INTERNAL WOUNDING ASSOCIATED WITH ATRINAL INJECTIONS IN NORWAY MAPLE

by Daniel C. Wright and John T. Moran[1]

Abstract. Ten Norway maple trees were examined to determine the internal injury (discolored wood) associated with trunk cankers induced by Atrinal injection. The trees were part of a study involving 225 trees injected with Atrinal in the Spring of 1984, in Westchester, New York. The amount of discolored wood associated with injection wounds varied from 7 to 38% at the injection site and up to 44% further away. The average volume of discolored wood at the injection site (10 inches above and below the injection point) was approximately 20%. The average volume of compartmentalization could be correlated with the size of external cankers. The pattern of internal compartmentalization was related to the size of the external canker. Internal decay begins after compartmentalized areas of trees are breached by a second wound. Current trunk injection practice involves trangential injections which greatly increase the probability of breaching existing compartmentalized areas. Actual wood decay was apparent in one tree of the ten examined. The results of this study demonstrate that injection of Atrinal or other growth regulators may cause extensive internal injury to trees.

Résumé. Dix érables de Norvège furent examinés afin de déterminer les dommages internes (bois décoloré) associés aux chancres sur le tronc causés par les injections d'atrinal. Ces arbres faisaient partie d'un étude portant sur 225 arbres injectés à l'atrinal au printemps 1984, à Westchester, New York. La quantité de bois décoloré associée aux blessures causées lors de l'injection variait de 7 à 38% au site d'injection et jusqu'à 44% plus à l'intérieur. Le volume moyen de bois décoloré au site d'injection (10 pouces au-dessus et en-dessous du point d'injection) fut approximativement de 20%. Le volume moyen de bois compartimenté pourrait être corrélé à la grosseur des chancres externes. Le patron interne du compartimentage ne fut pas relié à la grosseur des chancres externes. La carie interne débute après que les zones compartimentées sont brisées par une seconde blessure. Les pratiques courantes d'injection impliquent des injections tangentielles qui augmentent considérablement les probabilités de briser des zones compartimentées. La carie fut remarquée sur un arbre parmi les dix examinés. Les résultats de cette étude démontrent que l'injection d'atrinal ou d'autres régulateurs de croissance peut causer d'importants dommages internes aux arbres.

During the course of determining the effectiveness of trunk injected Atrinal on street trees of Westchester County, it was discovered that trunk cankering was an adverse side effect (11,12). Trunk cankers were apparent on many of these Atrinal injected trees, particularly smaller diameter trees. Trunk canker severity ranged from inconspicuous raised areas of bark to open lesions in which cambium dieback had occurred. The objective of this investigation was to determine the degree of internal injury caused by Atrinal injection and its correlation with trunk cankering.

Methods and Materials

Ten trees, that were injected with Atrinal 3 years previously, were cut down and sectioned to determine internal injury. All test trees were Norway maples (*Acer platanoides*), that ranged from 4.3 to 7 inches in diameter, that had been trimmed 10 to 50% (estimated), and injected 3 years previously. Trimming preceded injection.

Trunk sections approximately 24 inches above and below injection points were removed using a chainsaw. Each trunk section was further cut into 0.5 to 6 inch slices using a band saw. Narrow slices (0.5 inches) were made near injection points. Wider slices (2 to 6 inch) were made elsewhere.

Each trunk cross section was photographed and photocopied to determine the amount of discolored wood present. Discolored wood area was determined by cutting out and weighing photocopied images of affected and unaffected wood. Four replications of this technique were averaged together to determine a value for the area of discolored wood on a trunk section surface. Volume of discolored wood was estimated by multiplying the resulting area values by the average distance between corresponding cuts (area of discoloration upper surface + area of discoloration lower surface x height of cross section divided by 2). The percentage of discolored wood within 10 inches of the injection points was used for comparison purposes.

Linear regression analysis was used to establish a correlation between trunk canker size and percentage of wood discoloration. Performing other statistical analyses on these data is unwar-

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ranted due to the small number of observations. Observation of a "trend" over a particular set of the data, does not imply a true correlation.

Results

A summary of the data collected for each tree is given in Table 1. Not all injections within a given tree were made at the same height. For reference purposes, a median injection point, the effective mean of the actual injection points, was calculated by averaging the height of individual injections for each tree.

The average canker size was proportional to the amount of discolored wood (Figure 1). A regression analysis of the data predicts a fairly good fit (0.89) for a linear relation between canker size and discolored wood. The linear regression equation could be used to predict the probable amount of discolored wood present to within 5.5% (standard deviation =5.5%). However, this correlation is limited to estimating the amount of discolored wood present in Norway maples of less than 7 inch diameter growing in Westchester, New York. Also, the apparent correlation could not be used to predict the pattern of discoloration or the *amount of actual internal decay.*

The area of discoloration in small trees (less than 7 inches diameter) was proportional to the estimate amount of crown which was removed during trimming (Figure 2). This trend would support the notion of earlier reports that reduced translocation of Atrinal due to trimming might be detrimental, resulting in trunk cankering (11,12). The value at 50% crown removed represents the only anomaly in this set of data with reference to the observed trend. A much larger sampling is necessary to statistically prove the trend to be true.

For trees 4.3 to 7 inches diameter, tree size seems to be inversely proportional to the area of discoloration (Figure 3). This is expected, because, theoretically, the area of a tree section is proportional to the square of its diameter while area of wounding is linearly proportional. Statistical proof of this trend would require a larger sample. The trend depicted is not conclusive.

The area of discoloration underestimates the actual effective area of compartmentalization. The

Table 1. Summary of internal compartmentalization data.

Tree #	Affected[1] volume	Diameter[2] (in)	Trim %[2]	Canker[3] size	Decay
1	11.27%	3.7	30	0.70	no
2	5.45%	6.5	25	0.60	no
3	23.00%	3.4	50	1.50	no
7	28.04%	3.4	40	2.54	no
5	21.15%	5.2	30	1.80	no
6	20.09%	5.5	30	1.88	no
4	10.82%	3,8	25	0.51	no
8	35.37%	3.4	40	3.19	no
9	16.86%	3.4	30	1.02	no
10	30.74%	4.3	30	2.09	yes
average =	20.28%	4.3	33	1.58	
S.D. =	8.99%	1.0	7	0.85	
S.E. =	3.00%	0.3	2	0.28	

1 - Affected volume equals percentage of discolored wood within 10 inches of injection point.
2 Diameter and trim % data estimated at time of injection (11,12)
3 Average canker size present on tree. Canker size was determined by multiplying length and width measurements (inches) of each canker and dividing by 2 since the cankers are roughly deltoid in appearance.

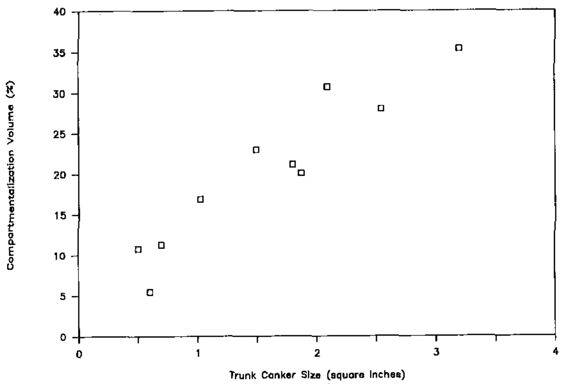

Figure 1. The correlation of canker size with amount of discolored wood.

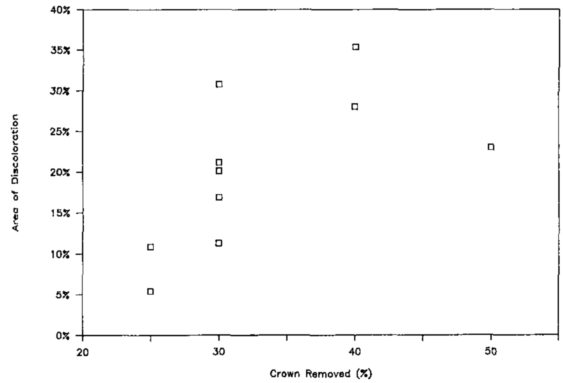

Figure 2. The area of discoloration compared to the amount of crown which was removed during trimming.

effective area of compartmentalization includes wood underlying discolored wood. As a extreme example, suppose a tree (12 inch diameter) had a continuous band of discolored wood, compartmentalized wood, one inch below its bark. Although, the innermost wood of the theoretical tree is not discolored, the effective compartmentalization of the tree is near 100%. The minimum effective compartmentalization of a tree due to injection wounds that ring a tree is dependent on the angle of injection (Figure 4). The greater the angle of injection the greater the effective area of compartmentalization.

Further, the estimates do not take into consideration the extent of affected wood in either direction from the injection point. The height of compartmentalization for Atrinal treated Norway maple seems similar to that created by tap wounds in sugar maple (8). Shigo and Sharron (8) determined that the height of discoloration due to tap wounds ranged from 12 to 32 inches above the wound and 10 to 28 inches below the wound. The minimum amount of discoloration associated with Atrinal injections was 10 inches above or below the injection point and exceeded 20 inches in most cases. Genotype differences may account for the variability in results obtained (9).

Discussion

The results and trends observed in this investigation by themselves can not be used to prove or disprove that Atrinal injection caused greater than expected internal damage to trees. However, the investigation has revealed that trunk injection does cause compartmentalization within a tree. The importance of this compartmentalization should be reviewed in light of our current understanding of how trees withstand decay (1,2,7,10).

Wood discolors due to the oxidation of various phenolic substances which are produced from existing stores of carbohydrates and other chemicals present within the compartmentalized areas (8). These phenolic substances act as deterrents to the growth of wood rotting fungi, and can effectively exclude their growth until callus tissue and new wood heals over the external wound. Unfortunately, these same phenolic substances are not as effective against the growth of other endemic species of fungi and bacteria. The internal growth of these organisms is slow within the compartmentalized area but due to the action of their metabolism, the nature of the phenolic substances is altered. Although not considered wood rotting organisms themselves, these pioneers set the stage for later infection by true wood rotting fungi (8).

There is good evidence that wood decay occurs when trees fail to heal over wounds or compartmentalized areas are rewounded. Shigo (5) found that *Fomes connatus* and *F. ingiarius,* two wood rotting fungi, were unable to infect freshly wounded tissues of *Acer rubrum* yet were able to infect discolored wood. These fungi could not even be reisolated after being inoculated in fresh wounds.

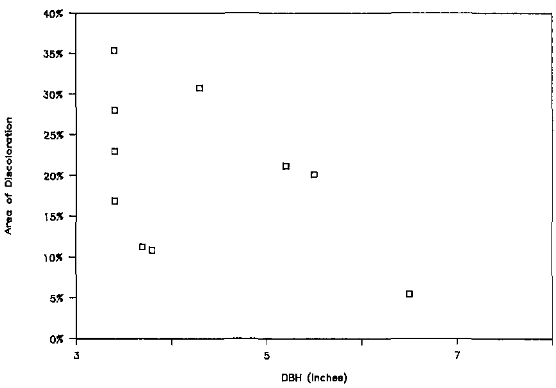

Figure 3. The area of discoloration compared to tree size.

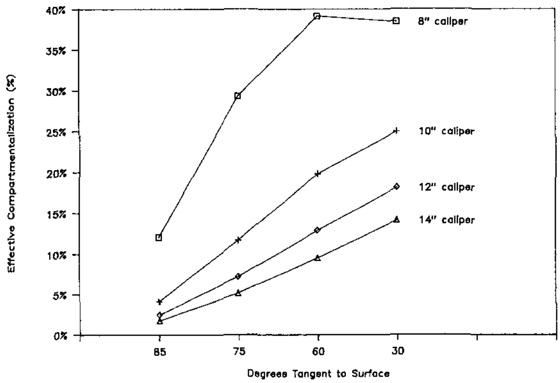

Figure 4. Minimum expected area of compartmentalization due to injection type wounds (three injection wounds spaced equidistantly apart and drilled tangentially with respect to the trunk surface).

Shigo and Sharron (8) demonstrated that *F. igniarius* could not grow on heat killed, sterile, clear wood in bottles, but could on blocks of discolored and slightly decayed wood. Santamour (4) found that in a study involving 150 red maples that had been chisel wounded, wood decay had dramatically increased in trees whose compartmentalized areas had been breached with an increment borer.

Injection of systemic chemicals is becoming a popular alternative to spraying such chemicals on trees. The presumed advantages are; less chemical needs to be applied, and little if any of the chemical affects non-target plants and animals. The wounding caused by drilling an injection hole seems to be considered a minor concern. One could argue that pruning wounds or the wounds caused by tapping a tree for maple syrup production do not seem to cause detrimental effects to the tree so why should injection wounds. The fallacy of this logic is that pruning wounds, tap wounds and injection wounds differ from each other substantially.

When pruning wounds are created, the entire portion of the tree above the wound is removed. The likelihood of rewounding the compartmentalized area below the wound is slight since further pruning of the tree at that location would usually involve new unwounded tissue, suckers and lateral branches.

Tap wounds, although made in the general area of injection wounds, affect less than 1% of the circumference of a tree. The number of taps drilled into a sugar maple is one for trees less than 16 inches diameter. An additional tap is considered for trees greater than 16 inches diameter. Consequently, the likelihood of rewounding an old tap wound is negligible.

Injection wounds differ considerably depending upon the chemical injected and its purpose. The injection of growth regulators usually requires several holes to be drilled to a depth of approximately 3 inches. Standard practice is to drill the injection hole on an angle versus straight towards the center of the tree. This has been recommended in order to intersect as much active xylem as possible to insure uniform uptake and distribution of growth regulators to the crown (3). However, the recommendation does not detail whether the angle of injection should be made in a clockwise or a counter-clockwise fashion. This might seem at first to be a superfluous point until future injections of the same tree are considered. If previous injections have not been uniformally made then the likelihood of rewounding the compartmentalized areas with subsequent injections increases dramatically.

The likelihood of rewounding the compartmentalized area increases exponentially as the angle of injection increases (Figure 5). This assumes three inch holes, 3/16 inches in diameter, with the number of holes drilled dependent upon the size of the tree. As the size of a tree increases, the probability of rewounding a compartmentalized area decreases. If all injection holes were drilled straight, radially, toward the center of a tree the probability of intersecting a previous radially drilled injection hole would be less than 5% for trees greater than 4 inches diameter.

Conclusions

Although it was possible to demonstrate that the degree of trunk cankering was proportional to internal discoloration, it proved impossible to predict the pattern of compartmentalization and internal decay. The pattern of compartmentalization will affect its probability of being breached in the future by a similiar wound. Internal decay can not be predicated on the basis of an external trunk canker.

Multiple tangential injections will predispose a

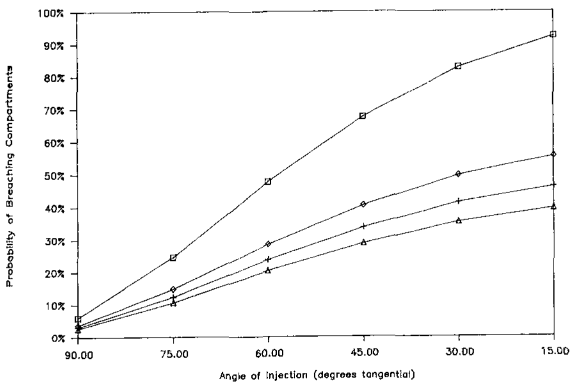

Figure 5. Probability of intersecting a previous injection wound given various angles of injection and size of trees (□-12" diameter, + - 20"diameter, ◊-27" diameter, Δ-35" diameter).

tree to internal decay. The probability of breaching a compartmentalized area of previously wounded tree increases dramatically as the angle of injection increases.

Trunk injection of any growth regulator that requires multiple injection holes should be discontinued. If the internal compartmentalization pattern can not be determined from external manifestations, and injection wounding has a high probability of breaching a compartmentalization wall, it would be foolhardy to make several such wounds in a tree. Development of application methods which cause less internal injury are needed if trunk injection is to be used in the future.

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Abstracts

DAVIDSON, J.A. and C.F. CORNELL. 1988. **IPM: parts and parcel.** Am. Nurseryman 167(8): 81-91.

Integrated pest management, part of the modern approach to producing and maintaining plants, addresses the following basic questions about pest control: Is a pest present? What type of pest is it? Where is the pest population located? Should you control the pest? What pest control method should you use? When should you apply the pest control? Was the pest control effective? IPM tries to answer these questions through an interdisciplinary approach that relies on monitoring plants frequently, integrating various pest control methods and evaluating the results.

DOUGHTY, S.C. 1988. **The basics of tree fertilization.** Am. Nurseryman 167(7): 67-72, 74, 76-77.

Tree fertilization encourages rapid root and shoot development and promotes general health and vitality. Newly planted trees benefit from yearly applications of fertilizer. Older trees do not need as much; one application every two to three years may be enough. To devise an efficient, cost-effective fertilization program, you must evaluate the following factors: The tree's need for fertilization. The amount and type of fertilizer to apply. The timing of fertilization. The fertilization method.