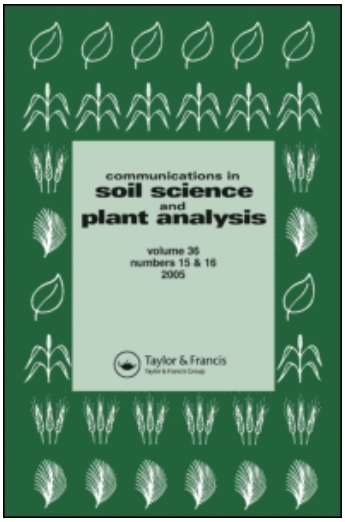

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Survey of Tissue Nutrient Levels in Vegetative Cuttings

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Nutrient ranges for finished plant production exist for many plant species, however, ranges (recommended or survey) do not exist for unrooted cuttings. A tissue nutrient survey was conducted during 2004–2008 on 44 plant genera commercially produced as unrooted cuttings. The objectives of this survey were to compare mean tissue nutrient levels from the selected plants to recommended ranges and to provide survey ranges for species for which sufficiency data are not available. Mean tissue levels in almost 50% of the unrooted cutting species surveyed were statistically similar to ranges established for finished plants. Species with nutrients that fell outside the recommended ranges did not reach critical minimum deficiency or toxicity levels. The nutrient ranges presented in this survey represent typical nutrient levels in cuttings of each species. Growers can use these ranges when interpreting tissue analysis reports of their unrooted cuttings and making corrective nutrient management decisions.

Keywords Propagation, recommended range, stock plant production, survey range

Introduction

Offshore production of unrooted cuttings of ornamental bedding is increasing, with three quarters of these imports coming from Costa Rica, Guatemala, and Mexico (U.S. Department of Agriculture 2007). Total sales increased from $23.7 million in 1997 to $61.2 million in 2006, and the total volume of units imported was near 900 million in 2006, twice that imported in 2000 (U.S. Department of Agriculture 2007).

Stock plant nutrition has been shown to affect subsequent rooting success of the vegetative cuttings (Dole and Gibson 2006). We found that tissue nitrogen (N), phosphorus (P), and potassium (K) concentrations in petunia tissue declined during propagation even under constant fertigation, from 6.6% N to 4.7% N (Santos et al. 2011). Unrooted cuttings with initially lower tissue nutrient concentrations are therefore at risk of falling below sufficiency ranges during propagation.

Tissue nutrient analysis is used to confirm deficiency symptoms, evaluate nutrient interactions, confirm uptake of applied nutrients, and establish recommended (sufficiency) or survey ranges. A recommended range is determined by testing plant tissue that appears

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near or above toxicity or below deficiency symptoms (Mills and Jones 1996). The goal is to develop a range that represents concentrations of a given nutrient that falls between deficiency and toxicity symptoms, at which growth rate and plant quality are acceptable for horticultural production (Mills and Jones 1996). During plant production, the objectives should be for the plant tissue results of a given crop to fall in the median of the recommended range. In contrast, survey ranges describe observed nutrient levels, which may or may not be adequate for plant health but represent typical ranges under current nutrient management practices (Mills and Jones 1996). The limitation is that the lower and upper limits of the survey range are not as clearly defined as those of the recommended range (Mills and Jones 1996).

Survey ranges in the current study were determined through evaluation of multiple tissue nutrient analyses of healthy-looking cuttings over time, a process that required much less time and materials than the procedures involved in determining recommended ranges. Recommended and deficiency ranges were quantified by Gibson et al. (2007) for more than 25 popular bedding plants produced as seed or vegetative cuttings based on growth response in hydroponic studies. Adequately fertilized stock plants provide cuttings with enough nutrient reserves to carry them through propagation. Nutrient ranges that apply to finished plant production may underestimate the nutrient reserves required by unrooted cuttings; however, ranges (recommended or survey) do not exist for unrooted cuttings. If the recommended ranges determined for finished plant production were also applicable to vegetative cutting production, cutting growers could use those ranges to adjust their irrigation and fertility programs accordingly.

The objectives of this survey were (1) to determine nutrient levels for commercially produced unrooted cuttings for which there are no recommended ranges and (2) to compare mean tissue nutrient levels from a survey of commercially produced unrooted cuttings to published recommended ranges.

Materials and Methods

Twenty-two domestic and offshore stock plant facilities and propagation greenhouses provided tissue samples from visually healthy stock plants or cuttings during 2004–2008 to Quality Analytical Laboratories (Panama City, Fl.), Soil and Plant Laboratory (Orange, Calif.), and University of New Hampshire Plant Diagnostics Laboratory (Durham, N.H.). The tissue samples were taken from the terminal growing tip, included both the stem and one or two sets of expanded leaves, and were representative of the cutting size, age, and quality for each particular species. The tissue sampling method differed from normal tissue sampling protocols as described by Mills and Jones (1996) because samples included the stem, recently mature leaves, and immature leaves. Companies participating in this survey remained anonymous, but each company had several years of experience and demonstrated success in rooted liner and finished plant production. Stock plant fertilization programs varied from operation to operation, depending on substrate type, water quality, and plant species. All stock producers used water-soluble fertilizers, and N concentration rates ranged from 150 to 250 $mg \cdot L^{-1}$ as recommended by Dole and Gibson (2006). Samples came primarily from cutting suppliers or were submitted immediately after cuttings were received in the United States by propagation greenhouses.

Participating companies were directed to follow the same sampling method. Samples were to be taken only from visually healthy and vigorous stock plants or cuttings and from a single cultivar per species. The same cultivar was sampled up to three times per production season. Samples were taken from a minimum of 15 plants if a company sampled

from its own stock, with 500 mg of dry weight per sample taken from entire unrooted shoot tips consistent with commercially produced cuttings. Each sample was air dried to avoid *Botrytis* or other disease issues during shipping, bagged separately, and labeled with the cultivar, species, location, and sample date. Samples were promptly shipped to the analytical labs within 24 h of collection.

Total elemental contents in oven-dried, ground plant tissue samples were determined by laboratory plant analysis (Jones 2001). Nitrogen was measured as total Kjeldahl N (TKN). The Kjeldahl N determination method used wet digestion in the presence of an oxidizer, sulfuric acid (H_2SO_4), potassium sulfate (K_2SO_4) to raise the boiling point of the acid, and a metal catalyst to transform the following forms of N [nucleic acids, nitrate (NO_3)-N, ammonium (NH_4)-N, and protein N] into ammonium (Mylavarapu and Kennelley 2002). Quantification of ammonium was accomplished through colorimetry distillation or ion-specific electrode (Mylavarapu and Kennelley 2002). Samples were prepared for analysis of the remaining nutrients by ashing, moistening with equal parts deionized water and hydrochloric acid (HCl), and then analysis of calcium (Ca), magnesium (Mg), P, K, sodium (Na), sulfur (S), aluminum (Al), manganese (Mn), copper (Cu), iron (Fe), zinc (Zn), boron (B), and molybdenum (Mo) using inductively coupled plasma (ICP) emission spectrometry (Mylavarapu and. Kennelley 2002). Aluminum was included in the analysis because in nonaccumulating species, at high concentrations, aluminum negatively affects growth at low substrate pH and in accumulating species, at low concentrations, aluminum can stimulate root growth (Marschner 1995). Therefore, the authors felt that although Al was not defined as an essential element, the typical ranges found in plant tissue were worth recording and monitoring.

Data were analyzed using Proc Means in SAS (version 9.1; SAS Institute, Cary, N.C.). Each sample submitted was identified as an experimental unit, and all cultivars within a given genus were grouped, except for *Impatiens* and *Pelargonium*, which were separated on a species basis. From 2004 to 2008, 4,863 tissue samples were collected from 22 companies for a total of 127 species. Forty-four of those species were sampled a minimum of 10 times from a minimum of two locations. Ranges presented for each species in the survey represented the 10th to the 90th percentiles of the overall sample nutrient ranges. These criteria were considered representative by the authors based on the sample size and source. The high and low values within those ranges were eliminated through presentation of the 10th to the 90th percentiles.

Means calculated in the tissue nutrient survey were compared to published ranges (Williams 2004; Gibson 2003; Pitchay 2002; Mills and Jones 1996; Erwin et al. 1992). These known ranges exist for 14 bedding plant species or genera, which were compared to the mean nutrient levels for corresponding plants in the survey, including *Argyranthemum, Angelonia, Sutera, Begonia, Brachyscome, Bracteantha, Calibrachoa, Impatiens walleriana, Impatiens hawkeri, Nemesia, Osteospermum, Petunia, Salvia,* and *Vinca major*. Critical minimum ranges determined from research by North Carolina State University were also included for comparison. The initial critical minimum values correlate to when visual deficiency symptoms were first apparent on the tissue, and the advanced values indicate when symptoms affected the growth and development of the plant tissue. Recommended and critical minimum ranges for macronutrients and micronutrients were determined, with the exception of N, using a Perkin-Elmer 3300 inductively coupled argon plasma emission spectrophotometer (Perkin-Elmer, Norwalk, Conn.), while total N was analyzed using a Carlo Erba NA 1500 nitrogen analyzer (Thermo Scientific, Waltham, Mass.) (Pitchay 2002).

Results

The survey data represent the typical nutrient levels in cuttings of each species and were divided into two tables, depending on whether recommended ranges already existed for the genus or species (Table 1) or there were no published recommended ranges (Table 2). Survey tissue nutrient means and ranges were organized by plant species (Table 2). Data presented in Table 2 are the first ranges published specifically for unrooted cuttings of those species. Variability tended to be greater in the mean micronutrient values than in the mean macronutrient values per species, as shown in the coefficients of variation (standard deviation/mean) for each species (Table 2). On average, the coefficients of variation by nutrient between species in Table 2 were 17, 27, 22, 40, 37, and 50% for N, P, K, Ca, Mg, and S, respectively, compared with 51, 66, 51, 66, 40, and 77% for Fe, Mn, Zn, Cu, B, and Mo, respectively. Similar trends were observed in Table 1, where coefficients of variation by nutrient between species were 17, 25 20, 35, 36, and 47% for N, P, K, Ca, Mg, and S, respectively, compared with 62, 58, 51, 88, 42, and 83% for Fe, Mn, Zn, Cu, B, and Mo (data not shown).

Substrate physical properties and pH varied between participating locations and could have influenced tissue nutrient concentrations by affecting nutrient availability for uptake. Substrates ranged from peat-based, to volcanic rock, to compost. In addition, water quality would affect the nutrients supplied to the stock plants at the different locations depending on the alkalinity and Ca, Mg, or Fe levels in the water. High coefficients of variation in Cu, Mn, Zn, or S may partly be a result of some plants being treated with fungicides containing one or more of these elements during the sampling period.

Nitrogen, Phosphorus, and Potassium

None of the plant species whose mean N, P, or K tissue nutrient levels were less than the recommended ranges fell below critical minimum levels (Table 1). No plant species showed higher mean tissue N levels than the recommended ranges: 50% (*Begonia, Impatiens wallerana, Nemesia, Impatiens hawkeri, Petunia, Salvia,* and *Vinca major*) were within range and 50% (*Angelonia, Argyranthemum, Bacopa, Brachyscome, Bracteantha, Calibrachoa,* and *Osteospermum*) were less than the recommended range.

For P, 57% of plant species (*Bacopa, Begonia, Nemesia, Impatiens hawkeri, Osteospermum, Petunia, Salvia,* and *Vinca major*) had mean P within range, 7% (one genus, *Calibrachoa*) showed greater P levels, and 36% (*Angelonia, Argyranthemum, Brachyscome, Bracteantha,* and *Impatiens wallerana*) had lower P levels.

Half of the plant species (*Angelonia, Begonia, Calibrachoa, Nemesia, Impatiens hawkeri, Petunia,* and *Salvia*) had mean K within the recommended range, 14% *(Impatiens wallerana* and *Vinca major*) were greater than the recommended range, and 36% (*Argyranthemum, Bacopa, Brachyscome, Bracteantha,* and *Osteospermum*) were lower.

Calcium, Magnesium, and Sulfur

Mean tissue levels were greater than the recommended range in 14% of species (*Brachyscome* and *Osteospermum*) for Ca, 29% (*Argyranthemum, Brachyscome, Bracteantha,* and *Calibrachoa*) for Mg, and 36% (*Argyranthemum, Bacopa, Calibrachoa, Impatiens hawkeri,* and *Vinca major*) for S. In addition, 64% (*Angelonia, Argyranthemum,*

Table 1
Tissue nutrient survey results [mean, standard deviation (std. dev.), 10th and 90th percentiles (survey range)] compared to published recommended ranges for 14 species[a]

Nutrient	Mean[b]	Std. dev.	Survey range	Recommended range	Critical minimum[b] Initial	Critical minimum[b] Advanced
Angelonia (*Angelonia angustifolia*), 71 samples, 5 locations[c]						
N (%)	4.05	0.55	3.43 to 4.66	4.63 to 5.06	2.82	1.70
P (%)	0.41	0.07	0.34 to 0.50	0.44 to 0.63	0.29	0.23
K (%)	**2.88**	0.50	2.36 to 3.34	2.82 to 3.47	2.03	1.49
Ca (%)	0.53	0.23	0.30 to 0.80	0.88 to 1.18	0.24	0.15
Mg (%)	**0.28**	0.09	0.19 to 0.39	0.24 to 0.30	0.16	0.13
S (%)	**0.34**	0.16	0.13 to 0.51	0.33 to 0.37	0.11	0.20
Fe ($mg \cdot L^{-1}$)	90.7	41.7	62.4 to 125.3	99.6 to 110.0	80.3	8.0
Mn ($mg \cdot L^{-1}$)	111.4	52.0	47.7 to 184.4	83.6 to 108.7	11.9	11.4
Zn ($mg \cdot L^{-1}$)	73.9	25.2	43.3 to 106.8	59.4 to 86.2	38.1	28.3
Cu ($mg \cdot L^{-1}$)	6.3	7.1	2.2 to 11.2	8.3 to 12.4	2.5	—
B ($mg \cdot L^{-1}$)	36.1	9.2	26.5 to 47.4	29.6 to 46.2	21.9	22.0
Mo ($mg \cdot L^{-1}$)	1.7	1.7	0.6 to 4.2	— to —	—	—
Al ($mg \cdot L^{-1}$)	62.2	71.2	11.3 to 168.9	— to —	—	—
Argyranthemum (*Argyranthemum frustescens*), 117 samples, 4 locations[d]						
N (%)	5.39	0.76	4.50 to 6.40	6.53 to 7.28	2.92	1.48
P (%)	0.53	0.13	0.37 to 0.70	0.58 to 0.73	0.32	0.06
K (%)	4.72	0.93	3.30 to 6.04	6.49 to 7.05	0.62	0.42
Ca (%)	1.30	0.28	0.99 to 1.67	1.78 to 1.79	0.92	0.24
Mg (%)	0.38	0.17	0.18 to 0.57	0.33 to 0.34	0.07	0.07
S (%)	0.90	0.41	0.45 to 1.44	0.27 to 0.30	0.18	0.06
Fe ($mg \cdot L^{-1}$)	117.9	66.1	64.0 to 201.4	56.0 to 66.0	36.9	23.0

(*Continued*)

Table 1
(Continued)

Nutrient	Mean[b]	Std. dev.	Survey range	Recommended range	Critical minimum[b] Initial	Critical minimum[b] Advanced
Mn ($mg \cdot L^{-1}$)	188.8	97.8	82.3 to 296.8	234.0 to 236.0	10.3	4.9
Zn ($mg \cdot L^{-1}$)	44.3	37.7	20.2 to 79.5	21.5 to 30.9	11.5	7.9
Cu ($mg \cdot L^{-1}$)	15.1	23.3	4.6 to 25.0	5.3 to 7.8	1.9	1.2
B ($mg \cdot L^{-1}$)	60.6	28.5	31.1 to 87.9	47.5 to 58.8	11.7	8.0
Mo ($mg \cdot L^{-1}$)	5.24	4.94	1.30 to 12.40	— to —	—	—
Al ($mg \cdot L^{-1}$)	49.48	37.09	16.29 to 109.71	— to —	—	—
Bacopa (*Sutera* spp.), 87 samples, 6 locations[e]						
N (%)	4.84	0.71	4.00 to 5.77	4.98 to 5.60	1.97	1.15
P (%)	**0.55**	0.17	0.38 to 0.80	0.49 to 0.61	0.12	0.05
K (%)	3.76	0.77	2.86 to 4.71	5.07 to 5.11	0.57	0.40
Ca (%)	0.91	0.36	0.56 to 1.35	1.35 to 1.66	0.34	0.17
Mg (%)	0.36	0.11	0.23 to 0.50	0.40 to 0.41	0.08	0.11
S (%)	0.51	0.23	0.25 to 0.70	0.34 to 0.45	0.11	0.07
Fe ($mg \cdot L^{-1}$)	114.2	82.5	66.3 to 167.0	55.6 to 60.5	40.7	28.4
Mn ($mg \cdot L^{-1}$)	123.8	72.3	55.4 to 194.6	95.8 to 115.0	5.7	3.8
Zn ($mg \cdot L^{-1}$)	47.8	21.1	27.5 to 81.0	22.1 to 27.4	9.5	8.2
Cu ($mg \cdot L^{-1}$)	15.8	12.2	4.9 to 36.3	6.8 to 7.8	1.8	1.6
B ($mg \cdot L^{-1}$)	**44.4**	26.5	23.9 to 72.1	39.1 to 48.5	6.2	5.0
Mo ($mg \cdot L^{-1}$)	3.1	2.3	1.2 to 6.3	— to —	—	—
Al ($mg \cdot L^{-1}$)	57.8	76.7	15.0 to 78.1	— to —	—	—

Begonia (*Begonia* × *hiemalis*), 49 samples, 3 locations[f]						
N (%)	**4.80**	0.87	3.60 to 6.00	2.00 to 6.00	1.50	1.39
P (%)	**0.44**	0.11	0.30 to 0.60	0.29 to 0.75	0.10	0.06
K (%)	**2.55**	0.46	1.82 to 3.03	2.25 to 6.00	0.75	0.52
Ca (%)	0.99	0.25	0.70 to 1.30	1.00 to 3.10	0.55	0.43
Mg (%)	**0.45**	0.15	0.31 to 0.64	0.30 to 0.88	0.10	0.11
S (%)	**0.61**	0.21	0.22 to 0.90	0.22 to 0.70	0.13	0.06
Fe ($mg \cdot L^{-1}$)	**171.5**	131.1	72.9 to 337.7	50.0 to 200.0	62.6	—
Mn ($mg \cdot L^{-1}$)	**77.4**	36.3	27.4 to 127.4	45.0 to 200.0	9.4	8.2
Zn ($mg \cdot L^{-1}$)	**55.2**	43.6	33.1 to 85.5	25.0 to 100.0	21.8	—
Cu ($mg \cdot L^{-1}$)	**10.9**	7.0	5.8 to 16.8	7.0 to 33.0	1.7	1.7
B ($mg \cdot L^{-1}$)	**47.1**	16.8	32.8 to 69.5	20.0 to 75.0	9.1	6.7
Mo ($mg \cdot L^{-1}$)	14.5	11.2	1.5 to 26.6	— to —	—	—
Al ($mg \cdot L^{-1}$)	94.1	67.2	27.6 to 189.8	— to —	—	—
Brachyscome (*Brachyscome* hybrid), 29 samples, 2 locations[g]						
N (%)	4.67	1.09	3.60 to 6.00	6.99 to 7.46	4.29	2.21
P (%)	0.56	0.14	0.39 to 0.70	0.58 to 0.61	0.27	0.23
K (%)	3.77	0.65	2.90 to 4.75	4.77 to 4.95	2.32	1.27
Ca (%)	0.90	0.46	0.53 to 1.15	0.67 to 0.83	0.18	0.14
Mg (%)	0.29	0.14	0.15 to 0.43	0.23 to 0.26	0.13	0.11
S (%)	**0.67**	0.20	0.48 to 0.98	0.31 to —	0.14	0.17
Fe ($mg \cdot L^{-1}$)	**125.5**	63.6	56.2 to 266.1	116.5 to 298.3	66.6	—
Mn ($mg \cdot L^{-1}$)	198.2	94.0	85.1 to 353.2	— to —	—	—
Zn ($mg \cdot L^{-1}$)	54.9	28.0	24.0 to 78.5	— to —	—	—
Cu ($mg \cdot L^{-1}$)	10.6	7.9	5.1 to 23.5	4.5 to 5.3	1.3	—
B ($mg \cdot L^{-1}$)	58.5	20.0	39.2 to 92.2	64.9 to 67.0	47.8	22.1
Mo ($mg \cdot L^{-1}$)	4.7	4.4	1.6 to 11.2	— to —	—	—
Al ($mg \cdot L^{-1}$)	37.4	33.8	7.4 to 71.7	— to —	—	—

(*Continued*)

Table 1
(Continued)

Nutrient	Mean[b]	Std. dev.	Survey range	Recommended range	Critical minimum[b] Initial	Critical minimum[b] Advanced
Bracteantha (*Bracteantha bracteata*), 136 samples, 5 locations[h]						
N (%)	4.91	0.83	3.83 to 5.90	5.51 to 6.33	3.19	1.76
P (%)	0.62	0.13	0.50 to 0.75	0.76 to 0.82	0.26	0.07
K (%)	4.92	0.97	3.60 to 6.31	6.04 to 6.74	1.08	0.77
Ca (%)	1.07	0.29	0.77 to 1.50	1.42 to 1.46	0.29	0.24
Mg (%)	0.37	0.13	0.20 to 0.52	0.21 to 0.29	0.12	0.06
S (%)	**0.68**	0.27	0.47 to 0.98	0.21 to —	0.09	0.05
Fe ($mg \cdot L^{-1}$)	94.4	34.5	57.2 to 139.0	61.4 to 89.9	41.2	27.2
Mn ($mg \cdot L^{-1}$)	196.0	86.3	91.5 to 324.0	117.4 to 174.3	40.1	5.4
Zn ($mg \cdot L^{-1}$)	89.2	33.3	49.4 to 130.8	32.0 to 34.4	18.3	10.8
Cu ($mg \cdot L^{-1}$)	8.5	9.0	3.1 to 15.5	5.8 to 6.8	2.9	1.4
B ($mg \cdot L^{-1}$)	61.3	20.9	37.4 to 90.7	28.5 to 31.2	17.1	5.6
Mo ($mg \cdot L^{-1}$)	5.9	4.4	1.7 to 12.8	— to —	—	—
Al ($mg \cdot L^{-1}$)	64.6	49.5	19.8 to 145.1	— to —	—	—
Calibrachoa (*Calibrachoa* × *hybrida*), 251 samples, 14 locations[i]						
N (%)	4.86	0.74	4.06 to 5.80	5.04 to 5.06	1.65	0.85
P (%)	0.46	0.14	0.30 to 0.63	0.36 to 0.42	0.16	0.05
K (%)	3.33	0.65	2.60 to 3.98	2.95 to 4.22	1.70	0.51
Ca (%)	0.90	0.41	0.48 to 1.37	1.48 to 1.84	0.37	0.11
Mg (%)	0.47	0.18	0.26 to 0.68	0.28 to 0.39	0.11	0.10
S (%)	0.67	0.38	0.23 to 1.13	0.44 to 0.61	0.15	0.21
Fe ($mg \cdot L^{-1}$)	115.9	82.4	59.0 to 199.7	68.0 to 110.4	77.5	40.6

Mn (mg·L^{-1})	**100.4**	66.0	41.4 to 166.5	70.4 to 107.7	34.9	6.3
Zn (mg·L^{-1})	50.4	35.8	26.0 to 68.6	27.4 to 43.9	16.0	10.8
Cu (mg·L^{-1})	10.9	14.4	4.3 to 17.0	9.4 to 9.9	2.6	2.3
B (mg·L^{-1})	51.2	21.3	29.4 to 80.9	32.0 to 37.4	6.4	2.4
Mo (mg·L^{-1})	7.8	5.5	2.3 to 15.4	— to —	—	—
Al (mg·L^{-1})	81.7	167.5	12.7 to 180.1	— to —	—	—
Bedding plant impatiens (*Impatiens wallerana*), 52 samples, 9 locations[j]						
N (%)	**4.49**	0.79	3.29 to 5.48	3.64 to 5.83	1.21	0.82
P (%)	0.64	0.19	0.42 to 0.86	0.77 to 0.92	0.08	0.07
K (%)	3.02	0.77	2.25 to 4.03	1.37 to 2.35	0.31	0.31
Ca (%)	**2.13**	0.43	1.50 to 2.61	1.75 to 2.40	0.34	—
Mg (%)	0.54	0.20	0.27 to 0.83	0.89 to 3.64	0.09	0.07
S (%)	0.59	0.45	0.29 to 1.18	0.83 to 0.87	0.21	0.10
Fe (mg·L^{-1})	196.4	130.6	89.7 to 308.6	107.0 to 130.0	55.4	43.8
Mn (mg·L^{-1})	175.0	109.7	83.1 to 321.0	329.0 to 419.0	10.4	7.6
Zn (mg·L^{-1})	62.3	29.7	33.0 to 93.8	57.0 to 67.0	26.1	23.4
Cu (mg·L^{-1})	12.2	7.4	5.8 to 19.0	20.0 to 37.0	2.5	2.7
B (mg·L^{-1})	38.5	19.9	21.3 to 69.3	23.0 to 25.0	14.1	10.0
Mo (mg·L^{-1})	13.6	7.7	4.4 to 25.9	— to —	—	—
Al (mg·L^{-1})	196.0	276.2	26.0 to 583.2	— to —	—	—
Nemesia (*Nemesia fruticans, N.* hybrids), 262 samples, 7 locations[k]						
N (%)	**5.23**	0.73	4.30 to 6.20	5.63 to 5.94	2.30	1.61
P (%)	**0.57**	0.10	0.46 to 0.71	0.51 to 0.59	0.10	0.04
K (%)	**3.25**	0.65	2.50 to 3.98	4.60 to 4.94	0.34	0.23
Ca (%)	**1.09**	0.31	0.75 to 1.50	1.50 to 1.64	0.56	0.34
Mg (%)	**0.45**	0.15	0.21 to 0.64	0.33 to —	0.08	0.06
S (%)	**0.56**	0.21	0.36 to 0.90	0.16 to 0.23	0.09	0.06
Fe (mg·L^{-1})	**129.7**	93.4	66.9 to 250.1	55.1 to 55.8	37.3	24.6

(*Continued*)

Table 1
(Continued)

Nutrient	Mean[b]	Std. dev.	Survey range	Recommended range	Critical minimum[b] Initial	Critical minimum[b] Advanced
Mn ($mg \cdot L^{-1}$)	**108.9**	64.9	54.7 to 182.0	81.2 to 112.5	6.7	6.0
Zn ($mg \cdot L^{-1}$)	**67.4**	35.3	44.2 to 94.6	20.0 to 22.0	13.8	13.3
Cu ($mg \cdot L^{-1}$)	**11.9**	8.0	6.6 to 19.1	5.9 to 7.0	1.5	1.8
B ($mg \cdot L^{-1}$)	**62.8**	33.3	36.0 to 96.0	42.0 to 43.4	8.1	4.6
Mo ($mg \cdot L^{-1}$)	**4.4**	5.2	1.4 to 8.3	— to —	—	—
Al ($mg \cdot L^{-1}$)	**47.5**	97.8	13.6 to 88.1	— to —	—	—
New Guinea Impatiens (*Impatiens hawkeri*), 675 samples, 9 locations[l]						
N (%)	**4.25**	0.85	3.15 to 5.36	2.00 to 4.50	1.95	1.09
P (%)	**0.46**	0.10	0.36 to 0.58	0.20 to 0.80	0.07	0.05
K (%)	**2.35**	0.43	1.86 to 2.87	1.50 to 4.50	0.53	0.50
Ca (%)	**1.73**	0.34	1.36 to 2.17	0.50 to 2.00	0.72	0.42
Mg (%)	**0.36**	0.14	0.22 to 0.56	0.30 to 0.80	0.07	0.07
S (%)	1.05	0.43	0.55 to 1.63	0.21 to 0.91	0.08	0.05
Fe ($mg \cdot L^{-1}$)	**133.7**	99.1	61.9 to 288.3	75.0 to 300.0	43.9	—
Mn ($mg \cdot L^{-1}$)	**109.6**	86.5	41.1 to 186.9	50.0 to 250.0	5.8	4.0
Zn ($mg \cdot L^{-1}$)	**50.5**	23.3	32.0 to 67.7	25.0 to 100.0	18.6	17.7
Cu ($mg \cdot L^{-1}$)	**6.0**	4.6	3.2 to 9.1	5.0 to 15.0	1.6	1.6
B ($mg \cdot L^{-1}$)	**38.1**	15.1	23.5 to 54.9	20.0 to 60.0	6.1	4.9
Mo ($mg \cdot L^{-1}$)	14.0	11.1	1.3 to 28.0	— to —	—	—
Al ($mg \cdot L^{-1}$)	64.4	88.2	18.2 to 123.4	— to —	—	—

Osteospermum (*Osteospermum hybrida*), 256 samples, 15 locations[m]						
N (%)	5.25	1.05	3.77 to 6.53	5.70 to 6.50	2.50	1.50
P (%)	**0.64**	0.20	0.43 to 0.90	0.30 to —	0.10	0.10
K (%)	3.78	0.76	2.97 to 4.67	4.50 to 5.00	0.70	0.50
Ca (%)	1.82	0.54	1.14 to 2.52	1.70 to 1.80	0.40	0.20
Mg (%)	**0.68**	0.25	0.39 to 1.02	0.50 to —	0.10	0.10
S (%)	**1.07**	0.60	0.29 to 1.88	0.20 to —	0.10	0.10
Fe ($mg \cdot L^{-1}$)	118.8	58.1	64.8 to 190.0	63.2 to 65.3	47.8	23.1
Mn ($mg \cdot L^{-1}$)	173.5	103.0	83.2 to 281.2	95.2 to 142.0	14.9	3.7
Zn ($mg \cdot L^{-1}$)	52.9	24.8	28.2 to 80.3	14.0 to 23.3	9.7	5.8
Cu ($mg \cdot L^{-1}$)	13.8	9.8	6.4 to 23.6	6.3 to 7.0	2.5	2.1
B ($mg \cdot L^{-1}$)	**58.1**	24.9	34.2 to 84.2	43.0 to 60.2	12.5	10.3
Mo ($mg \cdot L^{-1}$)	9.1	7.4	1.9 to 21.9	— to —	—	—
Al ($mg \cdot L^{-1}$)	62.7	109.2	17.8 to 112.4	— to —	—	—
Petunia (*Petunia* × *hybrida*), 373 samples, 11 locations[n]						
N (%)	**5.67**	0.88	4.50 to 6.80	3.85 to 7.60	2.06	1.32
P (%)	**0.59**	0.15	0.40 to 0.75	0.47 to 0.93	0.07	0.05
K (%)	**5.04**	0.84	4.02 to 6.02	3.13 to 6.65	0.69	0.63
Ca (%)	1.16	0.46	0.69 to 1.74	1.20 to 2.81	0.32	0.38
Mg (%)	**0.53**	0.20	0.29 to 0.82	0.36 to 1.37	0.08	0.06
S (%)	**0.79**	0.33	0.38 to 1.19	0.33 to 0.80	0.11	0.06
Fe ($mg \cdot L^{-1}$)	**119.3**	104.6	62.6 to 211.0	84.0 to 168.0	53.1	30.0
Mn ($mg \cdot L^{-1}$)	**84.8**	44.1	49.6 to 126.0	44.0 to 177.0	11.4	9.2
Zn ($mg \cdot L^{-1}$)	**51.5**	22.7	30.8 to 81.6	33.0 to 85.0	13.0	10.2
Cu ($mg \cdot L^{-1}$)	**11.6**	10.5	4.5 to 19.8	3.0 to 19.0	3.5	3.3
B ($mg \cdot L^{-1}$)	**41.1**	19.9	24.3 to 66.1	18.0 to 43.0	10.3	5.4

(Continued)

Table 1
(Continued)

Nutrient	Mean[b]	Std. dev.	Survey Range	Recommended range	Critical minimum[b] Initial	Critical minimum[b] Advanced
Mo ($mg \cdot L^{-1}$)	5.5	4.5	1.9 to 10.7	— to —	—	—
Al ($mg \cdot L^{-1}$)	95.9	139.2	16.2 to 248.3	— to —	—	—
Salvia (*Salvia nemorosa, S.× superba*), 56 samples, 3 locations[o]						
N (%)	**4.99**	0.72	3.99 to 5.80	2.38 to 5.61	2.22	2.01
P (%)	**0.34**	0.12	0.21 to 0.50	0.30 to 1.24	0.07	0.07
K (%)	**3.24**	0.62	2.41 to 4.06	2.90 to 5.86	0.22	0.20
Ca (%)	0.99	0.49	0.64 to 1.30	1.00 to 2.50	0.66	0.46
Mg (%)	**0.53**	0.18	0.36 to 0.78	0.25 to 0.86	0.09	0.07
S (%)	0.58	0.25	0.37 to 0.84	0.73 to —	0.10	0.13
Fe ($mg \cdot L^{-1}$)	**125.1**	67.5	60.1 to 225.8	60.0 to 300.0	52.0	—
Mn ($mg \cdot L^{-1}$)	**83.5**	62.1	36.5 to 185.4	30.0 to 284.0	5.1	4.2
Zn ($mg \cdot L^{-1}$)	**48.7**	19.0	28.1 to 73.3	25.0 to 115.0	12.0	11.3
Cu ($mg \cdot L^{-1}$)	**10.2**	7.2	4.9 to 17.3	7.0 to 35.0	1.8	1.8
B ($mg \cdot L^{-1}$)	**50.3**	19.8	30.4 to 71.0	25.0 to 75.0	9.3	8.8
Mo ($mg \cdot L^{-1}$)	4.8	3.9	1.2 to 12.6	— to —	—	—
Al ($mg \cdot L^{-1}$)	94.8	81.3	26.8 to 236.0	— to —	—	—
Vinca (*Vinca major*), 74 samples, 5 locations[p]						
N (%)	**4.93**	0.86	3.56 to 5.84	2.72 to 6.28	2.66	1.04
P (%)	**0.52**	0.12	0.38 to 0.66	0.28 to 0.64	0.07	0.04
K (%)	4.19	1.01	2.82 to 5.33	1.88 to 3.48	0.73	0.28
Ca (%)	0.67	0.35	0.40 to 0.90	0.93 to 1.13	0.32	0.28
Mg (%)	0.26	0.08	0.17 to 0.38	0.32 to 0.78	0.11	0.09

S (%)	0.97	0.59	0.27 to 1.87	0.22 to 0.50	0.09	0.07
Fe ($mg \cdot L^{-1}$)	63.1	38.7	32.5 to 106.9	72.0 to 277.0	29.0	16.4
Mn ($mg \cdot L^{-1}$)	51.6	33.3	29.0 to 89.2	135.0 to 302.0	9.3	5.2
Zn ($mg \cdot L^{-1}$)	**49.3**	17.9	30.1 to 70.0	30.0 to 51.0	12.3	6.4
Cu ($mg \cdot L^{-1}$)	**9.1**	7.3	3.0 to 16.8	6.0 to 16.0	1.4	1.0
B ($mg \cdot L^{-1}$)	**40.8**	12.9	26.6 to 62.6	21.0 to 49.0	10.5	7.9
Mo ($mg \cdot L^{-1}$)	9.2	7.2	1.4 to 20.6	— to —	—	—
Al ($mg \cdot L^{-1}$)	52.4	60.6	11.9 to 130.9	— to —	—	—

[a]Argyranthemum, Angelonia, Sutera, Begonia, Brachyscome, Bracteantha, Calibrachoa, Impatiens walleriana, Impatiens hawkeri, Nemesia, Osteospermum, Petunia, Salvia, and Vinca major.

[b]Values bold in the mean column were within the recommended range. Dashes indicate where reference values were not determined. Critical minimum values correlate to when initial and advanced deficiency symptoms were visible, as determined by North Carolina State University.

[c]Recommended range: Gibson et al. (2007), Williams (2004). Critical minimum: Williams (2004).

[d]Recommended range: Gibson et al. (2007), Pitchay (2002). Critical minimum: Pitchay (2002).

[e]Recommended range: Gibson et al. (2007), Pitchay (2002). Critical minimum: Pitchay (2002).

[f]Recommended range: Mills and Jones (1996) sufficiency data. Critical minimum: Pitchay (2002).

[g]Recommended range: Gibson et al. (2007), Williams (2004). Critical minimum: Williams (2004).

[h]Recommended range: Gibson et al. (2007), Gibson (2003). Critical minimum: Gibson (2003).

[i]Recommended range: Gibson et al. (2007), Williams (2004). Critical minimum: Williams (2004).

[j]Recommended range: Mills and Jones (1996) survey data. Critical minimum: Pitchay (2002).

[k]Recommended range: Gibson et al. (2007), Pitchay (2002). Critical minimum: Pitchay (2002).

[l]Recommended range: Gibson et al. (2007), Mills and Jones (1996) sufficiency data, Pitchay (2002), Erwin et al. (1992). Critical minimum: Pitchay (2002).

[m]Recommended range: Gibson et al. (2007), Pitchay (2002). Critical minimum: Pitchay (2002).

[n]Recommended range: Mills and Jones (1996) survey data. Critical minimum: Pitchay (2002).

[o]Recommended range: Mills and Jones (1996) sufficiency data. Critical minimum: Pitchay (2002).

[p]Recommended range: Mills and Jones (1996) sufficiency data. Critical minimum: Pitchay (2002).

Table 2
Tissue nutrient survey results [mean, standard deviation (std. dev.), coefficient of variation (standard deviation / mean), survey range (10th and 90th percentiles) for species in survey with a minimum of 10 samples from two or more locations

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
Ajuga (*Ajuga reptans*), 43 samples, 2 locations				
N (%)	4.50	0.58	13%	3.86 to 5.20
P (%)	0.49	0.12	25%	0.35 to 0.70
K (%)	3.72	0.72	19%	2.60 to 4.61
Ca (%)	0.95	0.35	36%	0.59 to 1.40
Mg (%)	0.30	0.11	39%	0.18 to 0.46
S (%)	0.54	0.33	61%	0.24 to 0.93
Fe ($mg \cdot L^{-1}$)	105.19	54.66	52%	61.01 to 172.00
Mn ($mg \cdot L^{-1}$)	62.86	29.43	47%	38.12 to 83.23
Zn ($mg \cdot L^{-1}$)	33.25	10.18	31%	24.78 to 50.33
Cu ($mg \cdot L^{-1}$)	13.42	6.74	50%	7.13 to 22.57
B ($mg \cdot L^{-1}$)	46.79	19.97	43%	29.17 to 66.51
Mo ($mg \cdot L^{-1}$)	4.12	2.05	50%	2.05 to 6.93
Al ($mg \cdot L^{-1}$)	115.31	236.60	205%	20.91 to 192.30
Bidens (*Bidens*), 20 samples, 2 locations				
N (%)	5.57	0.69	12%	4.40 to 6.30
P (%)	0.64	0.08	13%	0.51 to 0.74
K (%)	3.71	0.59	16%	3.16 to 4.51
Ca (%)	0.72	0.14	19%	0.61 to 0.82
Mg (%)	0.44	0.10	24%	0.37 to 0.57
S (%)	0.63	0.12	18%	0.53 to 0.78
Fe ($mg \cdot L^{-1}$)	162.53	149.96	92%	80.50 to 453.50
Mn ($mg \cdot L^{-1}$)	91.99	73.22	80%	38.13 to 134.70
Zn ($mg \cdot L^{-1}$)	56.06	20.95	37%	33.55 to 80.38
Cu ($mg \cdot L^{-1}$)	7.75	2.64	34%	4.83 to 10.38
B ($mg \cdot L^{-1}$)	61.17	23.53	38%	39.20 to 91.14
Mo ($mg \cdot L^{-1}$)	3.18	1.77	56%	1.71 to 4.22
Al ($mg \cdot L^{-1}$)	32.91	34.30	104%	12.76 to 64.65
Ceratostigma (*Ceratostigma*), 10 samples, 2 locations				
N (%)	3.38	0.66	20%	2.59 to 4.24
P (%)	0.24	0.06	26%	0.19 to 0.35
K (%)	1.54	0.47	31%	1.01 to 2.20
Ca (%)	0.68	0.59	86%	0.31 to 1.47
Mg (%)	0.44	0.24	55%	0.27 to 0.84
S (%)	0.46	0.16	34%	0.24 to 0.68
Fe ($mg \cdot L^{-1}$)	68.90	34.93	51%	45.48 to 127.28
Mn ($mg \cdot L^{-1}$)	50.43	51.03	101%	18.74 to 126.86
Zn ($mg \cdot L^{-1}$)	51.31	27.07	53%	27.50 to 91.16
Cu ($mg \cdot L^{-1}$)	10.58	2.00	19%	7.65 to 12.97

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
B ($mg \cdot L^{-1}$)	45.65	11.59	25%	28.34 to 58.37
Mo ($mg \cdot L^{-1}$)	4.75	4.85	102%	1.22 to 13.45
Al ($mg \cdot L^{-1}$)	65.86	81.28	123%	17.37 to 195.73
Coleus (*Solenostemon scutellariodes*), 56 samples, 5 locations				
N (%)	4.72	0.59	13%	4.00 to 5.44
P (%)	0.78	0.22	28%	0.50 to 1.10
K (%)	4.40	1.17	27%	2.80 to 6.40
Ca (%)	1.51	0.35	23%	1.11 to 2.10
Mg (%)	0.59	0.19	32%	0.39 to 0.86
S (%)	0.45	0.28	61%	0.23 to 0.76
Fe ($mg \cdot L^{-1}$)	136.46	76.06	56%	70.71 to 252.00
Mn ($mg \cdot L^{-1}$)	176.82	99.78	56%	69.33 to 338.20
Zn ($mg \cdot L^{-1}$)	84.15	65.79	78%	40.70 to 134.60
Cu ($mg \cdot L^{-1}$)	14.97	9.63	64%	7.12 to 28.89
B ($mg \cdot L^{-1}$)	48.22	16.03	33%	28.18 to 72.00
Mo ($mg \cdot L^{-1}$)	4.74	3.92	83%	1.42 to 8.19
Al ($mg \cdot L^{-1}$)	93.16	79.55	85%	18.86 to 230.70
Dahlia (*Dahlia* hybrids), 30 samples, 4 locations				
N (%)	5.07	1.04	21%	3.77 to 6.40
P (%)	0.78	0.20	25%	0.58 to 0.98
K (%)	4.34	0.74	17%	3.43 to 5.21
Ca (%)	1.12	0.34	31%	0.62 to 1.46
Mg (%)	0.50	0.13	27%	0.36 to 0.67
S (%)	0.43	0.20	46%	0.23 to 0.71
Fe ($mg \cdot L^{-1}$)	135.99	64.44	47%	81.34 to 231.94
Mn ($mg \cdot L^{-1}$)	123.92	75.78	61%	50.87 to 235.42
Zn ($mg \cdot L^{-1}$)	70.32	27.18	39%	43.62 to 103.83
Cu ($mg \cdot L^{-1}$)	16.13	8.01	50%	9.23 to 22.19
B ($mg \cdot L^{-1}$)	69.08	32.60	47%	42.40 to 103.18
Mo ($mg \cdot L^{-1}$)	2.76	2.79	101%	1.12 to 7.31
Al ($mg \cdot L^{-1}$)	85.84	79.55	93%	30.20 to 182.24
Diascia (*Diascia* hybrids), 40 samples, 6 locations				
N (%)	5.48	0.75	14%	4.69 to 6.10
P (%)	0.61	0.13	21%	0.48 to 0.71
K (%)	3.60	0.73	20%	3.00 to 4.41
Ca (%)	1.06	0.29	28%	0.75 to 1.52
Mg (%)	0.40	0.17	43%	0.23 to 0.67
S (%)	0.51	0.27	54%	0.14 to 0.81
Fe ($mg \cdot L^{-1}$)	131.23	52.76	40%	73.45 to 201.70
Mn ($mg \cdot L^{-1}$)	99.16	84.34	85%	38.36 to 135.20
Zn ($mg \cdot L^{-1}$)	46.68	14.91	32%	33.39 to 64.56

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
Cu ($mg \cdot L^{-1}$)	9.90	9.42	95%	4.59 to 14.99
B ($mg \cdot L^{-1}$)	42.46	15.27	36%	24.27 to 63.66
Mo ($mg \cdot L^{-1}$)	2.84	1.87	66%	1.31 to 5.13
Al ($mg \cdot L^{-1}$)	62.80	42.95	68%	20.37 to 121.67
Euphorbia (*Euphorbia*), 73 samples, 3 locations				
N (%)	4.55	0.73	16%	3.60 to 5.60
P (%)	0.59	0.25	43%	0.35 to 0.86
K (%)	2.89	0.56	19%	2.23 to 3.62
Ca (%)	1.11	0.55	50%	0.60 to 1.70
Mg (%)	0.38	0.18	49%	0.21 to 0.57
S (%)	0.56	0.39	70%	0.26 to 0.91
Fe ($mg \cdot L^{-1}$)	93.06	67.28	72%	50.67 to 138.90
Mn ($mg \cdot L^{-1}$)	73.79	37.06	50%	38.91 to 131.70
Zn ($mg \cdot L^{-1}$)	53.49	47.48	89%	28.69 to 66.91
Cu ($mg \cdot L^{-1}$)	8.00	6.64	83%	3.92 to 11.02
B ($mg \cdot L^{-1}$)	56.28	31.34	56%	24.14 to 106.10
Mo ($mg \cdot L^{-1}$)	10.65	5.96	56%	3.71 to 16.71
Al ($mg \cdot L^{-1}$)	53.48	54.40	102%	16.65 to 112.90
Fuchsia (*Fuchsia* hybrids), 64 samples, 9 locations				
N (%)	4.34	0.66	15%	3.30 to 5.15
P (%)	0.50	0.12	24%	0.35 to 0.69
K (%)	2.70	0.54	20%	2.05 to 3.40
Ca (%)	1.22	0.33	27%	0.84 to 1.60
Mg (%)	0.42	0.14	34%	0.27 to 0.66
S (%)	0.32	0.17	53%	0.13 to 0.52
Fe ($mg \cdot L^{-1}$)	200.74	122.82	61%	67.96 to 345.51
Mn ($mg \cdot L^{-1}$)	97.10	79.21	82%	36.93 to 190.00
Zn ($mg \cdot L^{-1}$)	52.65	19.51	37%	27.79 to 76.98
Cu ($mg \cdot L^{-1}$)	20.90	22.99	110%	7.52 to 35.89
B ($mg \cdot L^{-1}$)	49.69	17.68	36%	26.78 to 72.59
Mo ($mg \cdot L^{-1}$)	7.38	6.30	85%	1.57 to 15.75
Al ($mg \cdot L^{-1}$)	45.45	41.49	91%	11.75 to 106.20
Geranium hybrid, nonzonal (*Pelargonium*), 30 samples, 7 locations				
N (%)	3.55	0.79	22%	2.60 to 4.76
P (%)	0.52	0.10	19%	0.39 to 0.68
K (%)	2.96	0.42	14%	2.58 to 3.42
Ca (%)	1.11	0.24	22%	0.83 to 1.44
Mg (%)	0.25	0.05	20%	0.18 to 0.31
S (%)	0.15	0.04	25%	0.10 to 0.20
Fe ($mg \cdot L^{-1}$)	104.56	44.37	42%	63.45 to 156.97
Mn ($mg \cdot L^{-1}$)	190.17	89.35	47%	74.99 to 308.59

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
Zn ($mg \cdot L^{-1}$)	39.28	13.20	34%	24.90 to 53.99
Cu ($mg \cdot L^{-1}$)	9.17	4.04	44%	5.74 to 12.54
B ($mg \cdot L^{-1}$)	40.98	13.52	33%	24.94 to 58.52
Mo ($mg \cdot L^{-1}$)	3.36	1.58	47%	1.74 to 5.64
Al ($mg \cdot L^{-1}$)	99.89	72.93	73%	30.62 to 226.96
Geranium, ivy (*Pelargonium peltatum*), 66 samples, 7 locations				
N (%)	3.54	0.62	17%	2.97 to 4.09
P (%)	0.41	0.10	24%	0.30 to 0.57
K (%)	3.31	0.38	12%	2.80 to 3.76
Ca (%)	1.18	0.27	23%	0.90 to 1.55
Mg (%)	0.33	0.08	24%	0.24 to 0.38
S (%)	0.12	0.02	17%	0.10 to 0.15
Fe ($mg \cdot L^{-1}$)	113.64	37.48	33%	71.32 to 166.96
Mn ($mg \cdot L^{-1}$)	254.74	119.43	47%	103.55 to 444.19
Zn ($mg \cdot L^{-1}$)	26.37	9.74	37%	19.56 to 35.89
Cu ($mg \cdot L^{-1}$)	7.31	2.91	40%	4.07 to 12.49
B ($mg \cdot L^{-1}$)	50.20	17.55	35%	25.23 to 76.16
Mo ($mg \cdot L^{-1}$)	7.98	5.42	68%	3.18 to 13.87
Al ($mg \cdot L^{-1}$)	107.54	58.45	54%	33.83 to 194.31
Geranium, zonal (*Pelargonium hortorum*), 235 samples, 11 locations				
N (%)	3.55	0.81	23%	2.71 to 4.78
P (%)	0.41	0.11	28%	0.28 to 0.56
K (%)	2.76	0.57	21%	2.17 to 3.49
Ca (%)	1.15	0.30	26%	0.79 to 1.52
Mg (%)	0.32	0.09	27%	0.23 to 0.42
S (%)	0.15	0.07	43%	0.11 to 0.19
Fe ($mg \cdot L^{-1}$)	151.57	70.68	47%	78.34 to 252.23
Mn ($mg \cdot L^{-1}$)	302.64	152.58	50%	113.83 to 539.97
Zn ($mg \cdot L^{-1}$)	55.89	25.06	45%	27.54 to 88.64
Cu ($mg \cdot L^{-1}$)	10.10	8.14	81%	5.41 to 16.27
B ($mg \cdot L^{-1}$)	40.20	15.26	38%	25.31 to 56.24
Mo ($mg \cdot L^{-1}$)	4.15	2.46	59%	2.12 to 6.63
Al ($mg \cdot L^{-1}$)	167.96	107.17	64%	59.11 to 338.68
Helichrysum (*Helichrysum*), 14 samples, 5 locations				
N (%)	3.65	0.84	23%	2.40 to 4.45
P (%)	0.35	0.13	36%	0.23 to 0.61
K (%)	3.29	1.10	33%	2.40 to 5.06
Ca (%)	0.84	0.30	36%	0.50 to 1.26
Mg (%)	0.26	0.16	60%	0.13 to 0.57
S (%)	0.37	0.22	60%	0.19 to 0.68
Fe ($mg \cdot L^{-1}$)	175.07	106.89	61%	78.96 to 355.70

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
Mn ($mg \cdot L^{-1}$)	168.15	152.40	91%	50.78 to 274.00
Zn ($mg \cdot L^{-1}$)	69.49	45.31	65%	41.89 to 105.40
Cu ($mg \cdot L^{-1}$)	9.36	6.34	68%	3.82 to 19.42
B ($mg \cdot L^{-1}$)	53.46	26.69	50%	25.00 to 91.01
Mo ($mg \cdot L^{-1}$)	4.31	4.54	105%	0.73 to 10.00
Al ($mg \cdot L^{-1}$)	180.85	279.54	155%	32.06 to 299.77
Heliotropium (*Heliotropium arborescens*), 84 samples, 8 locations				
N (%)	4.50	0.71	16%	3.53 to 5.36
P (%)	0.71	0.18	25%	0.52 to 0.90
K (%)	3.10	0.74	24%	2.01 to 4.00
Ca (%)	2.50	0.71	28%	1.70 to 3.10
Mg (%)	0.68	0.25	37%	0.43 to 1.06
S (%)	0.69	0.28	41%	0.42 to 1.16
Fe ($mg \cdot L^{-1}$)	155.57	91.28	59%	74.77 to 272.00
Mn ($mg \cdot L^{-1}$)	138.68	81.18	59%	42.57 to 248.00
Zn ($mg \cdot L^{-1}$)	78.65	32.01	41%	37.16 to 111.00
Cu ($mg \cdot L^{-1}$)	22.05	16.93	77%	5.55 to 42.03
B ($mg \cdot L^{-1}$)	66.60	18.60	28%	47.36 to 94.89
Mo ($mg \cdot L^{-1}$)	4.13	3.82	92%	1.28 to 7.61
Al ($mg \cdot L^{-1}$)	60.33	43.62	72%	21.88 to 122.40
Ipomea (*Ipomea batatas*), 61 samples, 5 locations				
N (%)	5.11	0.78	15%	4.07 to 6.00
P (%)	0.72	0.20	28%	0.44 to 0.90
K (%)	4.17	0.50	12%	3.43 to 4.80
Ca (%)	1.10	0.38	35%	0.62 to 1.52
Mg (%)	0.41	0.15	36%	0.27 to 0.57
S (%)	0.67	0.31	46%	0.28 to 1.06
Fe ($mg \cdot L^{-1}$)	103.33	31.23	30%	67.18 to 136.00
Mn ($mg \cdot L^{-1}$)	118.87	66.17	56%	56.00 to 208.00
Zn ($mg \cdot L^{-1}$)	55.08	19.17	35%	33.15 to 85.41
Cu ($mg \cdot L^{-1}$)	16.20	19.20	119%	3.66 to 42.00
B ($mg \cdot L^{-1}$)	51.99	16.80	32%	36.00 to 71.76
Mo ($mg \cdot L^{-1}$)	5.20	3.82	73%	1.54 to 10.02
Al ($mg \cdot L^{-1}$)	65.47	60.83	93%	15.52 to 151.00
Lamium (*Lamium maculatum*), 19 samples, 3 locations				
N (%)	4.78	0.98	21%	3.52 to 6.09
P (%)	0.49	0.14	28%	0.31 to 0.70
K (%)	3.65	0.84	23%	2.69 to 4.84
Ca (%)	0.98	0.33	34%	0.68 to 1.42
Mg (%)	0.58	0.21	37%	0.20 to 0.81
S (%)	0.43	0.15	35%	0.20 to 0.61

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
Fe ($mg \cdot L^{-1}$)	76.89	36.10	47%	48.96 to 102.73
Mn ($mg \cdot L^{-1}$)	103.31	82.90	80%	24.89 to 271.30
Zn ($mg \cdot L^{-1}$)	41.15	22.04	54%	19.68 to 91.83
Cu ($mg \cdot L^{-1}$)	7.81	3.41	44%	3.99 to 14.95
B ($mg \cdot L^{-1}$)	47.30	18.02	38%	21.24 to 72.44
Mo ($mg \cdot L^{-1}$)	7.22	5.29	73%	0.92 to 15.91
Al ($mg \cdot L^{-1}$)	50.45	54.32	108%	19.53 to 88.82
Lantana (*Lantana camara* and *L. montevidensis*), 65 samples, 11 locations				
N (%)	4.35	0.72	16%	3.60 to 5.20
P (%)	0.55	0.17	30%	0.39 to 0.72
K (%)	3.05	0.54	18%	2.60 to 3.56
Ca (%)	1.18	0.26	22%	0.87 to 1.49
Mg (%)	0.49	0.14	28%	0.32 to 0.69
S (%)	0.41	0.34	81%	0.19 to 0.70
Fe ($mg \cdot L^{-1}$)	109.50	53.14	49%	62.36 to 158.46
Mn ($mg \cdot L^{-1}$)	126.50	80.73	64%	42.39 to 231.28
Zn ($mg \cdot L^{-1}$)	55.29	17.39	31%	34.25 to 76.50
Cu ($mg \cdot L^{-1}$)	10.75	5.55	52%	5.44 to 20.89
B ($mg \cdot L^{-1}$)	60.45	22.17	37%	36.83 to 88.58
Mo ($mg \cdot L^{-1}$)	2.62	1.61	61%	1.12 to 5.49
Al ($mg \cdot L^{-1}$)	70.21	90.86	129%	15.96 to 148.87
Lavandula (*Lavandula angustifolia, L. dentata,* and *L. stoechas*), 16 samples, 7 locations				
N (%)	3.40	0.63	18%	2.54 to 4.10
P (%)	0.38	0.13	33%	0.20 to 0.50
K (%)	3.43	0.68	20%	2.40 to 4.40
Ca (%)	0.78	0.27	35%	0.49 to 1.10
Mg (%)	0.30	0.07	22%	0.23 to 0.41
S (%)	0.21	0.10	46%	0.11 to 0.31
Fe ($mg \cdot L^{-1}$)	108.14	59.08	55%	46.58 to 222.55
Mn ($mg \cdot L^{-1}$)	122.88	116.69	95%	30.20 to 196.23
Zn ($mg \cdot L^{-1}$)	56.29	38.76	69%	23.13 to 129.63
Cu ($mg \cdot L^{-1}$)	11.44	8.41	74%	5.16 to 17.88
B ($mg \cdot L^{-1}$)	41.95	22.60	54%	19.60 to 83.19
Mo ($mg \cdot L^{-1}$)	1.63	1.30	80%	0.65 to 3.48
Al ($mg \cdot L^{-1}$)	110.09	96.64	88%	21.14 to 286.69
Leucanthemum (*Leucanthemum* × *superbum*), 14 samples, 5 locations				
N (%)	4.78	0.81	17%	4.10 to 6.10
P (%)	0.79	0.26	33%	0.41 to 1.20
K (%)	5.84	1.39	24%	4.34 to 7.90
Ca (%)	1.13	0.55	49%	0.50 to 1.80
Mg (%)	0.35	0.15	41%	0.18 to 0.60

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
S (%)	0.48	0.35	74%	0.13 to 1.05
Fe ($mg \cdot L^{-1}$)	85.28	30.87	36%	64.07 to 128.17
Mn ($mg \cdot L^{-1}$)	103.39	42.24	41%	48.27 to 159.90
Zn ($mg \cdot L^{-1}$)	55.09	18.71	34%	34.44 to 81.89
Cu ($mg \cdot L^{-1}$)	9.34	3.50	37%	5.11 to 12.47
B ($mg \cdot L^{-1}$)	51.01	20.19	40%	31.49 to 87.88
Mo ($mg \cdot L^{-1}$)	4.21	2.87	68%	1.39 to 7.72
Al ($mg \cdot L^{-1}$)	55.38	39.29	71%	25.36 to 113.74
Lobelia (*Lobelia erinus*), 22 samples, 5 locations				
N (%)	4.69	0.42	9%	4.34 to 5.21
P (%)	0.62	0.16	26%	0.41 to 0.78
K (%)	4.74	0.75	16%	3.96 to 5.62
Ca (%)	0.88	0.18	21%	0.67 to 1.10
Mg (%)	0.31	0.10	31%	0.22 to 0.47
S (%)	0.30	0.06	21%	0.22 to 0.37
Fe ($mg \cdot L^{-1}$)	170.11	99.30	58%	85.58 to 278.82
Mn ($mg \cdot L^{-1}$)	105.44	60.55	57%	47.78 to 150.18
Zn ($mg \cdot L^{-1}$)	75.23	48.54	65%	35.43 to 149.47
Cu ($mg \cdot L^{-1}$)	8.53	6.97	82%	3.11 to 24.00
B ($mg \cdot L^{-1}$)	33.56	19.11	57%	19.59 to 59.81
Mo ($mg \cdot L^{-1}$)	3.54	4.38	124%	1.06 to 5.43
Al ($mg \cdot L^{-1}$)	196.83	206.06	105%	52.54 to 504.80
Lysimachia (*Lysimachia congestiflora* and *L. nummularia*), 27 samples, 3 locations				
N (%)	4.23	0.52	12%	3.70 to 5.10
P (%)	0.45	0.12	26%	0.29 to 0.60
K (%)	3.35	0.93	28%	2.49 to 4.60
Ca (%)	0.53	0.58	109%	0.28 to 0.79
Mg (%)	0.22	0.18	85%	0.11 to 0.32
S (%)	0.40	0.21	53%	0.22 to 0.76
Fe ($mg \cdot L^{-1}$)	95.86	38.84	41%	65.88 to 172.90
Mn ($mg \cdot L^{-1}$)	56.67	56.97	101%	13.86 to 115.60
Zn ($mg \cdot L^{-1}$)	42.44	41.39	98%	18.67 to 74.40
Cu ($mg \cdot L^{-1}$)	5.70	4.26	75%	1.70 to 12.08
B ($mg \cdot L^{-1}$)	38.50	16.98	44%	19.92 to 70.24
Mo ($mg \cdot L^{-1}$)	8.12	6.03	74%	1.65 to 16.22
Al ($mg \cdot L^{-1}$)	56.90	44.70	79%	24.49 to 159.80
Mecardonia (*Mecardonia*), 10 samples, 3 locations				
N (%)	3.77	0.60	16%	2.88 to 4.45
P (%)	0.42	0.10	25%	0.27 to 0.55
K (%)	2.78	0.72	26%	1.97 to 3.89
Ca (%)	0.94	1.07	113%	0.28 to 2.92
Mg (%)	0.37	0.22	60%	0.19 to 0.75

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
S (%)	0.85	0.36	42%	0.40 to 1.37
Fe (mg·L^{-1})	93.80	66.71	71%	19.58 to 187.03
Mn (mg·L^{-1})	80.06	36.37	45%	43.38 to 132.20
Zn (mg·L^{-1})	75.77	63.16	83%	34.35 to 186.20
Cu (mg·L^{-1})	16.90	18.01	107%	2.40 to 47.87
B (mg·L^{-1})	43.42	18.33	42%	14.51 to 66.20
Mo (mg·L^{-1})	8.32	7.36	88%	2.00 to 21.17
Al (mg·L^{-1})	69.32	64.88	94%	16.96 to 167.75
Penstemon (*Penstemon*), 17 samples, 5 locations				
N (%)	3.82	0.75	20%	3.10 to 5.40
P (%)	0.51	0.09	17%	0.40 to 0.57
K (%)	2.72	0.69	25%	1.97 to 3.90
Ca (%)	0.75	0.24	32%	0.43 to 1.00
Mg (%)	0.36	0.09	26%	0.25 to 0.46
S (%)	0.50	0.54	108%	0.19 to 0.67
Fe (mg·L^{-1})	94.33	67.45	71%	44.45 to 153.46
Mn (mg·L^{-1})	70.19	47.79	68%	21.54 to 155.70
Zn (mg·L^{-1})	39.84	13.76	35%	27.88 to 67.14
Cu (mg·L^{-1})	5.12	3.09	60%	2.04 to 10.95
B (mg·L^{-1})	40.49	8.59	21%	26.95 to 54.00
Mo (mg·L^{-1})	1.77	1.03	58%	0.70 to 3.60
Al (mg·L^{-1})	33.61	23.51	70%	14.49 to 83.08
Perovskia (*Perovskia atriplicifolia*), 13 samples, 3 locations				
N (%)	3.59	0.93	26%	2.20 to 4.57
P (%)	0.46	0.12	26%	0.27 to 0.54
K (%)	3.30	0.83	25%	2.05 to 4.14
Ca (%)	0.62	0.17	27%	0.44 to 0.79
Mg (%)	0.19	0.05	26%	0.14 to 0.25
S (%)	0.35	0.17	47%	0.17 to 0.62
Fe (mg·L^{-1})	89.66	42.79	48%	43.60 to 136.89
Mn (mg·L^{-1})	62.62	61.62	98%	21.85 to 85.96
Zn (mg·L^{-1})	48.96	39.56	81%	27.07 to 75.87
Cu (mg·L^{-1})	6.16	3.69	60%	2.92 to 12.66
B (mg·L^{-1})	48.52	16.12	33%	31.85 to 71.61
Mo (mg·L^{-1})	2.31	1.56	68%	0.92 to 4.12
Al (mg·L^{-1})	116.80	218.59	187%	14.79 to 117.11
Phlox (*Phlox paniculata*), 108 samples, 6 locations				
N (%)	4.98	0.90	18%	3.70 to 5.93
P (%)	0.63	0.16	25%	0.40 to 0.79
K (%)	3.58	0.66	18%	2.80 to 4.35
Ca (%)	1.09	0.45	41%	0.77 to 1.40

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
Mg (%)	0.35	0.14	40%	0.19 to 0.53
S (%)	0.87	0.46	52%	0.38 to 1.39
Fe ($mg \cdot L^{-1}$)	171.77	120.60	70%	51.95 to 332.60
Mn ($mg \cdot L^{-1}$)	101.24	81.40	80%	36.15 to 169.50
Zn ($mg \cdot L^{-1}$)	73.80	52.21	71%	36.26 to 147.02
Cu ($mg \cdot L^{-1}$)	8.04	3.24	40%	3.78 to 12.20
B ($mg \cdot L^{-1}$)	63.56	33.72	53%	31.92 to 104.80
Mo ($mg \cdot L^{-1}$)	3.77	3.18	85%	1.10 to 8.86
Al ($mg \cdot L^{-1}$)	61.37	75.23	123%	13.92 to 143.20
Portulaca (*Portulaca oleracea*), 12 samples, 2 locations				
N (%)	3.94	1.26	32%	1.68 to 5.35
P (%)	0.68	0.39	57%	0.24 to 1.14
K (%)	6.18	3.32	54%	2.64 to 11.50
Ca (%)	0.99	0.47	47%	0.54 to 1.58
Mg (%)	1.34	0.75	56%	0.27 to 2.35
S (%)	0.52	0.32	60%	0.18 to 1.15
Fe ($mg \cdot L^{-1}$)	101.86	37.45	37%	74.50 to 160.90
Mn ($mg \cdot L^{-1}$)	315.36	181.76	58%	107.50 to 558.70
Zn ($mg \cdot L^{-1}$)	81.24	49.69	61%	26.94 to 155.00
Cu ($mg \cdot L^{-1}$)	13.39	9.16	68%	2.55 to 24.00
B ($mg \cdot L^{-1}$)	58.76	22.07	38%	43.36 to 73.94
Mo ($mg \cdot L^{-1}$)	4.04	4.41	109%	1.30 to 14.39
Al ($mg \cdot L^{-1}$)	77.16	89.55	116%	16.36 to 294.50
Scaevola (*Scaevola aemula*), 81 samples, 6 locations				
N (%)	4.56	0.74	16%	3.68 to 5.58
P (%)	0.57	0.22	39%	0.36 to 0.87
K (%)	3.72	0.65	18%	3.05 to 4.62
Ca (%)	1.77	0.43	24%	1.30 to 2.20
Mg (%)	0.44	0.17	39%	0.23 to 0.68
S (%)	0.91	0.52	57%	0.30 to 1.58
Fe ($mg \cdot L^{-1}$)	93.54	49.14	53%	61.99 to 126.71
Mn ($mg \cdot L^{-1}$)	107.76	55.47	51%	57.80 to 194.81
Zn ($mg \cdot L^{-1}$)	42.41	16.58	39%	25.58 to 65.48
Cu ($mg \cdot L^{-1}$)	6.95	7.29	105%	2.28 to 13.32
B ($mg \cdot L^{-1}$)	46.32	21.85	47%	31.64 to 61.32
Mo ($mg \cdot L^{-1}$)	5.19	4.87	94%	1.42 to 10.08
Al ($mg \cdot L^{-1}$)	60.85	62.37	103%	16.77 to 108.80
Sedum (*Sedum*), 12 samples, 3 locations				
N (%)	4.94	0.62	13%	4.20 to 5.70
P (%)	0.51	0.10	19%	0.40 to 0.60
K (%)	4.01	0.75	19%	3.30 to 5.10

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
Ca (%)	3.29	0.84	26%	2.40 to 4.12
Mg (%)	0.41	0.11	27%	0.30 to 0.52
S (%)	0.42	0.30	71%	0.19 to 0.80
Fe ($mg \cdot L^{-1}$)	78.45	42.77	55%	43.83 to 106.90
Mn ($mg \cdot L^{-1}$)	53.23	27.81	52%	15.51 to 85.28
Zn ($mg \cdot L^{-1}$)	67.76	30.66	45%	38.71 to 95.13
Cu ($mg \cdot L^{-1}$)	8.98	3.60	40%	5.25 to 14.49
B ($mg \cdot L^{-1}$)	44.80	22.07	49%	25.66 to 76.84
Mo ($mg \cdot L^{-1}$)	7.97	6.50	82%	3.80 to 18.01
Al ($mg \cdot L^{-1}$)	61.91	72.85	118%	16.86 to 108.48
Thunbergia (*Thunbergia*), 50 samples, 2 locations				
N (%)	5.16	0.71	14%	4.30 to 6.10
P (%)	0.84	0.20	23%	0.61 to 1.06
K (%)	4.09	0.78	19%	3.11 to 4.91
Ca (%)	0.67	0.31	46%	0.33 to 1.06
Mg (%)	0.32	0.06	18%	0.26 to 0.37
S (%)	0.25	0.04	16%	0.21 to 0.29
Fe ($mg \cdot L^{-1}$)	113.62	19.19	17%	91.73 to 134.72
Mn ($mg \cdot L^{-1}$)	130.08	101.10	78%	64.89 to 270.95
Zn ($mg \cdot L^{-1}$)	89.67	23.18	26%	60.76 to 111.82
Cu ($mg \cdot L^{-1}$)	13.34	2.74	21%	9.53 to 16.73
B ($mg \cdot L^{-1}$)	39.22	13.26	34%	27.52 to 62.34
Mo ($mg \cdot L^{-1}$)	2.09	1.57	75%	0.99 to 3.01
Al ($mg \cdot L^{-1}$)	37.51	26.05	69%	15.10 to 76.87
Torenia (*Torenia fournieri*), 86 samples, 6 locations				
N (%)	3.87	0.65	17%	3.00 to 4.80
P (%)	0.53	0.15	28%	0.37 to 0.70
K (%)	2.66	0.89	33%	1.86 to 3.42
Ca (%)	0.45	0.34	75%	0.26 to 0.61
Mg (%)	0.38	0.16	44%	0.20 to 0.60
S (%)	0.37	0.17	45%	0.16 to 0.61
Fe ($mg \cdot L^{-1}$)	130.74	53.16	41%	78.18 to 196.50
Mn ($mg \cdot L^{-1}$)	129.45	74.42	57%	58.79 to 226.60
Zn ($mg \cdot L^{-1}$)	54.48	24.70	45%	32.51 to 82.88
Cu ($mg \cdot L^{-1}$)	12.46	11.15	89%	5.72 to 18.05
B ($mg \cdot L^{-1}$)	63.52	22.74	36%	36.35 to 98.01
Mo ($mg \cdot L^{-1}$)	4.01	2.29	57%	1.50 to 7.42
Al ($mg \cdot L^{-1}$)	70.18	77.98	111%	18.03 to 126.64
Verbena (*Verbena canadensis, V.* x *hybrida, V. rigida, V. tenera,,* and *V. tenuisecta*), 249 samples, 9 locations				
N (%)	5.04	0.90	18%	3.91 to 6.20

(*Continued*)

Table 2
(Continued)

Nutrient	Mean	Std. dev.	Coeff. var.	Survey range
P (%)	0.56	0.13	23%	0.40 to 0.71
K (%)	3.10	0.67	22%	2.33 to 3.92
Ca (%)	1.39	0.49	35%	0.88 to 1.98
Mg (%)	0.51	0.17	34%	0.33 to 0.78
S (%)	0.73	0.36	49%	0.29 to 1.17
Fe ($mg \cdot L^{-1}$)	96.08	40.83	42%	59.56 to 145.20
Mn ($mg \cdot L^{-1}$)	90.23	46.05	51%	40.70 to 144.80
Zn ($mg \cdot L^{-1}$)	48.59	21.09	43%	29.35 to 77.27
Cu ($mg \cdot L^{-1}$)	9.42	7.42	79%	4.32 to 12.80
B ($mg \cdot L^{-1}$)	54.54	24.19	44%	29.63 to 86.14
Mo ($mg \cdot L^{-1}$)	5.17	4.07	79%	1.72 to 10.51
Al ($mg \cdot L^{-1}$)	59.03	57.81	98%	16.16 to 117.20

Bacopa, Begonia, Bracteantha, Calibrachoa, Petunia, Salvia, and *Vinca major*) of species were lower than the recommended ranges for Ca, 21% (*Bacopa, Impatiens wallerana,* and *Vinca major*) for Mg, and 14% (*Impatiens wallerana* and *Salvia*) for S. None of the species whose Ca, Mg, or S tissue nutrient levels were lower than the recommended ranges fell below critical minimum levels.

Micronutrients

Mean micronutrient levels were greater than the recommended range in 43% of plant species (*Argyranthemum, Bacopa, Bracteantha, Calibrachoa, Impatiens wallerana,* and *Osteospermum*) for Fe, 29% (*Angelonia, Bacopa, Bracteantha,* and *Osteospermum*) for Mn, 36% (*Argyranthemum, Bacopa, Bracteantha, Calibrachoa,* and *Osteospermum*) for Zn, 43% (*Argyranthemum, Bacopa, Brachyscome, Bracteantha, Calibrachoa,* and *Osteospermum*) for Cu, and 29% (*Argyranthemum, Bracteantha, Calibrachoa,* and *Impatiens wallerana*) for B. In addition, levels were less than the recommended ranges in 14% (*Angelonia* and *Vinca major*) for Fe, 29% (*Argyranthemum, Brachyscome, Impatiens wallerana,* and *Vinca major*) for Mn, 7% (*Brachyscome*) for Zn, 14% (*Angelonia* and *Impatiens wallerana*) for Cu, and 7% (*Brachyscome*) for B. Plant groups with Fe, Mn, Zn, Cu, and B tissue nutrient levels less than the recommended ranges did not fall below critical minimum levels, and plant groups with Fe, Mn, Zn, Cu, and B greater than the recommended range did not reach toxicity levels.

Conclusion

Maintaining tissue nutrient levels within the recommended ranges for each species is a prerequisite (necessary but may not be sufficient) for rooting success and uniform performance in the propagation environment. The nutrient ranges presented in this survey represent the typical nutrient levels in cuttings of each species. These ranges can be used by growers as an additional resource when interpreting tissue analysis reports of their unrooted cuttings

and making corrective nutrient management decisions should nutrient levels fall outside of the survey ranges.

Overall, 48% of mean tissue nutrient measurements in Table 1 fell within the recommended range, 25% were higher, and 27% were lower. Tissue levels in unrooted cuttings were similar to ranges established for finished plants, in spite of the difference in sampling procedures. Species with nutrients that fell outside the recommended ranges did not reach critical minimum deficiency or toxicity levels. Therefore, we conclude, based on the fact that 75% of the means calculated were either less than or within the recommended ranges, that where those ranges exist for finished plants, they can be applied to stock plant production of vegetative cuttings. However, unlike the species in Table 1, recommended and critical minimum ranges do not yet exist for each of the species in Table 2. The ranges presented in Table 2 should serve as a reference for typical tissue nutrient concentrations in cuttings of those species with the understanding that the determination of survey ranges is based on healthy plant tissue, as compared to recommended ranges, which incorporate more precision sampling of tissue with tissue nutrient deficiency symptoms, along with greenhouse-controlled experiments that evaluate deficiency symptoms by nutrient in hydroponic solutions.

References

Dole, J. M., and J. L. Gibson. 2006. *Cutting propagation: A guide to propagating and producing floriculture crops*. West Chicago, Illinois: Ball Publishing.

Erwin, J., M. Ascerno, F. Pfleger, and R. Heins. 1992. New Guinea *Impatiens* production. *Minnesota Commercial Flower Growers Association Bulletin* 41 (3): 1–15.

Gibson, J. L. 2003. Influence of mineral nutrition on stock plant yield and subsequent rooting of stem cuttings of *Scaevola*, New Guinea *Impatiens*, and vegetative strawflower. PhD diss., North Carolina State University.

Gibson, J. L., D. S. Pitchay, A. L. Williams-Rhodes, B. E. Whipker, P. V. Nelson, and J. M. Dole. 2007. *Nutrient deficiencies in bedding plants*. Ill.: Ball Publishing.

Jones Jr., J. B. 2001. *Laboratory guide for conducting soil tests and plant analysis*. Boca Raton, Fl.: CRC Press.

Marschner, H. 1995. *Mineral nutrition of higher plants*. London: Academic Press.

Mills, H. A., and J. B. Jones Jr. 1996. *Plant analysis handbook II: A practical sampling, preparation, analysis, and interpretation guide*. Athens, Ga.: MicroMacro Publishing.

Mylavarapu, R. S., and E. D. Kennelley. 2002. UF/IFAS Extension Soil Testing Laboratory (ESTL) analytical procedures and training manual (1248). Gainesville: University of Florida Institute of Food and Agricultural Sciences. Available at http://edis.ifas.ufl.edu/ SS312.

Santos, K. M., P. R. Fisher, W. R. Argo, E. H. Simonne, H. S. Carter, and T. Yeager. 2011. Timing of macronutrient supply during cutting propagation of *Petunia*. *HortScience*.

Pitchay, D. S. 2002. Impact of 11 elemental nutrient deficiencies on shoot and root growth and foliar analysis standards of 13 ornamental taxa with emphasis on ca and b control of root apical meristem development. PhD diss., North Carolina State University.

U.S. Department of Agriculture. 2007. Floriculture and nursery crops yearbook. Available at http://www.ers.usda.gov/publications/flo/2007/09Sep/FLO2007.pdf.

Williams, A. L. 2004. Foliar symptomology and tissue concentrations of five nutritionally deficient floriculture crops. Master's thesis, North Carolina State University.