Nitrogen Nutrition of Containerized Eastern Redcedar. II. Influence of Stock Plant Fertility on Adventitious Rooting of Stem Cuttings

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Abstract. Hardwood stem cuttings of eastern redcedar (*Juniperus virginiana* L.), taken from containerized stock plants fertilized weekly with 0, 5, 10, 20, 40, 80, 160, 320, or 640 ppm N, were treated with 7500 ppm IBA and placed under intermittent mist for 12 weeks. Foliar starch and sucrose concentrations within cuttings at time of excision were significantly correlated with percent rooting and root length, respectively. Of the mineral nutrients analyzed (N, P, K, Ca, Mg, Mn, and B), only B and K were significantly correlated with rooting response. A threshold N level (20 ppm), applied weekly, maximized rooting; higher concentrations decreased response. Although N fertilization of stock plants affected adventitious rooting, there were no significant correlations between foliar N levels and measures of rooting response. Chemical name used: 1 *H*-indole-3-butyric acid (IBA).

Eastern redcedar has long been valued for its durable red heartwood, and trees of sawtimber diameter are becoming less common. As an ornamental, the species is gaining popularity owing to diversity in growth form and tolerance to diverse cultural and environmental conditions. Although generally propagated sexually, seedlings of eastern redcedar display tremendous phenotypic variability. For this reason, in both forestry and horticulture, it is desirable to propagate the species vegetatively by stem cuttings.

One factor that influences rooting of cuttings is stock plant mineral nutrition (Blazich, 1988). Kraus and Kraybill (1918) first suggested that suboptimal N fertilization might enhance rooting (Haun and Cornell, 1951; Pearse, 1943; Rein et al., 1991) and proposed that N acts by altering stock plant carbohydrate : N ratio. This hypothesis, however, has received little experimental support (Veierskov, 1988), suggesting that N influences rooting through other mechanism(s). One major effect of N nutrition is alteration of mineral nutrient concentrations, and changes in stock-plant fertility might affect rooting response. Therefore, the objective of this study was to investigate the manner in which N fertilization of stock plants affects adventitious rooting of stem cuttings of eastern redcedar.

Materials and Methods

Containerized stock plants of eastern redcedar, arranged in a randomized complete block with 22 blocks, were fertilized weekly from 1 May to 1 Nov. 1989 with a complete nutrient solution containing 0, 5, 10, 20, 40, 80, 160, 320, or 640 ppm N (Henry et al., 1992). Hardwood stem cuttings were taken on 1 Dec. 1989. Poor growth resulted in little cutting material at 0, 5, and 10 ppm N, and these treatments were pooled as a single treatment (10 ppm) with 60 cuttings, 20 at each N level, collected

from the 22 blocks. Enhanced growth at 20 ppm N allowed a total of 60 cuttings to be taken from the 22 blocks. For the 40, 80, 160, 320, and 640 ppm treatments, 60 cuttings were collected from each of four groups (blocks 1-6, 7-12, 13-18, and 19-22), resulting in 240 cuttings per treatment.

Cuttings 12 cm long were taken from the upper third of the crown, kept on ice until completion of sampling, and stored at 4C for 2 days in plastic bags. After removal from storage, stem bases were recut and foliage stripped from the basal 4 cm. The proximal 3 cm of cuttings were treated for 1 to 2 sec with 7500 ppm IBA in 50% isopropanol and inserted in a raised greenhouse bench containing a moist rooting medium of 1 peat : 1 perlite (v/v). Cuttings were maintained under natural photoperiod, with day/night cycles of 22/16 $\pm$ 5C, and misted daily for 4 sec every 6 min (8:00 AM-6:00 PM). To control fungi, cuttings were sprayed initially and weekly thereafter, alternating methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl) and 3a,4,7,7a-tetrahydro-2-[(trichloromethyl)thiol]-1 *H*-isoindole-1,3(2 *H*)-dione (captan) at rates of 1.8 g-liter⁻¹ and 2.4 g-liter⁻¹, respectively.

After 12 weeks (1 Mar. 1990), cuttings were harvested and data recorded on percent rooting and root count, length, and dry weight; cuttings with at least one root $\geq$ 2 mm long were considered rooted. Roots were thoroughly washed with water before being dried at 70C for 48 h and weighed.

The design within the propagation bed was a randomized complete block with seven N treatments and six blocks. Both the 10- and 20-ppm treatments included 10 cuttings (one plot) per block. For the 40, 80, 160, 320, and 640 ppm treatments, identity of groups was maintained within mist-bed blocks; each block contained 10 cuttings from each of the four groups within a treatment. Initial data analysis indicated that, for these treatments, there was no significant ($P = 0.05$) group-to-group variation within blocks. Thus, treatment means for each block were averaged over groups and subjected to analysis of variance. PROC CORR (SAS Institute, 1990) was used to generate a correlation matrix between cutting nutrient concentrations (Henry et al., 1992) at time of excision and rooting characteristics.

Results and Discussion

Concentration of applied N significantly ($P = 0.01$) affected rooting response (Table 1). Although growth of eastern redcedar

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Table 1. Analysis of variance for measures used to assess the role of stock plant N fertilization on adventitious rooting response of hardwood stem cuttings of eastern redcedar.

Source of variation	df	Percent rooting	Mean square		
			Root		
			Count	Length	Dry wt
N concn	6	1137.37**	7.62**	2.26**	0.0071**
Blood	6	24.14	1.26*	0.60*	0.0002

Fig. 1. Adventitious rooting response of stem cuttings taken from containerized stock plants of eastern redcedar fertilized weekly with either 10, 20, 40, 80, 160, 320, or 640 ppm N. (A) percent rooting; (B) root count; (C) root length; (D) root dry weight. Each mean is based on six replications. Means for root count, root length, and root dry weight include data only for stem cuttings that rooted.

was optimal (90% maximum) at 100 to 150 ppm N (Henry et al., 1992), rooting of stem cuttings was maximized at 20 to 40 ppm (Fig. 1). This same concentration was required to elicit a threshold response; the responses at 20 ppm N were 1.6 (percent rooting), 2.2 (root count), 1.5 (root length), and 6.3 (root dry weight) times those at 10 ppm.

As N increased from 20 ppm to levels necessary to optimize growth (Henry et al., 1992), root count and dry weight declined significantly ($P = 0.05$); other measures remained unchanged. As reported for other species (Haun and Cornell, 1951; Pearse, 1943), N concentrations supraoptimal for growth decreased rooting. At 640 ppm N, all measurements, except root length, declined significantly ($P = 0.05$) compared to maximum response.

Although most fertility studies involving rooting relate response to N supply (Haun and Cornell, 1951; Pearse, 1943), carbohydrate and nutrient status of cuttings may be more important factors. Starch concentration, significantly correlated ($P = 0.05$, $r = 0.84$) with rooting percentage (Table 2), fluctuates widely during the year in conifers (Ericsson, 1979; Venator, 1982) and has often been associated with rooting response (Nanda, 1979; Reuveni and Raviv, 1980).

The significant correlation ($P = 0.05$, $r = 0.77$) between sucrose and root length (Table 2) supports Haissig's (1986) suggestion that nonstructural carbohydrates are mainly related to root growth. Sugars, in nonlipid-storing species, are the source

Table 2. Correlation coefficients between mineral nutrient and carbohydrate concentrations of stem cuttings of eastern redcedar and measures of rooting response.

Variable	Percent rooting	Rooting characteristic		
		Root		
		Count ^z	Length ^z	Dry wt ^z
Starch	0.84*	0.70	0.68	0.62
Hexose	0.53	0.62	0.39	0.22
Sucrose	0.72	0.72	0.77*	0.72
N	0.63	0.51	0.63	0.52
P	0.75	0.55	0.66	0.52
K	0.96**	0.75	0.83*	0.72
Ca	-0.69	-0.46	-0.58	-0.43
Mg	-0.75	-0.65	-0.74	-0.65
Mn	-0.60	-0.43	-0.57	-0.44
B	0.98**	0.80*	0.85*	0.76*

^zBased on the number of stem cuttings that rooted.

**Significant at $P = 0.05$ and 0.01 , respectively.

of energy and new carbon skeletons for adventitious root regeneration (Haissig, 1986; Veierskov, 1988).

A strong correlation ($P = 0.01$, $r = 0.96$) was observed between K level and rooting percentage (Table 2). Although mobilization studies have not revealed movement of K to stem bases during root initiation (Blazich et al., 1983; Good and Tukey, 1967), such studies differed from ours, since stock plants were of uniform fertility. Potassium redistribution might depend on cutting fertility at the time of excision and might not occur if initial levels are adequate to support rooting.

Potassium level was also correlated ($P = 0.05$, $r = 0.83$) with root length (Table 2). Blazich et al. (1983) reported K mobilization to stem bases following root initiation in auxin-treated cuttings of 'Convexa' holly (*Ilex crenata* Thunb.). Exogenously supplied K accelerates auxin-induced growth of excised coleoptiles (Hsiao and Lauchli, 1986) and may similarly stimulate root growth.

Potassium may be more important in adventitious rooting than previously supposed. The absence of a root system-reducing water uptake—stresses cuttings and influences cell expansion, turgor pressure, cell water content, and stomatal action (Haissig, 1986; Loach, 1988). Potassium affects these factors (Hsiao and Lauchli, 1986) and may modulate effects of water stress. In studies not involving rooting, high foliar K is associated with reduced transpiration in tree species (van den Driessche, 1984).

Boron was significantly correlated with rooting percentage ($P = 0.01$, $r = 0.98$), root count ($P = 0.05$, $r = 0.80$), length ($P = 0.05$, $r = 0.85$), and dry weight ($P = 0.05$, $r = 0.76$) (Table 2). Boron acts synergistically with applied IAA to enhance rooting percentage and root count in woody (Weiser and Blaney, 1960) and nonwoody (Middleton et al., 1978) species. It is unknown if a threshold B concentration is required, in addition to auxin, to initiate root primordia. Once roots are initiated, however, B must be present for growth to proceed beyond the very early ("preprimordial") stages of development (Middleton et al., 1978).

Although N fertilization of stock plants affected rooting (Fig. 1), there were no significant correlations between foliar N concentrations and rooting responses (Table 2). This result underscores the limitations of interpreting rooting data in relation to a single applied nutrient without monitoring the status of other nutrients within stock plants.

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