Response of Interveinally Chlorotic Red Maple Trees Treated with Medicaps or by Soil Acidification[1]

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Abstract

Four replicates of 6 treatments were imposed on a nursery block of interveinally chlorotic red maples (*Acer rubrum* 'Red Sundet' L.) when they were 5 years-old.
Throughout 2 growing seasons of foliar nutrient monitoring, the degree of chlorosis was more closely correlated with leaf concentrations of P and K (positive) than with Mn (negative).
Soil treatments which included subsoil acidification (H_2SO_4 + $MnSO_4$) were most effective in re-greening the trees and in increasing leaf Mn concentrations, height and diameter growth, and red fall color development. Mn-Medicaps were equally effective as the above treatments in decreasing leaf P and K concentrations and increasing shoot elongation rates. Surface soil acidification alone resulted in either negative or no effects on the health-related parameters measured.

Index words: *Acer rubrum* 'Red Sunset' L., chlorosis, foliar nutrients, iron efficiency, manganese deficiency, nutrient excesses, tree growth

Significance to the Nursery Industry

Should red maple be excluded from consideration in landscape designs where soils are alkaline, such as many urban areas of the Midwest, or is it worth the cost of special care? The research reported here provides some insights into special care techniques and examines some aspects of how they function. Subsoil acidification techniques, with or without supplemental manganese (Mn), have repeatedly produced dramatic results in urban lawn settings with respect to chlorosis abatement (8). Acidification treatments reported here also improved growth and fall color.

Treatments of alkaline soil that increase the leaf concentrations of phosphorus and potassium are clearly detrimental to interveinally chlorotic red maples. One should consider acid-forming fertilizers low in P and K for lawn care adjacent to these trees. Ammonium sulfate (21-0-0) is one such choice.

Introduction

Interveinal chlorosis of red maple (*Acer rubrum* L.) has been associated with leaf necrosis, early leaf fall, twig dieback, and an abnormal crown form (4). Compared with green leaves, interveinally chlorotic leaves of red maple have higher concentrations of phosphorus (P) and potassium (K) and lower concentrations of manganese (Mn) during most of the growing season (7). Manganese appears to be the most commonly deficient micronutrient in the Midwest, with reports of the symptomatic deficiency point (or deficiency threshold) varying within a foliar concentration range of 16–69 ppm (7, 12). Alkaline soil is the most commonly reported environmental factor associated with this problem in the Midwest, and corrective treatments have centered on Mn fertilization, primarily by trunk implantations, and on soil acidification (4, 8, 13, 14). The details of successful acidification techniques have not been reported.

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This paper describes the response of chlorotic 'Red Sunset' red maples to trunk implantations using Mn Medicaps or to one of several different soil treatments using sulfuric acid. The project from which the data were derived was supported by the Morton Arboretum and the DuPage County Forest Preserve District.

Materials and Methods

Treatments were imposed in 1984 on 5 year-old trees in a nursery planting. Tree stem diameters 60 cm (2 ft) above ground line ranged from 35–75 mm (1.4–3.0 in). Spacing was 3.0 m (10 ft) apart in rows 2.4 m (8 ft) apart. The entire block of trees encompassing those treated had not been out-planted due to the prevalence of interveinal chlorosis. Soil pH tests made in 1982 indicated that the soil around 3 chlorotic trees was alkaline throughout, and foliar samples taken from these 3 trees in June, 1983 averaged 11 ppm Mn. Alternate trees in the plantation rows were selected for treatments or controls with the intervening trees to act as untreated buffers. A total of 24 trees was selected consisting of 4 replicates of the following 6 treatments, imposed in spring, 1984:

C	=	controls
MC	=	trunk implantations of manganese sulfate ($MnSO_4$) as Mn-Medicaps
T	=	5 l (1.32 gal) 10% sulfuric acid (H_2SO_4) sprinkled on the soil surface
TM	=	treatment T plus 225 g (7.94 oz) $MnSO_4$ broadcast on the soil surface
TSM	=	treatment T plus 30 cm deep (1 ft) × 5 cm (2 in) diameter holes spaced 30 cm (1 ft) apart in rings around trunk at 30 cm (1 ft) and 60 cm (2 ft) distances, each hole filled with 10% H_2SO_4 + 16 g (0.56 oz) $MnSO_4$
TMSM	=	treatment TM plus same drilled hole treatment used in treatment TSM.

Trunk diameters at 60 cm (2 ft) above ground line were measured in May, 1985 and October 1987. Ten branches on the south half of each tree were used to measure the distance between bud scale scars as an estimate of mean annual twig elongation for the years 1982 through 1985. Total heights were measured in July, 1986 and September, 1987. Leaves were sampled in mid-July and late August, 1984, and early June and mid-July, 1985 for nutrient analysis following established procedures (6). Petioles were not separated from leaf blades before analysis. At each of the sampling times, a chlorosis index was calculated for each tree as previously described (8, 9). Total chlorophyll was determined for leaves sampled in August, 1984 and June, 1985. Autumnal coloration was visually rated on a scale of 0–5 (poor to best, respectively) by three different Forest Preserve District foresters in 1984, at which time notes were made as to which trees were completely defoliated by early November. Soil cores to a depth of 51 cm (20 in) were extracted from around each control tree and each subsoil-treated tree 14 months after treatment. Each core was subdivided into 10 cm (3.9 in) increments and a 1:1 soil-water ratio was made for glass electrode pH determination.

Pearson product moment correlation coefficients and t-statistics for comparison of sample means were generated via the local SAS statistical software (11).

Results and Discussion

Chlorosis index—foliar nutrient correlation. An increasing degree of chlorosis as measured by the chlorosis index was positively correlated ($\alpha = .05$) with the macronutrients K and P, suggesting excesses of these nutrients, and negatively correlated ($\alpha = .05$) with the micronutrient Mn, pointing to a deficiency of this element. The macronutrient most closely correlated with chlorosis varied among seasons, but was consistently more highly correlated than Mn and, on an overall basis, the sums of the P and K concentrations were slightly better correlated with the chlorosis index than either macronutrient alone (Table 1). Some researchers have emphasized that the K:Mn ratio can be more closely associated with the degree of interveinal chlorosis than individual element concentrations (6, 10). Evidence exists for Fe-Mn competition at the cellular level, and Somers and Shive related Mn deficiency symptoms to Fe:Mn ratios of greater than 2.5 (2, 3). Both of these ratios, as well as P:Mn and Mg:Mn, were closely related to the chlorosis index for the red maples in this study (Table 2). All of the 100% green trees had low Fe:Mn ratios (1–3) compared to those of the severely chlorotic ones (9–39).

Treatment effects on chlorosis changes. Chlorosis differences between groups were first visible in early July, 1984. By mid-July, 1984 the chlorosis index was 58% higher

Table 1. Pearson product moment correlation coefficients[z] relating the most closely correlated macronutrients and manganese with the chlorosis index for red maples.

Sampling Season	Macronutrient	P + K	Manganese
Mid-July, 1984	+0.682(P)	+0.693	−0.318[y]
Late August, 1984	+0.700(P)	+0.722	−0.605
Early June, 1985	+0.730(K)	+0.736	−0.678
Mid-July, 1985	+0.853(P)	+0.847	−0.583

[z] coefficients with positive signs signify that the nutrient involved *increases* as chlorosis increases; those with negative signs signify *decreases* as chlorosis increases

[y] not significant

Table 2. Pearson product moment correlation coefficients relating nutrient ratios with the chlorosis index for red maples.

Sampling Season	K/Mn	P/Mn	Mg/Mn	Fe/Mn
Mid-July, 1984	+0.712	+0.706	+0.715	+0.706
Late August, 1984	+0.749	+0.747	+0.758	+0.756
Early June, 1985	+0.877	+0.896	+0.880	+0.916
Mid-July, 1985	+0.874	+0.892	+0.884	+0.915

(ie., a greater degree of chlorosis) in trees receiving soil surface treatments only (T and TM treatments) as compared with control trees. In contrast, trees receiving the other treatments had become greener than the controls and this improvement became much more marked in the 1985 set of leaves. Treatments affecting the subsoil (TSM and TMSM) resulted in much greener leaves, with more total chlorophyll than those associated with any of the other treatments (Figs. 1 & 2). Trees treated with Medicaps became significantly greener than the controls and those trees receiving only soil surface treatments.

Treatment effects on foliar nutrients. Leaf Mn concentrations were not affected by soil surface treatments (Fig. 3a). Medicap effects on leaf Mn were no longer in evidence after 1984. In contrast, the persistent effect of the TSM and TMSM treatments maintained leaf Mn concentrations at levels well above the 16–20 ppm range considered by the senior author to be the deficiency threshold (7). Compared to controls, treated trees increased in leaf Fe at a lesser rate during the 2-year monitoring period, suggesting a negative effect of Mn on foliar Fe (Figure 3b). In control trees, the significant increase in foliar Fe between August 1984 and June 1985 probably reflects an increase in root-generated soil iron availability induced by an increasing chlorosis stress

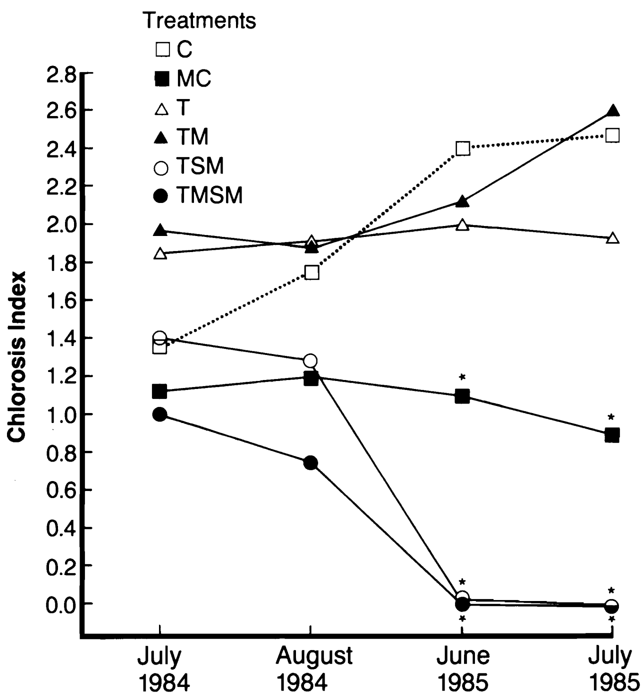

Fig. 1. Chlorosis index trends following spring, 1984 treatment of chlorotic red maples. * = significantly different from controls based on 0.05 level t-tests, no overlapping values, or both.

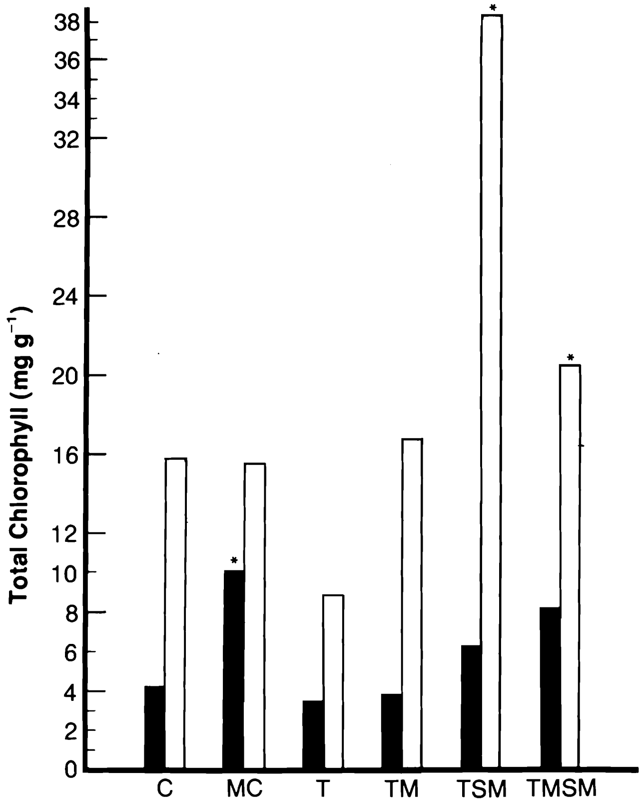

Fig. 2. Total leaf chlorophyll concentrations following spring, 1984 treatment of chlorotic red maples. * = significantly different from controls based on 0.05 level t-tests, no overlapping values, or both.

response (5). Such an interpretation is consistent with the view that red maple is an iron-efficient species (7). Leaf P concentrations of treated trees gradually declined from levels similar to the high values of the control trees, and a year after treatment, most values were significantly lower than those of the controls (Fig. 3c). This trend suggests an effect of $MnSO_4$ since it was the common constituent of the treatments that reduced foliar P concentrations most significantly. The mechanism of foliar P reduction evidently takes place within the vascular system since trunk implantations of $MnSO_4$ accomplished a reduction approximately equivalent to the most effective soil treatments. Since foliar P concentrations are positively correlated with the chlorosis index, the high leaf P concentrations in July, 1984 associated with the TM treatment suggest a partial explanation for the initially detrimental effects of that treatment.

The decline of K concentrations to levels below control values was most pronounced in the Medicap and subsoil treatment groups (Fig. 3d). These are the groups that re-greened significantly. Medicaps and treatments encompassing the subsoil were equally effective in lowering leaf K concentrations. The TM treatment, on the other hand, initially raised K concentrations substantially, possibly accounting for much of the detrimental effect of that soil surface treatment. The equally effective lowering of K concentrations by subsoil treatments and by trunk implantations suggests that the locus of action is in the vascular system.

In the 1985 leaves of the Medicap-treated trees, the improved green color persisted even though concentrations of Mn had dropped to levels virtually identical to the very low values in the leaves of chlorotic control trees. This favorable color persistence was closely related to decreases in leaf P and K concentrations. Elimination of excessive P and K concentrations has also been associated with the re-greening of chlorotic pin oaks and chlorotic peach trees (9, 16).

Effects on growth. From 1982 through 1984, shoot elongation was similar among trees from all treatment groups. In 1985, however, shoot elongation was significantly greater in trees treated with Mn-Medicaps and the 2 soil surface plus subsoil treatments (TSM and TMSM) when compared to untreated control trees (Table 3). Total height and diameter growth increments were greatest for trees receiving surface soil plus subsoil amendments (Tables 4 and 5, Fig. 4). The longevity of the diameter growth response through 1987 for the TSM and TMSM trees (Table 5) was commensurate with their superior leaf color and chlorophyll content assessed in 1985, and thus, may reflect increased photosynthetic carbon allocation to the cambium.

Table 3. Annual shoot elongation before and after 1984 treatment of chlorotic red maples.

	Mean shoot length (mm)			
Treatment/Year	1982	1983	1984	1985
C	86	183	141	95
MC	87	183	168	197[z]
T	88	198	153	119
TM	69	167	114	148
TSM	81	201	163	213[z]
TMSM	80	136	142	205[z]

[z] = significantly different from controls based on 0.05 level t-tests, no overlapping values, or both.

Table 4. Total tree heights following treatment of chlorotic red maples.

	Height (cm)	
Treatment/Year	**July, 1986**	**September, 1987**
C	380	398
MC	430	455
T	434	414
TM	407	405
TSM	481[z]	538[z]
TMSM	463[z]	476[z]

[z] = significantly different from controls based on 0.05 level t-tests, no overlapping values, or both.

Table 5. Diameter growth increments following treatment of chlorotic red maples.

	Diameter growth (mm)	
Treatment/Period	**5/85–9/86**	**9/86–10/87**
C	6	10
MC	8	17
T	7	10
TM	11	9
TSM	19[z]	19[z]
TMSM	18[z]	19[z]

[z] = significantly different from controls based on 0.05 level t-tests, no overlapping values, or both.

Fall color and leaf abscission. Based on 1984 observations, the rank order of average fall color ratings per treatment group was as follows: TMSM > TSM > T > MC > C > TM. Fall color ratings were inversely related to late summer foliar P. Since the amount of anthocyanin in plants is favored by P deficiency (2), the redder fall colors may reflect the effect of reduced foliar P. Early defoliation (before November 5) in 1984 was common among chlorotic control trees and characteristic of trees receiving surface soil treatments only. Regardless of treatment, every tree that

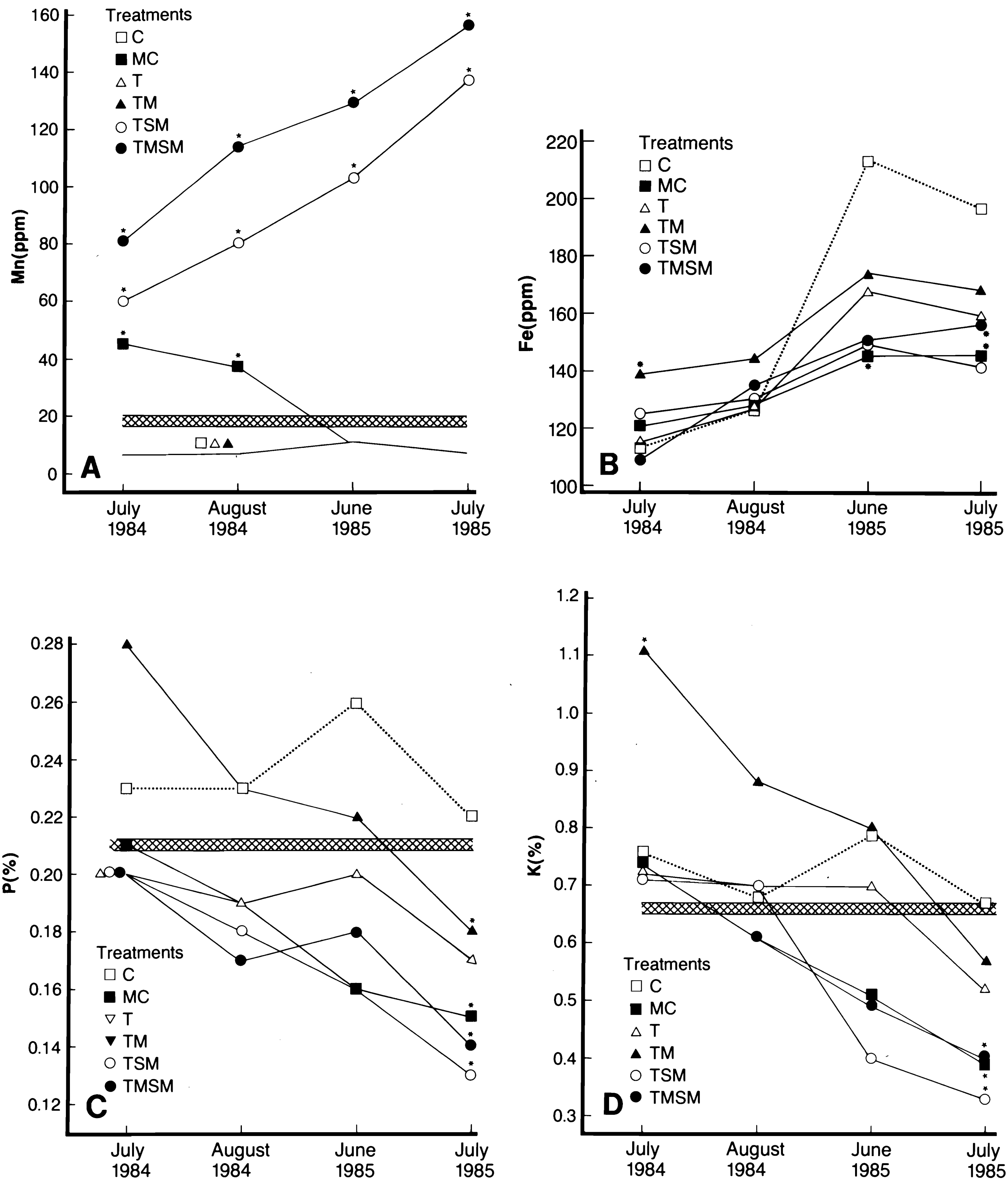

Fig. 3. Trends in leaf nutrient concentrations following spring, 1984 treatment of chlorotic red maples: A. Manganese, B. Iron, C. Phosphorus, D. Potassium. * = significantly different from controls based on 0.05 level t-tests, no overlapping values, or both.

Fig. 4. Red maple in center treated in spring of 1984 with surface soil application of sulfuric acid, and a subsoil application of sulfuric acid and manganese sulfate. Adjacent red maples are untreated buffer trees which have remained stunted and chlorotic.

defoliated early had late August leaf concentrations of Fe that were higher (> 135 ppm), or Mn that were lower (< 8 ppm) than any of the late-defoliating trees.

Subsoil acidity. Fourteen months after subsoil acidification with sulfuric acid, soil pH values averaged between 6.0 and 6.5 at depths between 30 and 51 cm (12 and 20 in) in the vicinity of the drilled holes, compared to an average pH of 7.5 at these depths around control trees. The contention that the acidity produced by the subsoil treatments is largely responsible for the higher leaf Mn concentrations is consistent with established relationships (1, 8).

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