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Effects of Diquat Applied to Exposed Roots of Black Willow

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Abstract

Practical and environmentally benign methods are continually being sought to chemically control tree root obstructions in municipal and agricultural drainage systems. In a greenhouse study designed to simulate sewer line conditions, diquat applications of 0.48 and 0.96 g ai/L resulted in partial and complete control, respectively, of treated roots of black willow (*Salix nigra* Marsh.). The higher rate significantly reduced the number and weight of new roots developing proximal to the area of herbicide exposure, suggesting that diquat was translocated. No damage to the shoot was observed, and diquat activity were unaffected by the presence of clay particles. These results suggest a previously undocumented mode of action for diquat that may have use in the management of tree root obstructions in municipal sewers and other drainage systems.

Key words: Diquat; Herbicide; Root-control; *Salix nigra*; Tree root

Introduction

Trees that are otherwise considered desirable components of urban landscapes cause costly management problems when their roots penetrate and proliferate within sewer lines and other drainage systems (Ahrens and others 1970). If root proliferation continues unabated, blockages and service disruptions result. Similarly, root penetration of perforated drainage tile often calls for the removal of trees in agricultural settings such as riparian buffers, where trees otherwise provide a myriad of environmental benefits (Hill 1996).

Black willow (*Salix nigra* Marsh.) occurs extensively throughout urban and agricultural landscapes in the eastern United States. Prolific root growth and tolerance of inundation permit this species to thrive in riparian and other hydric settings. However, these same characteristics contribute to the recognition of willows as particularly aggressive invaders and disruptors of sewer and agricultural drainage systems (Harris 1992; Rolf and Stål 1994).

Presently available, chemically based root control methods involve flooding the drainage pipe with a solution of metham sodium and dichlobenil. This practice, although effective, faces an uncertain future because of potentially negative impacts on treatment facilities and downstream aquatic systems. Alternative root control methods must be capable of rapidly killing roots within drainage systems to clear blockages without having an adverse impact on the health of aboveground portions of the tree. However, some translocation of herbicide beyond pipes would be useful in preventing immediate reinvasion by untreated roots.

Diquat has long been used to control weeds in aquatic systems, including ponds and drainage ditches. All available references indicate that foliar application is necessary because of (a) a mode of

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action involving disruption of the photosynthetic mechanism and (b) limited translocation caused by rapid cell death (Ahrens 1994). Proven compatibility with aquatic systems and the observation of desiccated leaves in treated vegetation provided encouragement to investigate the root control potential of diquat. However, the possible inactivation of diquat through sorption onto clay particles (Ahrens 1994) could potentially limit the use of diquat-based treatments in sewer and drainage system environments.

The objective of this study was to determine the impact of diquat on mortality and regrowth of exposed roots of black willow in a simulated sewer environment. The potentially mediating effects of clay on diquat activity were also assessed.

Materials and Methods

Black willow cuttings were taken on January 20, 1999, from trees of an unknown origin growing on the campus of Southern Illinois University, Carbondale, IL, and rooted in 262-mL tubes containing a 1:1 mixture of peat moss and white washed play sand. Tubes were perforated with a 2-cm^2 hole in the bottom and four 1.4-cm^2 holes on the sides, 2 cm above the bottom. Cuttings were then grown under greenhouse conditions in racks containing 12 tubes each with one cutting per tube. To facilitate root growth outside each tube, the racks were placed in aluminum roasting pans such that the base of each tube was suspended in a dilute aqueous nutrient solution. Water was added as needed, and a 20-20-20 NPK fertilizer was provided at a rate of 0.04 g/cutting per week into the pan. Root growth was further facilitated by maintaining the rooting zone in darkness by covering gaps between the edge of the rack and the pan with aluminum foil. Soil collected from the A Horizon of a Hosmer silt loam (Herman 1979) was introduced into the pan, allowing roots to grow in a soil and water slurry as they would be in sewer and drainage pipe environments. When cuttings had been growing for 6 months, intermingling exposed roots from adjacent cuttings were separated from one another, and fine roots were again allowed to regrow into the soil slurry. Furthermore, intermingling of roots among adjacent cuttings was prevented by twice-weekly manual separation of new root growth. Treatments began 3 weeks after initial root separation when shoots averaged approximately 0.8 m in height with healthy foliage. At the time of treatment, each cutting produced profuse growth of roots 0.3 cm in diameter or less. Roots were visibly and texturally indistinguishable in all respects from those typically found invading sewer lines. Immediately before treatment, the soil slurry was washed from all exposed roots on six cuttings per tray, permitting direct contact between chemical treatments and roots in the absence of clay particles. Roots from the six remaining cuttings in each tray received chemical treatments with the soil slurry intact.

Chemical applications consisted of three different treatments; two rates of diquat (Diquat, Zeneca Ag. Products, Wilmington, DE, USA) (0.48 or 0.96 g ai/L) and a no-diquat control. Diquat treatment rates were selected on the basis of results from our earlier unpublished studies, approximating the lowest concentrations producing complete mortality of roots in direct contact with the diquat solution. Each treatment, including the control, was applied in 1.0-L water solution with 2% alkyl polyglycoside-based foaming agent (AU-340, Adjuvants Unlimited, Tulsa, OK, USA) with a foam generator, simulating a standard application practice for controlling tree roots in sewer lines. All roots growing outside of the tubes were placed in contact with the foam solution for 20 min. Dense root growth at the time of treatment prevented the movement of foam into the tube containing the cutting. On removal from foam treatments, the cuttings and their exposed roots were returned to pretreatment nutrient and soil slurry solutions under shaded conditions, with residual foam permitted to maintain contact with exposed roots.

Three weeks after treatment, the exposed root systems were destructively sampled, dead roots discarded, and live roots separated into three categories: (a) suberized roots (suberized), (b) unsuberized roots, originating from exposed (treated) roots (unsuberized, exposed), and (c) new roots originating from roots inside the tube that had not been exposed to foam solution (unsuberized, unexposed). Roots were dried to a constant weight and weighed to the nearest 0.001 g. Foliar herbicide injury and loss of shoot vigor were assessed for all treated cuttings at the time of root harvest.

Each herbicide and root washing treatment combination consisted of six cuttings. Preliminary analysis of the data using a two-factor analysis of variance (SAS Institute 1989) indicated no significant differences in the level or nature of responses between the root washing and chemical treatments for any of the response variables. Therefore, the data for the root washing treatments were combined for further analysis using a one-factor completely randomized design. The value $\alpha < 0.05$ was used to determine significance with mean separation performed by Duncan's new multiple range test.

Table 1. Mean Number and Dry Mass for Three Categories of Roots from Black Willow Cuttings Exposed to Two Rates of Diquat and an Untreated Control

	Suberized		Unsuberized, Exposed		Unsuberized, Unexposed	
Treatments	No.	g	No.	g	No.	g
Control	7.4 a	0.849 a	36.8 a	0.261 a	8.2 a	0.042 a
Diquat 0.48 g ai/L	0.1 b	0.000 b	0.1 b	0.000 b	5.0 b	0.021 ab
Diquat 0.96 g ai/L	0.0 b	0.000 b	0.00b	0.000 b	0.6 c	0.001 b

Means within a column followed by the same letter are not significantly different ($\alpha < 0.05$). N = 12 for each treatment.

Results

Diquat at both rates tested significantly and drastically reduced the number and weight of suberized and unsuberized roots directly exposed to the treatment. Negligible survival was recorded for the lower rate, whereas complete mortality occurred under the higher rate (Table 1). Regrowth (number of roots) from roots that were shielded from the herbicide treatment by the planting tube was reduced by 39% and 93% relative to controls for the low and high rates, respectively. The biomass of growth from unexposed roots was reduced significantly (98%) for the higher rate of diquat only. No evidence of foliar damage or loss of shoot vigor was observed between the time of treatment and harvest.

Discussion

Both diquat treatments killed nearly all roots contacted, consistent with the results of several of our unpublished studies. The activity of diquat on tree roots is previously undocumented and is not consistent with the recognized mode of action as a photosystem I inhibitor. Diquat is known to be an oxidizing agent, and root mortality observed here may be a result of membrane desiccation, a phenomenon recorded in leaf tissue (Ahrens 1994). Further research would be needed to determine the mechanism responsible for the observed activity of diquat on root tissue.

Reduced root regrowth from untreated roots inside tubes was observed under the higher rate of diquat. It is most likely that lack of regrowth from these untreated roots was due to translocation rather than through direct uptake of foam residue after the return of roots to the nutrient and soil slurry solution. The small amount of foam residue clinging to roots and the great extent of herbicide dilution in the rooting environment supports this assertion. The apparent translocation and activity of diquat beyond the area of root exposure has practical significance for sewer and drainage pipe root control. In an operational setting, where treatments are confined within the drainage conduit, a chemical that causes mortality of roots to extend outside this area would slow the rate of root re-invasion, thereby increasing the amount of time before subsequent treatments are needed.

On the basis of these results, the potential for damage to aboveground portions of the tree resulting from translocated diquat appears to be small. The experimental system used in this study exposes a much higher proportion of a tree's root mass to herbicide treatments relative to trees treated in an operational setting. Previous research suggests that other herbicides (for example, triclopyr and sodium chlorate) are efficacious against roots and may be unsuitable for use in settings where aboveground damage is unacceptable because of significant upward translocation (Groninger and others 1997).

Diquat is tightly bound to clay particles and, to a lesser extent, by organic matter (Ahrens 1994). This phenomenon is important in limiting both the mobility of diquat in soils and reducing the opportunities for uptake by roots. The absence of treatment differences between roots coated in clay and those cleaned before treatment suggests that binding does not occur so rapidly as to preclude root uptake in an environment similar to that found in sewer and drainage systems.

The results of this study indicate that diquat has the potential to control exposed tree roots in aquatic environments without damaging aboveground portions of the plant. This has implications for managers of sewer systems, aquatic edges in landscaped environments, and drainage tile in forested riparian zones and other agroforestry settings, where root proliferation is undesirable or disruptive. The apparent compatibility of diquat with existing application methods, status as an approved aquatic herbicide, and low volatility suggests that diquat-based treatments may be a viable alternative to existing root control methods.

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