

REDUCTION OF OAK CHLOROSIS WITH WOOD CHIP MULCH TREATMENTS¹

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Abstract. Wood chip mulch and ammonium sulfate treatments around urban white oaks (*Quercus alba*) were associated with favorable changes in soil properties. Bulk density and pH were lower, and moisture content was higher under the mulch. Fine root development and number of mycorrhizal roots were also increased. Foliar manganese increased and phosphorous decreased. These changes were associated with a reduction of interveinal chlorosis.

Les paillis de copeaux de bois et les traitements au sulfate d'ammonium autour des chênes blancs (*Quercus alba*) en milieux urbains ont été associés à des changements favorables sur les propriétés du sol. La masse volumétrique et le pH du sol étaient inférieurs et le taux d'humidité était supérieur sous le paillis. Le développement des radicelles et le nombre de racines mycorrhizées étaient de même supérieurs. Le manganèse foliaire augmentait et le phosphore diminuait. Ces changements ont été associés avec une réduction des chloroses interveinales des feuilles.

Chlorosis, manifested by yellow leaves, has become a significant problem of mature urban oaks in the Midwest. Other decline symptoms are frequently associated with chlorosis. Most of the affected trees are growing on residential property, parks and parkways, usually with turfgrass established around them.

Several factors can contribute to chlorosis. Mineral deficiencies have often been implicated, especially in alkaline soils where iron and manganese are less available to plants. Himelick and Himelick, however, found only a limited response of white oaks to systemic iron and manganese treatments (12). Turfgrass can be a stronger competitor than trees for soil nitrogen (20, 25, 30). Various stress factors can contribute to chlorosis and to tree decline. Compacted soils with poor drainage and aeration, for example, are common in urban areas, and chlorosis can be aggravated by high levels of soil moisture (28). Soil moisture extremes, either too much or too little moisture, are sometimes associated with iron and manganese deficiency symptoms (13, 18).

A well-developed root system is important for the uptake of soil moisture and nutrients. In many urban soils, the root growth of trees is inhibited by compaction, low oxygen, and extremes in soil moisture and soil temperature (7, 26, 27). In addition, tree root densities are often reduced when roots of turf grasses are present (2, 4, 8, 16, 25, 29). Ectomycorrhizae, which have been shown to greatly increase plant growth and nutrition (10), cease to absorb nutrients under conditions of high soil moisture and the reduced availability of oxygen that results (5, 9, 23).

Jacks (14) and Harris (11) point out that the presence of mulch on the soil surface improves the rooting environment by inducing favorable changes in evapotranspiration, soil structure (aggregation), water and oxygen infiltration, drainage, water-holding capacity, temperature, fertility and biological activity. The application of mulch should not only increase soil moisture and nutrient availability but also lead to an improved root system that more fully utilizes the available soil moisture and nutrients. The interaction among these favorable changes in the rooting environment should reduce stress and improve vigor and leaf color. The field tests presented here report results on the use of wood chip mulch and ammonium sulfate to improve the root environment of large chlorotic white oaks (*Quercus alba*).

Methods

Mature park and parkway white oaks in Lake Forest, Illinois, with moderate to severe chlorosis, were chosen for study in August of 1979. Thirty-eight trees 45-76 cm (18-30 in.) dbh were mulched with approximately 8 cm (3 in.) of fresh wood chips within an area approximated by the dripline. Additional chips were added periodically to maintain this depth. Ammonium sulfate at 29 pounds per 1000 ft² (141 g/m²) [6 lbs. N/1000 ft² (29

¹Supported in part by the City of Lake Forest, Illinois.

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g/m²) was applied to the chips each spring for four years to help acidify the soil and to avoid a nitrogen deficiency related to decomposition of the mulch. An additional ten trees 38-71 cm (15-28 in.) dbh were not mulched and served as controls. An established lawn was left undisturbed around these trees.

Root, soil and foliar sampling was done in August of 1983. Sampling of each of the 48 trees was not possible because of the time and labor required to process the samples. Instead, eight mulched trees and four controls chosen from two parks sites and a school yard were included in the study.

Separate soil cores, 7.0 cm (2.75 in) diameter and 15 cm (6 in) deep, were taken approximately 2 m from the trunk of each tree for soil and root analysis. Soil moisture content, bulk density and pH measurements were performed according to the methods of Blake (3), Gardner (6) and Peech (21), respectively. After separating all soil, organic debris, and herbaceous roots from the oak roots, total root length measurements were taken on each sample using Newman's (19) line intersection method. To evaluate mycorrhizal infection, randomly selected portions of the root samples were cleared and stained using the procedure of Phillips and Hayman (22). Quantitative measurements were achieved with a modified gridline intersection method (15) that relied on the presence of a Hartig net as a criterion for ectomycorrhizal infection. Total length of mycorrhizal roots (mycorrhizal density) was calculated by multiplying root density by the percent mycorrhizal infection, which yielded the length of mycorrhizal roots per unit (cc) of soil.

For foliar analysis, leaves were taken from representative branches on the lower half of each tree (leaves from the upper half could not be reached with the equipment available). The petioles were removed and the leaves were rinsed in distilled water, oven-dried at 70C and ground in a Wiley mill. The nitrogen was determined by the standard Kjeldahl method. All other elements were determined spectrometrically using standard methods. A color rating scale of 1 (chlorotic) to 10 (green) was used to measure response to treatment. Color ratings were made on all 38 trees and represented the average

determined by two people for each tree.

Treatment effects were determined by one-way analysis of variance with significance at the 5% level.

Results and Discussion

The mulch treatment had several effects on soil properties that are considered favorable for root development (Table 1). Bulk density of the mulched soil was significantly lower than that of the control, 0.73 vs 1.14 g/cc. The extremely low bulk density of the mulched soils can probably be attributed to high levels of organic matter due to the natural incorporation of the decomposing mulch and to reduced impact of foot traffic and mowing equipment. The control density of 1.14 g/cc is low compared to the density of some urban soils, and certainly well below a density of 1.4-1.6 g/cc, which inhibits the penetration of roots (1, 31).

Moisture content was higher under the mulch, 30.8 percent compared to 18.9 percent under the turf, but the difference was not statistically significant because of the large variation of individual values. Mulch reduces evaporation from the soil surface and the elimination of the turf reduces transpiration. The changes in these soil properties were dramatic when observed in the field. The sampling was done during a very dry period and the soil in the grassy control area was dry, dense, and hard. The soil under the mulch was moist and friable.

The pH of the mulched soil was significantly lower than that of the control, 5.8 vs 6.7. This

Table 1. Soil properties and root development levels resulting from wood chip mulch treatment.

Character	Mulched	Control
Bulk density (g/cc)	0.73*	1.14
Moisture content (% dry wt.)	30.80**	18.90
Root density (mm root length/cc soil)	6.16**	3.20
Mycorrhizal infection level (% infection)	31.80**	14.50
Mycorrhizal density (mm infected root/cc soil)	1.95*	0.46
Foliage color change (units on a scale of 10, positive change = greener foliage)	+1.00*	+0.27
Soil pH	5.8*	6.7

* Statistically different from control at the 1% level

** Though differences between means are large, statistical significance was not achieved because individual values were highly variable.

reduction could be the result of the ammonium sulfate application, but it may also have been due to the improved structure and drainage of the mulched soil. In well-drained, moist soils, basic ions are readily leached through the profile, rendering the soil more acid (11). Acidic by-products from the decomposition of the mulch may also have contributed to the reduction of pH.

The improved soil conditions resulted in greater development of the root system. Fine root densities of oaks in the mulched soils were nearly twice as high as those of the controls. The percent of mycorrhizal roots was more than twice as high in mulched as in control soils. Neither difference was statistically significant due to large variations, a problem that is quite common in root samples. When the total lengths of mycorrhizal roots were calculated, the increase due to the mulch treatment was statistically significant. The large increase in mycorrhizal fine roots would certainly lead to better utilization of soil resources by the oak root system. This, in turn, should decrease the probability of stress due to drought and of nutrient deficiency in the foliage.

Foliar nutrient levels for manganese and phosphorus showed large differences between the treatment and the control (Table 2), and the differences could be related to the reduction in soil pH. Foliar manganese levels were nearly twice as high in the mulched trees as in the control trees (209 ug/g to 106 ug/g), but the individual values were highly variable and not significantly different. Manganese deficiency is sometimes implicated in white oak chlorosis, and this increase among mulched trees might account in part for the reduction of chlorosis. Foliar phosphorous was significantly lower in the mulched trees (0.19 vs 0.32 percent dry weight). High levels of phosphorous have been related to iron deficiency because phosphorous tends to inactivate iron via precipitation of iron phosphate within the plant (17, 24). Thus, more iron may have been available to the plant without increasing the total amount present in the leaves. Iron added to plants in previous trunk injection studies on white oak (12) could have been rendered unavailable by the high phosphorous content of the leaves.

Both the mulched and control trees were greener at the end of the experiment, but the change in color was significantly greater in the

mulched trees. Severity of stress varies with each growing season. If chlorosis is related to stress, that relationship could account for the slight greening of the control trees during the four years of the experiment. Differences in stress from year to year could also explain the yearly variation in severity of chlorosis symptoms often observed. Though a mineral deficiency might be involved, it could not have been the only cause of the chlorosis, or the controls would not have improved as they did without the addition of the deficient nutrient(s).

Summary

Mulch treatments contributed to physical and chemical improvements in the soil. The soil was less compacted and had a lower pH. Soil moisture was higher during dry periods, making more water available to the oaks at critical times. Reduced evaporation and the elimination of competition from turf for soil moisture and nutrients, are two major effects of the mulch treatments. Though not measured directly, total water holding capacity and drainage were probably also improved, as indicated by the improved soil structure and the increased organic matter from the decomposing mulch. Decomposition of the organic mulch also releases nutrients into the soil. The pH was lower, thereby making more manganese available to the plant.

These soil improvements led to increased development of the fine root system and mycorrhizae, which in turn increases a tree's ability to absorb available water and nutrients from the soil. The combined effects of improved soil conditions,

Table 2. Foliar nutrient status of mulched and control trees.

Nutrient	Foliar nutrient levels (ug/g dry wt.)	
	Mulched	Control
Zinc (Zn)	48	42
Manganese (Mn)	209**	106
Iron (Fe)	123	133
Calcium (Ca)	17,900	16,600
Potassium (K)	24,700	24,900
Nitrogen (N)	23,800**	22,500
Phosphorous (P)	1,900*	3,200

* Statistical different from control at the 5% level

** Though differences between means are large, statistical significance was not achieved because individual values were highly variable.

greater availability of nutrients, and increase of the fine root density result in improved tree vigor and a more green foliage.

The results of this study shows that the enhancement of the root systems through soil improvement is a valid way to improve the condition of oaks and reduce chlorosis. One limitation of the application of mulch and fertilizer is that improvement of growth and leaf color can be slow to materialize on older trees. Chlorosis usually increases over a period of several years, therefore, a slow acting, but long lasting, remedy is a sound approach. The mulched trees still appeared very green and vigorous in 1989, demonstrating the long lasting results of this treatment. Substituting mulch for the bluegrass lawn under the tree canopy may be objectionable to some homeowners, but permitting lawn grass to remain in the tree root zone has proven to be detrimental and may result in further decline of chlorotic trees.

Acknowledgment. The authors would like to thank Dr. E. Thomas Smiley, currently at Bartlett Tree Research Laboratory, Charlotte, NC, for his assistance in foliar nutrient analysis.

Literature Cited

1. Barley, K.P. and E.L. Greacen. 1967. *Mechanical resistance as a soil factor in influencing the growth of roots and underground shoots*. Advances in Agronomy 19:1-43.
2. Bedford, Duke of, and S.U. Pickering. 1919. *Science and Fruit Growing*. Macmillan, London.
3. Blake, G.R. 1965. Bulk Density. pp. 374-390. In Black, C.A. (Ed.). *Methods of Soil Analysis*. American Society of Agronomy, Inc., Madison, WI.
4. Fraedrich, S.W. and D.L. Ham. 1982. *Wood chip mulching around maples: Effect on tree growth and soil characteristics*. J. Arboric. 8:85-89.
5. Gadgil, P.D. 1972. *The effect of waterlogging on radiata pine and Douglas fir*. New Zealand J. For. Sci. 2:222-226.
6. Gardner, Walter H. 1965. Water Content. pp. 82-127. In Black, C.A. (Ed.) *Methods of Soil Analysis*. American Society of Agronomy, Inc., Madison, WI.
7. Gilman, E.F., I.A. Leone and F.B. Flower. 1987. *Effect of soil compaction and oxygen content on vertical and horizontal root distribution*. J. Environ. Hort. 5:33-36.
8. Green, Thomas L. and Gary W. Watson. 1989. *Effects of turfgrass and mulch on the establishment and growth of bare-root sugar maples*. J. Arboric. 15:268-272.
9. Harley, J.L., C.C. McCready, J.K. Brierley and D.H. Jennings. 1956. *The salt respiration of excised beech mycorrhizas II. The relationship between oxygen consumption and phosphate absorption*. New Phytol. 55:1-28.
10. Harley, J.L. and S.E. Smith. 1983. *Mycorrhizal Symbiosis*. Academic Press, New York, NY.
11. Harris, R.W. 1983. *Arboriculture: Care of Trees, Shrubs, and Vines in the Landscape*. Prentice-Hall, Inc., Englewood Cliffs, NJ.
12. Himelick, E.B. and K.J. Himelick. 1980. *Systemic treatment for chlorotic trees*. J. Arboric. 6:192-196.
13. Hutchinson, T.C. 1970. *Lime chlorosis as a factor in seedling establishment on calcareous soils*. New Phytol. 69:143-157.
14. Jacks, G.V., W.D. Brind and Robert Smith. 1955. *Mulching*. Commonwealth Bureau of Soil Science, Tech. Comm. No. 49.
15. Kormanik, P.P. and A.C. McGraw. 1982. Quantification of vesicular-arbuscular mycorrhizae in plant roots. pp. 37-46. In Schenck, N.C. (Ed.). *Methods and Principles of Mycorrhizal Research*. The American Phytopathological Society. St. Paul, MN.
16. Larson, M.M. and G.H. Schubert. 1969. *Root competition between ponderosa pine seedlings and grass*. USDA For. Serv. Res. Pap. RM-54.
17. Mengel, K. and E.A. Kirby. 1982. *Principles of Plant Nutrition*. International Potash Instit. Worblaufen-Bern, Switzerland.
18. Mortvedt, J.J., P.M. Giordano and W.L. Lindsay. 1972. *Micronutrients in Agriculture*. Soil Sci. Soc. Am., Madison, WI.
19. Newman, E.I. 1966. *A method of estimating the total length of roots in a sample*. J. Appl. Ecol. 3:139-145.
20. Nielsen, A.P. and R.C. Wakefield. 1978. *Competitive effects of turfgrasses on the growth of ornamental shrubs*. Agron. J. 70:39-42.
21. Peech, Michael, 1965. Hydrogen-ion activity. pp. 905-913. In Black, C.A. (Ed.). *Methods of Soil Analysis*. American Society of Agronomy, Inc., Madison, WI.
22. Phillips, J.M. and D.S. Hayman. 1970. *Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi and rapid assessment of infection*. Trans. Brit. Mycol. Soc. 55:158.
23. Read, D.J. and W. Armstrong. 1972. *A relationship between oxygen transport and the formation of the ectotrophic mycorrhizal sheath in conifer seedlings*. New Phytol. 71:49-53.
24. Rediske, J.H. and O. Biddulph. 1953. *The absorption and translocation of iron*. Plant Physiol. 28:576-593.
25. Richardson, S.D. 1953. *Root growth of Acer pseudoplatanus L. in relation to grass cover and nitrogen deficiency*. Meded. Landbouwhoges. Wageningen. 53:75-97.
26. Ruark, G.A., D.L. Mader and T.A. Tattar. 1983. *The influence of soil compaction and aeration on the root growth and vigour of trees—A literature review*. Part I. Arboric. J. 6:251-265.
27. Ruark, G.A., D.L. Mader and T.A. Tattar. 1983. *The influence of soil compaction and aeration on the root growth and vigour of trees—A literature review*. Part II. Arboric. J. 7:39-51.
28. Wallace, A. and O.R. Lunt. 1960. *Iron chlorosis in horticultural plants, a review*. Proc Amer. Soc. Hort. Sci. 75:819-841.
29. Watson, Gary W. 1988. *Organic mulch and grass competition influence tree root development*. J. Arboric. 14:200-203.
30. Whitcomb, Carl E. 1981. *Response of woody landscape plants to Bermudagrass competition and fertility*. J. Arboric. 7:191-194.
31. Zisa, R.P., H.G. Halverson and B.B. Stout. 1980. *Establishment and early growth of conifers on compact soils in urban areas*. USDA For. Ser. Res. Pap. NE-451.