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Foliar Nutrition of *Serianthes nelsonii* Seedlings as a Conservation Tool

Thomas E. Marler
Western Pacific Tropical Research Center, University of Guam, Mangilao, GU 96923

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***Abstract.* Conservation of the endangered *Serianthes nelsonii* is constrained by lack of research. Transplanted containerized plants die in the competitive in situ environment. This study determined if foliar applications of nutrient solution could replace edaphic fertilizer applications for mitigating competition for soil nutrients. Weekly sprays with 0.1× Hoagland solution were compared with weekly drenches of 0.5× Hoagland solution. Plants receiving edaphic or foliar nutrition were not different in height, and height growth was 72% above that of control plants. Similar results were obtained for stem diameter and leaf number. Leaf nutrient concentrations were not different for the two nutrition treatments, but stem nutrient concentration differences were dependent on the element. Stem copper, nitrogen, phosphorus, potassium, and zinc concentrations were not different for edaphic vs. foliar nutrition. Contrarily, stem boron, calcium, iron, magnesium, and manganese concentrations were greater in plants receiving edaphic nutrients. The results indicate nutritional needs of recently out-planted plants may be supplied directly to leaves to mitigate below-ground competition for nutrient resources.**

Conservation of the endangered *S. nelsonii* has suffered from a history of limited research (Marler et al., 2021). A chronic conservation failure has been mortality of container-grown plants after transplanting to in situ forests. Limited root growth at the time of transplanting (Marler, 2019) and competition for resources in this biodiverse setting (Marler and Musser, 2015) have been identified as causes of in situ seedling mortality.

Mineral nutrients are derived from the soil, and soil-applied fertilizers form the foundation of horticultural mitigation of deficiencies. Under some conditions, these added nutrients may become unavailable to the managed plants due to soil characteristics or plant competition. Foliar applications and trunk injections of nutrients have been used to mitigate these conditions. This study determined if foliar applications of nutrient solutions to *S. nelsonii* seedlings could generate growth and tissue concentrations similar to soil-applied solutions.

Methods

The study was conducted in a conservation nursery in Angeles City, Philippines. The seedlings were sourced from urban street trees on Rota Island, and original provenance was not known. The seedlings were initially grown in tubes (5-cm diameter, 12-cm depth) and were 27.8 ± 1.1 cm tall (mean ± SE) with a basal diameter of 5.1 ± 0.2 mm at the initiation of the study. Seedlings were bare-rooted on 5 Nov. 2017 and planted individually in 2.6-L containers in a medium composed of one-third loam soil and two-thirds quarried river sand. The soil ensured a suite of nutrients to sustain limited growth of control plants, and the sand ensured adequate drainage in the containers. This substrate was impoverished, as indicated by soil analyses that revealed total nitrogen was 4.9 ± 0.2 $mg \cdot g^{-1}$, available phosphorus was 5.9 ± 0.5 $mg \cdot kg^{-1}$, and exchangeable potassium was 29.6 ± 1.6 $mg \cdot kg^{-1}$ (mean ± SE, n = 4).

The plants were sorted into three treatments. Control plants received no nutritional applications. Plants in the foliar treatment received weekly sprays of 0.1 × Hoagland solution. Every fully expanded leaf was sprayed using the standard horticultural protocol of application until initial runoff. Plants in the soil-applied treatment received weekly drenches of 0.5 × Hoagland solution. Each container received 200 mL of solution. Daily irrigation using deep well water was provided with care to refrain from wetting the leaf surfaces. Initial plant height and basal stem diameter were measured. The plants were grown under 50% shadecloth and rainfall protection until 15 Jan. 2018.

Ending height, basal stem diameter, and leaf number were measured. The terminal 15 cm of each stem was pruned and separated into stem and leaf tissues. All tissue was washed four times in reverse osmosis water to remove all nutrients adhering to the organ surfaces. Nutrient concentrations were quantified using previously described methods (Marler, 2021). The tissue was dried at 75 °C for 24 h and milled to pass through 20-mesh screen. Total carbon and nitrogen were determined by dry combustion (FLASH EA1112 CHN Analyzer; Thermo Fisher, Waltham, MA). Samples were digested by a microwave system with nitric acid and peroxide, then boron, calcium, copper, iron, magnesium, manganese, phosphorus, potassium, and zinc were quantified by inductively coupled plasma optical emission spectroscopy (Spectro Genesis; SPECTRO Analytical Instruments, Kleve, Germany).

Each response variable was subjected to one-way analysis of variance (Proc GLM; SAS Institute, Cary, NC). Growth was calculated as the difference in height and stem diameter from the initial to the final measurements. Tukey's honestly significant difference was used for pairwise comparisons for significant response variables.

Results

Growth was similar for plants receiving the two nutrient application treatments (Fig. 1). The increase in height was 72% above, increase in diameter was 29% above, and ending leaf number was 64% above that of control plants.

Leaf nutrient concentrations were not different between the two nutrition treatments, but one or both treatments exhibited leaf concentrations greater than control plants for eight of the 11 nutrients (Table 1). The exceptions were boron, carbon, and copper.

Stem nutrient concentration differences were heterogeneous among the nutrients (Table 1). Stem boron, copper, nitrogen, phosphorus, potassium, and zinc concentrations were not different for edaphic vs. foliar nutrition. In contrast, stem calcium, iron, magnesium, and manganese concentrations were greater in plants receiving edaphic applications than plants receiving foliar applications. As expected, most of the nutrients in stems of the plants receiving edaphic applications were greater than stems of control plants. In addition, eight of the 11 nutrients exhibited greater stem concentrations for the foliar application treatments than for the control treatment.

Discussion

The results indicate nutritional needs of recently out-planted *S. nelsonii* plants may be supplied as sprays to aboveground organs to mitigate the below-ground competition for nutrient resources. Phosphorus and potassium limit in situ *S. nelsonii* productivity more than other nutrients based on leaf stoichiometry (Marler, 2021). Plants receiving the foliar applications exhibited leaves with 56% greater phosphorus and 35% more potassium than control plants. More importantly, plants receiving foliar applications exhibited stems with 75% more phosphorus and 45% more potassium than control plants, indicating efficient mobilization of foliar-applied nutrients into the stem tissue.

Nitrogen, phosphorus, potassium, and zinc are resorbed in senescing *S. nelsonii* leaves more efficiently than other nutrients (Marler, 2021). Although the control plants in this study exhibited leaf mortality, no leaf mortality

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T.E.M. is the corresponding author. E-mail: marler.uog@gmail.com.

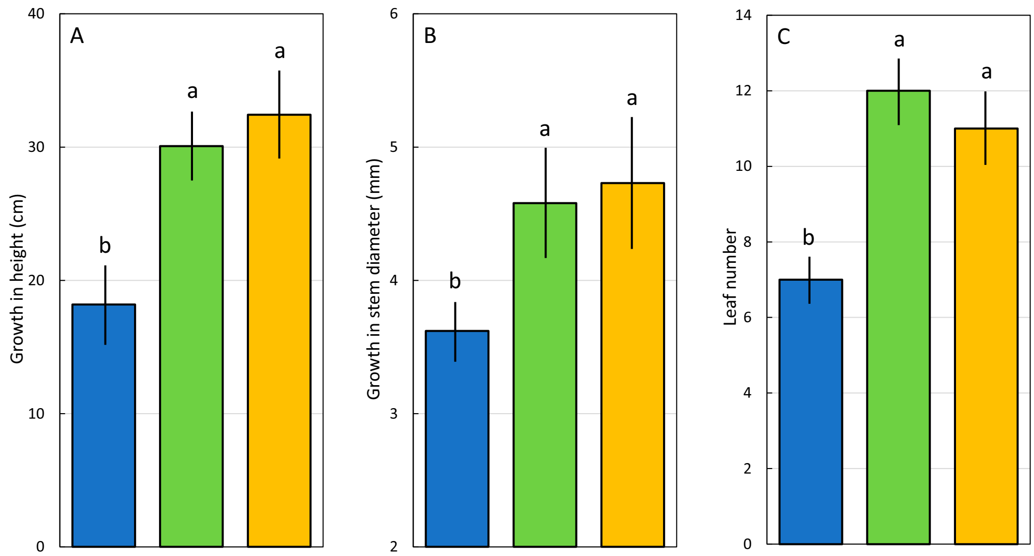

Fig. 1. Size of *Serianthes nelsonii* seedlings as influenced by nutrition treatments. Blue = control; green = edaphic nutrition; yellow = foliar nutrition. (**A**) Increase in stem height; (**B**) increase in stem diameter; (**C**) final leaf number. Bars with same letters are not different. Mean ± SE, n = 8.

occurred in the nutrient application treatments. The substantial increase in stem concentrations of these nutrients deserves further study, as the results indicate translocation from leaf to stem occurred in the absence of leaf senescence. The observation that leaf longevity increased in plants receiving either nutrient treatment also deserves further study as one approach for increasing plant productivity.

The mechanistic details of these plant behaviors may be more fully understood with more refined methods; for example, use of solution applications that ensure homogeneous total nutrient applications between the two treatments. Moreover, endorsement of this conservation protocol requires repeating the methods in situ. One caveat of my methods is that rainfall was excluded from the experimental plants. This is not feasible in a forest setting. Rainfall may affect the results in two ways. First, tissue concentrations may be less than reported here if nutrients are washed off by rainfall before absorption into the laminae. Second, tissue concentrations may be more than reported here if some surface nutrients are washed into the soil where they may be absorbed by the roots. Moreover, plant responses to horticultural manipulations may be affected by con- and interspecific competition, so the efficacy of this newly described management protocol in situ is not known until it is repeated in a competitive forest.

This study adds to a growing body of adaptive management lessons that inform conservation decisions for this endangered endemic tree species (Marler et al., 2021). For example, treatments that increase relative root growth in a container nursery appear to be mandatory to improve posttransplant survival, and two protocols have been identified to achieve this goal (Marler, 2019; Marler and Callaway, 2021). As a late successional species, studies indicate shade is mandatory for germination and growth of seedlings and saplings (Marler et al., 2015). Grafting scions on congeneric rootstocks may be used to mitigate the constrained seed supply (Marler, 2017).

Table 1. Foliar and stem nutrient concentrations of *Serianthes nelsonii* seedlings as influenced by edaphic versus foliar nutrition. Mean ± SE, n = 8.

Nutrient	Control	Edaphic nutrition	Foliar nutrition	$F_{2,21}$	P
Leaf					
Boron	33.1 ± 1.6 a[z]	35.1 ± 1.9 a	35.7 ± 1.7 a	0.726	0.496
Calcium	10.6 ± 0.5 b	12.1 ± 0.6 ab	12.8 ± 0.8 a	4.997	0.017
Carbon	447 ± 3 a	452 ± 2 a	450 ± 2 a	1.474	0.252
Copper	2.5 ± 0.3 a	2.9 ± 0.3 a	3.1 ± 0.3 a	1.209	0.318
Iron	38.8 ± 2.8 b	59.1 ± 4.2 a	57.1 ± 5.3 a	7.772	0.003
Magnesium	2.1 ± 0.1 b	2.9 ± 0.1 a	2.8 ± 0.1 a	19.557	<0.001
Manganese	24.1 ± 1.9 b	32.4 ± 3.4 a	33.9 ± 3.5 a	3.547	0.047
Nitrogen	15.1 ± 1.0 b	22.5 ± 1.5 a	21.2 ± 1.2 a	9.976	<0.001
Phosphorus	1.6 ± 0.1 b	2.6 ± 0.1 a	2.5 ± 0.1 a	30.798	<0.001
Potassium	11.2 ± 0.4 b	14.8 ± 0.5 a	15.1 ± 0.6 a	21.904	<0.001
Zinc	20.4 ± 1.9 b	36.6 ± 2.5 a	36.4 ± 2.8 a	14.847	<0.001
Stem					
Boron	9.7 ± 0.3 b[z]	11.7 ± 0.7 a	10.4 ± 0.5 ab	10.265	<0.001
Calcium	15.1 ± 1.1 a	14.7 ± 0.3 a	11.7 ± 0.2 b	8.480	0.002
Carbon	426 ± 1.8 a	427 ± 2 a	433 ± 3 a	3.369	0.058
Copper	3.1 ± 0.3 a	4.0 ± 0.8 a	3.9 ± 0.3 a	1.452	0.257
Iron	42.8 ± 2.5 a	44.5 ± 3.5 a	29.4 ± 1.2 b	3.986	0.034
Magnesium	2.4 ± 0.1 b	3.1 ± 0.2 a	2.5 ± 0.1 b	11.089	<0.001
Manganese	5.2 ± 0.3 b	6.8 ± 0.4 a	5.1 ± 0.4 b	6.345	0.007
Nitrogen	5.7 ± 0.6 b	8.8 ± 1.0 a	8.7 ± 0.4 a	6.725	0.006
Phosphorus	1.6 ± 0.2 b	2.7 ± 0.1 a	2.8 ± 0.1 a	21.821	<0.001
Potassium	10.4 ± 0.1 b	14.9 ± 0.8 a	15.1 ± 0.7 a	18.672	<0.001
Zinc	24.1 ± 1.4 b	37.5 ± 4.3 a	34.5 ± 2.7 a	5.481	0.012

[z]Means within a row not followed by the same letter are significantly different at $P \leq 0.05$.

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