growth of a subsequent gladiolus cormel crop without fertilization of the soil, it is assumed that a large portion of the second fertilizer application was not available to the chrysanthemums. Oertli and Lunt (6) reported that availablity of coated fertilizer was reduced 30 to 50% by surfact placement in comparison to soil incorporation. Waters (8) reported that heavily coated 14-14-14 placed in deionized water for 1, 8, and 64 days had 10, 38, and 88% soluble salts in solution, respectively, of that for equivalent amounts of water soluble 10-10-10 fertilizer when measured by conductivity. In Expt. II insufficient fertilizer residue was present to permit proper growth of the second crop of chrysanthemums for the first 6 weeks regardless of rate. Insufficient N appeared to be the first limiting factor. This is reflected in the chemical responses (Table 3).

In both experiments keeping quality decreased and post-harvest breakdown increased as the rates of fertilizer increased. Hobbs and Waters (2) observed similar results with soluble fertilizer salts. Later factorial experiments with N, K, and lime indicated that N was a prime factor in enhancing susceptibility of chrysanthemums to *B. cinerea* (2, 10).

Tissue analyses showed that the leaves were more responsive to fertilizer and contain considerably more of the various elements than the flowers. The K content of the leaves in all crops was rather low and the Ca content fairly high. This antagonism is apparently a contributing factor to lineal growth increases in response to fertilizer rates.

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COPPER DEFICIENCY OF SOME CONTAINER GROWN WOODY ORNAMENTAL PLANTS

R. D. DICKEY[1]

ABSTRACT

It was shown that physiological disorders of *Camellia japonica* 'Tricolor', *Jasminum multiflorum*, *J. nitidum* and Indian azalea varieties 'Formosa' and Fielder's White', growing in metal containers were caused by a deficiency of copper.

Characteristic foliage symptoms of Cu deficiency common to the plants studied were: chlorosis, dwarfing, "cupping", tip and marginal burn and premature leaf abscission. Shoot symptoms most commonly associated with Cu deficiency on these plants are shortened internodes, multiple buds and dieback of shoot terminals. This depression of growth severely dwarfed acutely affected plants.

Differences in degree of Cu deficiency under similar growing conditions of some *Camellia japonica* varieties, 2 species of *Jasminum* and Indian azalea varieties 'Formosa' and 'Fielder's White', indicate a variety and species difference in susceptibility to Cu deficiency.

Soil applications of copper sulfate and copper chelate in solution were equally effective in correcting Cu deficiency, but copper sulfate is much less expensive than copper chelate. Copper deficiency of several experimental plants was corrected by either Copper A, basic copper sulfate or copper-lime mixture applied as a foliage dip.

Florida Agricultural Experiment Stations Journal Series No. 2247.

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INTRODUCTION

An abnormal foliage condition, similar in

appearance to copper (Cu) deficiency of tung, *Aleurites fordi* Hemsl. (2, 3), was observed on 3 old *Camellia japonica* L. plants in the field in northern Florida during summer of 1959. Subsequently, similar symptoms appeared on container grown plants of *C. japonica* 'Tricolor' at Gainesville and were identified by Dickey (1) in 1961 as Cu deficiency. Furthermore, physiological disorders similar in appearance to those previously identified on tung and camellia have been observed in several Florida commercial nurseries on container grown plants of *Jasminum multiflorum* Andr., *J. nitidum* Skan. (erroneously *J. ilicifolium*) and 2 Indian azalea varieties.

These experiments deal with identification, description and correction of physiological disorders of *C. japonica* 'Tricolor', *J. multiflorum*, *J. nitidum* and Indian azalea varieties 'Formosa' and 'Fielder's White'. These plants showed symptoms similar in appearance to previously reported Cu deficiency of tung and *C. japonica* 'Tricolor' (1, 2, 3).

Materials and Methods

Plants in all experiments were grown either in 6" Lerio metal cans (145 cu. in.) or No. 10 food cans (185 cu. in.).

When foliage treatments were made, spraying was simulated by dipping tops of plants in the mixtures, taking care to prevent them from running down plants into the containers.

Fertilizer was applied in solution at monthly intervals uniformly to all plants in the various experiments at the rate of 6,000 ppa per year of 6-6-6-2 (N, P_2O_5, K_2O, MgO).

Plants were selected primarily for uniformity of size and degree of Cu deficiency symptoms. Average Cu deficiency score of each treatment of all experiments was the same at experiment's initiation. Degree of Cu deficiency symptoms was determined by rating plants using this rating system: 1-none; 2-slight; 3-moderate 4-severe; 5-very severe. Response to treatments in all experiments was based on score of the new growth which developed after treatments were applied, because leaves affected before treatment are usually beyond recovery.

Experiments

Camellia japonica L.

Experiment 1—A physiological disorder of *C. japonica* 'Tricolor' developed during the summer of 1961 on plants growing in 6" metal containers in a 1-1-1 soil mixture by volume of sphagnum peat, horticultural perlite and fine sandy soil. Severely affected plants were divided into 2 groups on June 28, 1961, and one group was sprayed with a solution containing 3 pounds of Copper A in 100 gallons of water; the second group was an untreated check. Plants sprayed with Copper A produced some normal growth in 30 days, and by October 31, all treated plants had made normal growth while the untreated plants continued to show medium to severe symptoms. This work by Dickey (1) established this disorder as a Cu deficiency.

Experiment 2—A second experiment was initiated June 4, 1964, to test effects of copper sulfate and copper chelate applied to the soil in solution, both at 2 rates (50 and 100 ppa) and a 2-2-100 copper-lime spray on correcting Cu deficiency of *C. japonica* 'Tricolor'. There was an untreated check.

Rooted cuttings were potted October 9, 1963, in a 1-1-1 soil mixture by volume of sphagnum peat, horticultural perlite and fine sandy soil in 6" metal containers. These plants were kept in the greenhouse until spring, then moved to 50% saran shade. Deficiency symptoms appeared with resumption of growth in the spring of 1964. Plants evidencing medium to severe symptoms were used to start the experiment June 4. Treatments were assigned to their field locations in randomized block design; there were 11 replications and the experimental unit was 1 plant.

All Cu treatments markedly reduced symptoms on new growth (Table 1) by July 2, 28 days after treatment, and there was a further decrease in symptoms by July 17 and August 18, 43 and 75 days, respectively, following treatment. Untreated plants continued to show severe symptoms. All Cu treatments were equally effective in correcting Cu deficiency.

Symptoms—Visual symptoms of Cu deficiency appeared on young growing tissue. In mild stages terminal leaves had somewhat irregular margins, were lighter green in color and were thickened and leathery as compared with normal leaves. As symptoms increased in severity, terminal leaves of shoots were much reduced in size and were lighter green in color than normal leaves, and a marginal burn developed. This killing of marginal leaf tissue produced irregular broken margins as the growing leaf expanded. Severely affected leaves may be thickened, roughened and

less pliant than normal leaves. In advanced stages premature leaf fall occurred so acutely affected plants may have shoots showing severe defoliation.

Shoot growth is much reduced on severely affected plants by shortening of internodes. Growing tips of some defoliated terminal shoots may dieback in varying degree. Multiple buds may develop on acutely affected plants and they sometimes produce shoots, but the resulting small slender twigs soon die. Severely affected plants in containers may die if not given copper.

Jasmium multiflorum Andr.

Experiment 1—Plants of *J. multiflorum* evidencing symptoms similar to those previously identified on camellia and tung as Cu deficiency (1, 2, 3), were observed in some Florida commercial nurseries during 1963. Because of the similarity of symptoms, this disorder was suspected of being a Cu deficiency.

A preliminary experiment using 10 severely affected plants in No. 10 food cans, obtained from a commercial nursery, was initiated July 10, 1963. Treatments were: 3 plants untreated; copper sulfate solution to soil—0.5 gm each to 3 plants, 1.0 gm to 1 plant; copper chelate in solution to soil—0.5 gm each to 2 plants, 1.0 gm to 1 plant. The 7 treated plants produced normal growth 3 to 4 weeks after treatment, while the untreated plants continued to show severe symptoms. This preliminary experiment suggests this disorder was caused by a Cu deficiency.

Experiment 2—Rooted cuttings of *J. multiflorum* were potted in 6" metal cans in sphagnum peat on June 1, 1963, and placed under 50% saran shade. A few plants showed Cu deficiency symptoms by July 14, and by November 1 many plants evidenced severe to very severe symptoms. These plants, though moved to a warm greenhouse on November 1, made little growth during November and December except to form multiple buds extensively in leaf axils of many plants.

An experiment was initiated January 14, 1964, with severely affected plants, to test effects of copper sulfate and copper chelate applied to the soil in solution, at the rates of 159 and 318 ppa of copper sulfate and 54 and 108 ppa of copper chelate, and basic copper sulfate as a foliage dip at the rate of 3 pounds in 100 gallons of water. There was an untreated check. The experiment was set up in the greenhouse in randomized block design; there were 7 replications, and the experimental unit was 1 plant.

Copper treatments (Table 2), except the basic copper sulfate dip, had greatly reduced symptoms by March 26, 62 days after treatment, and by June 12, 150 days after treatment, all plants were

Table 1. Effect of copper sulfate and copper chelate applied to the soil in solution and a copper-lime spray in correcting copper deficiency of Camellia japonica 'Tricolor'. 1964.

Treatments applied on June 4, 1964	Average score of copper deficiency symptoms on different dates*			
	June 4	July 2	July 17	Aug. 18
Untreated check	4.1	4.1	4.2	4.0
50 ppa copper sulfate	4.1	2.6	1.8	1.5
100 ppa copper sulfate	4.1	2.8	2.4	1.7
50 ppa copper chelate	4.1	2.5	2.0	2.0
100 ppa copper chelate	4.1	2.2	1.5	1.6
Copper-lime mixture - 2-2-100	4.1	2.7	1.8	1.8
LSD - .05		0.8	1.0	1.0
.01		1.1	1.4	1.4

*Copper deficiency rating scale: 1 - normal; 2 - slight; 3 - moderate; 4 - severe; 5 - very severe.

producing normal growth in the 4 copper treatments applied to the soil (Fig. 1). Plants given the basic copper sulfate dip were retreated May 21, and by June 12, 22 days later, all retreated plants were producing normal growth. The untreated plants showed very severe symptoms for the experiment's duration.

Jasminum nitidum Skan.

A physiological disorder, similar in appearance to that identified as Cu deficiency on *J. multiflorum*, has been observed on *J. nitidum* in Florida nurseries. An experiment was initiated May 12, 1965, to determine if symptoms observed on this plant were caused by a deficiency of Cu when rooted cuttings of *J. nitidum* were potted in a Cu deficient Florida (Florahome) peat in 6" metal container and placed in the greenhouse. Seven plants showed mild symptoms by June 14, and enough severely affected plants were available to set up the experiment on July 4. There were 2 treatments: an untreated check and copper sulfate applied to the soil in solution at rate of 75 ppa. A completely random design was employed, there were 12 plants receiving each treatment and the experimental unit was 1 plant.

Some plants given Cu produced normal growth by July 16, 12 days after treatment, and by August 3, 30 days following treatment, all plants given Cu produced normal growth while untreated plants continued to show severe symptoms (Table 3). These data indicate the observed disorder of *J. nitidum* was caused by a Cu deficiency (Fig. 2).

Symptoms—In mild stages leaves at the tip of a growing shoot were smaller than normal leaves, showed mild interveinal chlorosis, became slightly to moderately "cupped" and some affected leaves showed a mild tip and marginal burn. One or more shoots on an affected plant may show this condition.

In acute stages leaves were much reduced in size, showed interveinal chlorosis and were strongly "cupped" with their margins turned upward. A severe tip and marginal burn was evident on young leaves soon after they unfolded from the growing shoots (Fig. 2). Premature leaf abscission frequently occurred, especially at shoot terminals, and some affected shoots may dieback in varying degree.

Acutely affected plants were smaller than normal plants the same age (Figs 1, 2,), and this reduction in size was caused by a decrease in number and length of internodes and size of leaves. Rooted cuttings planted in a Cu deficient potting medium may make very little growth for several months following transplanting, and may develop multiple buds extensively in the leaf

Table 2. Effect of soil applications of copper sulfate and copper chelate in solution and basic copper sulfate spray in correcting copper deficiency of Jasminum multiflorum. 1964.

Treatments applied on January 14, 1964	Average score of copper deficiency symptoms on different dates*				
	Jan. 14	Mar. 26	Apr. 19	May 21	June 12
Untreated check	5.0	5.0	5.0	5.0	5.0
159 ppa copper sulfate	5.0	1.1	1.0	1.0	1.0
318 ppa copper sulfate	5.0	1.4	1.3	1.3	1.0
54 ppa copper chelate	5.0	1.3	1.0	1.0	1.0
108 ppa copper chelate	5.0	1.1	1.0	1.3	1.0
Basic copper sulfate - 3 lbs to 100 gals water (Retreated May 21)	5.0	4.1	4.4	4.4	1.0
LSD - .05		0.9	0.6	0.9	0.6
.01		1.2	0.8	1.2	0.8

*Copper deficiency rating scale: 1 - normal; 2 - slight; 3 - moderate; 4 - severe; 5 - very severe.

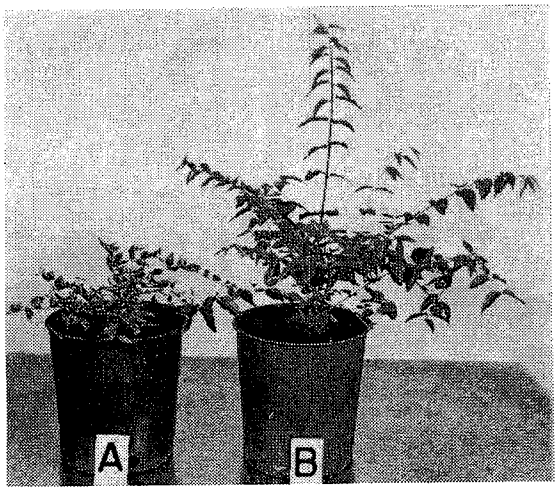

Figure 1.—Typical treated and copper deficient Jasminum multiflorum plants. (A) Untreated check. (B) Copper sulfate applied to soil in solution at rate of 50 ppa. Condition of (B) was similar to that of (A) when treated January 4, 1964. Copper treatment has effected complete control of copper deficiency, while (A) continues to show acute symtoms. Photograph taken July 31, 1964.

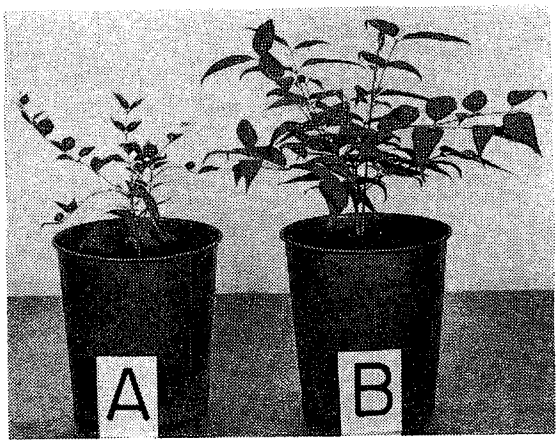

Figure 2.—Typical treated and copper deficient Jasminum nitidum plants. (A) Untreated check. (B) Copper sulfate in solution applied to soil at rate of 75 ppa. Condition of (B) similar to that of (A) when treated July 4, 1965. Copper treatment has effected complete control of copper deficiency, while (A) continues to show acute symptoms. Photograph taken September 26, 1965.

axils. Multiple buds of some plants develop into shoots which increase the bushy rosette-like appearance of such plants. Copper deficiency symptoms are very similar on *J. multiflorum* and *J. nitidum* (Figs 1, 2).

Rhododendron indicum Small *'Fielder's White' Azalea*

Rooted cuttings were potted in Florida (Florahome peat in 6" metal containers on February 9, 1965. Mild symptoms appeared on some plants by the third week in April and rapidly increased in severity and number of plants affected.

An experiment was initiated May 11 using medium to severely affected plants. Treatments were: an untreated check, copper sulfate applied to the soil in solution at rates of 50 and 100 ppa, and foliage dips of basic copper sulfate at the rate of 3 pounds in 100 gallons of water and a 3-3-100 copper-lime mixture.

Considerable response was apparent 16 days after treatment, and 28 days following treatment all plants given Cu to the soil or as a foliage dip were producing normal, vigorous growth while untreated plants continued to show severe symptoms (Table 4, Fig. 3).

Table 3. Effect of copper sulfate applied to soil in solution in correcting copper deficiency of Jasminum nitidum. 1965.

Treatment applied July 4, 1965	Avg. score of copper deficiency symptoms on different dates*			
	July 4	July 16	July 26	Aug. 3
Untreated check	4.0	4.0	4.2	4.0
75 ppa copper sulfate	4.0	2.2	1.5	1.0
LSD - .05		1.2	1.1	0.4
.01		1.7	1.6	0.5

*Copper deficiency rating scale: 1 - normal; 2 - slight; 3 - moderate; 4 - severe; 5 - very severe.

'Formosa' Azalea

Symptoms similar to those identified on tung and camellia (1, 2, 3) as Cu deficiency appeared on many plants in 2 experiments with 'Formosa' azalea soon after growth started in the spring of 1963. Plants of both experiments were growing in 6" metal containers in a 1-1-1 soil mixture by volume of sphagnum peat, horticultural perlite and fine sandy soil. When symptoms appeared, all plants in both experiments were treated with copper sulfate in solution to the soil at the rate of 50 ppa. In 10 to 14 days all affected plants were putting out normal growth (Fig. 4).

Experiment 1—Rooted cuttings of 'Formosa' azalea (120 plants) were potted in Florida (Florahome) peat January 28, 1965. Symptoms developed slowly and sparingly, first appearing on 2 plants May 5. A small experiment was set up August 10 using 10 moderately affected

Table 4. Effect of copper sulfate applied to soil in solution and foliage applications of basic copper sulfate and a copper-lime mixture in correcting copper deficiency of 'Fielder's White' azalea. 1965.

Treatments applied on May 11, 1965	Average score of copper deficiency symptoms on different dates*			
	May 11	May 27	June 8	July 26
Untreated check	3.9	4.4	4.6	4.1
50 ppa copper sulfate	3.9	1.5	1.0	1.0
100 ppa copper sulfate	3.9	1.4	1.0	1.0
Basic copper sulfate - 3 lbs to 100 gals water	3.9	1.6	1.0	1.0
Copper-lime mixture - 3-3-100	3.9	1.8	1.0	1.0
LSD - .05		0.6	0.2	0.3
.01		0.8	0.3	0.4

*Copper deficiency rating scale: 1 - normal; 2 - slight; 3 - moderate; 4 - severe; 5 - very severe.

plants. The 2 treatments were: an untreated check and copper sulfate applied to the soil in solution at rate of 50 ppa. A completely random design was employed; there were 5 plants receiving each treatment, and the experimental unit was 1 plant.

On September 10, 31 days after treatment, plants given Cu developed normal growth while untreated plants showed moderate symptoms (Table 5). This evidence suggests that the observed disorder was caused by a Cu deficiency.

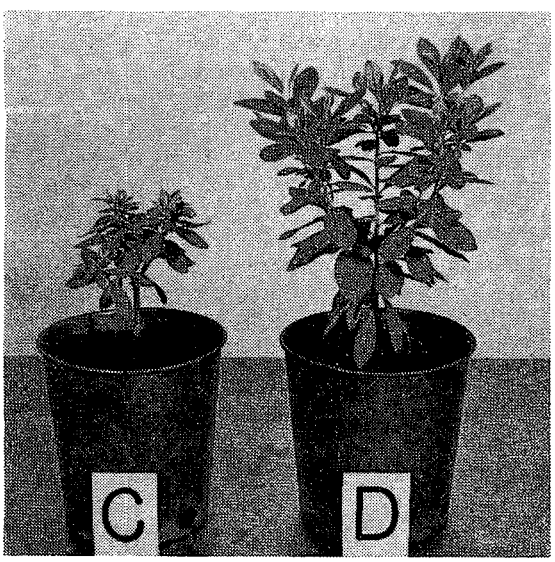

Figure 3.—Typical treated and copper deficient 'Fielder's White' azalea plants. (C) Untreated check. (D) Copper sulfate in solution applied to soil at rate of 50 ppa. Condition of (D) similar to that of (C) when treated May 11, 1965. Copper treatment has effected complete control of copper deficiency, while (C) continues to show acute symptoms. Photograph taken June 19, 1965.

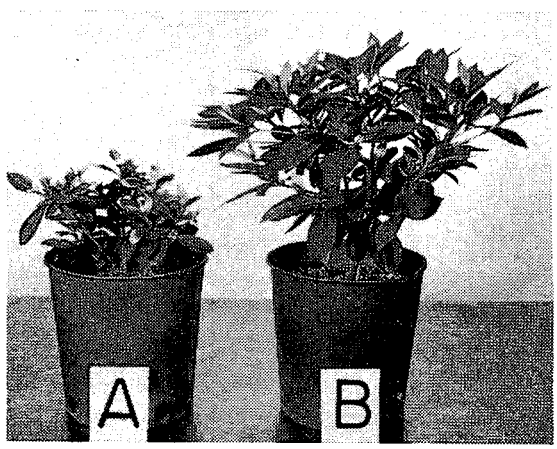

Figure 4.—Typical copper deficient (A) and normal (B) plants of 'Formosa' azalea. (A) Typical symptoms of copper deficiency—chlorosis, small terminal leaves, tip burn and dwarfing. Photograph taken March 29, 1963.

Table 5. Effect of copper sulfate applied to soil in solution in correcting copper deficiency of 'Formosa' azalea. 1965.

Treatments applied on August 10, 1965	Average copper deficiency score on different dates*		
	Aug. 10	Aug. 25	Sept. 10
Untreated check	3.2	3.2	3.0
50 ppa copper sulfate	3.2	2.8	1.0
LSD - .05		NS	0.8
.01		NS	1.1

*Copper deficiency rating scale: 1 - normal; 2 - slight; 3 - moderate; 4 - severe; 5 - very severe.

Symptoms—Leaves at shoot terminals became chlorotic, were slightly to severely reduced in size and sometimes developed tip burn, depending on severity of the disorder. Young leaves of both varieties evidenced a chlorosis over the entire leaf, and this pattern continued with 'Fielder's White' after the leaves matured, but as 'Formosa' leaves aged they showed a decided contrast between the yellow tip and margins and remaining greener portions of the leaves (Figs. 3, 4).

Shoot growth was greatly retarded, because of shortened internodes, and subsequent growth of buds in these leaf axils produced a rosette-like appearance. Shoots may dieback from the tips on severely affected plants (Figs. 3, 4).

Discussion

Cuttings of *Jasminum multiflorum* and *J. nitidum* were potted June 1, 1963, in imported sphagnum peat in 6" metal containers. A few *J. multiflorum* plants showed symptoms 45 days later, and by November 1, many plants showed severe Cu deficiency. Fifteen months after potting *J. nitidum* plants were still growing normally. Plants of these 2 *Jasminum* species growing in commercial nurseries in containers have been observed where many *J. multiflorum* plants showed medium to severe Cu deficiency symptoms, while in a nearby group of *J. nitidum* only a few plants were showing slight to medium symptoms

One hundred and twenty 'Formosa' azalea and 68 'Fielder's White' azalea cuttings were potted in Florida (Florahome) peat in 6" metal containers on January 28 and February 9, 1965, respectively. Many 'Fielder's White' plants were severely affected by early May, while only 2 'Formosa' plants showed mild symptoms at this time.

Several *Camellia japonica* varieties were grown in containers at Gainesville in previously described peat-perlite-sand mixture, and only 'Tricolor', 'Lady Clare' and 'Elegans' have shown Cu deficiency symptoms. Mild Cu deficiency symptoms have been observed on 'Elegans' and 'Lady Clare' plants growing in Arredondo loamy fine sand at the Horticultural Unit, Ganesville.

These observations suggest there is a decided species and variety difference in susceptibility to Cu deficiency.

Many woody plants produced by Florida ornamental nurseries are grown in containers and many different kinds of materials are used in making their potting media. However, common ingredients of these media include some form of peat (native or imported), sand mucks, native sandy soils, builders sands, wood shavings, sawdust and perlite, all potentially low in Cu.

Any potting medium containing one or more of these ingredients may be low in Cu and have the potential of producing Cu deficiency on plants growing therein, especially the Cu deficiency susceptible plants reported here. Other ornamental plants than those reported here may show Cu deficiency symptoms when grown under similar conditions.

Because of delay in starting growth following potting in a Cu deficient medium, reduction in size and quality of affected plants and possibility of increased susceptibility to cold injury, a preventive Cu treatment should be given to all newly potted woody ornamental plants.

In these experiments soil applications of copper sulfate and copper chelate in solution were equally effective in correcting Cu deficiency, but copper sulfate is much less expensive than copper chelate. Fifty ppa of both Cu sources was as effective as the larger rates. Foliage sprays of copper-lime mixture, Copper A and basic copper sulfate (one exception—*J. multiflorum* Experiment 2) were as good as soil applications of copper sulfate and copper chelate in solution. The nurseryman may then choose the method of application best adapted to his operation.

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