ADVERSE EFFECTS OF ATRINAL (DIKEGULAC) ON PLANE TREE, RED MAPLE, AND NORWAY MAPLE

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Abstract. The adverse effects of trunk injected Atrinal (Maag, Inc.) were monitored to determine factors which may influence their occurrence. The foliar appearance of Atrinal injected plane tree, red maple, and Norway maple trees was used as an indication of phytotoxicity. Planes were the most sensitive to the phytotoxic effects of Atrinal followed by red maple, then Norway maple. Symptoms of Atrinal-induced phytotoxicity included wilting, curling, increased pubescence, and marginal necrosis on leaves. These symptoms gradually disappeared over the growing season. Injection points, monitored to determine wound healing, developed lesions, sunken areas, and bark discoloration which we describe as trunk canker. The degree of trunk cankering was correlated with Atrinal injection and the percentage of crown removed during trimming.

Atrinal (Dikegulac Sodium or Na 2,3:4, 6-di-o-[1-methylethylidiene]-L-xylo-2-hexulofuranosonic acid) is used as a pinching agent for ornamentals and as a growth retardant for hedge plants (10, 11, 12, 13), and trees, using trunk injection methods (3, 4, 6, 7, 8, 9). Atrinal sometimes causes phytotoxicity (5), observed as chlorosis, and marginal leaf necrosis. As part of an efficiacy study begun in 1984, the phytotoxicity of Atrinal, applied by trunk injection, was monitored and correlated with environmental and arboricultural factors.

By the end of 1985, some trees had developed trunk cankers at injection points associated with Atrinal treatment. During the summer of 1986, trunk cankers were apparent on many of the trees in the study. The extent of the trunk canker problem was also monitored to learn more about its occurrence, cause, and any mitigating factors.

Materials and Methods

In 1984, 300 trees under power lines in Yonkers, White Plains, and New Castle, in southeastern New York were selected for Atrinal injection. Trees with excessive dead wood, wounds, insect damage, or girdling roots were excluded. The trees selected included plane tree (*Platanus acerifolia*), red maple (*Acer rubrum*), and Norway maple (*Acer platanoides*). Trees were randomly chosen for treatment with Atrinal and as controls in a ratio of approximately 3:1, respectively (227 treated, 73 untreated).

All trees were pruned in the spring of 1984 prior to injection with Atrinal. Trimming was performed by crews in accordance with utility specifications.

Before each tree was injected, the following data were collected: house number (for future tree identification); species; diameter at breast height (dbh); general condition (previous growth, dead wood); girdling or exposed roots; wounding; date of trimming; percentage of crown removed during trimming; and area of crown trimmed. During Atrinal treatment, information on soil conditions (soluble salts, pH, moisture) and additional growth data were collected.

Atrinal was injected according to the procedure developed by the USDA-ARS (2). Holes (7/32 inches diameter, 1.5 inches deep) were drilled in the tree approximately 3 feet above the ground. Trees greater than 16 inches dbh received 6 treatment holes; trees less than 16 inches dbh received 3 treatment holes.

The Atrinal formulation containing 18.5% active ingredient was diluted with water (100 ml of Atrinal per liter of water). The volume of diluted Atrinal to be applied was determined by one of two formulas:

Application volume (ml) (trees less than 16 inches dbh) = $(\text{dbh})^2 \times 1.59$

Application volume (ml) (trees more than 16 inches dbh) = $\text{dbh} \times 25.45$

The Atrinal was injected equally into the drilled holes. Injections occurred May 16 to June 15, 1984 when most leaves were half expanded.

Many trees were rejected during the study because of heavy aphid infestation, homeowner objection to Atrinal treatment, tree trimming, live electric wire position that would make data collection hazardous, and damage to roots due to new sidewalk installations.

The foliage of all trees was visually rated on a scale: 0-4, four times during the summer and early fall of 1984, 1985, and 1986. A rating of 0 indicated excellent health and no phytotoxicity; rating of 4 indicated extreme phytotoxicity, the tree being fully defoliated.

A trunk canker rating scale was utilized to evaluate the degree of injury at the injection sites. A rating of 0 indicated very little or no apparent canker; injection wounds, if any, completely healed with no abnormal enlargement. A 1 rating indicated trunk cankers less than 1" above and below the injection points. A 2 rating indicated trunk cankers 1" to 1.5" above and below injection points. A 3 rating indicated trunk cankers greater than 1.5" above and below injection points. And a 4 rating the same as 3, but with unhealed wounds. Figure 1 depicts an example of a trunk canker which was rated as a 4 on this scale.

Samples of wood and bark from trunk cankers and areas free of perceived cankers were excised aseptically with alcohol-flamed chisels. The samples were placed in petri dishes with moistened filter paper to promote sporulation from fruiting bodies in the samples. Fungal isolates were plated on potato dextrose agar, incubated for several days, and identified to determine if a single fungus could be consistently isolated in association with the trunk cankers.

Using the results of an F test, statistical significance was determined by calculation of either uncorrected or corrected (based on a t-distribution) confidence intervals. Comparisons were assessed at the 95% confidence level.

Results and Discussion

Phytotoxicity. The phytotoxic effects of Atrinal were most visible on plane tree leaves, where wilting, curling, increased pubescence, and marginal necrosis appeared (Table 1). Norway maple also exhibited a temporary phytotoxic reaction on younger trees. Red maples were variable in their phytotoxic reaction. These conditions improved with time, as did the appearance of all trees injected with Atrinal (Table 1). The phytotoxic response of other tree species to Atrinal applications has been described (1, 10).

Our results indicate that the phytotoxic effects of Atrinal are temporary; the difference in phytotoxicity between treated and control trees improved for plane tree and red maple comparing 1984 through 1986 (Table 1). Treated Norway maples actually looked better than controls in 1985 although the differences were not significant. Plane tree was the most sensitive to Atrinal, followed by red maple and Norway maple, which was injured the least. By 1985, phytotoxicity rating of treated planes was rated only 7% less than that of control trees, indicating a slight residual phytotoxic response 2 years after injection. Treated red and Norway maples had phytotoxicity ratings within 1% of their respective controls in 1985 and 1986. The concentration of Atrinal remaining within a tree two years after injection, if any, is apparently slightly above the threshold for phytotoxicity in plane tree, but well below the threshold for red and Norway maple.

Trunk canker. Both red and Norway maples exhibited trunk canker at injection points for three years after application: 75% of all red maples had

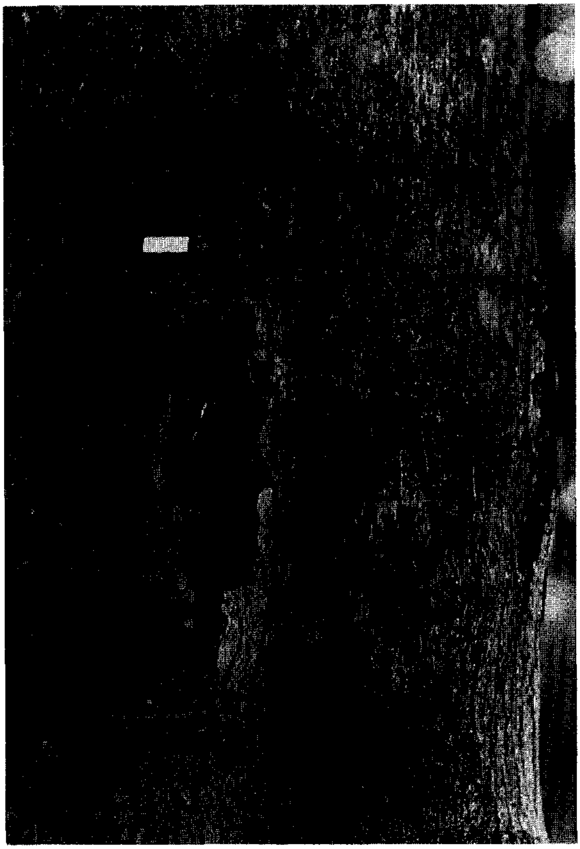

Figure 1. Photo of trunk canker on Norway maple. Bar equals 1 cm. Tree diameter approximately 6 inches.

some trunk canker (rating greater than 0); 35% of all red maples had considerable trunk canker (rating greater than 2). In contrast, 46% of all Norway exhibited some trunk canker, and 6% of all Norway maples exhibited considerable trunk canker. Red maple was more sensitive to Atrinal induced trunk canker than Norway maple (Table 2).

A *Fusarium* was the only fungus isolated consistently from the trunk canker wound area and it could have been an endemic saprophyte. The fungus also was isolated from wood and bark samples taken from uninfected areas of both untreated and treated trees. Similiar wounds in untreated trees failed to produce canker lesions. Although these observations suggest that the cankers are not caused by a biotic component, they do not preclude the existence of one.

When comparing trunk canker in Atrinal injected trees with tree diameter, it appears that Norway maples, 5" to 6.2" dbh, and red maples, 18.9" to 22" dbh were injured the most (Table 3). The influence of size on Atrinal-induced trunk canker is difficult to interpret as there were no Norway maples included in the study greater than 15.4" and no red maples less than 9" in diameter, hence there is little overlap. The lack of an overall trend of trunk canker versus size groups of either species suggests that size is not a major factor in determining occurrence of trunk canker.

The percentage of crown removed markedly affected the amount of trunk canker (Table 4). As the percentage of crown removal increased, the occurrence and severity of Atrinal-induced trunk canker also increased. Red and Norway maples with more than 25% of their crown removed exhibited the most injury, quantitatively and qualitatively.

The loss of foliage reduces the uptake potential of the tree, hence a greater concentration of Atrinal remaining at the injection site might injure the cambium. Although a single injection probably would have minimal long-term effects, repeated applications could result in tree mortality. Additionally, it is apparent that certain species are more sensitive to trunk canker than others; e.g., red maple versus Norway maple. This may be due to differences among species in the relative uptake of a chemical such as Atrinal and should also

Table 1. Average phytotoxicity ratings based on foliar appearance of treated and untreated trees.[1]

Species	*1984*	*1985*	*1986*
Plane			
treated	1.4*	1.0	0.1
untreated	0.9	0.7	0.0
Red maple			
treated	1.0	0.8	0.7
untreated	0.7	0.7	0.8
Norway maple			
treated	0.4	0.2	0.2
untreated	0.3	0.2	0.1

[1]Ratings based on June inspections of foliage (0 = no phytotoxicity).
* = significantly different from control (95% confidence level), standard errors approximately 0.1 for each group.

Table 2. The percent occurrence of trunk canker by severity in Atrinal-treated trees. Degree of severity is based on ratings defined in Methods and Materials.

n[1]	*treated*	*Severity*			
		1	*2*	*►2*	*total*
Plane tree					
13	yes	0	7	0	7
4	no	0	0	0	0
Red maple					
45	yes	24	16	35	75
18	no	11	0	5	16
Norway maple					
138	yes	29	11	6	46
49	no	4	6	0	10

[1]sample size.

Table 3. The percent occurrence of trunk canker in treated red and Norway maples for different size classes of trees. Degree of severity is based on ratings defined in Methods and Materials.

DBH[1]	*Severity*			
(inches)	*1*	*2*	*►2*	*total*
Red maple				
9-13	44	22	22	88
13-16	22	11	33	66
16-19	22	22	11	55
19-23	3	1	4	8
Norway maple				
3-3.5	26	20	20	66
3.5-5	31	19	18	68
5-6	40	40	13	93
6-16	40	13	6	53

[1]each size range represents a quartile grouping for each species.

Table 4. The effect of percentage of crown removed on the occurrence of trunk canker in treated red and Norway maples. Average trunk canker rating based on ratings defined in Methods and Materials.

Species	*Percentage of crown removed during trimming*				
	5	*10*	*20*	*30*	►*30*
Red maple	1.5	1.36	1.77	2.83	---
Norway maple	0.36	0.32	0.6	1.13	1.29

be factored into calculations of the amount of chemical applied.

The influence of crown removal on chemical effectiveness needs further investigation. Formulas for determining concentrations of a chemical to be applied in similar situations should include the influence of crown size, crown removal, and species. Timing of application may also be critical with respect to uptake of the chemical, so that injury to the cambial tissue is less likely to occur.

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