Mineral Deficiency Symptoms of Some Herbaceous Species

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Abstract
Plants of Achillea 'Cloth of Gold,' Aquilegia 'Dragonfly Mixture,' Chrysanthemum morigolium 'Ginger,' Coreopsis 'Sunray,' Dianthus plumarius 'Double Mix.' Lythrum virgatum 'Morden's Gleam,' and Veronica spicata 'Red Fox' were grown using sand culture, hydroponic techniques, and modified Hoagland's solutions to induce nutrient deficiency symptoms. The symptoms appeared after various lengths of time, depending on several factors: the species, the treatment received, the season, and the method used to propagate the plant (either seed or cutting). The symptoms produced were similar to classic textbook nutrient deficiency symptoms, with a few variations. A photographic record was kept to document the symptoms as they appeared and progressed throughout the study. The hydroponic methods used to induce the deficiency symptoms were very effective in that they allowed the deficiencies to manifest themselves relatively quickly, they reduced the possible effects of residual nutrients contained in a soil-based medium, and they were easy to reproduce. In repeating this study, it might be effective to run the treatments for a fixed length of time (e.g. 100 days) and record the changes in the expressed deficiency symptoms on a regular basis as time passed. Photographs, especially close-up, supplemented by written observations, were useful as they, especially close-ups, showed a substantial amount of the detail and coloration of the deficiency symptoms, as well as being reproducible and serving as a permanent record.

Introduction
The use of the herbaceous perennials by the homeowner and in the commercial landscape industry has increased significantly over the past ten years. According to a survey by the Gallup Organization for the National Gardening Association, the percentage of households expressing interest in information related to growing perennials increased from 16% to 19% for the one-year period from 1986 to 1987, adding an additional one million households. Of the 229 members the Professional Plant Growers Association (PPGA) responding to a 1989 members' survey, almost half (126 of 229) reported that they grew perennials. Their perennials had a cumulative value of almost $4 million, representing an average value of $38,072 per respondent, or 4% of the value reported for all crops. Rough calculations, extending these figures to the entire wholesale bedding plant industry, estimate perennials to have an annual value of $66.4 million out of the total approximation of $800 million for U.S. bedding plants. These figures do not include mail order sales and other (non-bedding plant) growers' sales of perennials. Respondents' commentaries suggests a strong market for perennials, but information and education, especially for consumers, is a serious need. A non-representative sampling of retail nursery activities was taken by the Garden Center Institute, asking in which product categories they expected a sales increase. Perennials ranked number two nationally, behind annuals/transplants, with 78.2% of all retailers expecting an increase in sales in 1988 (Voigt, 1989; Voigt, 1990).

In spite of the increasing popularity of herbaceous perennials, very little information is available on their nutritional requirements beyond general recommendations. A wide variety of fertilization methods is currently in use by commercial perennial growers (Frett et al, 1988; Duarte, 1988; Perry and Adam, 1990; Peterson, 1985).

The purpose of this study is to induce and document mineral deficiency symptoms in several genera of herbaceous perennials in several genera of herbaceous perennials. It is hoped this study will serve as groundwork for determining optimum rates of major nutrients for perennial production and culture.

Materials and Methods
Cuttings (5 cm in length) of *Chrysanthemum morifolium* 'Ginger', and *Veronica spicata* 'Red Fox' were taken from field-grown plants and were rooted in perlite under intermittent mist, using natural daylength and ordinary tap water. *Achillea* 'Cloth of Gold,' *Aquilegia* 'Dragonfly Mixture,' *Coreopsis* 'Sunray,' and *Dianthus plumarius* 'Double Mix' were grown from seed.

Plastic pots (11.5 cm square by 9.5 cm tall, with a volume of 700 ml) were lined with 30 cm lengths of glass wool spread to cover the holes in the bottom of the pots, then filled with grade 16 silica sand. Perforated Visqueen cover was used instead of glass wool to line the plastic pots for some species. The Visqueen produced good results (i.e. prevented leakage of sand and provided sufficient drainage) and was less expensive than glass wool. When the cuttings had rooted and the seedlings were approximately 5 cm tall, the plants were placed in the prepared pots and treatments commenced. Three replications of the eight treatments were prepared, totaling 24 pots of each species. Each pot was watered daily with 160 ml of one of the eight solution treatments.

The eight fertilizer solutions were prepared in 20-liter carboys using deionized water. These treatments included a complete fertilizer solution (the control), and solutions deficient in nitrogen (-N), phosphorus (-P), potassium (-K), calcium (-Ca), magnesium (-Mg), sulfur (-S), and iron (-Fe) as described by Hoagland (Hoagland and Arnon, 1950), with some modifications. As the deionized water registered a pH of 4.03 and the "complete" solution had a pH of 4.65,

Hoagland's procedure was modified accordingly to adjust the pH of the treatment solutions to attain acceptable levels. A saturated solution of calcium hydroxide was added dropwise to all solutions except the -Ca solution, to which a saturated solution of potassium hydroxide was added, until the pH was between 6.2 and 6.7. Sequestrine 138 was substituted for 0.5% iron tartrate solution to deliver 10 ppm in the nutrient solutions. The -Fe solution was made using the complete solution omitting the iron. Photographs were taken at the beginning of the treatment and at intervals during the study to catalog the progress of the deficiency symptoms. When the treatments ended the plants were harvested and dry weights measured.

Results

The following section will be a general description of the deficiency symptoms exhibited by the seven species used in this study. A more detailed description of the symptoms produced by each species in included in Table and Table 2 contains dry weight comparisons of deficient plants to normal plants.

-N Treatment. All species receiving -N treatments showed little or no new growth through the period of the treatment. A red coloration appeared on some older leaves and on margins of those new leaves that did appear. Leaves exhibited venal chlorosis leading to necrosis.

-P Treatment. Plants deficient in phosphorus were stunted, with smaller leaves than normal. The color of the plants tended to be a darker green than the control, and older leaves becoming necrotic, beginning at the edges and tips.

-K Treatment. Potassium-deficient plants were stunted. The older leaves were chlorotic, most having necrotic spotting, spreading to full necrosis of the leaves.

-Ca Treatment. The plants deficient in calcium tended to be stunted and died very quickly, long before plants receiving the other treatments. Calcium deficiency symptoms tended to appear in the apex of the plants, causing the new leaves to be puckered, cupped, and generally deformed with necrotic edges. The apex usually died quickly. The older leaves had large necrotic areas, dying from the tip in.

-Mg Treatment. Plants with magnesium deficiencies were stunted, with the older leaves exhibiting chlorosis beginning at the tips and margins, and showing some red coloration. Entire plants were paler than the control.

-S Treatment. Plants tended to be somewhat stunted and had a bright lime green color with an upward, vertical orientation to the leaves. Newer leaves showed some red pigmentation on the margins.

-Fe Treatments. All plants receiving the **-Fe** treatment were the same size or larger than the controls and generally appeared healthy. Some plants showed a hint of interveinal chlorosis, while some showed no treatment effect.

Conclusion

In general, the deficiency symptoms induced in the herbaceous perennials used in this study were similar to the classic textbook deficiency symptoms described for other types of plants, although each species manifested these symptoms a little differently. (See Tables 1 and 2 for specific symptom descriptions and dry weights.)

The sand/hydroponic culture technique used in this study was very effective and are easily reproduced. The use of deionized water and inert media, i.e., perlite and sand, eliminated the potential for nutrient contamination and allowed results to be achieved more quickly than would have been possible with non-inert media such as a soil- or non-soil-based potting mix. Using 11.5 by 9.5 cm pots avoided waterlogging or excessive drying of the sand typical of larger or smaller pots.

Since these treatments were conducted at different times of the year, and since some plants were taken from cuttings and some grown from seed, counting the number of days for symptoms to appear was not practical. Plants grew more slowly in the winter than in the spring and summer, even though all were grown in the greenhouse. Generally it took longer for symptoms to appear in the winter and on cuttings than in the summer and from seed.

Very little research has been done to date on the nutrition requirements of perennials because of the wide variety of perennial plants, their different needs, and the difficulties involved in doing this kind of research. As more herbaceous perennials are grown commercially as bedding plants, field-grown cut flowers, pot plants, and nursery stock, the demand for higher quality plants will also increase. This kind of research would be of significant value in improving the quality of these plants during production and overwintering, in protecting the environment by avoiding luxury consumption by the plants and the over-application of fertilizer by the grower, as well as aiding the homeowner and landscape industry in caring for perennials in the landscape setting (Halvorsen, 1988).

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Table 2. Effect of withholding nutrients on the dry weight of selected herbaceous perennials.

	Achillea	Aquilegia	Chrysanthemum	Coreopsis	Dianthus	Lythrum	Veronica
Nutrient	Dry Weight (G)						
Complete	6.55	4.52	3.31	8.14	7.90	3.61	2.10
-N	0.24	0.33	0.72	0.55	0.59	0.53	0.17
-P	1.24	0.87	0.73	2.15	1.49	1.44	0.30
-K	3.57	2.76	1.22	3.37	3.07	3.87	0.58
-Fe	4.51	4.09	4.38	7.41	9.31	3.41	1.88
-Ca	1.29	0.37	0.51	1.89	0.97	1.77	0.24
-S	2.61	1.48	0.63	3.65	2.48	3.53	1.08
-Mg	2.82	1.40	2.39	7.74	2.82	1.84	1.44
Treatment began	12/28/89	12/28/89	7/13/89	12/28/89	12/28/89	6/28/89	7/10/89
Harvested	4/25/90	4/25/90	9/12/89	4/25/90	4/25/90	7/26/89	9/12/89

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Table 1. Nutritional deficiency symptoms for selected herbaceous perennials.

	Achillea	Aquilegia	Chrysanthemum	Coreopsis	Dianthus	Lythrum	Veronica
-N	Stunted (no new growth, leaves becoming necrotic	Older leaves chlorotic, becoming necrotic, young leaves have red margins, stunted, very little new growth	Stunted; chlorotic; necrotic edges of lower leaves; some red tint to most chlorotic of older leaves.	Stunted; veinal chlorosis; no new growth, backs of leaves are purple.	Stunted; leaves very narrow, lower leaves red.	Very little new growth, pale with slight red coloration in leaves and stems, leaves small in size.	No new growth; leaves chlorotic with some red coloration on margins leading to necrosis.
-P	Stunted, leaves narrow, medium to dark green, lower leaves becoming necrotic.	Older leaves chlorotic with purple margins, newer leaves very dark green with red tint especially toward margins, purple petioles, stunted.	Leaves smaller, chlorotic edges and tips on lower leaves.	Stunted, leaves smaller, newer leaves necrotic at tips, curling, some new leaves dying before opening.	Stunted, narrow leaves, little branching, older leaves reddish becoming necrotic.	Stunted, leaves smaller and narrower with some necrotic spots.	Little new growth, new leaves small with red margins, older leaves necrotic.
-K	Stunted, older leaves yellowing and dying from tips in (no spots), leaves tend to droop.	Older leaves chlorotic with brown spots becoming necrotic, new leaves still have fairly good color with slight chlorosis on margins.	Stunted, older leaves necrotic beginning with tip burn, chlorotic mottling turning to necrotic spots.	Slightly stunted, older leaves developed brown spots spreading to full necrosis of leaves.	Extended intemodes, not much branching, colder leaves developed white spots (freckled).	Darker green, smaller leaves, new leaves had quilted, puckered appearance, some red color to stems and leaves.	Little new growth, newer leaves had interveinal chlorosis with tip necrosis leading to death of lower leaves.
-Ca	Apex dead or deformed, stunted, other leaves dying from tip in.	New leaves deformed, dead, plants died halfway through treatment.	Very little or no new growth, leaves puckered of deformed, very dark in color, tip burn.	New leaves have necrotic tips, curled, older leaves cupped, some have large necrotic area.	Stunted, apex dying, newer leaves deformed, some red on lower leaves.	Stunted, older leaves had small necrotic spots and tip burn, newer leaves curled downward and puckered at center vein.	Dear in 30 days.
-Mg	Stunted, older leaves yellowing from edges in.	Older leaves losing chlorophyll, turning white, stunted, new leaves look fine.	Pale, mottled new leaves with pin dot necrosis. Older leaves darker than new and had tip burn.	Newer leaves showing veinal chlorosis beginning at petiole end, leaves narrow and pointed.	Entire plant paler green, leaves narrow, older leaves necrotic at tips, chlorotic.	Stunted, necrotic areas on older leaves leading to death and abscission, some red color or nonnecrotic areas.	Newer leaves chlorotic (pale green), turned under, with some veinal puckering, stunted, older leaves showed red coloration.
-S	Bright lime-green color, upward pointed leaves, stunted.	New leaves lighter green with slightly purple edges, stunted, older leaves necrotic.	No new growth, leaves large, very dark green and curled under.	Stunted, bright lime green color (some chlorosis), leaves pointed and upward facing.	Leaves and intemodes longer, slightly paler green little branching.	New leaves showed slight necrosis and red pigmentation leaves had tendency toward vertical orientation.	Some interveinal chlorosis, slightly smaller leaves, some vertical orientation (but slight).
-Fe	No noticeable difference.	No noticeable difference.	Very little noticeable difference.	No noticeable difference.	No noticeable difference.	Hint of interveinal chlorosis, slight lengthening of intemodes.	Hint of interveinal chlorosis.