Nitrogen Nutrition of Containerized *Anemone* x *hybrida*[1]

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Abstract

Uniform single crown plantlets of *Anemone* x *hybrida* Paxton 'Margarete' were grown in 3.8-liter (#1) containers filled with a substrate of composted pine bark:sand (8:1 by vol). Plants were fertilized three times weekly for 15 weeks with a complete nutrient solution at nitrogen application rates (NARs) of 10, 40, 80, 150 or 300 mg/liter (ppm) nitrogen (N), in a constant ratio of 1 ammonium:2 nitrate. All other nutrients were held constant. Leaf area, top dry weight, and root dry weight increased with increasing NAR until reaching a plateau at a NAR of 144 ± 21 mg/liter (ppm), 158 ± 28 mg/liter (ppm), and 119 ± 30 mg/liter (ppm), respectively. The proportion of fine roots to thick roots was unaffected, and production of propagation material (root cuttings) reached a plateau at a NAR of 108 ± 28 mg/liter (ppm). Leaf concentrations of N, P, and K at maximum leaf area were 4.7%, 0.5%, and 3.5%, respectively.

Index words: Ranunculaceae, ornamentals, herbaceous perennials, mineral nutrition, propagation, container culture.

Significance to the Nursery Industry

Fall flowering anemones (Ranunculaceae) are popular herbaceous perennials that have been grown in American gardens since the mid-1800s. Flowering reliably in late summer and throughout the fall, they provide color at a time when few other perennials are in bloom. No information relative to the fertility requirements of these plants is currently available, other than general recommendations for herbaceous perennials. In addition, propagators have reported difficulties in producing suitable starter plants of fall flowering anemones, and growers in the United States must import them from Europe in order to meet demand (4). Dubois et al. (4) have outlined a successful method of propagation by root cuttings, but no information is available regarding the quantity of propagation material (root cuttings) produced by stock plants, and the influence of fertility on that quantity.

Our results demonstrate that N supplied three times weekly at rates of approximately 150 mg/liter (ppm), in a ratio of 1 ammonium:2 nitrate, maximizes plant growth. A somewhat lower rate of N [108 ± 30 mg/liter (ppm)] maximizes production of propagation material. Rates of N above these, and up to 300 mg/liter (ppm), neither increase nor decrease the values attained by these growth parameters and should be avoided for both economical and environmental reasons.

Introduction

Anemone x *hybrida* is one of four closely related species referred to collectively by the common name 'Japanese anemone', or, perhaps more accurately, 'fall flowering anemone'. Fall flowering anemones comprise *A. hupehensis* Lemoine, including *A. hupehensis* var. *japonica* (Thunb.) Bowles & Stearn, *A. tomentosa* (Maxim.) S.J. Pei, *A. vitifolia* Buch.-Ham., and *A.* x *hybrida*, which itself results from the cross of *A. hupehensis* x *A. vitifolia* (2, 7, 11). Their graceful flowers, held well above the mass of basal foliage, have accounted for their continuous popularity in both European and American gardens since the mid 1800s. They tolerate a wide range of growing conditions, although they perform best with some protection from direct sun, in USDA hardiness zones 5 to 8. Their autumn flowering attribute makes them especially valuable in the landscape, because of the limited number of plants blooming at that season (2, 8).

At present, information concerning fertility requirements of fall flowering anemone is lacking. Published N recommendations for herbaceous perennials vary from 100 to 200 mg/liter (ppm) applied at every irrigation to between 100 and 150 mg/liter (ppm) once weekly, depending on species (1, 14). Maximum plant growth has been reported to occur at a nitrogen application rate (NAR) of 166 mg/liter (ppm) applied at every irrigation in Blackfoot daisy (*Melampodium leucanthum* Torr. and A. Gray) (6), and 400 mg/liter (ppm) applied weekly in 'Stella de Oro' daylily (*Hemerocallis* L. x 'Stella de Oro') (15). As a consequence, growers often apply large quantities of mineral nutrients to maximize growth thereby increasing the potential for nutrient losses. An optimized nutrient regime should supply the minimum amount of nutrients necessary to sustain maximum growth, thus reducing both cost and nutrient effluents. Since N typically elicits the greatest growth response in plants, the first objective of this study was to establish the response of relevant growth parameters to applied N in *A.* x *hybrida,* and a second objective was to establish the relationship of NAR and tissue concentrations of N and other mineral nutrients.

Furthermore, in an unpublished survey conducted by the authors, propagators of perennials across the United States indicated they are unable to meet the demand from growers for *A.* x *hybrida.* Propagation is normally accomplished by division or root cuttings, with very low multiplication rates in either case. Dubois et al.(4), however, reported on a method by which 90% to 100% of root cuttings from two cultivars of *A.* x *hybrida* produced plantlets. Since N does not appear to affect the proportion of root cuttings that result in a viable plantlet (success rate) (4), the N concentration that results in the greatest production of propagation material also results in the greatest multiplication rate. Therefore, the third and final objective was to determine the influence of varying rates

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Table 1. Concentration of mineral nutrients in nutrient solution.

Mineral nutrient[z]	Concentration [mg/liter(ppm)]
N from NH_4	3.3 to 100
N from NO_3	6.7 to 200
P	50
K	150
Ca	191
Mg	48
S	99
Fe	5.00
B	0.50
Cu	0.02
Mn	0.50
Mo	0.10
Zn	0.05

[z]Sources of nutrients: NH_4NO_3, $Ca(NO_3)_2$, KH_2PO_4, K_2SO_4, Ca acetate, $MgSO_4$, iron chelate (DPTA), H_3BO_3, $CuSO_4$, $MnCl_2$, $(NH_4)_6(Mo_7O_{24})$, and $ZnSO_4$.

of N applied to containerized plants of *A.* x *hybrida* on the quantity of propagation material produced.

Materials and Methods

On October 1, 1998, 50 uniform single-crown plantlets of *A.* x *hybrida* 'Margarete' were potted individually in 3.8-liter (#1) containers filled with a substrate of composted pine bark:sand (8:1 by vol), amended with 2.4 kg/m^3 (4 lb/yd^3) dolomitic limestone. The plantlets were produced from root cuttings, and were never fertilized. They were placed in a heated 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.

Treatments were initiated October 5. Plants were grown under natural irradiance from 8:00 AM to 5:00 PM and were exposed to a night interruption from 11:00 PM to 2:00 AM using incandescent bulbs. The bulbs 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 tops of the containers with a cosine corrected LI-COR model LI-185A Quantum/Radiometer/Photometer (LI-COR, Lincoln, NE). Plants were irrigated every Monday, Wednesday, and Friday with a complete nutrient solution (Table 1) providing five N concentrations [10, 40, 80, 150 or 300 mg/liter (ppm)], with a constant ratio of 1 ammonium:2 nitrate. All other nutrient concentrations were constant, and pH of the solutions was adjusted to 6.0. Irrigation volume was 200 ml at initiation, and was increased as needed throughout the study to maintain a 0.25 leaching fraction, as monitored every 2 weeks. Container leachate was collected 2 days after treatment initiation and every 2 weeks thereafter using the pour-through nutrient extraction method (17), to determine electrical conductivity (EC) and pH of the substrate solution.

After 15 weeks, roots were washed free of substrate, and each plant separated into leaf blades, petioles, crowns, and roots. Leaf area was measured using a LI-COR 3000 leaf area meter. The root system of each plant for five replications was weighed, then separated further into roots of sufficient diameter to be used as cuttings [mean diam. = 3.6 mm ± 0.37 standard error (SE) (0.14 in ± 0.015 SE)] (hereafter referred to as 'propagation material'), and roots of diameter <3.1 mm (0.12 in), which were judged to be too small for propagation. Fresh weight of propagation material was recorded, and length and area were measured using a Monochrome Agvision System 286 Image Analyzer (Decagon Devices, Inc., Pullman, WA). All tissue was dried for 96 hr at 70C (160F), and weighed. Leaf blades and roots from five replications were processed appropriately for N, P, K, Ca, Mg, S, B, Mn, and Zn analyses (12), which were performed at the Analytical Service Laboratory, Department of Soil Science, North Carolina State University.

The experimental design was a randomized complete block with 10 single-plant replications per treatment. Treatments consisted of the five specified N concentrations. Data were subjected to analysis of variance, regression analysis, and a segmented regression (quadratic-plateau) was fit to the data (PROC NLIN) (16).

Results and Discussion

Growth. Leaf area, leaf dry weight, petiole and crown dry weight, and root dry weight, were all affected by NAR. Coefficients for pairwise correlation of leaf area, leaf dry weight, and petiole and crown dry weight were >0.98. Therefore only data for leaf area, top dry weight (sum of leaf, petiole, and crown), and root dry weight are presented.

Leaf area and top dry weight increased with increasing NAR, until reaching a maximum plateau at 144 ± 21 SE mg/

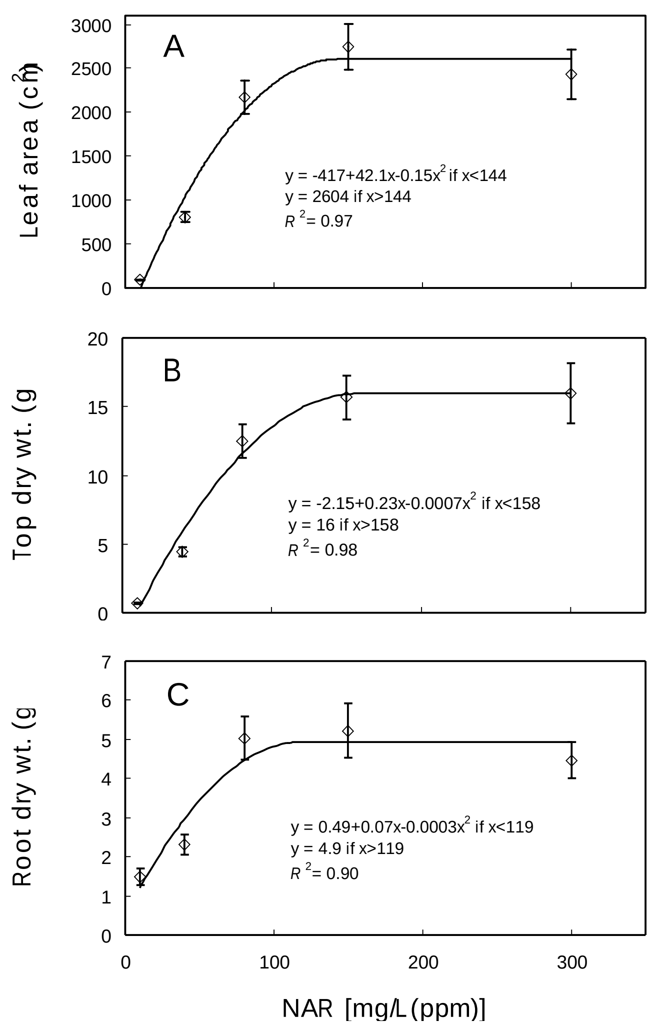

Fig. 1. Effect of nitrogen application rate (NAR) on growth of 'Margarete' anemone (n = 10). (A) leaf area, (B) top dry weight, and (C) root dry weight. Vertical bars represent standard errors of the means.

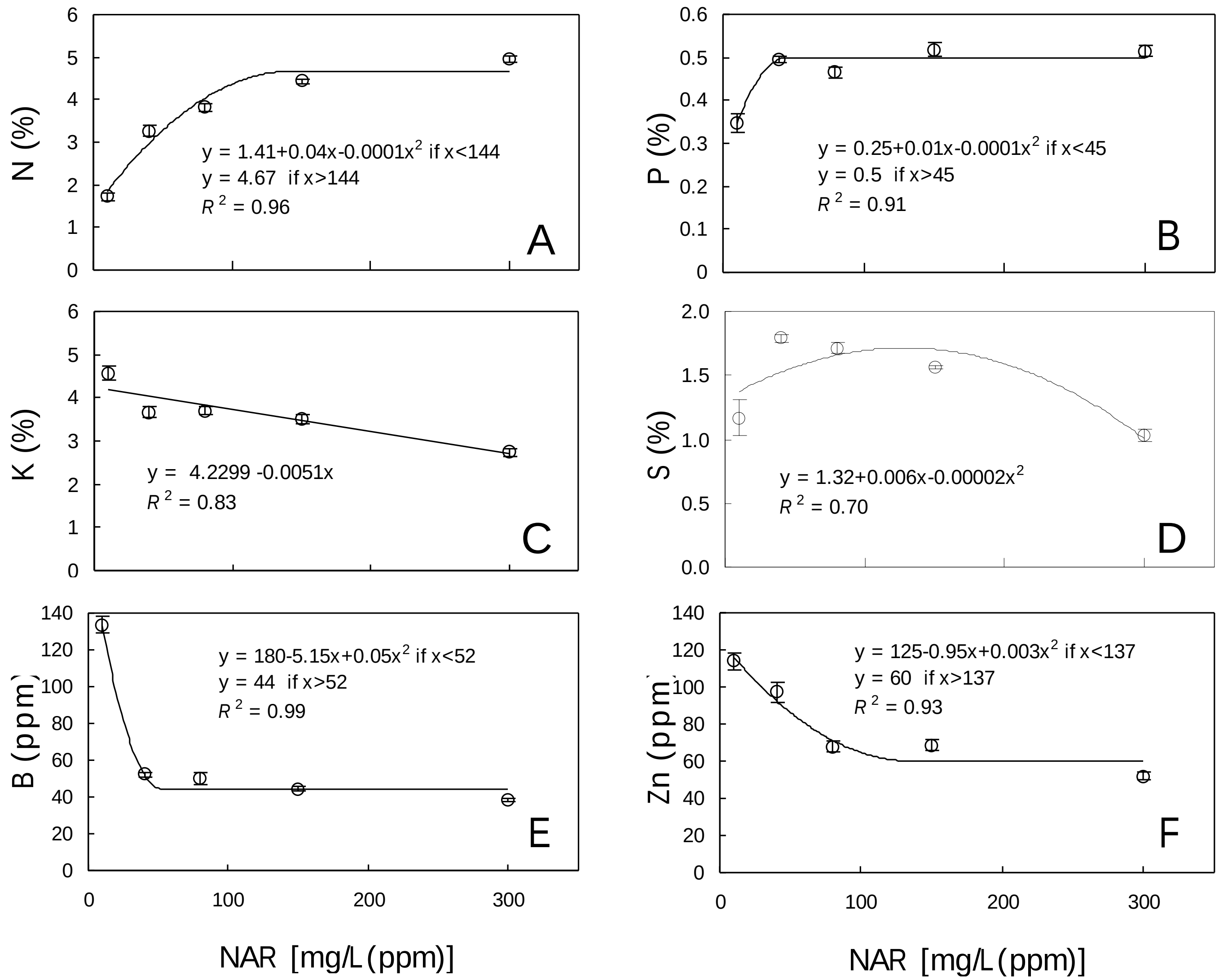

Fig. 2. Effect of nitrogen application rate (NAR) on foliar mineral nutrient concentrations of 'Margarete' anemone (n = 5). (A) nitrogen, (B) phosphorus, (C) potassium, (D) sulfur, (E) boron, and (F) zinc. Vertical bars represent standard errors of the means.

liter (ppm) and 158 ± 28 SE mg/liter (ppm), respectively (Fig. 1A and B). An average leachate EC of 1.61 dS/m over the course of 11 weeks corresponded to a NAR of 150 mg/liter (ppm). These values are markedly higher than those reported for woody ornamentals, such as 'Tonto' crape myrtle (*Lagerstroemia* L. x 'Tonto') (3) where the same parameters reached maxima at a NAR of 60 mg/liter (ppm), or 'Green Giant' arborvitae (*Thuja* L. x 'Green Giant') (5), for which N at 100 mg/liter (ppm) was sufficient to attain maximum top dry weight. They are similar, however, to those reported for Blackfoot daisy (6), another herbaceous perennial that attained maximum growth with N at 166 mg/liter (ppm), but considerably lower than for 'Stella de Oro' daylily (15), where maximum top dry weight occurred at 400 mg/liter (ppm). These disparities attest to the existence of marked differences among the nutritional requirements of various herbaceous perennials, and warrant continued investigation of optimal fertility regimes for a broader variety of such plants.

Interestingly, the response of root dry weight to increasing N showed an increase followed by a maximum plateau (Fig. 1C). This coincides with a prevalent pattern across plant species (10), including 'Stella de Oro' daylily (15). It is, however, in sharp contrast with the rapid decline in root dry weight with increasing NAR, followed by a minimum plateau, described for 'Tonto' crape myrtle (3) and 'Green Giant' arborvitae (5). This may simply reflect the differing role of the root system in herbaceous and woody perennials. Roots of herbaceous perennials are responsible for survival of the plant beyond a single year after the annual disappearance of aerial portions, as opposed to woody plants, where both aerial and soil-borne organs share that role. Increasing the amount of nutrient resources apportioned to the roots when those resources increase might thus constitute a greater survival advantage in herbaceous than in woody perennials.

Mineral nutrient concentrations. Foliar mineral concentrations of N, P, K, S, B, and Zn were affected by NAR (Fig. 2), whereas concentrations of Ca (mean = 2.2% ± 0.03 SE), Mg (mean = 0.3% ± 0.009 SE), and Mn (mean =72 ppm ± 5 SE) were not (data not presented). Foliar concentrations of N, P, B, and Zn responded in a quadratic-plateau fashion; the response of S was quadratic; and that of K was linear. All values were within reported ranges for other herbaceous genera within the Ranunculaceae (12). The predicted maximum

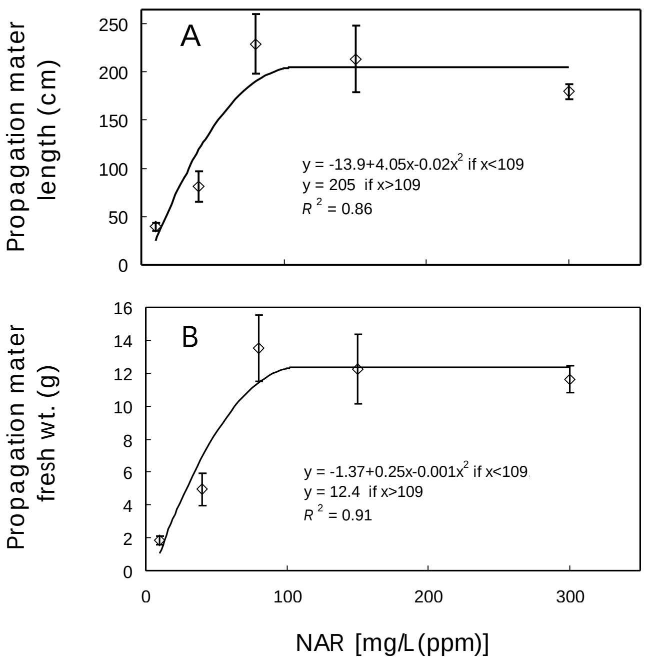

Fig. 3. Effect of nitrogen application rate (NAR) on yield of propagation material (root cuttings) of 'Margarete' anemone (n = 5). (A) cumulative length of propagation material and (B) cumulative fresh weight of propagation material. Vertical bars represent standard errors of the means.

foliar concentration of N (plateau) is 4.67 ± 0.1%, at a NAR of 144 ± 14 SE mg/liter (ppm). This is similar to the NAR predicted for maximum leaf area [144 mg/liter (ppm)] and top dry weight [158 mg/liter (ppm)]. From this we conclude that foliar concentrations of N lower than approximately 4.7% may be indicative of less then optimal top growth. For all other nutrients (P, K, Ca, Mg, S, B, Mn, and Zn), foliar concentrations observed in the present study at a NAR of 150 mg/liter (ppm) should be considered indicative of good plant vigor, although optimal levels were not determined directly. Caution should thus be exercised in interpreting the behavior of nutrients other than N when applied N was not optimal. In particular, this study did not provide data regarding the foliar concentrations that might constitute deficiency for nutrients other than N.

Propagation material. Total length of propagation material produced per plant was affected by NAR, following a quadratic-plateau pattern, with a maximum of 205 ± 17 SE cm predicted at 109 ± 30 SE mg/liter (ppm) (Fig, 3A). Fresh weight of propagation material followed a similar pattern, with a maximum at 108 ± 29 SE mg/liter (ppm) (Fig. 3B). Using 4-cm (1.6 in) long root cuttings, as in the protocol described by Dubois et al. (4), each stock plant would yield 51 ± 4 root cuttings. Since the percentage of root cuttings that result in viable plantlets is between 90% and 100% , and does not appear to be affected by the rate of N applied to stock plants (4), each stock plant grown for 15 weeks could generate 42 to 55 starter plants.

The mean diameter of roots suitable for propagation (diam. = 3.1 mm), and the proportion of such roots relative to finer roots (fresh weight / fresh weight) were unaffected by NAR (data not presented). This should be interpreted cautiously, however, as these plants were grown under long day conditions, and morphological changes relating to photosynthate storage can be triggered by shortening photoperiod (9, 13).

Summary. A complete nutrient solution providing N at approximately 150 mg/liter (ppm) in a ratio of 1 ammonium:2 nitrate, applied three times weekly, provided optimal growth of 'Margarete' anemone. NARs up to 300 mg/liter (ppm) were neither detrimental, nor advantageous to plant growth, and should be avoided. At a NAR of 150 mg/liter (ppm), single crown plantlets planted in 3.8-liter (#1) containers grew into large, robust plants within 15 weeks. Leaf nutrient concentrations at this NAR were comparable to other members of the Ranunculaceae. Plants used as stock plants for propagation by root cuttings will yield the most propagation material when supplied with a NAR of approximately 110 mg/liter (ppm). Dubois et al. (4) have reported that 12 weeks are sufficient to regenerate plantlets from root cuttings. Thus, a full cultural cycle, from propagation by root cuttings to production of a finished or saleable plant can be completed in 27 weeks, possibly less.

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