SYSTEMIC TREATMENT FOR CHLOROTIC TREES

by E.B. Himelick and Kirk J. Himelick

Abstract. Ferric citrate injected in powdered form was effective in correcting iron chlorosis of pin oak, cypress, red oak, sweet gum, and swamp white oak. Chlorotic white oak and American sycamore did not respond significantly to systemic iron treatments. Both ferric ammonium citrate and ferric citrate were effective in correcting moderate to advanced stages of chlorosis in large pin oak and sweet gum. An inexpensive method of injecting premeasured chemical powders is reported.

Yellow foliage and slow growth are commonly found on many tree species planted along streets and around homes where the original topsoil has been removed or mixed with the subsoil. The average urban soil has relatively poor physical, chemical, and biological characteristics. Root development and penetration are greatly reduced in clay subsoils that lack adequate aeration and water drainage. Additionally, available nutrients and organic matter are often critically low.

Chlorosis, manifested by yellow leaves, commonly occurs on pin oak, sweet gum, white oak, bald cypress, river birch, silver and red maple, and hackberry. The visual symptoms of chlorosis develop because of a reduction in chlorophyll production in the leaf tissue. The cause for chlorosis is usually attributed to reduced availability of one or more of the soil nutrient elements such as iron, manganese, nitrogen, potassium, magnesium, boron, zinc, copper, and molybdenum. Even excessive amounts of some elements may cause chlorosis. Other factors such as low temperatures, reduced sunlight, high soil moisture, and excessive applications of calcium and possibly phosphorus in fertilizers and irrigation water can also cause the development of chlorosis. Commonly, this condition is attributed to a deficiency of either iron or manganese caused by a high soil pH. This theory is supported by circumstantial evidence that yellow trees frequently do "green up" after being treated with a compound containing either iron or manganese. The authors have added circumstantial evidence as a result of data presented in this publication, however, there may be other causes for chlorosis in urban trees that have not been discovered and injection of iron or manganese may serve only to temporarily mask the symptoms of a possible infectious agent. Systemic methods for temporarily correcting iron and manganese deficiencies of shade trees have been reported by several investigators (1, 2, 3, 4, 5, 6, 7).

The studies reported here were designed to determine the relative efficacy of ferric citrate and ferric ammonium citrate in correcting chlorosis when injected into chlorotic pin oak, sweet gum, and other species growing randomly along selected city streets. Combinations of ferric ammonium citrate, a soluble NPK, and a slow-release nitrogen source were included in these studies. Tests were made at three locations.

University of Illinois Campus

Methods. Six tree species were included in tests initiated in 1974. The species were pin oak (*Quercus palustris*), bald cypress (*Taxodium distichum*), red oak. (*Q. rubra*), swamp white oak (*Q. lyrata*), sweet gum (*Liquidambar styraciflua*), and American sycamore (*Platanus occidentalis*). The trees were located on the Urbana campus of the University of Illinois and were 6-40 inches (0.15-1.0 m) in diameter at breast height (dbh). Pin oaks (6-inch) were treated in mid-July of 1974, and the other tree species in early June of 1975. A reagent grade of ferric citrate powder (18.5% Fe) was trunk-injected into holes drilled at a height of 3.5 feet and 4 inches apart in the trunk. A 7/16-inch spiral wood bit in an electric drill was used to drill the holes.

Each hole was injected with 1.5 grams of powder, using a 3 ml plastic syringe with the tip removed (Fig. 1). The holes were sealed with tight-fitting corks. Each cork was cut off flush with the bark and sprayed with tree dressing paint (Fig. 2). As the callus formed the cork was pressed tight and after a few weeks was ejected.

A color rating of 1 (chlorotic) to 10 (green foliage) was used to measure response. Ratings were made on the day of treatment and in

September one or two growing seasons after treatment. Randomly selected, chlorotic trees were left untreated and served as controls.

Results. The ferric citrate treatments were effective on pin oak, cypress, red oak, swamp white oak, and sweet gum (Table 1). Only slight response was obtained on American sycamore. The treatments were most effective on pin oak, bald cypress, and red oak: these species exhibited a lower initial color rating. Pin oaks treated in mid-July did not respond significantly to treatment until the following spring. The treatment remained effective for two growing seasons. The response of swamp white oak was less striking, although all control trees became more chlorotic throughout the observation period. Chemical phytotoxic symptoms were not observed on any of the tree species.

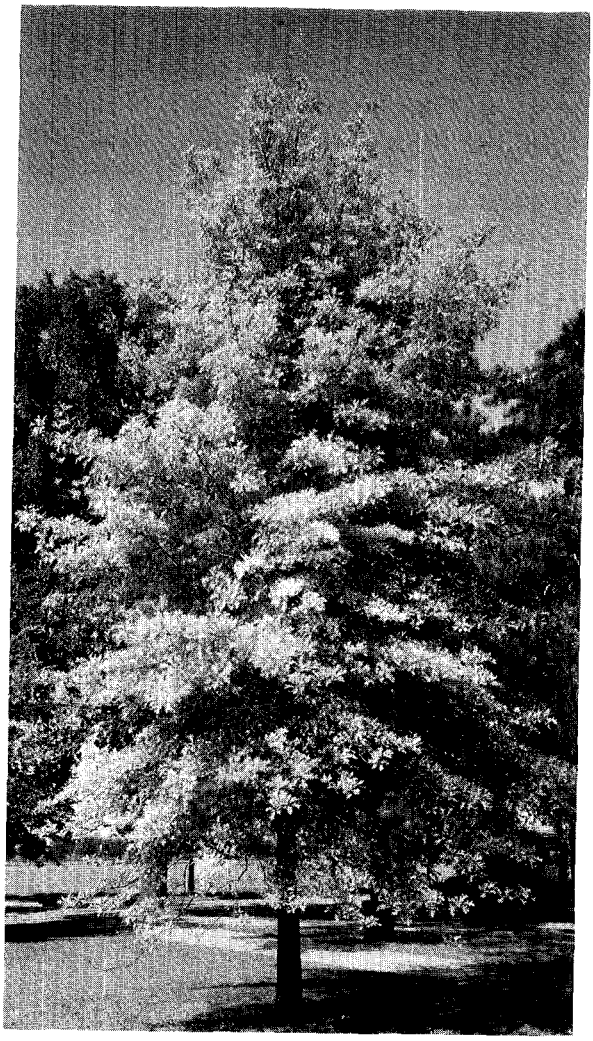

Fig. 1. A pin oak showing advanced symptoms of chlorosis, or yellowing, of the foliage. Systemic treatment with an iron compound generally corrects the iron deficiency for about three years.

Callus closure of the holes was complete in one growing season for all species. Sap flow was observed occasionally from holes made in sweet gum and pin oak. The 4-inch spacing of drilled holes was sufficiently close to obtain good distribution of the ferric citrate throughout the crown.

The pH of soil randomly sampled 10-15 cm (4-6 in) deep from around 50 pin oak and 30 sweet gum trees exhibiting both normal and chlorotic foliage was tested. The pH ranged from 5.7 to 7.9: avg. 6.9 for chlorotic trees and 6.6 for non-chlorotic trees. The soil pH was not directly correlated with chlorosis over this narrow range.

City of Urbana, Illinois

Methods. A survey of city-owned trees in Urbana was made in the summer of 1975. Of 214 pin oaks, 33.2% were chlorotic and of 317 sweet gums 26.2% were chlorotic. The following year additional trees became chlorotic.

In 1977, parkway pin oak and sweet gum trees were treated. Six types of Medicap treatments

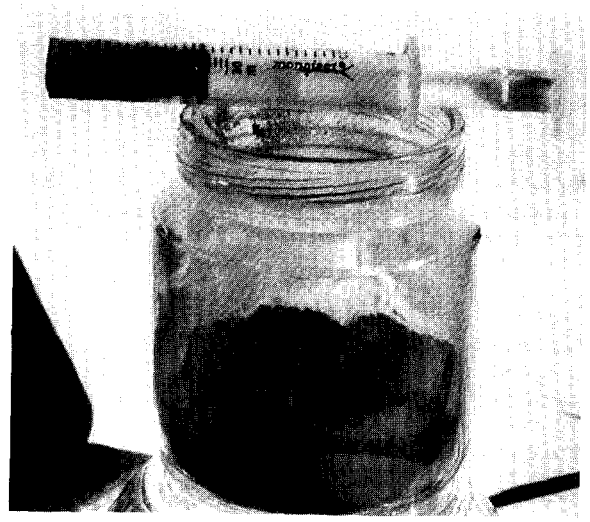

Fig. 2. A 3 ml plastic syringe with the tip end removed to facilitate loading with powdered ferric citrate.

(Table 2) were compared with ferric citrate treatments. The Medicap formulations were ferric ammonium citrate alone and in combination with either a soluble NPK or a slow-release N. The rate of chemical used and the spacing of drilled holes were the same for each tree species. Ferric citrate was injected at 4 in spacings and the Medicap cartridges were implanted at 5-6 in spacings. The trees were treated between May 24 and June 3, 1977. Color ratings were made the day of treatment and in the latter part of July of the three following growing seasons. Chlorotic pin oak and sweet gum trees randomly selected throughout the city were left untreated as controls. The average twig growth on the lower two-thirds of the crown of each tree was measured in September at the end of the second growing season.

Results. The pin oaks responded well to all iron treatments and to combinations of iron and nutrients (Table 2). The color response of sweet gums (Table 3) was not generally as definite. Twig growth response of sweet gums was satisfactory in all treatments using iron. Trees treated with iron as ferric citrate responded the most. Distribution of the chemical was more uniform than in other treatments. This may have been due to closer spacing of holes. Ferric ammonium citrate plus NPK gave better color response in pin oak than did ferric ammonium citrate alone. Some response was observed from NPK alone in both pin oak and sweet gum. Slow-release N alone gave no response.

City of Highland Park, Illinois

Methods. Chlorotic white oaks growing on parkways in Highland Park, Illinois were treated with iron or manganese. Ferric ammonium citrate (Medicap Fe28) and manganese sulfate (Medicap Mn), size 0 and 000 cartridges, were implanted in holes 10-13 cm (4-5 in) apart around the trunk. The trees (avg. 20.8 in, 53 cm dbh) were treated during the first weeks of May, 1978. The trees treated had been chlorotic for 2-6 years. Color ratings were made on June 7 and August 1, 1978 and August 23, 1979.

Results. The color response of chlorotic white oaks was limited (Table 4). There was no difference in response to iron or manganese. Low soil moisture did not account for the poor response since there was above-average rainfall during the test period. Phytotoxicity was not observed on the treated trees.

Table 1. Response of six tree species on the University of Illinois campus to treatments with ferric citrate powder.

Tree species	Number of trees	Average dbh (inches)	Color Rating[3] Initial	Final	Difference
Pin oak[1]	5	6	2.2	7.9	5.7
Control	3	6	2.2	2.8	0.8
Pin oak[2]	8	16	5.2	6.9	1.7
Control	10	15	3.8	3.6	−0.2
Bald cypress[2]	5	18	4.3	7.7	3.4
Control	3	24	3.0	3.7	0.7
Red oak[2]	3	8	5.2	7.3	2.1
Control	2	10	7.0	7.0	0.0
Swamp white oak[2]	15	6	6.6	7.0	0.4
Control	13	6	7.1	6.1	−1.0
Sweet gum[2]	7	10	6.5	8.4	1.9
Control	4	17	6.0	6.3	0.3
American sycamore[2]	2	12	5.0	6.3	1.3
Control	3	15	6.0	7.0	1.0

[1]Treated July 24, 1974; color rating taken at end of two growing seasons (early September, 1975).
[2]Treated June 17-19, 1975; color rating taken at end of first growing season (early september, 1975).
[3]Color code: 1-6, shades of yellow; 7-10, shades of green; 10, dark green.

Table 2. Treatment of chlorotic pin oak in 1977.

Treatment	Number of trees	Color rating[1] May 1977	July 1977	July 1978	July 1979	Twig growth (inches) 1978
Ferric citrate[2]	32	4.5	7.4	7.7	6.5	6.8
Ferric ammonium citrate[3]	14	5.3	7.1	7.1	6.4	6.9
Ferric ammonium citrate + NPK[4]	14	4.6	7.0	7.1	7.2	6.6
Ferric ammonium citrate + N[5]	10	4.6	5.9	5.7	5.3	5.7
NPK[6]	10	6.2	6.6	7.1	6.6	4.6
NPK + slow-release N[7]	6	5.2	5.8	6.6	5.4	4.8
N (slow-release)[7]	11	6.0	6.1	6.2	5.9	4.3
Control	12	5.7	6.3	6.3	5.8	4.3

Average tree size: 13.2 in dbh (range 4-24 in).

[1]Color code: 1-6, shades of yellow; 7-10, shades of green; 10, dark green.

[2]Purified powder form, 1½ g/hole, holes 4 in (10 cm) apart.

[3]Medicap Fe28, size 0, 3/8 in (1.1 cm), trees 4-11 in (10-28 cm) dbh; size 000,0.5 in (1.27 cm) in larger trees.

[4]Medicap formulation of Fe + soluble NPK, size 000 in trees 4-11 in dbh and size 11/16 in (2.1 cm) in larger trees.

[5]Medicap formulation of Fe28 and slow-release N, size 0 in trees 4-11 in dbh and size 000 in larger trees.

[6]Medicap formulation with soluble NPK alone, size 0 in trees 4-11 in dbh and size 000 in larger trees.

[7]Medicap formulation with slow-release N only, size 0 used in trees 4-11 in dbh and size 000 in larger trees.

[8]Medicap formulation of slow-release N, size 000 used in trees 4-11 in dbh and 11/16 in cartridge in larger trees.

Table 3. Treatment of chlorotic sweet gum in 1977.

Treatment	Number of trees	Color rating[1] May 1977	July 1977	July 1978	July 1979	Twig growth (inches) 1978
Ferric citrate[2]	11	6.3	8.7	8.3	7.4	9.0
Ferric ammonium citrate[3]	10	6.1	8.1	8.0	7.1	8.6
Ferric ammonium citrate + NPK[4]	10	6.7	8.3	8.0	7.8	7.8
Ferric ammonium citrate + N[5]	10	6.3	8.1	7.9	6.7	7.1
NPK[6]	10	6.6	8.3	8.1	7.3	6.4
NPK + slow-release N[7]	6	6.5	8.1	7.8	7.0	6.0
N (slow-release)[7]	9	5.7	7.1	6.8	6.6	5.5
Control	11	6.4	7.6	7.7	6.6	5.2

Average tree size: 12.0 in dbh (range 5-33 in).

[1]Color code: 1-6, shades of yellow; 7-10, shades of green; 10, dark green.

[2]Purified powder form, 1½ g/hole, holes 4 in (10 cm) apart.

[3]Medicap Fe28, size 0, 3/8 in (1.1 cm), trees 4-11 in (10-28 cm) dbh; size 000, 0.5 in (1.27 cm) in larger trees.

[4]Medicap formulation of Fe + soluble NPK, size 000 in trees 4-11 in dbh and size 11/16 in (2.1 cm) in larger trees.

[5]Medicap formulation of Fe28 and slow-release N, size 0 in trees 4-11 in dbh and size 000 in larger trees.

[6]Medicap formulation with soluble NPK alone, size 0 in trees 4-11 in dbh and size 000 in larger trees.

[7]Medicap formulation with slow-release N only, size 0 used in trees 4-11 in dbh and size 000 in larger trees.

[8]Medicap formulation of slow-release N, size 000 used in trees 4-11 in dbh and 11/16 in cartridge in larger trees.

Table 4. Treatment of chlorotic white oak in 1978.

Treatment	Number of trees	Color rating 6/78	Color rating 8/78	Color rating 8/79	Color increase 1st year	Color increase 2nd year
Ferric ammonium citrate	26	5.4	6.1	6.4	0.7	1.0
Manganese sulfate	7	5.6	6.2	6.4	0.5	0.8
Control	10	3.9	4.0	4.8	0.1	0.9

Average tree size: 20.8 in dbh (range 14-30 in).

Discussion and Conclusions

Trees growing under urban conditions frequently exhibit different nutrient deficiency symptoms. These symptoms are often difficult to diagnose. Correcting the deficiency can be expensive and may be effective for only a few years. Chlorotic untreated trees usually continue to decline. Systemic treatments for chlorosis caused by iron or manganese deficiency may prolong the life, improve the vigor, and increase the aesthetic value of treated trees.

The use of ferric citrate or ferric ammonium citrate, as reported here, provides a reasonably effective and economical way of treating large chlorotic trees. Timing of treatment is important. March, April, and May treatments of pin oak were found to be effective for 3 to 4 years. Treatment of chlorotic sweet gum trees were effective for 2 to 3 years. Response from mid- or late-summer injections was poor during the remainder of the growing season and was only effective for 1 or 2 years following treatment.

The results of treatment were more pronounced in trees showing advanced stages of chlorosis than in those exhibiting early stages of chlorosis. It is advisable to begin treating chlorotic trees before they have advanced to the later stages of chlorosis and decline. Foliage injury was not observed on any of the treated trees. The drilled holes in most species were closed by callus formation by the end of one growing season; slow-growing trees sometimes required 2 years of callus growth. Bleeding (gummosis) of sweet gum sometimes occurred around the holes, particularly in extremely chlorotic trees of low vigor.

Systemic nutrient treatments cannot be expected to correct all chlorotic problems or to keep the foliage green. When the micro elements, manganese or iron, are unavailable, the macro elements, nitrogen and phosphorus, and other micro elements may also be limited. In this study, the soil pH was not directly correlated with the presence or absence of chlorosis.

Combinations of drought, poor soil structure, and a declining root system will significantly affect the response obtained from systemic iron treatments. A chlorotic tree with a potentially high aesthetic value, therefore, should be fertilized and regularly watered during drought periods in addition to being systemically treated for a trace-element deficiency.

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Plant Pathologist, Illinois Natural History Survey, and Lecturer, Ornamental Horticulture, University of Illinois, Urbana, Illinois 61801, respectively.