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Copper Deficiency of Manzanita Grown in a Bark-sand Mixture

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Abstract. **The new growth of manzanita (*Arctostaphylos densiflora* M.S. Baker and other *Arctostaphylos* spp.) grown in a nursery in a mix of 2 fir bark : 1 sand (v/v) in plastic containers remained very small and showed some necrosis. Tissue analysis indicated a possible copper deficiency. The addition of 8 mg of copper as copper sulfate per 15 cm pot produced normal growth. The application of boron or calcium was not effective in controlling the problem.**

There is an increase in the use of soilless mixes in the production of container-grown nursery plants. Such mixes may include various proportions of peat, bark or sawdust from different woody plants, sand, vermiculite, expanded pumice, or polystyrene particles. These mixes have many advantages but also may cause nutrient disorders, particularly in regard to some of the micronutrients.

Recently, a nursery in Saratoga, Calif., began using a mixture of 2 shredded fir bark: 1 Aptos alluvial sand (v/v). Subsequently, a problem appeared in which the new growth of manzanita 'Howard McMinn' was retarded shortly after the cuttings were transplanted into the mix. The leaves remained very small, and when fully expanded, were one-third to one-half the size of leaves on unaffected plants. The tips of leaves on affected plants occasionally were pinched and failed to open completely. Frequently the ends of such leaf tips were necrotic, and in some plants, there was a failure of the growing point. Leaves on affected plants were not chlorotic but were a deeper green than comparable leaves on unaffected plants. Internodes were shortened causing affected plants to be stunted and more compact than unaffected plants. Rooted cuttings of the plant had been transplanted into the soilless mix in 15 cm plastic cans (2¾ liter volume). Urea formaldehyde, single super phosphate, potassium nitrate, calcium carbonate, dolomite, gypsum and iron sulfate were added to the mix. Plants were irrigated each time with a nutrient solution containing ammonium nitrate, potassium nitrate, chelated iron, manganese, and copper. The latter was added at 0.11 ppm. The micronutrients zinc, boron, and molybdenum were not included. A saturation paste extract of this mix had a pH of 6.8. Although the growth problem was most severe in the cultivar Howard McMinn, it also occurred on *A. stanfordiana* subsp. *bakeri* (Eastw.) *A. hookeri* G. Don., *A. pajaroensis* Adams x *A. obisbonensis* Eastwood and *A. uva-ursi* (L.) Spreng. x *A. nummularia* Gray "Emerald Carpet."

Free-hand sections and isolations from affected tissues failed to reveal bacterial or fungal plant pathogens. Since growing point failure suggested a nutrient deficiency, possibly of B, Ca, Cu, or Zn, samples of affected leaves were analyzed for the macronutrients Ca, Mg, and K, and for the micronutrients Fe, Mn, Zn, and Cu using atomic absorption instrumentation. Tissues were not analyzed for B. Samples of leaves from plants not showing symptoms also were analyzed for comparison with affected leaves.

A comparison of the analyses of the mineral content of young leaves from affected plants with those from unaffected plants showed that of the elements tested, only Cu was in lower amounts in the leaves from the affected plants. (Table 1). Additional evidence of a Cu deficiency was found by comparing the data from manzanita with the critical nutrient levels of deficiencies found by other investigators working with 5 commonly-grown ornamental plants. These included carnation (*Dianthus caryophyllus* L.) (3), rose (*Rosa odorata* Sweet) (2), chrysanthemum (*Chrysanthemum morifolium* Ramat) (7), geranium (*Pelargonium hortorum* Bailey) (6) and poinsettia (*Euphorbia pulcherrima* Willd.) (4). Of the 7 nutrients determined for the affected manzanita, only Ca and Cu were considerably below the critical deficiency levels of the 5 ornamentals reported (Table 1).

To determine if a deficiency was causing the problem, an experiment was started using affected plants of *A. densiflora* "Howard McMinn" growing in a mixture of 2 shredded fir bark: 1 sand (v/v). Fertilizer was added to duplicate cans as follows: Cu at the rate of 8 mg/ 15cm plastic can added as copper sulfate; B at the rate of 4mg/ can added as boric acid, and Ca added at the rate of 3.2 gm of gypsum/ can. In addition, duplicate cans were given one liter of half-strength Hoagland's solution (5) in 50 ml increments during the first 3 weeks of the experiment. This solution contained 0.01 ppm Cu.

Within 2 months, the plants treated with Cu resumed growth and produced normal-sized leaves (Fig. 1). The difference between

Table 1. Mineral analysis of manzanita leaves and deficiency levels of rose, carnation, chrysanthemum, poinsettia, and geranium.

	Leaf Content (dry basis)							
Crop	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn ppm	Cu ppm	Reference
Manzanita								
affected[z]	1.64	0.35	0.17	157	32	42	3.0	
nonaffected[z]	0.87	0.22	0.09	104	27	38	3.7	
Rose	1.8	1.0	0.25	50	30	15	5.0	(2)
Carnation	2.0	0.6	0.15	30	30	15	5.0	(3)
Chrysanthemum	2.15	0.46	0.055	---	---	15	1.0	(7)
Poinsettia	1.0	0.5	0.2	50	30	15	1.0	(4)
Geranium	0.62	0.77	0.14	60	9	6	5.5	(6)

[z]Average of analyses of 20 samples (fresh weight) from 3 different plants.

Table 2. Response of manzanita to several fertilizer treatments to control small leaves when grown in a mixture of 2 fir bark: 1 sand (v/v).

Treatment[z]	Elements added per 15 cm can (mg)	Dry wt. of new growth (g)
Control	---	2.6 b[y]
Boric Acid	B 4	1.9 b
Copper sulfate	Cu 8	24.8 a
Calcium sulfate	Ca 740	2.0 b
1 liter ½ Hoagland's	Complete	2.3 b

[z]Initially all pots received dolomite added to the mix and N, P, K, S, Ca, Mg, and iron chelate added as a nutrient solution following planting.
[y]Means separated by Duncan's multiple range test, 5% level.

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Fig. 1. Manzanita plants growing in fir bark-sand medium. Plant on right received 8 mg copper whereas plant on left received no copper.

the Cu treatments and all other treatments was substantial after 5 months. At that time, all new leaves on the plants were removed, oven dried, and weighed. Weights of the new growth are shown in Table 2. The leaves, as measured by the dry weights, were significantly larger in the Cu treatments than in any other treatment. The new leaves on plants not receiving Cu not only remained small, but some were necrotic.

The use of synthetic soilless mixes for container-grown plants has become very common, and with such mixes, complete fertilizer must be added. Although the fertilizer program at the nursery in Saratoga included an adequate supply of major elements, it did not supply all of the micronutrients. In some mixes for nursery-grown plants, soil is included as one ingredient, and in these media, the soil usually supplies the micronutrients needed. If soil is omitted, all micronutrients as well as the macronutrients need to be added.

The Cu deficiency problem is compounded by the tendency of some forms of organic matter to fix the element so that it is unavailable to plants (1). This fixation could occur when materials, such as fir bark, are included in a mix. The results shown in Table 2, suggest such an effect with fir bark. When a liter of half-strength Hoagland's solution was added to the manzanita plants, no improvement resulted, even though 0.01 mg/liter of Cu was supplied. In a typical hydroponic system, this amount of copper would have been sufficient, but, because of the organic matter used in the mix, enough Cu apparently was fixed so that the plants did not receive enough to avoid deficiency symptoms. These results also help to explain why, even though Cu was being added in the irrigation water, the level of Cu did not supply the plants the amount necessary for the conditions under which they were being grown.

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A More Sensitive Insect Bioassay for Naturally Occurring Plant Products

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Abstract. **Concentrations from 0.00 to 7.00 mg/ml of 2-tridecanone were applied directly to the bottom of petri dishes or to filter paper in dishes and assayed with tobacco hornworm larvae (*Manduca sexta* L.). The rate and extent of hornworm mortality were greater in the assay without filter paper. The LC_{50} for the assay with filter paper was 10.6 μg/cm² and 4.1 μg/cm² without filter paper. These results indicate that the test without filter paper is a more sensitive bioassay for antibiotic effects on tobacco hornworm larvae.**

The wild tomato species *Lycopersicon hirsutum* Humb. & Bonpl. and *L. hirsutum* f. *glabratum* C.M. Mull have been reported to be resistant to many arthropod pests (1, 4, 5, 6, 10). The compound 2-tridecanone has been isolated from the foliage of *L. hirsutum* f. *glabratum* (9) and implicated as the principal toxic factor to *Manduca sexta* L. and *Heliothis zea* Boddie (11). Both pure 2-tridecanone and foliage extracts of *L. hirsutum* f. *glabratum* caused mortality of *M. sexta* and *H. zea* larvae by contact and vapor action (3, 7). The 2-tridecanone vapor surrounding the foliage of *L. hirsutum* f. *glabratum* has been implicated as a cause of *H. zea* mortality (3).

Two other methyl ketones and some volatile terpenes also comprise the essential oils of *L. hirsutum* and *L. hirsutum* f. *glabratum* (9). 2-Undecanone and 2-dodecanone are present in plants of both taxa but have been reported to be less toxic to *H. zea* than 2-tridecanone (2). Consequently, the differential pest resistance observed between *L. hirsutum* and *L. hirsutum* f. *glabratum* (4, 8) may be related to quantitative and/or qualitative differences of these or other compounds.

In the bioassay employed, which was modified from that of Kennedy and Yamamoto (1979), tobacco hornworm larvae were placed on filter paper treated with plant extracts or pure compounds, and mortality was determined at regular intervals. Since hornworm mortality differs between *L. hirsutum* and *L. hirsutum* f. *glabratum*, work is in progress to fractionate plant extracts via HPLC and test the fractions for antibiotic activity. Since small quantities of material are derived in this manner, assays must be as sensitive as possible. We report here a more sensitive test for tobacco hornworm responses to 2-tridecanone.

Aliquots (0.6 ml) of 13 different concentrations of 2-tridecanone (Pfaltz and Bauer, Stamford, Conn.) in hexane, ranging from 0.00 mg/ml to 7.00 mg/ml, were applied directly to the bottom of 100 mm × 20 mm glass petri dishes, or were applied to 90 mm circles of Whatman no. 1 filter paper in the bottom of dishes. The hexane was allowed to evaporate completely, and then 10 newly hatched, 1st instar larvae from a stock colony maintained on artificial diet (12) were placed in the dishes and the dishes sealed with Parafilm. Experiments were conducted at 23°C, and all treatments were duplicated. Hornworm mortality was determined after 2, 4, and 6 hr. Multiple regression analysis and analysis of variance were performed on the data.

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