Table 1. Effect of potassium rate on number of lesions on *Calathea picturata* 'Vandenheckei' caused by *Drechslera setariae*.

	Mean number of lesions				
Potassium rate g/m³	Test 1 June 14 1989	Test 2 March 1 1990	Test 3 March 21 1990	Test 4 July 13 1990	Overall mean
0	86*[z]	14.2 ns	20.0 ns	11.9**	33.0
700	46	13.8	10.7	5.5	19.0
1400	55	11.2	14.6	4.9	21.4
2800	46	9.0	14.1	4.5	18.4

[z]Significant effects were denoted at the 5% level (*), the 1% level (**) or not significant (ns).

ratings. Number of lesions per plant was recorded approximately 2 to 3 wk after inoculation.

Results and Discussion

The rates of potassium tested did not affect the height, number of leaves or the quality of the calatheas even when no potassium was supplied. In contrast, potassium rate did affect the number of lesions caused by *D. setariae* (Table 1). Plants which received any level of potassium had about half the number of lesions of plants which did not receive any potassium. Although Tests 2 and 3 showed only marginally significant results ($P<0.10$), the same trend occurred as for Tests 1 and 4. When the four tests were analyzed together, the difference between the treatment without potassium and the three with potassium becomes clearer.

Although some of these plants did not receive any potassium, they did not show any reduction in growth or plant quality during the test period of about 3 months. No signs of potassium deficiency developed when plants were observed for 6 months (unreported data). Leachate soluble salts at 2 months were about 300, 500, 1200, and 975 μmhos/cm for the 0, ½, 1, and 2 × treatments, respectively. These tests indicate the importance of supplying calatheas with potassium for disease resistance and that the lowest rate (700 g/m³) provided the same effect as four times that rate. However, use of this potassium rate may, under some conditions, result in potassium deficiency since calatheas are a relatively slow growing, long-term crop.

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Pin Oak Root Injury from Soil Acidification with Sulfuric Acid[1]

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Abstract

Sulfuric acid soil treatments that have been used to reduce soil pH in the landscape can cause root damage. When 5 cm (2 in) diameter holes were filled with 33% (4 N) sulfuric acid, pH reduction of one-half unit or greater was limited to soil within 5 cm (2 in) of the treatment hole and persisted less than 2 years. Fine root density was significantly reduced and root tip injury was significantly increased within 15 cm (6 in) of the treatment hole. Cambium of woody roots greater than 3 mm (0.1 in) diameter was killed up to 25 cm (10 in) from the application hole. Destruction of the cambium would result in the death of the roots beyond the point of cambium injury and may be responsible for crown dieback which sometimes develops following acid treatments in the landscape.

Index words: *Quercus palustris*, chlorosis, root injury, soil acidification

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Significance to the Nursery Industry

Chlorosis associated with alkaline soils and iron deficiency is common in Midwest landscapes. Sulfuric acid treatments have been used to acidify soil around established chlorotic trees (4). Root damage resulting from acid treatments was evaluated; results indicate that substantial root damage is likely to occur beyond the area in which soil pH is reduced. This root injury may be associated with dieback of the crown sometimes observed following use of acid treatments in the landscape. Risk of serious root damage is great and use of sulfuric acid treatments in the landscape cannot be recommended until more is learned about the relationship between root injury and crown decline. Proper species selection should be emphasized at the time of planting to avoid the need for soil acidification.

Introduction

Chlorosis associated with nutrient deficiencies induced by soil alkalinity is common on some tree species in the landscape (2). Sulfuric acid has been used for rapid acidification of alkaline soils (1, 4, 5). Soil application of a caustic chemical, such as sulfuric acid, may be destructive to roots. Root loss may be minor if damage is limited to fine roots, which can be replaced rapidly. The injury may be more serious and longer lasting, if the cambium of larger woody roots is injured by the acid. The entire distal portion of the roots will die beyond the point where the roots are girdled by the acid. Since trees typically have 4–11 major roots (6), if only one major root is killed, as much as 25% of the total root system can be lost. Sudden severe root loss can lead to crown stress and dieback. This can be easily observed on construction sites and transplanted trees. Severe dieback has been observed in the landscape on chlorotic pin oaks that have recently been treated with sulfuric acid. The objective of this study was to examine the extent of tree root injury in the soil surrounding sulfuric acid treatment holes.

Methods and Materials

The study was conducted at the Morton Arboretum, Lisle, Illinois, in a stand of even aged pin oak (*Quercus palustris*) trees. These trees had been planted as seedlings on 4 m (13 ft) centers in 1956, and averaged 27 cm (10.6 in) DBH. The soil was a fine textured, tile-drained, Typic Haplaquoll, slightly acid (6.1–6.5) at 0–30 cm (0–12 in) depth, and circumneutral (6.6–7.3) at 30–60 cm (12–24 in) depth. The pin oaks on this site have had a history of moderate chlorosis.

Seven trees were chosen for the study. Two 5 cm (2 in) diameter, 30 cm (12 in) deep holes were drilled 1.35 m (54 in) apart and 0.9 m (36 in) from the trunk of each tree on June 16, 1987. One hole of each pair was filled slowly with 1 l of 4 N (33% of concentrate) sulfuric acid, which is typical of the strength currently being used for landscape treatments (Messenger, personal communication). The other hole was left unfilled as a control. Though holes for acid treatments in a previous study (5) and in landscape use (Messenger, personal communication) have been 60 cm (24 in) deep, holes in this study were drilled only 30 cm (12 in) deep to allow root and soil sampling deeper than the treatment hole.

Four pairs of treatment holes were used for replicated measurement of soil pH and fine root density. Samples were taken 7, 21, and 49 days after treatment in 1987, and again 770 days after treatment in 1989. On each sampling date, the same 4 treatment holes and distances from the holes were used, but samples were taken in a different direction from the treatment hole. For pH determinations, 60 cm (24 in) deep, 2 cm (0.75 in) diameter cores were taken with a standard soil sampling tube at 5 cm (2 in) intervals, out to 20 cm (8 in) from the treatment holes. Soil pH was determined using the electrometric method in a 1:1 (by vol) soil/water ratio (3).

Fine root densities in soil from 0–15 cm (0–6 in) from the treatment hole were determined by core sampling (7). On each sampling date, two 7 cm (2.8 in) diameter cores were removed adjacent to both the treatment and control holes. The first core was immediately adjacent to the acid treatment hole, and the second was adjacent to the first in a radial direction. There was approximately 0.5 cm between cores. Each core was 45 cm (18 in) deep. Alternate 7.5 cm (3 in) segments of each core were discarded to minimize sample volume and processing time.

After fine root densities were determined, the condition of the root tips was examined microscopically to determine the extent of damage caused by the acid treatment. The number of injured root tips was counted and then calculated as a percentage of total tips in the sample.

The remaining three pairs of treatment holes were used for assessing the condition of woody roots. Roots 3 mm (0.12 in) diameter and larger were examined from a 60 cm long × 5 cm wide × 60 cm deep (24 × 2 × 24 in) monolith of soil transecting the treatment hole and perpendicular to a line between the trunk and the treatment hole (see Figure 1). The location of each root and any evidence of injury from the acid treatment were recorded.

Statistical analysis was accomplished using the Solo Statistical System, Version 2.0. One-way analysis of variance was used to study the effect of the soil treatment. Means were separated using the Newman-Keul's procedure and contrasted with t-tests, with significance at 5 percent (0.05).

Results and Discussion

Acid treatments resulted in a pH reduction of as much as 5 units within the first 6 days (Fig. 2). The reduction of pH diminished with soil depth and distance from the treatment hole. pH reduction of one-half unit or greater was limited to soil within 5 cm (2 in) of the treatment hole. Soil pH measurements were similar for all remaining 1987 sampling dates and are not presented. Two years after treatment, the pH of the treated soil was once again similar to the untreated soil at all depths. The duration of pH reduction from similar treatments has been reported as 14 months (4, 5).

Roots of all sizes were damaged by the acid treatment. Fine root injury occurred over the entire area sampled (up to 15 cm {5 in} from the treatment hole) within the first 7 days after treatment. Root tip damage data show evidence of fine root damage from the acid on the first sampling date, though there was no difference in root density at this time (Table 1). A reduction in fine root density around the treatment hole was detected by surface area measurements only after the damaged roots had deteriorated, 21 days after treatment. Normal root tip attrition and typical damage from sample processing procedures account for what might seem like high numbers of damaged root tips in the control samples. The differences in root density and root tip damage were maintained through 49 days after treatment (Table 1) indicating early damage and no net replacement of fine roots in treated soil.

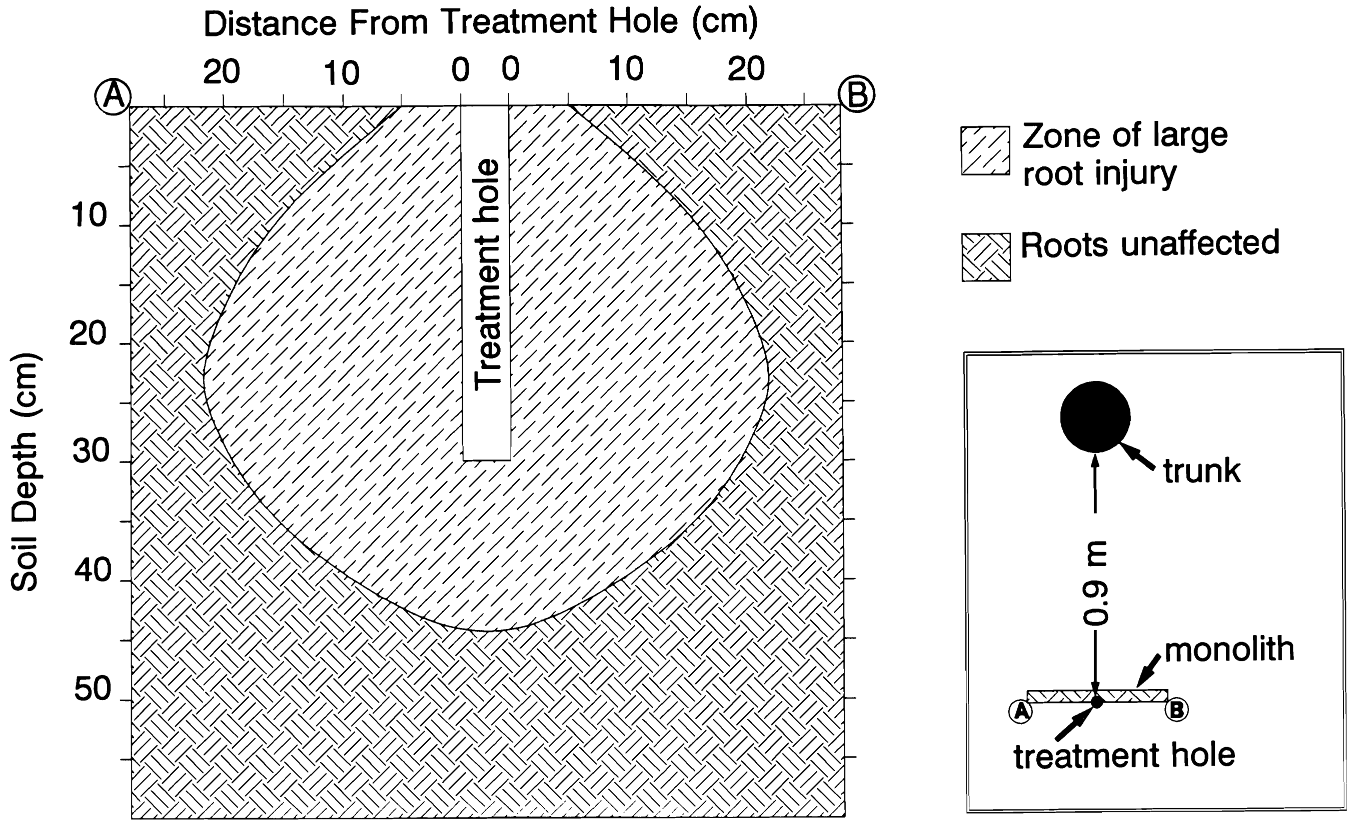

Fig. 1. Zone of root injury 10 days after sulfuric acid is applied to the soil. Location of each individual injured root was mapped on a grid pattern in the field. Illustration in box shows the location of the soil-root monolith relative to the tree and treatment hole. Points A and B are corresponding reference points.

Two years after treatment, root density in the acid treated soil remained lower than the control root density. The higher root densities in both the treated and control soils in 1989 is attributed to differences in the soil environment associated with drought. The high spring water tables normally present (within 15 cm {6 in} of the surface) were absent in spring drought years 1988 and 1989. Improved soil aeration during the spring period of active root growth for 2 years in succession may account for generally improved fine root development.

Woody roots (>3 mm diameter) around the treatment holes also showed evidence of injury within 10 days. Discoloration and sponginess of cambium tissues was observed. The zone of woody root injury was approximately 55 cm (18 in) diameter at its widest point, 25 cm (10 in) below the surface. The distribution of injured roots observed 10 days after treatment is illustrated in Figure 1. Further discoloration and decomposition of the root bark and cambium tissue was on successive sampling dates made it clear that the injured roots were dead. Controls showed no evidence of root injury.

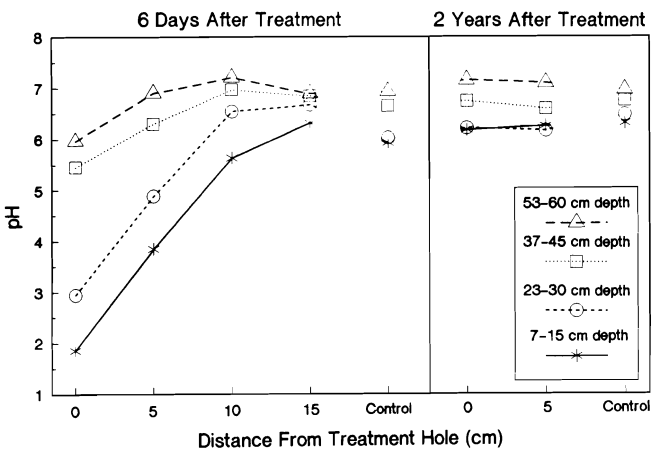

Fig. 2. Soil pH changes associated with acid treatments 6 and 770 days after treatment.

Table 1. Average reduction in fine root density and damage to root tips resulting from soil application of sulfuric acid.

Days after treatment	Fine root density (mm surface area/cm soil)		Damaged root tips (percent)	
	Sulfuric acid	Control	Sulfuric acid	Control
7	1.51 b[z]	1.82 b	83.9 a	59.3 ay
21	0.82 c	1.30 by	81.3 a	44.5 ay
49	0.77 c	1.26 by	83.6 a	49.3 ay
770	2.65 a	3.94 ay		

[z]Data in the same column bearing the same letter were not significantly different (5% level) using one-way analysis of variance with separation of means using the Newman-Keuls procedure.

[y]Indicates significant difference between sulfuric acid treatment and controls at the 0.05 level.

Root injury was observed more than 15 cm (6 in) beyond the zone in which the pH was altered. Damage to woody roots can be much more serious than loss of fine roots. Cambium injury that girdles a small section of root will result in death of the entire root beyond the point of injury, potentially causing extreme tree stress if a substantial portion of the root system is lost.

The requirements for separation of treatment holes in this experiment precluded the use of numerous, closely spaced (2 or more concentric rings of holes 60 cm {24 in} or less apart) treatment holes around each tree, as is commonly used in the landscape (Messenger, personal communication), and thus no changes of any kind were observed in the crown. It is not possible to predict how seriously an individual tree may be stressed by the loss of a portion of the root system as a result of the acid treatment, but it is conceivable that substantial root damage followed by a period of water stress could result in visible injury to the crown. Comparison with transplanted trees would indicate that trees with immature foliage would be the most vulnerable. In the landscape, crown damage seems to most often follow spring acid treatments.

Although the extent of root injury may vary with different soil types, the practice of reducing soil pH with sulfuric acid or other strong chemicals near existing trees must be approached with caution. This study shows that the pH reduction is confined to a small area and may be short-lived, while root injury can occur well beyond the zone of pH reduction and long-term damage may occur. Repeated acid treatments may be necessary to maintain low soil pH, compounding the root injury and chances for crown damage.

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Economic Feasibility of a Shade Tree Container Production System[1]

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Abstract

An economic model was developed to estimate the feasibility of producing red oak (*Quercus rubra*) whips in an established container nursery. Cost per plant was compared for a simulated container nursery of 6.88 and 13.76 ha (17 and 34 acres) at different levels of production. Variable cost per plant ranged from \$3.48 when producing 100 plants to \$3.16 when producing 4,160 or more. Fixed cost per plant was \$.42 to \$.55 higher in the small nursery, depending upon level of production. Total cost per plant varied from \$3.86 to \$4.59, depending upon nursery size and level of production. Sensitivity analysis indicated that total cost per plant is less responsive to changes in wage rate than changes in interest rates on operating capital. Reducing losses during the rapid-growth and overwintering phases of production is necessary in order to minimize total cost per plant.

Index words: Economics, container nurser, *Quercus rubra*

Significance to the Nursery Industry

This study has examined the expected costs of producing red oak whips in $CuCO_3$ treated containers. Depending upon the level of production, total cost per plant ranged between \$4.28 and \$4.59 for the 6.88 ha (17 acre) container nursery and \$3.86 to \$4.18 for the 13.76 ha (34 acre) nursery. Compared to the current alternatives, a five foot bare-root whip costing approximately \$7.05 in 1990 or a five foot branched whip costing \$10.40, there is an economic incentive for existing container nurseries to examine this new production system and begin supplying container-produced whips to field nurseries. Additionally, because the plants produced in the new system possess a vigorous root system and have been shown to reach saleable size quicker and with fewer losses (Chinery and Struve, unpublished data,

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