EFFECT OF ENVIRONMENT, TREE SIZE AND PRESENCE OF WETWOOD SYMPTOMS ON INJECTABILITY OF AMERICAN ELM[1]

by Robert W. Stack

Abstract. During 1981 and 1982, 134 large elm trees growing on a college campus in Fargo, ND were injected with Arbotect for protection against Dutch Elm Disease. Chemical was applied at the "Minnesota 3X" rate using standard Elm Research Institute injection apparatus. Records were kept for tree size, condition, and wetwood symptoms and for amount of chemical applied and time required for uptake. Weather records were also compared. Findings for both years were similar. Time per tree for a full dose was nearly constant for trees of all sizes (25 cm to 95 cm diam). Individual trees were quite variable, the extreme cases differing six-fold. Injections on cool, cloudy or rainy days took longest and those on warm sunny days took least time. Presence of wetwood symptoms on the tree did not correlate with injectability.

Résumé. En 1981 et 1982, 134 gros ormes situés sur le campus universitaire de Fargo, ND, furent injectés avec de l'Arbortect pour les protéger contre la maladie hollandaise de l'orme. Le produit chimique fut appliqué au taux "Minnesota 3X", une norme de l'Institut de recherches sur l'orme. Des données furent prises sur la grosseur de l'arbre, sa condition de santé, les symptômes de maladie (coeur mouillé), les doses d'injection et les temps d'absorption. Les conditions météorologiques furent aussi décrites. Les résultats pour les deux années furent similaires. Le temps d'absorption d'une dose complète fut pratiquement constant pour les arbres de toute grosseur (25 à 95 cm de diamètre). Les arbres individuels réagirent assez différemment, les valeurs extrêmes différant de 6 fois quant au temps d'absorption. Les injections lors de journées fraîches, nuageuses ou pluvieuses présentaient un temps d'absorption plus élevé tandis que celles lors de journées chaudes ensoleillées prenaient le moins de temps. La présence de symptômes du coeur mouillé sur un arbre n'était pas corrélée à l'injection.

Like many other college campuses, that of North Dakota State University in Fargo, ND was planted with numerous American elms, many dating from the founding of the college in 1889. Unlike other regions of the US, North Dakota was not originally forested except along rivers and only a few native tree species occur. In addition, the harsh continental climate of the northern Great Plains severely limits the non-native tree species available. Part of the mood of a college campus comes from the open spaces planted with large old trees; creation of this environment requires use of large, long-lived tree species. Of the tree species native to or reliably hardy on the Northern Plains, American elm best fills the bill. Loss of this tree will have a permanent impact on the ability of campus planners to maintain or recreate the campus atmosphere.

Dutch elm disease (DED) has destroyed the trees on many college campuses, altering not just their appearance but their atmosphere or mood, a factor sometimes unrecognized until lost. During the 1970's considerable developmental work was done to produce an injectable systemic fungicide to combat DED (2, 4). From those early studies it became clear that annual injections would cause unacceptable damage to the trees, despite their efficacy in controlling DED. More recently, studies were done at the University of Minnesota to test the feasibility of applying enough chemical to last for more than one year (7). The most successful material for this type of application was Arbotect (thiabendazole hypophosphite or TBZ-P) at a dosage sufficient for three years, which has come to be known as the "Minnesota 3X" rate (6). A more recent study has confirmed effectiveness at this rate (3).

Dutch elm disease has been present in Fargo, ND since 1973 but until the early 1980's few trees were lost because of a strong, well-funded city forestry program. The campus of North Dakota State University, with ca 200 large elms lies within the city and has benefited from the municipal program since the campus is bounded on two sides by residential areas with many boulevard elms.

Methods

In 1981, following the first major outbreak of DED on the campus of North Dakota State Univ., a

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campaign of prophylactic injection was decided upon, the aim of which was to treat all the major elm trees on the main campus. To minimize injury to the trees and allow an orderly distribution of the work, the then-still-experimental "Minnesota 3X" rate of Arbotect was selected with one-third of the trees to be treated each year.

Of the American elms located within the campus DED control zone, 54 trees were injected in 1981 and 86 in 1982, the years represented in this report. Trees ranged in size from 25 to 95 cm dbh and in age (in 1981) from 25 to 90+ years. Trees were located both along boulevards and in open lawn areas.

Injections were done using standard procedures (6). Injectors were the Elm Research Institute (ERI) low pressure system with 55 L fiberglass tanks, vinyl tubing and plastic tees (4). Holes 8.8 mm (5/16 in) diam were drilled with a twist bit in an electric drill at ca 15 cm spacing around the root flare or collar of the trees (a few trees in 1981 had some holes on the lower stem). Concentration of Arbotect solution was 3.0 g a.i./liter and the amount of chemical solution used, based on the tree size, and was 3.0 g a.i./liter / 1.86 cm diam. (=12 oz/5 inch diam.) (7).

Records were available for 51 of the 54 trees treated in 1981 and for 83 of the 86 trees treated in 1982. Data included size, site, condition, amount of chemical applied, time treatment was started, time required for treatment, phytotoxicity, and evidence of wetwood symptoms on the tree. Data were incomplete for a few trees. National weather service records for Fargo were examined for the period. Because of the proximity of the treatment site to a principal weather station, records of temperature, sky cover, precipitation and wind were available for 3 hr intervals for all days when injections were done. Injection time was compared to these weather variables.

Injections were done in mid-June through mid-July 1981 and in July 1982. Rainfall during these periods was near normal in both years. Temperatures were slightly below normal in June 1982 but near normal in July of both years. Trees injected in 1981 were re-examined in 1983 to determine extent of healing of injection wounds; those results are presented elsewhere (5).

For convenience I shall use the term "injectability" to mean how readily a tree takes up chemical solution, without regard to whether the source of variability in that measure is inherent in the tree itself or conditioned by environmental factors. Injectability in this discussion is inversely proportional to the time a tree requires to accept a full dose of solution.

In a controlled experiment one selects trees of certain sizes, as nearly uniform as possible (3, 7). Within each size class, the volume applied would be the same for each tree and differences in rate of uptake could be expressed as volume per hour. In the present case, the treatments were not part of a designed experiment but observations made during actual field work. Trees varied in size and the amount of chemical solution applied to each tree was calculated from its diameter, so a measure of uptake such as volume per hr is clearly biased. Correcting this rate for tree size, however, allows separation of the dosage calculation from other factors. Two dosage-independent measures were used in the analyses which follow. Rate of uptake is expressed as liters per hour per centimeter of diameter (l/hr/cm) and time per tree. Since most applicators are concerned with how long a particular job will take, the time per tree statistic is probably the more useful.

Results

Injection time per tree averaged 3.2 hr in 1981 and 2.8 hr in 1982. Times were more variable across size classes in 1981 than in 1982. There was no relationship between tree size (dbh) and time required for the tree to accept a full dosage of solution nor between size and rate of uptake in either year (Table 1A, 1B). Within size classes the range of injection time was great, from 1 hr to 9 hr in 1981 and from 1.5 hr to 7 hr in 1982.

The weather factor that showed the greatest association with injection time was air temperature. At temperatures below 18°C trees took an average of 3.7 hr to inject. That time decreased as air temperature rose and above 28°C it was 2 hr or less (Table 2). This relationship was observed in both years. When considered as an independent factor, sky cover (SC) was also related to injection time. Time was shortest under clear skies (SC = O) and longest under complete overcast (SC = 1.0) (Table 3).

There was no effect of time of day on injectability. Trees injected in the morning required the same time as from those treated in the afternoon (Data not shown). No injections were done in evenings. Trees that took all or almost all day were not counted in the morning/afternoon determination. While injection time on rainy days was longer, there was no correlation with amount of precipitation during that day or with total precipitation during the preceeding 24-48 hr or during the previous 7 or 30 days.

Other factors considered in relation to injection time included presence of wetwood symptoms on the trees and occurrence of phytotoxicity symptoms following injection. No consistent relationship between wetwood symptoms and injection time was seen in either year (Table 4). In contrast, there was a relationship between injection time and subsequent appearance of phytotoxicity symptoms. The average injection time for trees subsequently showing severe phytotoxic reactions was greater than that for trees subsequently showing few or no symptoms (Table 5). Development of subsequent phytotoxic symptoms was not related to weather factors at time of treatment. Phytotoxic symptoms were not related to tree size.

Table 1a. Effect of tree diameter on injectability of mature American elm trees in 1981.

Size class (dbh cm)	Number of trees	Chemical uptake	
		Time (hr)	*Rate l/hr/cm)*
<50	15	3.4 (1-8.)*	0.35
50-62	13	3.5 (2-9)	0.30
63-75	12	2.4 (1.5-4)	0.39
>75	11	3.3 (1.5-9)	0.45
Total	51		
Mean		3.2	0.37

*Mean (range)

Table 1b. Effect of tree diameter on injectability of mature American elm trees in 1982.

Size class (dbh cm)	Number of trees	Chemical uptake	
		Time (hr)	*Rate l/hr/cm)*
<50	30	2.8 (1.5-7)*	0.81
50-62	26	3.0 (1.5-7)	0.67
63-75	22	2.8 (1.5-6.5)	0.74
>75	5	2.8 (2-3.5)	0.72
Total	83		
Mean		2.8	0.75

*Mean (range)

When rate of wound healing after 2 yr was compared with time required for injection, a significant relationship was found. Trees which had mostly (>75%) healed had required an average injection time of 2.4 hr while trees which healed more slowly (≤70% closed) had required an average of 3.7 hr to inject. Because healing was found to be strongly related to tree size (5), most of the smaller (<50 cm) trees fell into the well-healed class. To make the distribution of tree size in the mostly healed and less well healed classes similar, the trees smaller than 50 cm were excluded for a second analysis. After this adjustment for interaction of size and healing, the difference in times between the two healing classes was even more dramatic—fast healing trees larger than 50 cm diam had required only 1.8 hr to inject while slow healers had needed 3.5 hr (Table 6).

Of the 135 trees, nine required more than twice the average time for injection. Of those nine, six were injected on cloudy, cool or rainy days. Seven other trees injected on the same cool, cloudy days had an average injection time of 3.6 hr, longer than the 3.0 overall average but much less than the 7.2 hr average of the "long time" group. Weather alone probably is not responsible for extremely long injection times, but no other obvious factor was observed. Of the other 3 "long time" trees, two had suffered severe crown reduction through pruning and one was later found to have had thermal root damage.

Discussion

In a review of factors affecting injection of elms, Kondo (2) surmised a strong relationship between factors affecting transpiration and uptake of injected chemicals. He cited work indicating best uptake on warm, sunny days, Our results agree. It might have been expected that injections during mornings or afternoons would have been faster but that was not the case here. While wind affects transpiration, and probably injectability, there were so few calm days during this study that no comparisons could be made.

Table 2. Effect of air temperature on injectability of mature elm trees.

	Air temperature (C)					
	18	*19-21*	*22-24*	*25-27*	*28-30*	*31*
	Mean time per tree					
1981						
Time (hr)	4.4	3.0	3.0	3.1	2.1	1.4
No. of trees	3	10	14	8	6	7
1982						
Time (hr)	3.0	3.1	2.8	2.5	1.9	2.1
No. of trees	3	11	22	32	9	6
Two-year average						
Time (hr)	3.7	3.1	2.9	2.8	2.0	1.8

Table 3. Effect of sky cover on injectability of mature elm trees.

	Sky cover			
	Clear 0	*Partly .1-.2*	*cloudy .4-.7*	*Cloudy .9-1.0*
	Mean time per tree			
1981				
Time (hr)	2.5	3.8	3.5	3.8
No. of trees	14	10	4	14
1982				
Time (hr)	2.3	2.5	2.3	3.6
No. of trees	9	12	45	17
Two-year average				
Time (hr)	2.4	3.1	2.9	3.7

Table 4. Effect of wetwood symptoms on injectability of elm trees.

	Time per tree			
Wetwood	*None/trace*	*Slight*	*Moderate*	*Severe*
1981				
Time (hr)	3.3	2.9	2.7	3.3
No. of trees	21	13	11	6
1982				
Time (hr)	2.7	2.5	2.2	2.8
No. of trees	57	12	4	1

Table 5. Injection times of mature elm trees in relation to subsequent phytotoxicity.

Symptoms	*Trace*	*Slight*	*Moderate*	*Severe*
1981				
Time (hr)	2.6	3.4	3.7	6.5
1982				
Time (hr)	2.6	4.6	--*	--*

*No trees in this category.

Table 6. Injection times of mature elm trees which later healed injection holes rapidly or slowly.

	Degree of healing after 22 months	
1981	*High (>75%)*	*Low (<70%)*
All trees		
Number	27	19
Time (hr)	2.4	3.7
Trees 51 cm		
Number	16	18
Time (hr)	1.8	3.5

Stack (5) previously reported that presence of wetwood symptoms on trees did not indicate whether the subsequent healing of injection holes would be rapid or slow. The results presented here show that external wetwood symptoms are not a reliable indicator of injectability. While trees which have excessively long injection times did not always show subsequent phytotoxicity or slower healing, those phenomena did occur more often in such trees.

Lanier (3) argued that dosages of injected fungicides should not be based strictly on diameter but he based this on trees much smaller than would ordinarily be considered for commercial treatment. None of the trees in this study was of such a small size as to make dosage adjustments necessary. The smaller trees in this study did not show more phytotoxic symptoms than the larger trees.

The tree injection program at NDSU has continued until the present with the trees injected in 1981 being retreated in 1984 and 1987 and the 1982 trees in 1985. There have been no apparent ill effects of injection on the trees, which are in good condition. Indeed, treated trees appear to have greener and more luxuriant growth in the year following treatment. Several of the trees originally part of this study have been removed for street construction and two were lost to storm damage but no losses have been associated with injection wounding and no cankering has been observed, unlike the experience of Campana et al.(1).

It is not possible to establish causal relationships using correlative observations. Nonetheless, such correlations may provide useful clues to actual processes and may also provide an empirical guide for practitioners.

Businessmen may be more used to making decisions using such empirical information than are scientists and it is with a view to giving practitioners some useful tools rather than to demonstrate biological principles that this paper is offered.

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Abstract

GLENISTER, C.S. 1987. **The story of a successful biological control.** Am. Nurseryman 165(8): 102-109.

A bacterium can be used to prevent crown gall on nursery stock. The control system is so unique that, even today, strain K84 remains the only beneficial bacterium that has ever been commercially produced for plant disease control. In the US, use of strain K84 has concentrated on prevention of galling on stone fruits and cane berries as well as euonymus, clematis and other ornamentals. The results have been especially impressive because strain K84 has often been highly successful where conventional control measures have failed. The crucial pathogen transfer process from gall bacteria to wound holds the key to the effectiveness of strain K84. The beneficial bacteria prevent crown gall on many species of plants by inhibiting the attachment of the crown gall bacteria to the wounded plant cells. Unfortunately, scientists have not yet found any bacteria or fungi that can satisfactorily control the strains of crown gall bacteria that attack grape and apple and are resistant to agrocin 84.