# MANGANESE DEFICIENCY — CONTRIBUTORY TO MAPLE DECLINE?[1]

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**ABSTRACT.** Studies of maple problems in Michigan beginning in 1970 have shown that the problem occurs on soils of high pH (7.1-8.0). Foliar treatment with various micronutrients initially showed the problem to be related to manganese deficiency. Spraying chlorotic trees can effect a significant, though not complete, positive color change. Treatment through systemic means shows promise, with $MnSO_4$ implantation superior to other methods researched to date. Results are not as quickly and markedly effective as similar treatment reported for pin oak chlorosis with iron. Maple manganese deficiency is described.

The chosen title suggests *the* answer to maple decline, a malady of maples, especially sugar, which has received much attention over the last decade or more. However, a word of caution is in order. Rather than *the* answer, *an* answer to maple decline is proposed. Much more needs to be done on this problem but some cautiously optimistic suggestions relative to a maple problem are offered.

In his review of miscellaneous pathology of sugar maple, Hepting (1971) placed maple decline problems into five categories: 1) the New England and Lake States roadside maple problem; 2) the general maple decline of the Northeast; 3) the insect-induced sugar maple blight of northern Wisconsin; 4) the sapstreak disease of North Carolina and the Lake States; and 5) the pathology of sugar bush maples. This paper deals primarily with the first two, and thus in no way claims to be *the* answer to all maple decline problems.

Welch (1963) reported on maple decline in the Northeast and his summarized description of the symptoms at that time were: "twig and branch dieback involving mainly the upper crown, but often the lower also; foliage showing chlorosis, premature coloration, dwarfing, cupping, or abscission; and with no cankers specifically involved".

In recent years, highway salt has been suggested as significantly affecting maple decline, especially in New England (Rich, 1971). Mader, *et al* (1969) suggest an influence of nitrogen levels as related to sugar maple decline.

### Description of Symptoms

The research reported here was initiated in August, 1970, when the authors were asked to provide assistance in identifying a problem with maple trees in Rogers City, Michigan. Sugar maple leaves showed chlorosis and necrosis and the trees were in a low state of vigor; not unlike maple decline. A nutrient deficiency problem was suspected.

During the next two years, further observations were made and initial experiments begun, with the following findings:

1) The condition occurs in sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), and Norway maple (*Acer platanoides*), but seems to occur most frequently in the sugar maple. It is currently also suspected on birch (*Betula papyrifera* and *B. pendula*), mountain ash (*Sorbus aucuparia*), and sweetgum (*Liquidambar styraciflua*).

2) Not all trees showed chlorosis. In many cases adjacent trees showed no chlorotic symptoms.

3) The first leaves of the new growing season appear green to slightly yellow.

4) Initially the chlorosis is marginal and interveinal with the major leaf veins remaining green.

5) By the first week of June, new growth at the end of the branches varies between trees, from green to severely chlorotic. In some cases the youngest leaves have a distinctive red pigmentation.

6) As the growing season progresses into the middle of July the new leaves of affected trees are often completely chlorotic.

[1] Presented at The International Shade Tree Conference in Detroit, Michigan in August 1975.

7) In most cases, the affected leaves show marginal and inter-veinal necrosis by the later part of July.
8) Leaf fall in autumn occurs much earlier on chlorotic than on healthy trees.
9) Highway salt does not appear significantly related; trees are often completely removed from any salt source.
10) Many trees are globe-formed with a closely rounded crown; as if sheared.
11) This globe form is a result of yearly dieback of the terminal portion of twigs. (Manganese and iron are immobile elements in plants and hence affect terminals first.)
12) Leaf tissue nutrient levels were analyzed (Table I). Nitrogen, potassium, phosphorous, iron, copper, boron, manganese, zinc, and aluminum contents were determined. The data showed possible, but inconclusive evidence of deficiencies of manganese, iron, zinc, and copper. Foliar nitrogen showed little difference between chlorotic and healthy leaves, being 1.76 and 1.90 percent respectively. Mader (1969) has suggested 1.5 percent as the critical nitrogen level in Massachusetts.
13) Soil samples were taken at each of five sites in Rogers City where chlorotic trees appeared. The soils are of the Longrie, Summerville, and St. Ignace soil series. The texture of the soils range from sandy loam to loam and contain much gravelly and stony material of limestone origin. Test results show low but not critical nutrient levels of manganese, zinc, copper, and iron (Table III). However, the soil tests also showed the pH of the soils to be very high (ranging from 7.6 to 8.0, the mean pH being 7.72).

It is common to expect that in soils of high pH, manganese, zinc, and iron will be bound up in the soil in unavailable forms (e.g., The manganese ion occurs in the soil in three forms; the divalent, trivalent, and tetravalent ions. Only the divalent ion is utilized in plant metabolism. In the presence of basic, or high pH soils the divalent ions are oxidized to the unavailable trivalent and tetravalent ions, thus rendering them unusable in plant metabolic processes.) It is apparent, therefore, that the total quantity of an element may be present in the soil in concentrations that would not normally be considered critically low, but may exist mainly in an unavailable form, thereby creating a deficiency similar to the well known "lime-induced iron chlorosis of pin oak".

Based on plant composition data and visual symptoms of plant nutrient deficiencies, copper, zinc, manganese, and iron were thought to be deficient (Table I). The problems of determining the nutrient, or combination of nutrients responsible for the nutritional disorder were pursued in the following manner:

**Table I.** Average nutrient levels of healthy and chlorotic maples. (Rogers City, MI( September 2, 1971

| | Chlorotic (6) | Healthy (3) |
|---|---|---|
| % | | |
| N | 1.76 | 1.90 |
| K | .79 | .70 |
| P | .24 | .24 |
| Ca | 1.88 | 1.92 |
| Mg | .22 | .18 |
| ppm | | |
| Na | 130 | 78 |
| Mn | 14 | 30 |
| Fe | 32 | 37 |
| Cu | 4 | 6 |
| B | 55 | 38 |
| Zn | 12 | 13 |
| Al | 59 | 57 |

**Table II.** Selected soil test results for five locations within Rogers City, MI, 1971

| | | ppm | | |
|---|---|---|---|---|
| Sample | pH | Zn | Mn | Fe |
| 1 | 7.7 | 19.2 | 16 | 60 |
| 2 | 7.7 | 30.0 | 22 | 52 |
| 3 | 8.0 | 5.6 | 14 | 28 |
| 4 | 7.6 | 5.6 | 13 | 28 |
| 5 | 7.6 | 6.8 | 10 | 44 |
| Mean | 7.72 | 13.4 | 15.0 | 45.6 |

## Manganese Determination

Eleven treatment combinations of chelated micronutrients (metal ions surrounded by helical hydrocarbons) were applied to each of six trees located in Rogers City in June, 1972. The eleven treatments consisted of chelated nutrients: manganese, iron, zinc, copper, magnesium, a complete fertilizer plus micronutrients (GA5-111), and a control. Individual branches were immersed in one-gallon jars of the chelate solutions for one minute to assure adequate contact with the leaf surfaces.

Prior to treatment, leaf samples were taken for laboratory analysis. The results of this analysis reaffirmed that the deficiency was not conclusive on the basis of foliar analysis alone.

Fifty days after treatment the treated leaves were examined and rated on a visual basis for color (0 being extremely chlorotic/necrotic and 9 being a healthy green leaf). The difference between the color value of the treated leaves and the color value of the untreated portion of the tree was referred to as the net change in color, or 'net greening effect' (Table III).

**Table III.** Color response of five sugar maple trees 50 days after treatment with various sequestrene*- chelated micronutrients. (Rogers City, MI) 1972

| Treatment | Rate tsp/gal | June Av Color | August Av Color | Average Improvement |
|---|---|---|---|---|
| Mn | ½ | 5.6 | 8.6 | 3.0 |
| Zn | 1½ | 4.6 | 4.6 | 0.0 |
| Cu | ¾ | 3.8 | 3.8 | 0.0 |
| GA5-111 | 4 oz. | 5.0 | 7.4 | 2.4 |
| Fe330 | 1½ | 4.0 | 4.6 | .6 |
| Control | —— | 3.8 | 3.8 | 0.0 |
| Mn(liquid) | 1½ | 4.8 | 7.2 | 2.4 |
| Mg | ½ | 4.6 | 4.2 | -0.4 |
| Mn | 1½ | 5.2 | 8.0 | 2.8 |
| Zn | 3 | 5.0 | 5.2 | 0.2 |
| Fe138 | ½ | 5.0 | 5.4 | 0.4 |

*Sequestrene is a registered Ciba-Geigy Corporation trade mark. Rates tested as suggested by manufacturer.

There was positive correlation between treatment and a positive 'net greening effect' in 4 of the treatments. These treatments were all manganese-containing chelates: the experimental multi-nutrient GA-5-111, granular sequestrene manganese at both high and low concentrations, and the liquid form of sequestrene manganese. The four treatments showing greater than 2.4 'net greening effect' were judged significantly different from those showing a low or negative 'net greening effect'. Utilizing Friedman's ranking method for randomized blocks, it was determined that the effect of the manganese treatments was significant at the 0.995 level with 10 degrees of freedom. No other treatments were effective.

Leaves were sampled and tissue analyzed. Data from the analysis were grouped according to response: 1) a significant greening response to treatment, and 2) no positive response to treatment. The "combined" data show that the levels of most nutrients remained about equal in those responding and those not responding to treatment (Table IV). However, the manganese content of the leaf tissue showing a response contained approximately 800 percent increase in this element over those that did not respond to the treatments.

**Table IV.** Comparison of mean nutrient content of sugar maple leaves by response to micro-nutrient treatment. (Rogers City, MI) August 3, 1972.

| | No Response (Chlorotic) | Response (Green) |
|---|---|---|
| % | | |
| P | .39 | .31 |
| Cu | 1.99 | 2.34 |
| Mg | .24 | .23 |
| ppm | | |
| Na | 151.1 | 170.5 |
| Mn | 2.1 | 17.9 |
| Fe | 35.2 | 28.3 |
| Cu | 9.8 | 7.7 |
| B | 57.7 | 71.2 |
| Zn | 20.7 | 16.8 |
| Al | 54.2 | 49.2 |

## Practical Methods

Following the positive results with foliar treatment in 1972, a more practical method of uniform treatment was sought in 1973. Various concentrations of manganese were sprayed on the foliage and applied into the soil with a water lance. The experimental locations were expanded to Alpena, 35 miles south of Rogers City; foliar screening in Flint and Lansing; and further observations in Sault Ste. Marie and Munising, in Michigan's Upper Peninsula. Results of the 1973 "practical application trials" in Rogers City and Alpena are reported in Table V.

The 1973 results suggest that spraying of manganese chelate at the rate of ½ teaspoon per gallon produces significant positive results. However, the treatment consisting of the complete fertilizer plus micronutriends (GA5-111) was more effective. This may be related to interactions, or the carrier effect of nitrogen as demonstrated by Wittwer (1965). Iron produced no

**Table V.** Color response to spray[1] and soil application of micronutrients (1973) sequestrene*-chelated

| Treatment and Location | Rate tsp/gal | Number of Trees | Average Improvement |
|---|---|---|---|
| Rogers City | | | |
| Mn | ¼ | 1 | 2.0 |
| Mn | ½ | 6 | 2.66 |
| Mn | 3 | 4 | 2.0 |
| soil Mn | ¼/hole | 4 | 0.0 |
| GA5-111 | 2 oz. | 4 | 3.0 |
| Alpena | | | |
| Mn | ½ | 3 | 3.0 |
| Mn | 3 | 2 | 2.25 |
| soil Mn | ¼/hole | 2 | 0.0 |
| Fe 330 | 1½ | 2 | 0.0 |

[1]Each tree was treated on one side and a comparison made with the unsprayed portion of the tree.

*Sequestrene is a registered Ciba-Geigy Corporation trade mark.

visual improvement on sugar maples as it did on pin oak. Soil-applied chelated manganese was of little value since the chelating agent used with manganese is not effective at high soil pH levels. The results of soil pH tests on 106 soils sampled during 1973 and 1974 and ranging in texture from sand to clay, show an average pH of 7.624 (range of 7.0 to 8.1).

Spraying with manganese was shown to be of significant value in treating sugar maples. Unfortunately, spraying is still not very practical since applications must be made annually and even twice a year to insure satisfactory results. The cost and inconvenience is prohibitive for most people.

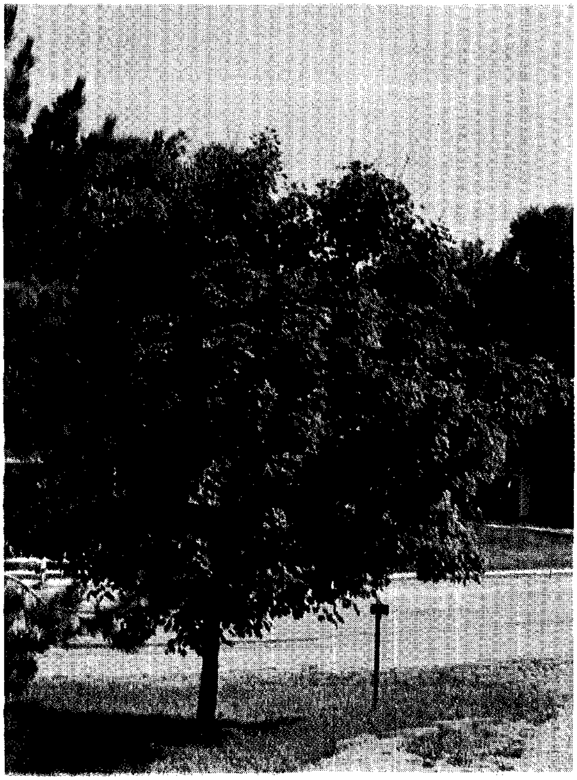
Trunk injection was initiated in the search for a long-lasting, practical, effective, and economic method of manganese treatment. Owing primarily to late application (June 26-28), a positive response to treatment was not evident in 1974. In 1974 trunk applications of liquid and encapsulated manganese were carried out in 5 cities. The liquid injections were a manganese chelate and a multinutrient chelate and the capsule contained soluble 28 percent manganese as manganese sulfate. Neely (1973) suggested that implantation of iron-containing capsules was preferable over other methods for treating pin oaks showing iron chlorosis symptoms.

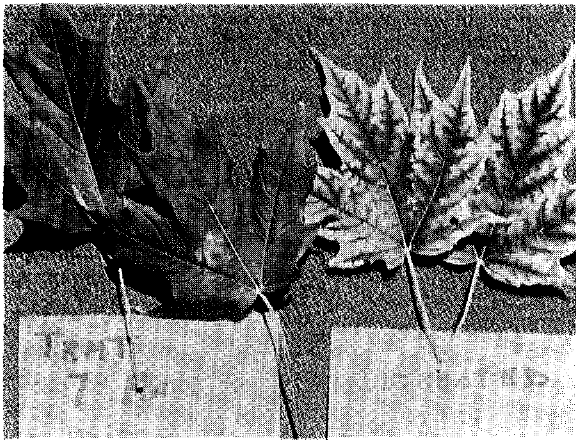
The results of the treatments applied in June, 1974, and measured in June, 1975, indicated that the 28 percent encapsulated manganese sulfate provided the best overall improvement except at one location (Table VI). The two liquid injection methods were less promising except at the Rogers City location where the differences obtained were not significant. It is, however, quite possible that the injection method could be improved, since some difficulty was noted in effecting uptake and a more soluble, or translocatable carrier might be available as alluded to by Neely (1973). He also suggested that for iron treatments of pin oak the effect may last from two to

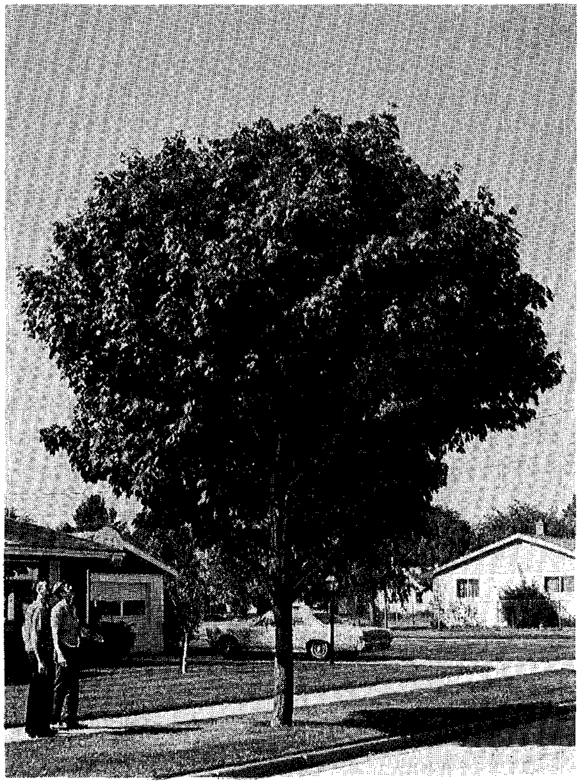
**Table VI.** Greening effect of various manganese treatments[1] to chlorotic maples in June, 1974 as recorded June, 1975

| Location and Treatment[1] | Number of Trees | Average Leaf Color Ratings 6/74 | 6/75 | One-Year Improvement |
|---|---|---|---|---|
| Flint | | | | |
| $MnSO_4$ 28% | 4 | 4.875 | 7.125 | 2.25 |
| Mn chelate | 4 | 5.125 | 5.25 | .125 |
| Check | 4 | 6.0 | 5.125 | -.875 |
| Complete | 2 | 6.25 | 7.0 | .75 |
| Saginaw | | | | |
| $MnSO_4$ 28% | 6 | 4.75 | 6.66 | 1.91 |
| Mn chelate | 5 | 5.2 | 5.4 | .20 |
| Check | 4 | 5.5 | 4.5 | -1.00 |
| Complete | 3 | 4.83 | 4.83 | 0.00 |
| Alpena | | | | |
| $MnSO_4$ 28% | 7 | 4.07 | 6.64 | 2.57 |
| Mn chelate | 7 | 4.07 | 5.21 | 1.14 |
| Check | 5 | 4.20 | 4.70 | .50 |
| Complete | 3 | 4.83 | 6.33 | 1.50 |
| Rogers City | | | | |
| $MnSO_4$ 28% | 7 | 4.0 | 5.214 | 1.214 |
| Mn chelate | 5 | 4.6 | 6.10 | 1.50 |
| Check | 4 | 4.875 | 5.625 | .75 |
| Complete | 2 | 4.75 | 6.0 | 1.25 |
| Lansing | | | | |
| $MnSO_4$ 28% | 4 | 4.25 | 7.0 | 2.75 |
| Mn chelate | 4 | 4.75 | 4.875 | .125 |
| Check | 3 | 4.833 | 4.833 | 0.00 |
| Complete | 2 | 4.5 | 5.5 | 1.00 |
| Average | | | | |
| $MnSO_4$ 28% | 28 | 4.399 | 6.410 | 2.071 |
| Mn chelate | 25 | 4.680 | 5.380 | .700 |
| Check | 20 | 5.050 | 4.950 | -.10 |
| Complete | 12 | 5.00 | 5.875 | .875 |

[1] Treatments were: $Mn\text{-}SO_4$-28% soluble encapsulated (Medicaps, Creative Sales, Fremont, Nebraska); Mn chelate and complete were liquid injections.







**Sugar maple chlorosis in Michigan. Symptoms before and after manganese treatments. Crown symptoms (upper left). Leaf chlorosis and recovery (upper right). Crown recovery (lower left). Nino Mauro and Jim Kielbaso examine a maple treated 45 days earlier with a manganese trunk implant (lower right).**

four years. The data presented here are of only one year duration and although manganese deficiency symptoms have been corrected they have not been as rapid or as successful as the iron treatment of pin oak for correcting iron deficiency.

Neely (1973) noted that maples were injured by the very treatments which improved oak, namely iron. When dealing with different species of trees precautions must be exercised in the concentrations of treatments. For this reason the manganese treatments applied in this study were kept at a low, safe level. No phytotoxic effects of manganese have been observed on treated trees.

Sugar maples have responded more favorably than red maples. Many trees have shown erratic, spotty improvement. This is likely a result of too little concentration owing to implantations being too widely spaced. Most were implanted 5 to 6 inches apart around the trunk. Four to five inches is suggested for a more uniform greening effect.

**Discussion**

Some correction of "maple chlorosis" has been accomplished with manganese. Research has confirmed that especially sugar and red maples, and Norway maple to a lesser extent, suffer from manganese deficiency on high pH soils. Manganese deficiency symptoms have thus far been observed by the authors in 17 locations in Michigan and Wisconsin, with on-going experiments at 8 of these locations. Cooperative experiments have also been initiated in Glens Falls, N.Y. where manganese problems on maples, identical to those observed in Michigan, appear to exist.

The manganese syndrome appears man-related and it could also be reported as a perturbation syndrome. The authors have not yet found a tree exhibiting the problem in a "natural" (undisturbed) situation. Although at first appearing natural, a more intensive observation reveals some disturbance around each manganese-deficient tree. Where surface soil underlayment is calcareous any disturbance will likely change the soil pH and thus restrict the availability of manganese. The organic matter buildup, common to "natural" sites, is not found in residential areas and this fact may partially explain the cause of the problem.

Maples have been treated with various sources of manganese and different methods employed for their application. Although encouraging, the results have not yet been as dramatic as those obtained in pin oak chlorosis treatment. Implantation of manganese sulfate has so far proven to be the most effective form of manganese treatment, although results are slow and seemingly only on new growth.

At least one group of "maple declines" may now be more properly referred to as maple chlorosis, maple manganese deficiency, or lime-induced manganese deficiency.

Further research is being conducted to find a more effective source of manganese for correcting "maple chlorosis"; and to observe and determine the duration of the greening effect resulting from manganese treatments.

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