DUTCH ELM DISEASE CONTROL: ECONOMICS OF GIRDLING DISEASED ELMS TO IMPROVE SANITATION PERFORMANCE

by William N. Cannon, Jr., Jack H. Barger and David P. Worley

Abstract. Early detection and immediate girdling plus prompt removal (within 20 work days) of diseased elms saved more elms at a lower cost than sanitation practices in which diseased elms were just removed promptly or were allowed to remain standing into the dormant season. A 5-year case history demonstrated savings of 25 percent in total cost and an additional 163 elms per thousand.

Research to improve community Dutch elm disease control programs has shown that an intensive sanitation program results in fewer elms lost to the disease than a sanitation program in which diseased elms are left standing into the dormant season (Barger 1977). Intensive sanitation is a program of frequent surveys (at least three during the growing season) of the elm population with each survey followed by prompt removal of diseased elms within 20 work days after symptoms are observed. A 3-year case history of such a sanitation program demonstrated a substantial improvement in control: a saving of 92 more elms per thousand while costing 25 percent less (Cannon, Barger, and Worley 1977).

Removal of diseased elms, directly after expert diagnosis, controls Dutch elm disease by disrupting root-graft transmission of the fungus *Ceratocystis ulmi* (Buism.) C. Moreau, by removing the pathogen reservoir from the elm population, and by removing breeding sites of the bark beetle vectors. *Scolytus multistriatus* (Marsham) and *Hylurgopinus rufipes* (Eichhoff). The importance of each of these factors may vary at different times in different communities.

Despite intensive sanitation methods, elms may die from Dutch elm disease via transmission of the fungus through root grafts. In rows of closely spaced elms where root-graft transmission of the fungus from diseased to adjacent elms is possible, immediately girdling of diseased elms could limit the spread of the fungus (Fig. 1). The efficacy of this technique in controlling Dutch elm disease was shown by Barger and others (1982). By following a rigorous program of girdling elms immediately upon expert detection of the disease and promptly removing those trees, they significantly reduced the disease rate.

This may seem to be a drastic method of disease control because girdling kills the tree. This thought is reinforced if the tree is an elm that exhibits only the earliest symptoms of Dutch elm disease. However, communities trying to maintain large numbers of street-side elms may find it worthwhile to sacrifice those diseased elms to protect the remaining elm population.

Here, we discuss the cost of girdling diseased elms, and the extent to which this technique can improve sanitation-program performance. Using a strictly financial approach, we assessed the costs of survey and disease detection, girdling diseased elms, and tree removal in terms of the municipal budget. We realize that this approach excludes significant portions of the Dutch elm disease picture. The value of elms, alive and well, in city neighborhoods greatly overshadows the cost of the disease control programs presented here. The physical, biological, and social benefits of saving elms are much greater than any monetary savings to be gained.

Survey and Girdling Analyses

In a large-scale pilot test involving 7,000 city-owned street-side elms, Barger and others (1982) tested 3 kinds of sanitation practices. We classified these practices by the time of tree death or removal after detection of the disease: (1) *delayed* (conventional sanitation) — a survey to detect diseased elms in August followed by removal of those trees during the fall and winter months; (2) *prompt* (invensive sanitation) — surveys in June, July,and August, each followed by removal of diseased elms within 20 work days after symptoms were observed; (3) *girdling-plus-prompt* — surveys in June, July, and August in

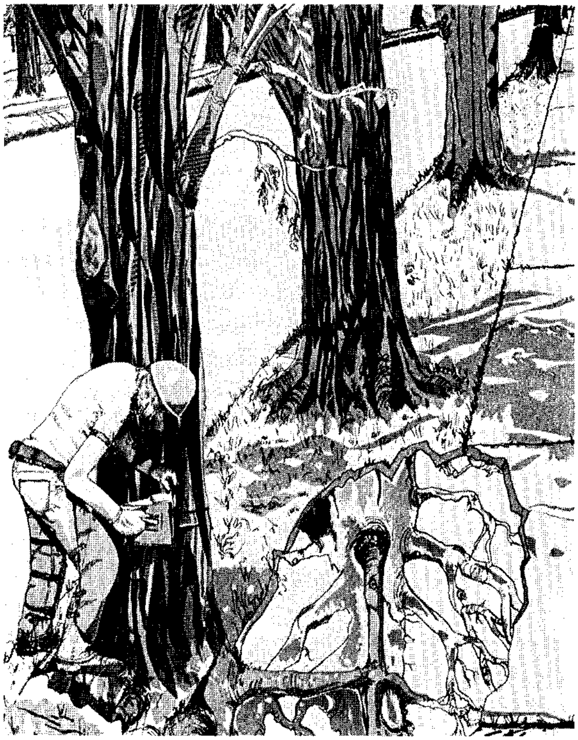

Fig. 1. A diseased elm being girdled to disrupt root-graft transmission of the fungus to adjacent elms.

which each diseased elm detected was immediately girdled and subsequently removed within 20 work days.

The performance and cost of surveying for diseased elms as described for *delayed* and *prompt* tree removal were reported by Cannon and others (1977). The performance and cost of girdling diseased elms for the *girdling-plus-prompt* sanitation technique were determined using gross job time studies (Worley et al. 1965).

The number of trees surveyed and the number and diameter at breast height (dbh) of diseased trees detected and girdled were tallied during the three surveys. Girdling time began when the chain saw was started to make the first of the two cuts shown in Figure 2a and continued through the process of chopping out the wood between the two cuts (Fig. 2b) until after the third cut was completed as shown in Figure 2c.

Girdling Performance and Costs

The average time to complete the girdling process shown in Figure 2 was 3.7 minutes per elm. However, smaller elms ranging from 10 to 20 inches (25.4 to 50.8 cm) dbh were girdled in 2.5 minutes. Elms, regardless of size, that had convoluted boles were girdled in an average of 5 minutes. Statistical analyses showed that these time estimates are significantly different from each other. These statistics are presented in detail in the Appendix.

The cost of the individual jobs comprising Dutch elm disease control programs of 39 municipalities were compiled by Cannon and Worley (1976). Survey costs in 1972, our base year, averaged 20 cents per tree per survey. Tree removal cost averaged $125. We have updated these figures by correcting for inflation each year with the producer price indexes; in terms of 1980 dollars, survey costs would be 42 cents per surveyed tree and tree removal would cost $265. Our data showed that at 42 cents per tree it would cost $62 per hour to detect diseased elms with our rigorous survey technique (Cannon et al. 1977).

Because girdling has not been a part of on-going Dutch elm disease control programs, there is little municipal experience on which to base costs of this technique. From the point of view of control-program operation, however, girdling is an extension of the survey process. Instead of marking a tree for later removal, the survey team proceeds to girdle the tree. Therefore, we consider the hourly cost of survey to be applicable to the girdling operation. When we used the hourly cost of survey and the average time of 3.7 minutes to girdle an elm, the 1980 cost of the girdling process averaged $3.82 per girdled tree.

Elm Losses

In 1973, prior to this study, the test areas had fair performance records with elm losses averaging about 5 percent per year. For the 5-year study, we tabulated annual elm losses (Barger et al. 1982) following the three diseased-elm-removal strategies (Table 1).

We demonstrated that the *girdling-plus-prompt removal* strategy was significantly better than either *prompt* or *delayed removal.* After an initial high disease rate, elm losses the second year in the *girdling-plus-prompt removal* group were less,

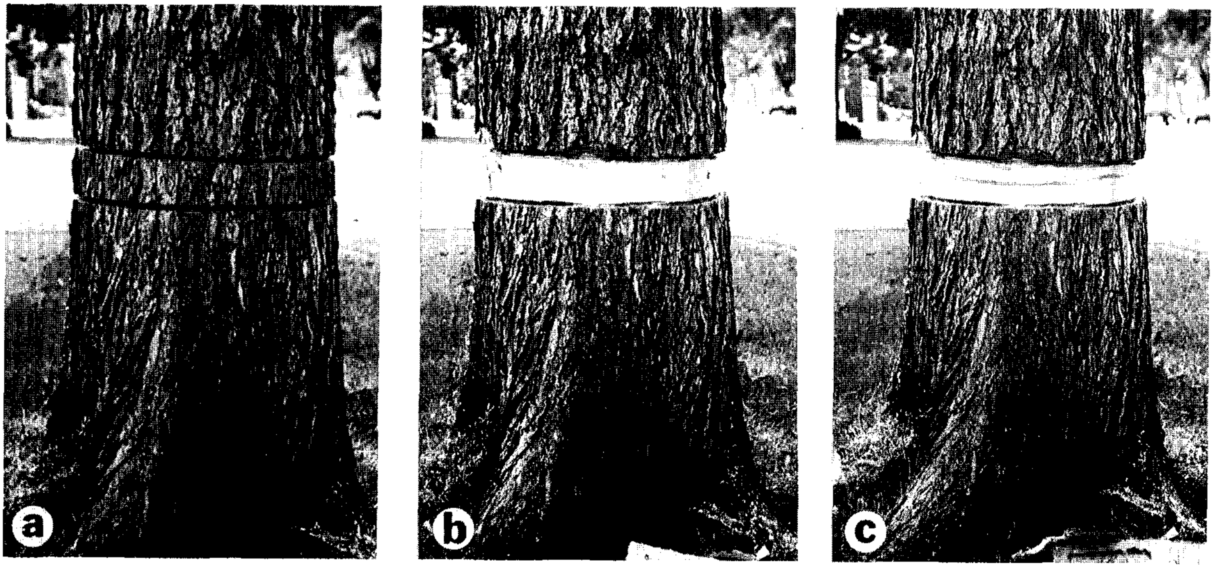

Fig. 2. Girdling process: (a) initial parallel cuts made with a chain saw to girdle a diseased elm, (b) sapwood removed from between the initial saw cuts, and (c) a third cut made into the wood to assure vessels are severed.

but not significantly less, than those sustained under the *prompt-removal* treatment. However, by the third year, 1976, a statistically significant difference was generated. If the experiment had ended in 1975, this improved performance would not have been detected. Only through Barger's conscientious, sustained effort were we able to realize that this strategy pays off by reducing elm losses. The beneficial effect of girdling, though insignificant at first, builds over time.

Program Budgets

What did it cost, in terms of an annual budget, to achieve this improvement? An example of how the cost of a *girdling-plus-prompt-removal* program might compare with those of *prompt* or *delayed-removal* programs is given in Table 1. Our 5-year case history is presented to illustrate the budget for each program. We used the girdling performance and costs developed earlier in this paper and updated survey and tree-removal costs from Cannon and Worley (1976) and Cannon and others (1977). Individual tree-removal costs were increased by 20 percent for the *girdling-plus-prompt* and *prompt* programs, because crews return again and again to the same areas to remove diseased trees.

The cost figures in Table 1 are historical costs based on the year in which they were incurred. These costs may be adjusted to a common year or updated with the method shown by Cannon and Worley (1980).

After 5 years, the cost of the *delayed-removal* program was almost $80,600 per thousand original elms, the *prompt-removal* program $65,200, and the *girdling-plus-prompt-removal* program $60,200 (Table 1). Tree-removal costs were 98 percent of the cost of the *delayed-removal* program, 96 percent of the cost of the *prompt-removal* program, and 94.5 percent of the cost of the *girdling-plus-prompt-removal* program. Survey costs were 1.5 percent, 4 percent, and 4 percent of the respective costs of these programs. The girdling technique cost 1 percent of its program total. The total cost of the *girdling-plus-prompt-removal* program was only 75 percent of the cost of the *delayed-removal* program. By girdling diseased elms, the cost of the *prompt-removal* program was reduced by 8 percent.

Table 1. Comparison of three diseased-elm-removal practices based on a 5-year study by 1,000-tree units.

Treatment and year	Elms[a] Beginning of season	Elms[a] Diseased removed	Survey	Historical costs (dollars)[b] Girdling	Historical costs (dollars)[b] Removal	Historical costs (dollars)[b] Total
Girdling-plus-prompt removal[c]						
1974	1,000	56	498	138	11,254	11,890
1975	944	35	517	95	7,683	8,295
1976	909	47	518	132	10,796	11,446
1977	862	39	518	115	9,399	10,032
1978	823	69	519	217	17,802	18,538
Total		246	2,570	697	56,934	60,201
Prompt removal[c]						
1974	1,000	47	500		9,446	9,946
1975	953	39	522		8,562	9,084
1976	914	65	518		14,930	15,448
1977	849	58	505		13,978	14,483
1978	791	61	500		15,738	16,238
Total		270	2,545		62,654	65,199
Delayed removal[d]						
1974	1,000	63	267		10,560	10,827
1975	937	60	273		10,985	11,258
1976	877	112	268		21,456	21,724
1977	765	79	245		15,879	16,124
1978	686	95	233		20,425	20,658
Total		409	1,286		79,305	80,591

[a]Elm loss data from Barger 1977, Barger, Cannon, and DeMaggio 1982.

[b]Adjusted from 1972 cost data (Cannon and Worley 1976) with the average wholesale price index each year for 1974 through 1978 with the method of Cannon and Worley (1980).

[c]Surveys made in mid-June, when 61% of the total diseased elms were identified; mid-July, 32%; late August, 7%. Survey cost and girdling cost (in 1978 dollars) set at $51 per hour. First survey at 34 cents per tree, subsequent two surveys at 1% disease rate at 15.5 cents per tree each survey. Cost of intensive tree removal set at $258 (cost of conventional removal plus 20% for extra effort required).

[d]Costs (in 1978 dollars) based on data from Cannon and Worley (1976): one survey at 34 cents per tree, and conventional removal during dormant season at $215 per tree.

Table 2. Savings in cost of control based on a 5-year study of 3 tree removal strategies, by 1,000-tree units.

Year	Girdling-plus-prompt versus Prompt $	Girdling-plus-prompt versus Prompt %	Girdling-plus-prompt versus Delayed $	Girdling-plus-prompt versus Delayed %	Prompt versus Delayed $	Prompt versus Delayed %
1974	(1.944)[a]	(16)	(1,063)	(9)	881	8
1975	789	9	2,963	26	2,174	19
1976	4,002	26	10,278	47	6,276	29
1977	4,451	31	6,092	38	1,641	10
1978	(2,300)	(14)	2,120	10	4,420	21
Total	4,998	8	20,390	25	15,392	19

[a]Bracketed numbers represent "negative savings" or losses.

More Elms Cost Less

More elms can be saved for a longer time by incorporating the girdling technique into a *prompt-removal* sanitation program. The results of the three diseased-elms-removal strategies were superimposed on the records in Figure 3 that show the length of time in which save-the-elms goals can be achieved with fair (5 percent annual loss) or good (3.5 percent annual loss) program performance levels (Cannon and Worley 1976). *Prompt removal* offered an immediate and sustained gain in numbers of elms saved. *Girdling-plus-prompt-removal* showed a smaller increment in improvement towards good performance. Comparison of the percentage of increase in elms saved (Fig. 4) shows that, for all but the first 2 years, *girdling-plus-prompt-removal* was superior to *prompt removal* alone. The 5-year total (Table 1) reveals that 3 percent more elms were saved with *girdling-plus-prompt-removal.*

Let us assume that this reduction in disease rate cannot be further improved and that the limits of this technique have been reached. Then, if the present disease rates were to persist, in about 2 more years 50 percent of the original elms would have been lost to the disease in the areas with *delayed* removal. It would take 8 more years before the elm population would be reduced to this level in areas with *girdling-plus-prompt-removal.* This highlights the improvement offered by this technique.

Actually, if the technique of girdling diseased elms was used, wherever appropriate, in a community-wide program, we might expect the disease rate, despite annual fluctuations, to decrease over time to some lower level. As fewer elms are lost to Dutch elm disease, control efforts will offer greater protection to the surviving elms. This will be especially true if consistent on-going control efforts are applied to the entire elm population.

We indicated earlier that the 5-year cost of *girdling-plus-prompt-removal* was about $20,000 less or 25 percent less than the cost of *delayed removal* (Table 2). Our experience summarized in Tables 1 and 2 enables us to put the cost savings, associated with doing a better job of disease control, on a per original-tree basis.

Beginning with 1,000 trees, the first 5 years of control cost about $81 per tree for the *delayed-removal* program. Only $1.28 was for survey costs whereas $79 was for the tree removal costs. As we intensified our control efforts by *prompt removal,* the total bill was $65 per tree; a savings of $15. Tree removal costs were reduced dramatically to $63 per original tree; a savings of $6. But survey costs doubled to $2.55 per tree. *Girdling-plus-prompt-removal* decreased costs even further. The total cost of this alternative was $60 per tree, which saved $18 over the *delayed*

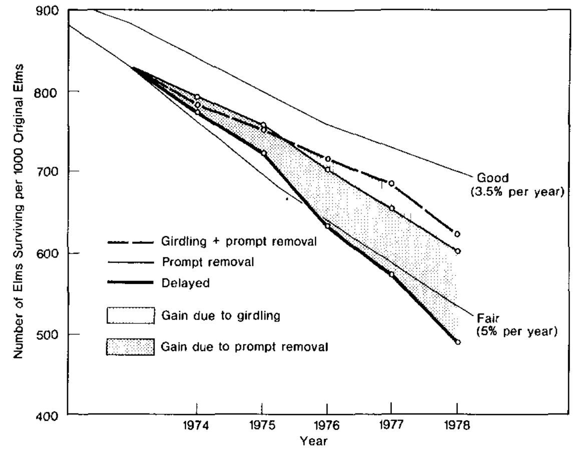

Fig. 3. Number of elms surviving three sanitation practices judged against control-program performance levels.

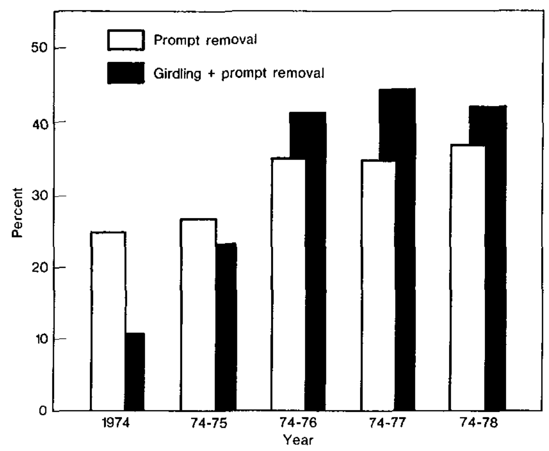

Fig. 4. Percentage increase in elms saved by prompt or girdling-plus-prompt removal compared to the delayed removal program.

or $7 over the *prompt-removal* alternatives. Major savings of $6 per tree in tree removal costs were realized by spending slightly more for surveys, including 70 cents per tree for girdling. Each added increment in control effort has lessened the total cost as well as saved elms. Thus, it is possible to have more elms for less annual cost.

Table 3. Statistics of girdling time for categories of elms observed to have Dutch elm disease.

			Girdling time (min)	
Category	*No.*	*Percent of total*	*Mean*	*Standard deviation*
Convoluted	20	33	5.0**	2.059
Nonconvoluted				
10-20 in. dbh	17	28	2.5**	0.881
21-38 in. dbh	24	39	3.5**	1.215
All elms	61	100	3.7	1.749

[a]**Means significantly different from each other at the 0.01 level, student's t test.

The Sanitation Picture

Sanitation is the mainstay of most successful community control programs. Barger (1977) demonstrated that a big improvement in saving elms can be made by frequent surveys followed by *prompt removal* of diseased elms. Additional elms can be saved if diseased elms are girdled as soon as symptoms are observed and then promptly removed (Barger et al., 1982). However, the increment of improved performance over that of *prompt removal* is smaller than that of a *prompt removal* program over *delayed* sanitation (Fig. 3). We would expect subsequent improvements in sanitation performance to be of even less magnitude than that obtained by girdling.

Sanitation techniques have evolved toward earlier detection and earlier removal of diseased elms. Girdling such trees is the most efficient and cost-effective technique to date for treating street-side elms on a community-wide basis. Further improvements await technological breakthroughs in detecting diseased elms and limiting the spread of the fungus.

Summary

A control technique, such as *girdling-plus-prompt removal*, that can reduce the number of elms to be removed and that costs less than removing those trees will fit well into a municipal budget and release funds for other urgent tasks. We found that a sanitation program of early detection and immediate girdling of diseased trees, followed by prompt removal, saved money as well as elms:

More elms at less cost

	Elms remaining after 5 years		Ave. total cost for 5 years	
Control tactic	*No. per thousand*	*% increase*	*Dollars per tree*	*% decrease*
Delayed removal	591		81	
Prompt removal	730	20	65	20
Girdling-plus-prompt removal	754	28	60	25

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Appendix

We classified the elms girdled in this study by whether or not the bole of the tree was convoluted at the point of girdling and by 2 diameter classes — 10 to 20 inches (25.4 cm to 50.8 cm) and 21 to 38 inches (53.3 to 96.5 cm) dbh. There were no elms less than 10 inches or more than 38 inches dbh. One-third of the elms were convoluted (Table 3). Of the remaining two-thirds, 42 percent were in the smaller and 58 percent in the larger diameter class.

We found that if an elm was convoluted, there was no statistically significant difference between the two dbh classes as to the time required to girdle the tree. Significant differences were found between the following three groups: (1) convoluted elms took an average of 5 minutes to girdle (Table 3); (2) the larger nonconvoluted elms took 3.5 minutes; (3) the smaller nonconvoluted elms to an average of 2.5 minutes to girdle. The overall average girdling time was 3.7 minutes.

If the representation of these categories of elms in the street-side trees is known, then an accurate financial estimate could be made based on the girdling time for each category. Because it is not likely that managers would have such information about the elm population of the urban forest at the outset of a control program, we chose to apply our findings to the average situation using the 3.7 minutes average girdling time.

To the time needed to survey a unit a 1,000 trees, we added 3.7 minutes for each tree girdled. If 10 elms were found to be diseased, then 37 minutes were added to the survey time. If the elms were easier to girdle, that is they were in the smaller category dbh, then only 25 minutes need be used. If the elms were convoluted, then 50 minutes would be more appropriate. Although we have used the average of 3.7 minutes per tree throughout for our cost comparisons, the following equation can be used to compute costs for the other two categories of elms:

Adjusted girdling cost = (cost based on 3.7 min/tree) × (k_1 or k_2)

where

k_1 = 0.67 for the smaller easier-to-girdle elms.

k_2 = 1.35 for the convoluted more-difficult-to-girdle elms.

Contributed Abstract

HIGH TEMPERATURE LIMB BREAKAGE

by W. Douglas Hamilton

Richard Harris, Department of Environmental Horticulture, University of California, Davis, has been pursuing information about causes of sudden limb breakage for many years. As more historical records and new information are investigated, we are coming closer to understanding causes and can take measures to prevent hazardous situations.

High temperature limb breakage or *summer branch drop,* as it is called in England where it is fairly common, is also known in South Africa and Australia. In California it was recorded on *Quercus lobata* (white oak) as early as 1882. Since then it has been reported in California on several species of elm, eucalyptus, oak and pine, and on London plane, deodar cedar, silk oak, and Indian laurel.

High-temperature limb breakage occurs out on a limb, not at the crotch. The break may be quite jagged or short and at right angles to the branch length. The wood at the point of the break may appear sound. Limbs that fail are usually mature, large in diameter, horizontal, and healthy in appearance. Also, they are usually branches that have extended considerably. Young and vigorous maturing trees of susceptible species appear less prone to the problem, while over-mature and senescent trees may repeatedly shed branches, at least in England. The time of occurrence in California is usually on a hot, calm afternoon in August or September; in England, it usually occurs on a warm, calm afternoon following a rain that has broken a prolonged dry spell.

Evidence to explain high-temperature limb breakage is lacking. Brashness, where the wood has become brittle, may cause a branch to be more susceptible to breakage. Many limbs that fall, however, do not appear to have brash wood. Another predisposing cause may be small fractures developing when an extended limb twists or when other conditions prevail to cause internal cracking.

Where large branches of mature trees extend over structures and people-use areas, it may be advisable to shorten such branches. In young trees, such limbs should be avoided by removing them while they are small and the tree is vigorous; less decay and rapid wound closure should result.

Information and editorial assistance by Richard Harris, Professor of Environmental Horticulture, University of California, Davis, California is gratefully acknowledged.

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