Soil pH and the Foliar Macronutrient/Micronutrient Balance of Green and Interveinally Chlorotic Pin Oaks[1]

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Abstract

Soil pH values around chlorotic pin oaks and green pin oaks were significantly different to a depth of 55 cm. Throughout that depth, average values around green trees were 6.1-6.8; those around chlorotic trees averaged 7.2-7.4 and were within a total range of 6.7-7.9. Mean foliar concentrations of Fe, Mn, and Zn were each significantly lower in chlorotic tree foliage for at least 1 of the 3 seasonal sampling periods. Mean concentrations of P, K, and Mg were each significantly higher in chlorotic tree foliage for at least 1 of the 3 sampling periods. Eighty-six percent of all chlorotic tree samples (159) could be distinguished from all green tree samples (124) either by lower micronutrient concentrations or higher macronutrient/micronutrient ratios. As treated trees progressed from a chlorotic to a totally green condition, each underwent reductions in foliar N and P concentrations. Green trees fertilized with ammonium phosphate had significantly lower concentrations of Fe, Cu, and K + Ca + Mg concurrent with significantly higher concentrations of N and P when compared to the controls. It is concluded that chlorotic pin oaks should not be deemed as simply iron-deficient and that indiscriminant fertilization of pin oaks or the lawns around them with NPK fertilizers may be deleterious.

Index words: chlorosis, foliar macronutrient/micronutrient balance, NP fertilization, pin oak, soil pH

Introduction

Chlorosis associated with die-back and death of pin oak *(Quercus palustris* Muenchh.) has been recognized for at least half a century (5). Nevertheless, it is still a serious urban shade tree problem in a large area of the U.S.

The chlorotic condition of pin oaks is attributed to a lime-induced iron deficiency based upon several studies which have implicated alkaline soils and have reported a re-greening of foliage in response to various iron treatments (7, 8, 16, 21, 22). Foliar diagnosis of the problem has not been sufficiently utilized. McHargue and Roy (12) reported Fe concentrations that were considerably higher in chlorotic than in green foliage. Although not ascribed as relevant by reviewers, manganese and copper concentrations were 11 and 6 times greater, respectively, in the green foliage than in the chlorotic foliage. The Fe concentrations in these chlorotic leaves were discussed by Stone (23), who suggested the possibility that the high concentrations were attributable to airborne contamination. The anomaly remains unexplained.

Despite the development of several techniques to improve the leaf color of chlorotic pin oaks with iron applications, some treated trees do not show any improvement, while others improve only partially. Commonly, treated trees improve substantially but only for 1-3 years.

Investigations at the Morton Arboretum were begun in 1978 to test the value of foliar nutrient monitoring as a diagnostic tool for assessing the nutrient balance of pin oaks in relation to chlorosis and to monitor the nutrient concentration responses to various treatments designed to correct chlorosis in pin oaks. This paper addresses the nutrient balance in relation to chlorosis.

Interveinal chlorosis of plants, including trees, may be a symptom of a deficiency of iron, manganese, zinc, or copper (23, 24). The solubility and plant uptake of all 4 of these micronutrients, as well as aluminum, is reduced when soil pH values exceed the 5.2-6.2 range (2, 20). Chlorotic plants on alkaline soils may be characterized by low foliar concentrations of one or more of the 4 micronutrients noted and by high foliar concentrations of N, P, K, and Mg (6, 9, 15). High foliar levels of both P and K may interfere with the activity of ions critical to chlorophyll formation (3, 11); for example, fertilization of black spruce *(Picea mariana)* with N and P increased foliar P and decreased foliar Mn, Cu, and Zn (1). Fertilization of Scots pine *(Pinus sylvestris)* with NPK also depressed levels of foliar Mn, Cu, and Zn (25). The form of nitrogen taken up by plants may also play a role in chlorosis. Excessive uptake of NO_3-N has been associated with chlorosis both in agricultural crops and in tree species (17, 26). Nelson and Selby (17) observed that for 2 species of conifer, nitrate as a sole source of nitrogen induced chlorosis and especially high foliar concentrations of Mg and K. The optimum pH for nitrate formation in soils is 7.5 (14). Thus, it may be inferred that chlorosis associated with alkaline soils is likely to involve a multi-factor nutrient imbalance rather than simply a deficiency of 1 nutrient.

Materials and Methods

Twelve chlorotic pin oaks at the Morton Arboretum were sequentially treated over a 5-year period with various combinations of Hi-Acid fertilizer 28N-7.9P-6.6K (28-18.5-8) with micronutrients, sulfuric acid, Mn or Fe Medicaps, ammonium sulfate, aluminum sulfate, and manganese sulfate. These trees were diagnosed visually and by foliar nutrient monitoring before and after treatments between May, 1978, and July, 1982. Ten green and 3 chlorotic trees of similar age served as controls and were sampled on the same dates

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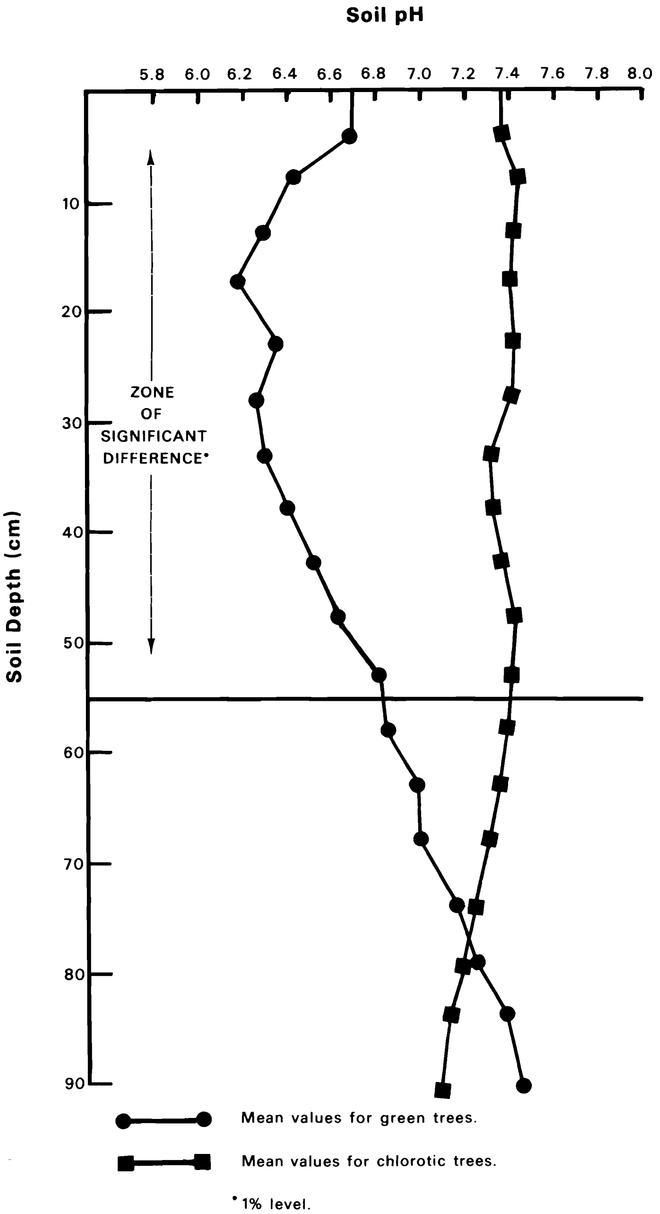

Fig. 1. Soil reaction profiles associated with untreated green and chlorotic pin oak trees.

as treated trees. All trees were 25-30 years old in 1978 and ranged in diameter at breast height (dbh) from 20-60 cm (8-24 in). Heights ranged from 8-12 m (26-40 ft).

Soil cores to a depth of 90 cm (3 ft) were collected beneath 9 of the chlorotic trees before treatment and cores were collected at 6 of the green tree sites during the spring of 1978. Soil pH was determined at 5 cm (2 in) intervals on each core, using a 1:1 soil-water volume ratio on fresh samples.

Foliar samples were collected from all trees on the same day in early June, mid-July, and late August to early September each year. Each sampling consisted of 25-30 fully-expanded leaves composited from the upper, middle, and lower crown of each tree. It was not possible to obtain leaves exclusively from the south side of each tree, but the north side was avoided. Immediately after collection, leaves were oven-dried at 70 °C (158 °F) for 24 hours. The dried leaves were ground in a Wiley mill fitted with a 20 mesh screen. The ground samples were analyzed by emission spectrograph and micro-Kjeldahl (for N) methods.

To test the suspected role of N and P on chlorosis, a study was conducted on a 25-year-old green pin oak plantation. All the plantation trees were within the diameter and height ranges of those used in the diagnostic study. The soil type throughout the plantation is Ashkum silty clay loam, a Typic Haplaquoll in the fine, mixed, mesic family. The mean pH within the upper 90 cm (3 ft) is as follows with no significant variations within the plantation:

Depth		
cm	inches	pH
0-10	0-4	6.0
10-20	4-8	6.4
20-30	8-12	6.4
30-45	12-18	6.5
45-60	18-24	6.7
60-75	24-30	6.8
75-90	30-36	6.9

Every other tree in every other row was numbered. Four numbered trees served as controls, 4 were fertilized with 1.35 kg (3 lb) of triplesuperphosphate 0N-19.8P-0K (0-46-0) per tree and 4 with 1.35 (3 lb) of ammonium phosphate 18N-19.8P-0K (18-46-0) per tree in May, 1981, and again in July, 1981. Both fertilizers were applied at a rate of 1 lb/100 ft² each time. The treatments were systematically spaced so as to have each treatment cover the same range of any minor soil variations that might exist.

Results and Discussion

Soil pH profile

Mean soil pH values to a depth of 75 cm (30 in) around chlorotic trees were higher than those around green trees (Figure 1). To a depth of 55 cm (22 in), this difference was significant (10). Within the upper 55 cm, no individual soil pH value below 6.7 was encountered around the chlorotic trees. The magnitude of the soil pH values suggests a limited availability of iron, manganese, zinc, and copper throughout the major portion of the root system of the chlorotic trees, since root system excavations and moisture uptake studies indicate that the bulk of the root system is confined to the upper 60 cm (2 ft) of soil (13).

The source of alkalinity around chlorotic trees is dolomitic gravel used in road and parking lot construction or calcareous glacial till exposed during grading operations prior to tree planting.

Foliar nutrients

Chlorotic trees treated with a surface soil application of sulfuric acid in April, 1980, began to turn green by mid-summer, 1980. Five of these became completely green by mid-summer, 1981. Therefore, micronutrient and macronutrient concentrations in leaves from untreated green trees for the 5-year period were compared with concentrations in chlorotic tree leaves sampled in 1978 and 1979 only.

Mean concentrations of Zn were significantly higher in green trees for all 3 subseasons. Mean concentrations

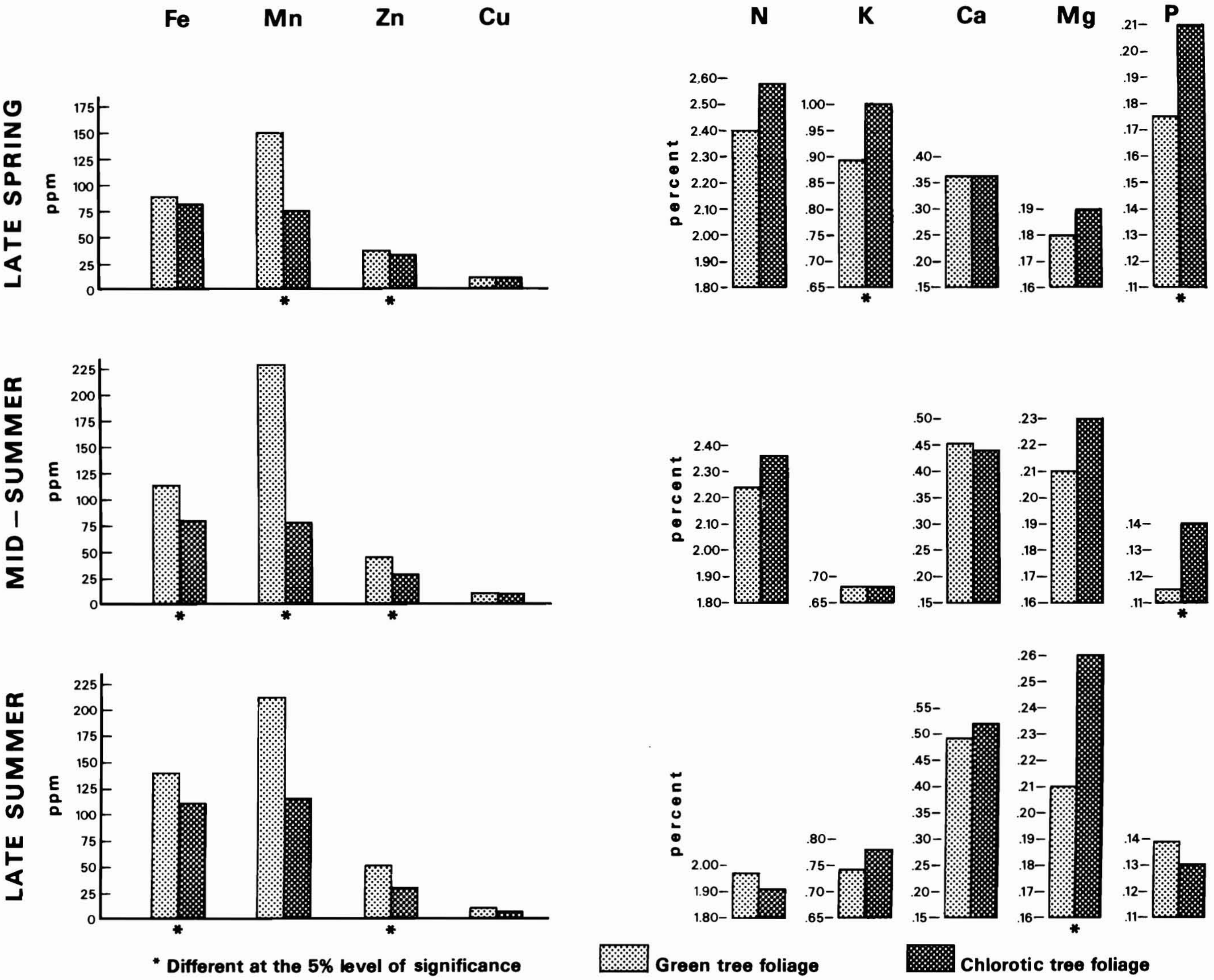

Fig. 2. Comparison of seasonal nutrient concentrations in foliage of green and chlorotic pin oak trees.

of Fe in green trees were significantly higher in mid- and late summer only, while mean concentrations of Mn in green trees were significantly higher in late spring and mid-summer only. Phosphorus and potassium were significantly higher in chlorotic foliage in late spring; phosphorus alone in mid-summer; and magnesium in late summer (Fig. 2).

The lowest concentrations of Fe and Mn found in green tree foliage over the 5-year period vary with subseason. Those of Zn and Cu do not (Fig. 3). Of the 155 samples from chlorotic trees, manganese was most frequently below the minimum for green trees at each season, followed by iron in late spring, zinc in mid-summer, and copper in late summer. The proportions of chlorotic samples with seasonal concentrations of 1 or more of these micronutrients falling below the green tree minimums are: late spring, 53%; mid-summer, 72%; and late summer, 66%.

A total of 54 samples from the chlorotic trees did not have micronutrient concentrations below any of the green tree minimums. Among these 54, late spring samples were significantly higher in mean K and mean P + K concentrations, mid-summer samples were significantly higher in mean P + K concentrations, and late summer samples were significantly higher in mean Mg concentrations than those of the green tree samples at these times. Several individual values of N, P, K, and Mg exceeded the highest seasonal values determined for green trees. Phosphates and other ions present in the leaves may inhibit iron and zinc utilization (3, 18); and some workers have correlated foliar macronutrient/micronutrient ratios with micronutrient deficiency symptoms (19). Based on these findings, K:micronutrient, P + K:micronutrient, and Mg:micronutrient ratios were calculated for all the green tree foliar samples (Table 1). These ratios were then compared with those of the 54 chlorotic samples. Thirty-three of the 54 samples had high foliar macronutrients in relation to micronutrients, i.e., each of the 33 samples had macronutrient:micronutrient ratios exceeding 1 or more of the maximum values for green trees show in Table 1. The high ratios that distinguished chlorotic tree samples from green tree samples were primarily K:Mn, Fe, or Zn in late spring; P + K:Zn or Mn in mid-summer; and

Mg:Mn in late summer. Ninety-eight percent of all late summer leaf samples from chlorotic trees had either micronutrient concentrations below green tree minimums or macronutrient:micronutrient ratios above green tree maximums. Respectively, 75% and 89% of the total number of late spring and mid-summer samples from chlorotic trees had nutrient concentrations or ratios that were outside the range found in green trees.

When the ratios used in Table 1 are calculated from the seemingly anomalous foliar concentrations reported by McHargue and Roy (12), the chlorotic foliage of their study trees is characterized by a K/Mn ratio that exceeds the green tree range reported here for either mid-summer or late summer samples, suggesting that chlorosis in these workers' trees may have been more a function of a potassium-manganese imbalance than a mis-diagnosis of an iron deficiency.

Five initially chlorotic trees treated for chlorosis became totally green during 1980 and 1981. Significant reductions in foliar concentrations of N, P, and Mg were associated with this change in leaf color. Micronutrient changes associated with chlorosis reduction varied from tree to tree; in 4 of the 5 trees, either Fe, Mn, or Zn increased into the concentration range established for green trees.

In the phosphorus fertilization experiments, foliage collected the first week in June showed no significant differences in any nutrient concentrations among treatments, though there was a suggestion of an effect on Fe and Mn which exhibited a similar gradient of decreasing concentrations from controls through P-treated and N+P-treated trees. By late summer, mean foliar concentrations of all cationic nutrients and aluminum were less in the phosphorus-treated trees (Fig. 4). Boron was not affected; means (not shown) were all 27 ppm. Phosphorus and nitrogen concentrations exhibited a gradient of increasing concentrations from controls through P-treated to N+P-treated trees. All the cationic nutrients appear to have been reduced by P or NP fertilization. Statistical significance is attached to the low values of Fe and Cu and the low sums of K+Ca+Mg. No chlorosis was observed. However, only among the fertilized trees did some replicates approach the chlorotic-green threshold values for Mn and Zn. Therefore, there is some reason to suspect that phosphorus fertilization may reduce foliar concentrations of all 4 of the micronutrients: Fe, Mn, Zn, and Cu—especially since this has been documented in other studies (1, 19).

Significance to the Nursery Industry

Interveinal chlorosis of pin oaks at the Morton Arboretum is associated with mean root zone soil pH values above 7.2 and no individual values below 6.7. Pin oaks should not be planted on such soils unless managers are willing to cope with chlorosis.

It is conjectural to refer to pin oak chlorosis as "iron chlorosis" in that multi-micronutrient deprivation and multi-macronutrient excesses characterize chlorotic pin oak trees on alkaline soils. Different visual symptoms of different combinations of these nutrient aberrations were not apparent, although rosetting, russetting, and

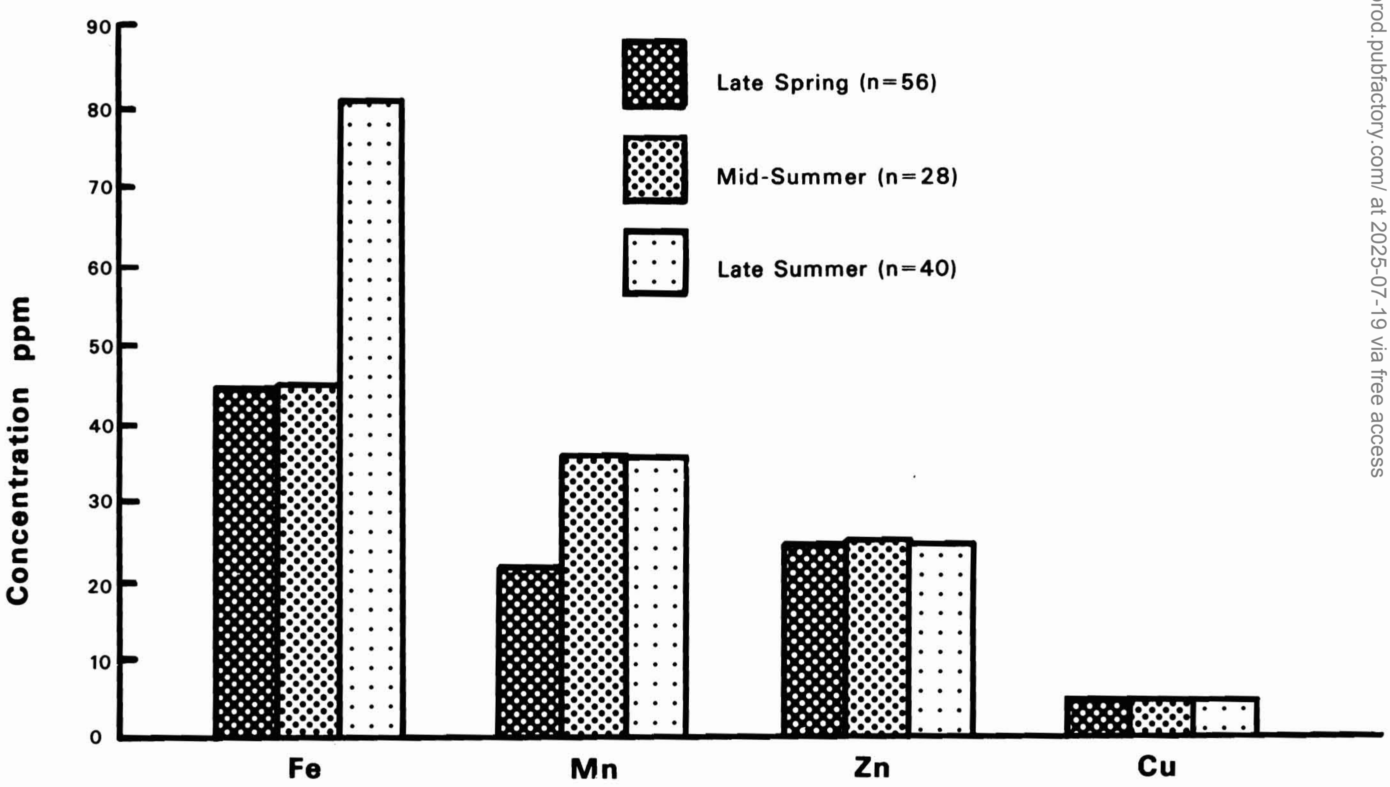

Fig. 3. Minimum concentrations of foliar iron, manganese, zinc, and copper in green pin oaks.

necrotic spotting were sometimes associated with interveinal chlorosis.

Nitrogen, phosphorus, and potassium fertilization of lawns around established pin oaks is ill-advised unless deficiencies of these nutrients are identified.

Table 1. Maximum macronutrient: micronutrient ratios in green pin oak foliage by season.[z]

Nutrient ratio	Season		
	Late spring	Mid-summer	Late summer
K/Fe	166	170	87
K/Mn	341	214	236
K/Zn	367	355	342
K/Cu	2075	1960	1975
P+K/Fe	202	193	103
P+K/Mn	423	243	214
P+K/Zn	441	352	408
P+K/Cu	2525	2275	1960
Mg/Fe	50	39	32
Mg/Mn	95	69	45
Mg/Zn	84	103	100
Mg/Cu	575	480	600
Sample size (n)	56	28	40

[z]Ratios were calculated for each of the 124 green tree samples collected during the 5-year study; the table values represent the highest seasonal values of each ratio.

Literature Cited

1. Alban, D.H. and R.F. Watt. 1981. Fertilization of black spruce on poor site peatland in Minnesota. North Central Forest Exp. Sta. Research Paper NC-210. 10 p.

2. Baird, J.V. and C.D. Sopher. 1978. Soil and Soil Management. Reston Publishing Co., Reston, VA.

3. Biddulph, O. and C.G. Woodbridge. 1952. The uptake of phosphorus by bean with particular reference to the effects of iron. Plant Physiol. 27:431-444.

4. Brown, A.L., B. Krantz, and J.L. Eddings. 1970. Zinc-phosphorus interactions as measured by plant response and soil analysis. Soil Sci. 110: 415-420.

5. Chadwick, L.C. 1935. Chlorosis of pin oaks. Proc. Amer. Soc. Hort. Sci. 33:669-673.

6. Gauch, H.G. 1972. Inorganic Plant Nutrition. Dowden, Hutchinson, and Ross, Inc., Stroudsburg, PA.

7. Hacskaylo, J. and P. Struthers. 1959. Correction of lime-induced chlorosis in pin oaks. Ohio Agric. Res. Dev. Ctr. Res. Cir. 71; 5 p.

8. Himelick, E.B. and K.J. Himelick. 1980. Systemic treatment for chlorotic trees. J. Arboriculture 6:192-196.

9. Iljin, W.S. 1951. Metabolism of plants affected with lime-induced chlorosis (calciose). I. Nitrogen metabolism. Plant & Soil 3:239-256.

10. Karl, R.C. 1980. Foliar nutrient monitoring and treatments of chlorotic pin oaks. M.S. Thesis. Northern Illinois University, DeKalb, IL.

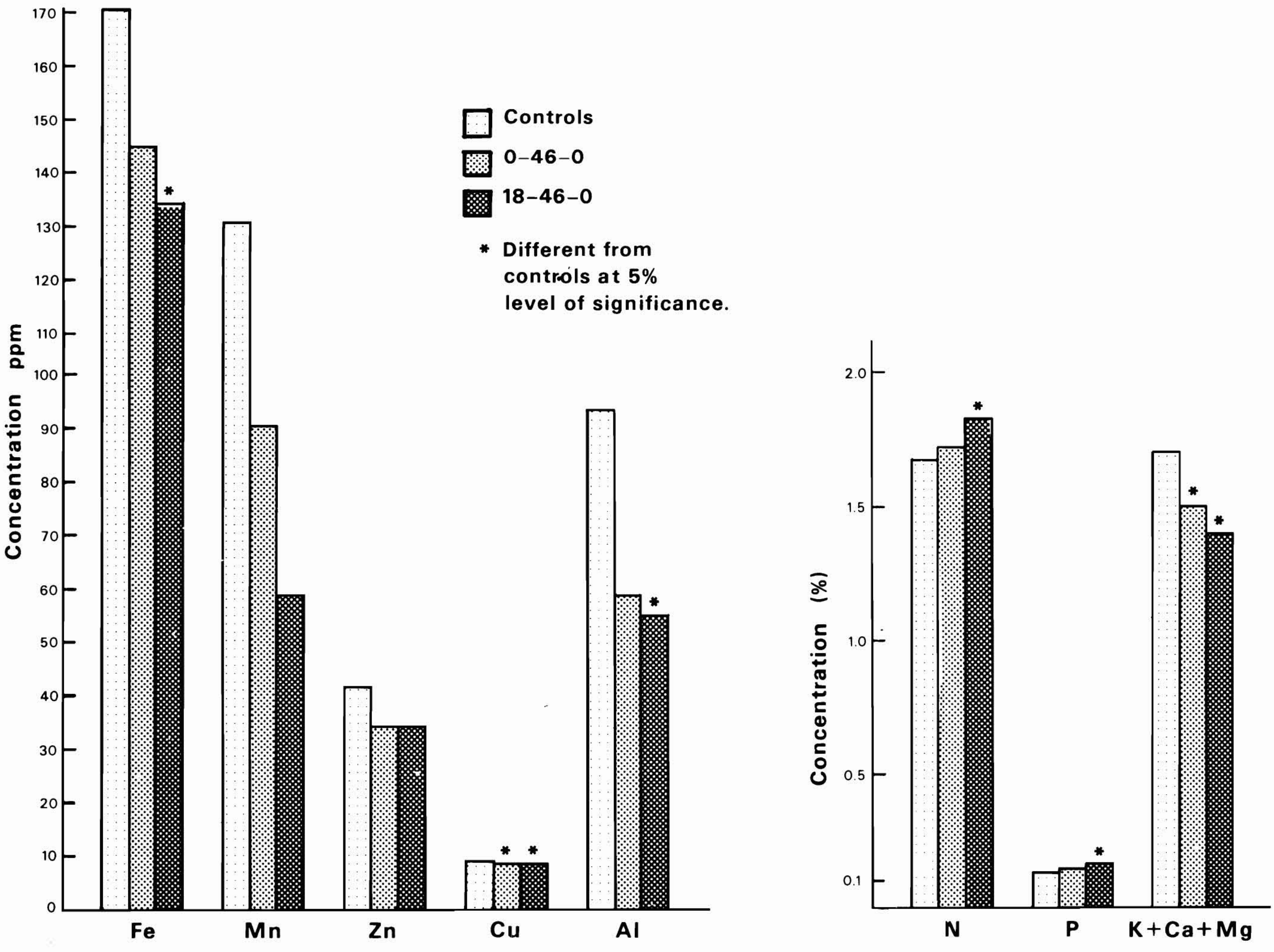

Fig. 4. Effect of high phosphorus fertilizers on the foliar nutrient balance of green pin oaks.

11. Lindner, R.C. and C.P. Harley. 1944. Nutrient interrelations in lime-induced chlorosis. Plant Physiol. 19:420-439.

12. McHargue, J.S. and W.R. Roy. 1932. Mineral and nitrogen content of the leaves of some forest trees at different times in the growing season. Bot. Gaz. 94:381-393.

13. Messenger, A.S. and G.H. Ware. 1981. Damage to building foundations: do tree roots play a role? The Morton Arboretum Quarterly 17:1-7.

14. Mortvedt, J.J. 1976. Soil chemical constraints in tailoring plants to fit problem soils. 2. Alkaline soils. pp. 142-149. *In* Proc. Workshop on Plant Adaptation to Mineral Stress in Problem Soils. Ed. M.J. Wright. Cornell Univ. Agric. Exp. Sta., Ithaca, NY.

15. Nakos, G. 1979. Lime-induced chlorosis in Pinus radiata. Plant & Soil 52:527-536.

16. Neely, D. and D.F. Schoenweiss. 1974. Correction of pin oak chlorosis. Arborists News 39:37-40.

17. Nelson, L.E. and R. Selby. 1974. The effect of nitrogen sources and iron levels on the growth and composition of Sitka spruce and Scots pine. Plant & Soil 41:573-588.

18. Olsen, R.A., R.B. Clark, and J.H. Bennett. 1981. The enhancement of soil fertility by plant roots. Amer. Sci. 69:378-384.

19. Olsen, S.R. 1972. Micronutrient interactions. *In* Micronutrients in Agriculture. Eds. J.J. Mortvedt, P.M. Giordana, and W.L. Lindsay. Soil Sci. Soc. Amer., Madison, WI

20. Reid, D.A. 1976. Genetic potentials for solving problems of soil mineral stress: aluminum and manganese toxicities in the cereal grains. *In* Proc. Workshop on Plant Adaptation to Mineral Stress in Problem Soils. Ed. M.J. Wright. Cornell Univ. Agric. Exp. Sta., Ithaca, NY.

21. Schoenweiss, D.F. 1968. Control of iron-deficiency chlorosis of northern pin oak. Results of 1967 Fungicide-Nematocide Tests, Amer. Phytopath. Soc. 23:110-111.

22. Smith, E.M. 1976. Pin oak chlorisis—a serious landscape problem. Amer. Nurseryman 143:15, 16, 44.

23. Stone, E.L. 1968. Microelement nutrition of forest trees: a review. *In* Forest Fertilization. Tennessee Valley Authority National Fertilizer Development Center, Muscle Shoals, AL.

24. Tisdale, S.L. and W.L. Nelson. 1969. Soil Fertility and Fertilizers. the Macmillan Co., New York, NY.

25. Veijalainen, H. 1977. Use of needle analysis for diagnosing micronutrient deficiencies of Scots pine on drained peat lands. Comm. Instituti Forestalis Fenniae 92:1-32.

26. Wadleigh, C.H. and J.W. Shive. 1939. Organic acid content of corn plants as influenced by pH of substrate and form of nitrogen applied. Amer. J. Bot. 26:244-248.

Effects of Wounding and Auxin Treatment on Rooting Stem Cuttings of Fraser's Photinia[1]

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Abstract

Light or heavy wounding applied to stem cuttings of Fraser's photinia *(Photinia x fraseri* Dress) had little effect on stimulating rooting. The greatest response from wounding was realized when used in combination with a 5000 or 10,000 ppm indolebutyric acid (IBA) solution. Satisfactory rooting, however, was attained by IBA treatment alone.

Index words: propagation, auxin, indolebutyric acid

Introduction

A common practice when preparing stem cuttings of Fraser's photinia *(Photinia x fraseri* Dress) for rooting is to first administer a heavy wound followed by auxin treatment (1). Recent preliminary studies at N.C. State Unversity have indicated that light wounding or no wounding at all may be satisfactory, provided proper auxin treatment is used. Therefore, the following study was undertaken to investigate the effects of various wounding treatments with and without subsequent auxin application on the rooting of Fraser's photinia stem cuttings.

Material and Methods

Hardwood, terminal stem cuttings, each 15 to 20 cm (6 to 8 in) long of Fraser's photinia were taken on February 3, 1982 from stock plants growing under uniform fertility levels at Goldsboro, North Carolina. As cuttings were harvested, they were sealed in plastic bags, placed in a cooler with ice, transported to Raleigh, and stored overnight in the dark at 4 °C (39.2 °F). The next day, cuttings were trimmed from the base to 10 cm (3.9 in), leaves removed from the basal 5 cm (2.0 in) and the following treatments employed: (1) nontreated, (2) 5000 ppm (0.5%) indolebutyric acid (IBA), (3) 10,000 ppm (1.0%) IBA, (4) light wound, (5) light wound + 5000 ppm IBA, (6) light wound + 10,000 ppm IBA, (7) heavy

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