' arborvitae (*Thuja* L. x 'Green Giant') were grown in 3.8 liter (#1) plastic containers containing a pine bark:sand (8:1 by vol) substrate. Plants were fertilized three times weekly for 15 weeks with a complete nutrient solution at N application rates (NARs) of 0, 10, 20, 40, 80, 160, or 320 mg/liter (ppm) supplied as ammonium nitrate (NH_4NO_3). Both shoot and root dry weights were significantly affected by NAR. Maximum shoot weight, as predicted by a quadratic plateau model, was reached at a NAR of approximately 100 mg/liter (ppm), representing a 200% increase over controls [0 mg/liter (ppm) N]. Maximum and minimum root dry weights occurred at 0 mg/liter (ppm) N and approximately 50 mg/liter (ppm) N, respectively, representing a 37% decrease. Root length decreased 36% at a NAR of approximately 50 mg/liter (ppm). Root diameter (root area ÷ root length) increased before reaching a plateau at approximately 130 mg/liter (ppm) N indicating that root length decreased faster than root area at low N concentrations. Shoot concentrations of N, P, Mg, and S were maximized at approximately 71, 41, 48, and 52 mg/liter (ppm) N, respectively. Uptake of K and Ca were unaffected by N concentrations.

Index words: arborvitae, carbon partitioning, container production, fertilization, mineral nutrition.

Significance to the Nursery Industry

'Green Giant' arborvitae (*Thuja* L. x 'Green Giant') is an upright, pyramidal landscape tree that has attracted the attention of the nursery industry. Valued for its lustrous green summer foliage, rapid growth rate, and ease of propagation by stem cuttings, the tree is an attractive specimen when planted alone, or forms a dense evergreen screen when planted in rows. However, specific information pertaining to nutritional requirements for containerized culture of 'Green Giant' is unavailable. Our results indicate that applying N as ammonium nitrate (NH_4NO_3) at rates >100 mg/liter (ppm) does not increase shoot dry weight or mineral nutrient uptake. Root dry weight and length do not continue to decrease at N application rates (NARs) >50 mg/liter (ppm). Increasing NAR beyond 100 mg/liter (ppm) N will neither improve shoot growth nor prove detrimental to root growth. Electrical conductivity (EC) of substrate solution for treatments that maximized growth were within the recommended range for container-grown nursery crops (13). Therefore, 100 mg/liter (ppm) N, applied three times weekly, is recommended for maximum growth of 'Green Giant'.

Introduction

'Green Giant' arborvitae is an exciting plant gaining in popularity throughout the nursery trade (7). Its rapid growth, attractive foliage, and ease of propagation by stem cuttings have been discussed previously (3). Optimum NAR for containerized growth of this cultivar, however, is unknown. Determining a fertilization regime to maximize plant growth with minimum mineral nutrient inputs is essential to increase nursery profits while reducing nutrient leaching and thus potential environmental hazards.

Nitrogen is the mineral nutrient that most influences plant productivity (6, 8). Optimum NAR and overall response to increased NAR can vary by species and frequency of application. As little as 20 mg/liter (ppm) N applied daily was shown to maximize height and stem diameter of 'Carolina Sapphire' smooth Arizona cypress [*Cupressus arizonica* var. *glabra* (Sudw.) Little 'Carolina Sapphire'] (14), whereas 25 mg/liter (ppm) N resulted in maximum growth of 'Elegans Aurea' Japanese cedar [*Cryptomeria japonica* (L. f.) D. Don 'Elegans Aurea'] (5) when nutrients were applied three times weekly. Increasing nutrient concentrations often becomes necessary as intervals between applications increase (16). Sixty mg/liter (ppm) N was necessary to achieve maximum growth of fertigated 'Tonto' crape myrtle (*Lagerstroemia indica* x *fauriei* 'Tonto') (2).

Nitrogen fertilization affects many plant growth parameters although the N concentration and the magnitude of those changes vary by species (16). Therefore, the objective of this study was to determine the optimal NAR for maximum growth of containerized 'Green Giant' arborvitae.

Materials and Methods

On December 10, 1997, uniform rooted stem cuttings of 'Green Giant' arborvitae were potted into 3.8 liter (#1) black plastic containers with a pine bark:sand (8:1 by vol) substrate amended with 1.8 kg/cu m (4 lbs/cu yd) dolomitic limestone. Containers were placed in a glass greenhouse under natural photoperiod and irradiance with days/nights of 24 ± 5C (75 ± 9F)/18 ± 5C (65 ± 9F) and irrigated with tap water until treatment initiation.

On January 12, 1998, treatments were begun. Plants were grown under natural irradiance from 8:00 am to 5:00 pm and received a night interruption from 11:00 pm to 2:00 am from incandescent bulbs. The bulbs provided a photosynthetic photon flux of 3.6 $\mu mol \cdot m^{-2} \cdot s^{-1}$ plus photomorphogenic radiation of 0.7 $W \cdot m^{-2}$ as measured at the tops of the containers with a cosine corrected LI-COR model LI-185A Quantum/Radiometer/Photometer (LI-COR, Lincoln, NE).

The experiment was a randomized complete block design with nine single-plant replications per treatment. Treatments

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

Mineral nutrient	Source	Concn. [mg/L (ppm)]
N	NH_4NO_3	0 to 320
P	$K_2H_2PO_4$	30
K	K_2SO_4	50
Ca	Ca acetate	100
Mg	$MgSO_4$	25
Fe	Iron chelate (DTPA)	5
B	H_3BO_3	0.50
Cu	$CuSO_4$	0.02
Mn	$MnCl_2$	0.50
Mo	$(NH_4)_6(Mo_7O_{24})$	0.10
Zn	$ZnSO_4$	0.05

consisted of complete nutrient solutions (Table 1) varying only in N concentration [(0, 10, 20, 40, 80, 160 or 320 mg/liter (ppm)], supplied as ammonium nitrate (NH_4NO_3). Solution pH ranged from 6.3 to 6.5. Container leachate was collected to determine electrical conductivity (EC) of substrate solution, using the pour-through nutrient extraction method (15), 14 days after treatment initiation and every 2 weeks thereafter. Nutrient solutions [200 ml (7 oz) at weeks 1 to 13, 275 ml (9 oz) at weeks 13 to 15] were applied every Monday, Wednesday, and Friday at a volume sufficient to maintain a 25% leaching fraction that was monitored every 2 weeks. No other irrigation was required.

After 15 weeks, roots were washed free of substrate and each plant separated into shoots and roots. Dry weights were determined after drying at 70C (158F) for 96 hr. Prior to drying, five replications were used to determine root area and root length using a Monochrome Agvision System 286 Image Analyzer (Decagon Devices, Inc., Pullman, WA). Measurements were used to calculate root:shoot ratio (root dry weight ÷ shoot dry weight) and root diameter (root area ÷ root length). Shoots from five replications were processed appropriately for N, P, K, Ca, Mg, and S analyses (5, 14) that were completed at the Analytical Service Laboratory, Department of Soil Science, North Carolina State University. Data were subjected to ANOVA, regression analysis, and a segmented linear regression (quadratic plateau) was fit to the data using PROC NLIN (12).

Results and Discussion

Statistical analyses were performed on all data, with and without controls [0 mg/liter (ppm) N] and results were similar. Therefore, results presented include control data.

Shoot dry weight increased quadratically with increasing NARs (Fig. 1A) up to 205 mg/liter (ppm). However, we believed the quadratic model did not represent the best relationship between shoot dry weight and NAR. Therefore, a quadratic plateau was fit to the data, producing a better fit (R^2 = 0.93) and predicting maximum shoot dry weight at approximately 100 mg/liter (ppm) N (Fig. 1B). Electrical conductivity of substrate solution at maximum growth averaged 0.94 dS/m, which is within the recommended range for liquid fertilized container-grown nursery crops (13).

The quadratic plateau model has two advantages since it predicts more accurately the response of shoot weight to NAR, and it indicates maximum shoot weight (7 g) was reached at a rate less than half predicted by the quadratic model. If the quadratic model is predicting accurately the response of shoot weight to NAR, but the plateau model is chosen when recommending fertilizer application, shoot dry weight would decrease 12.5%. However, if the plateau model is correct, and the quadratic model is chosen when recommending NAR, then 202% excess N is applied. Thus, a quadratic plateau predicts nearly the same growth with half the applied N. The reduction in applied N will reduce fertilizer costs while minimizing potential environmental hazards from runoff. This pattern was observed for all measured parameters. Therefore, only quadratic plateau models will be presented.

Root dry weight decreased rapidly with increasing NAR until reaching a minimum plateau (1 g) at approximately 50 mg/liter (ppm) N (Fig. 2A). Other researchers (2, 6) have noted a similar root response to increasing NAR. Root:shoot ratio decreased with increasing NAR (data not presented), and was similar to responses reported in the literature (6). Ameziane et al. (1) observed root lengths of common chicory (*Cichorim intybus* L.) were similar when plants were grown at 37 or 248 mg/liter (ppm) N, and concluded a decrease in root:shoot ratio was a result of the greater increase in shoot dry weight. Data herein support this conclusion as root dry weight remained constant at NAR >50 mg/liter (ppm) (Fig. 2A), whereas shoot dry weight continued to increase up to 100 mg/liter (ppm) N (Fig. 1B).

Mean root length of control plants [0 mg/liter (ppm) N] was 400 cm (157.5 in), and declined rapidly to 255 cm (100 in) at approximately 50 mg/liter (ppm) N where it remained throughout the higher NARs (Fig. 2B). Greater root lengths

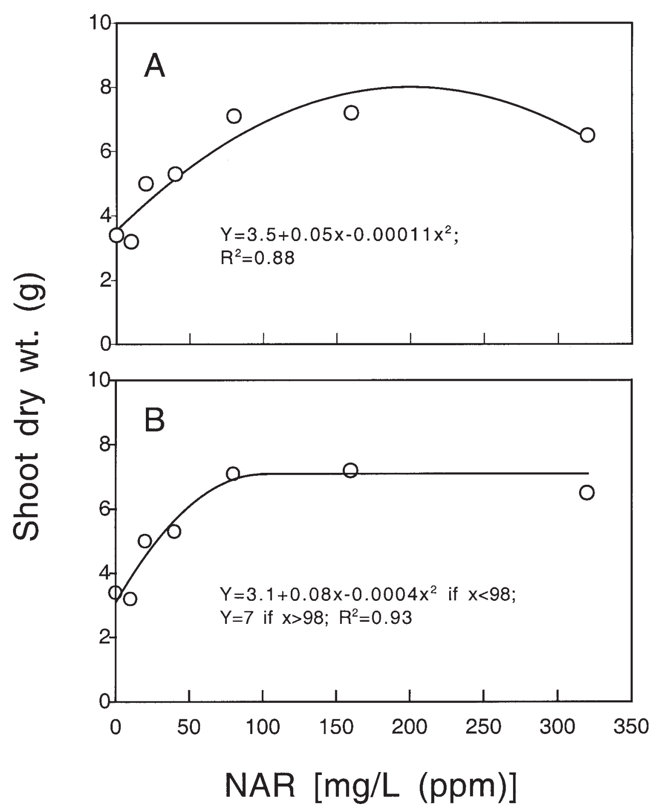

Fig. 1. Effect of nitrogen application rate (NAR) on shoot dry weight of 'Green Giant' arborvitae (n = 9). A) quadratic model. B) quadratic plateau model.

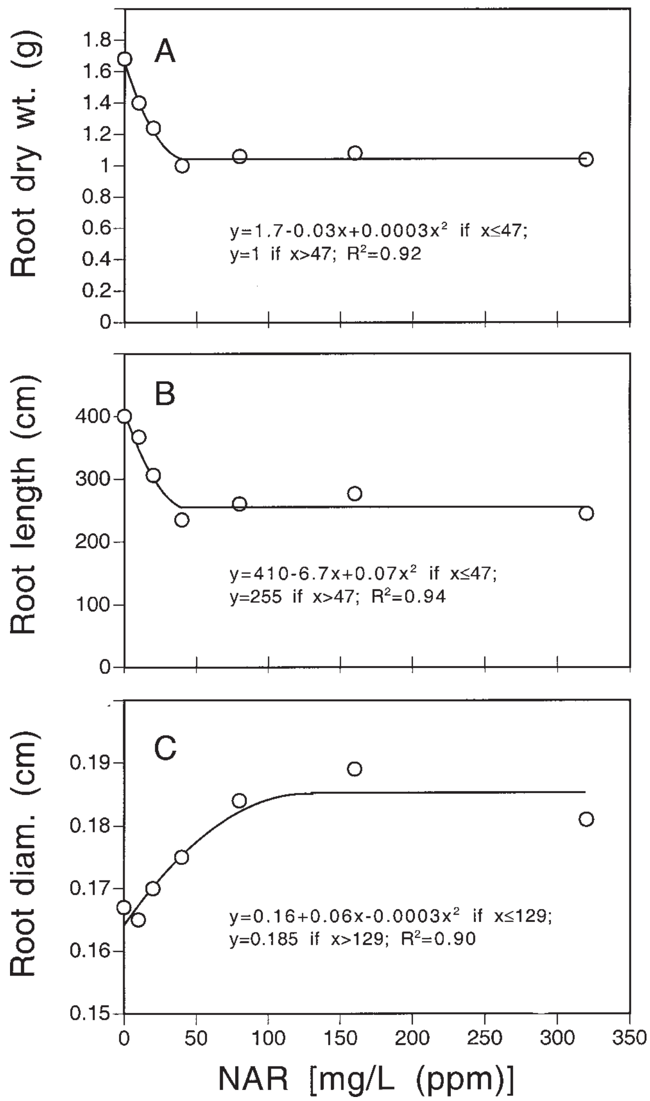

Fig. 2. Effect of nitrogen application rate (NAR) on (A) root dry weight (n = 9), (B) root length (n = 5), and (C) root diameter (n = 5) of 'Green Giant' arborvitae.

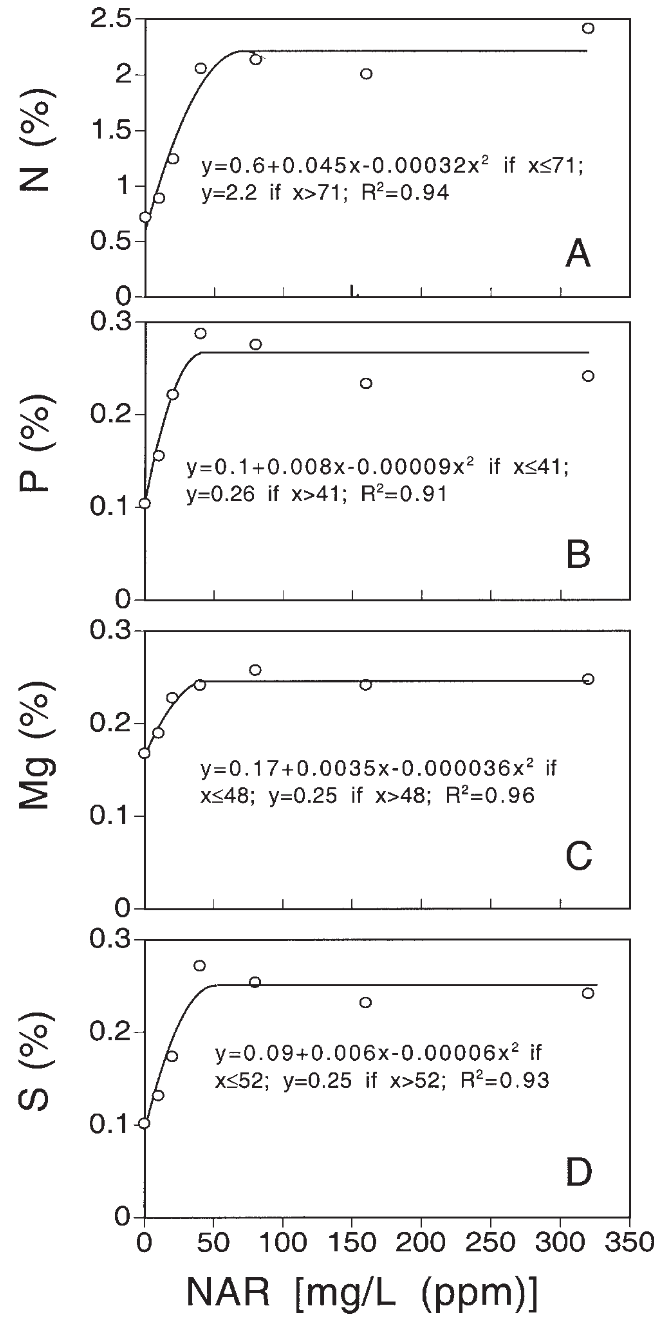

Fig. 3. Effect of nitrogen application rate (NAR) on shoot nutrient concentration (n = 5) of 'Green Giant' arborvitae. A) nitrogen, B) phosphorus, C) magnesium, and D) sulfur.

at low NARs are observed commonly (2, 10, 11). Reallocation of reduced N from shoots to roots, and alterations in carbohydrate partitioning have been shown to occur in N stressed plants resulting in continued root growth (11). Ameziane et al. (1) reported net photosynthesis was unaffected although a decrease in shoot dry weight was observed for plants growing in supra- or sub-optimal concentrations of nitrate. These results suggest that when N is limiting, excess fixed carbon is allocated to the roots where it is used for growth (6, 10). When soils are deficient in N, plants retain a greater portion of N in the roots (10, 11) resulting in less reduced N in the shoot. Henry and Raper (4) proposed that root extension and N uptake compete for soluble carbohydrates provided by the shoot. As N uptake and root extension both require respiratory energy provided as shoot-produced carbohydrates, root extension would be favored in a soil deficient in available N. Likewise, roots of plants growing in soils sufficient in available N contain very low concentrations of soluble carbohydrates (4), perhaps accounting for reductions in root length.

Increasing NARs increased root diameter to a maximum of 0.185 cm (0.07 in) at a concentration of approximately 130 mg/liter (ppm) N (Fig. 2C) indicating root length decreased faster than root area with increasing NARs. As supporting evidence, root area was unaffected by N (data not presented). Although root length of N sufficient plants was 36% less than control plants, root area did not change. These results suggest that 'Green Giant' may be maintaining an optimal root area (surface area for N absorption) that maximizes uptake of available N, regardless of root length.

Shoot nutrient concentrations of N, P, Mg, and S were increased significantly by increasing NAR (Fig. 3). Shoot N concentration reached a maximum of 2.2% at a predicted NAR of approximately 70 mg/liter (ppm) and remained constant throughout the remaining NAR. This shoot N concentration is higher than the 0.7% to 1.5% reported for western red cedar (*T. plicata* J. Donn ex D. Don) (9). In the current study, N concentration of control plants (0.72%) fell within the reported range, and treatment with ≥40 mg/liter (ppm) N produced shoot N concentrations (2.1%) in excess of the range. Shoot dry weight, however, was highest at NARs of approximately 100 mg/liter (ppm) N (Fig. 1B), suggesting that 'Green Giant' has a higher N requirement than western red cedar. This result was somewhat expected given the rapid growth rate of 'Green Giant'.

Excluding control plants, shoot concentrations of P were in the reported mean range of western red cedar (9), whereas uptake of Mg and S were greater than expected. Under field conditions, increased concentrations of P are often observed with ammonium based fertilizers due to their acidifying effect (9). Increased concentrations of Mg with increasing NAR might be expected as it is a vital component of chlorophyll and a cofactor for many regulatory enzymes (9), all of which should increase due to increasing NAR. Likewise, since S is also attributed to many proteins and enzymes associated with growth, S concentration should increase with increasing NAR (6, 9). Shoot concentrations of K and Ca were unaffected by N treatments with mean concentrations of 1.27% and 1.31%, respectively. This result was surprising since nutrient acquisition of K, Mg, and Ca is usually influenced negatively by ammonium as they compete for binding sites (6). However, these concentrations were greater than those of western red cedar suggesting again, that 'Green Giant' has a higher mineral nutrient requirement than other species of arborvitae (*Thuja* L.).

Solutions of approximately 100 mg/liter (ppm) N applied three times weekly are optimal for shoot growth of 'Green Giant' and no more detrimental to root growth than NARs of approximately 50 mg/liter (ppm) (a sub-optimal concentration for shoot growth). At this optimal concentration, shoot nutrient concentrations were well within or exceeded the accepted levels reported, and growers can expect rapid growth of rooted cuttings.

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