An Appraisal of

OAK WILT CONTROL PROGRAMS

in Pennsylvania and West Virginia

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A THREAT TO OAK FORESTS

OAK WILT, caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt, is a threat to oak forests in the 21 States where it is known to occur. Catastrophic losses to this disease, feared by many in its early history, have fortunately not materialized. Still, thousands of oaks succumb to oak wilt annually, and there is no assurance that this rate of loss is static.

Attempts to control oak wilt, ranging from relatively small-scale experiments to statewide programs, have been made in many States. Among the few currently active, those of Pennsylvania and West Virginia are notable for their size and duration. The pest-control organizations of the Pennsylvania Department of Agriculture and the West Virginia Department of Agriculture have vigorously pursued well-organized statewide oak wilt control programs in their respective States for more than 15 years. Further, these organizations, in cooperation with the Northeastern Area Branch of State and Private Forestry and the Northeastern Forest Experiment Station of the USDA Forest Service, have, since 1958, conducted special studies to measure the effectiveness of these control efforts. This is a report on the results of those studies through 1968.

THE CONTROL PROGRAMS

The oak wilt fungus spreads from diseased trees to healthy trees in at least two ways: below ground through naturally occurring root grafts, and above ground by insect vectors. Control measures employed in both Pennsylvania and West Virginia are designed to prevent spread by reducing or isolating the fungal inoculum at its source.

The Pennsylvania Method

In the Pennsylvania control program, an aerial detection survey is made, providing complete coverage of the infected portion of the State. More heavily infected areas are resurveyed as many as five times each year. Ground surveys are also made incidental to checking all suspect trees located from the air. Diseased oaks and healthy oaks within 50 feet of and of the same species group as the diseased tree are felled. Stumps of all diseased and healthy trees cut are poisoned with the herbicide Ammate.

The diseased trees are felled to hasten drying and reduce the number of fungus mats formed between the bark and wood. These mats are a source of inoculum for spread of the fungus by sap-feeding beetles. The surrounding healthy trees are cut to prevent spread by root grafts and to prevent aboveground spread of the pathogen by eliminating the nearest suscepts. Herbicide application to the stumps hastens root kill, shortening the time that the roots can serve as reservoirs of inoculum and pathways of below-ground fungus spread.

The West Virginia Method

In the West Virginia control program an aerial detection survey is made, providing complete coverage of the entire State. The more heavily infected areas are resurveyed as frequently as every 2 weeks during the growing season. Supplementary ground surveys are made incidental to checking all

suspect trees located from the air. All diseased trees located are treated by chopping a girdle into the heartwood, completely around the tree at a convenient height. The bark on the bole and buttress roots from the girdle to ground line is removed. The deep girdle and basal bark removal hastens drying of the tree, thus preventing or reducing the formation of fungus mats.

CONTROL PROGRAM APPRAISAL STUDIES

The first study to appraise oak wilt control programs was made from 1958 through 1963. The results: 77 percent fewer diseased trees occurred on plots treated by the Pennsylvania method and 46 percent fewer diseased trees on plots treated by the West Virginia method than on check plots receiving no treatment (*Jones 1965*). Of equal importance was evidence that rate of fungus spread on check plots increased with time.

However, unavoidable features in the design of this study caused reservations about the validity of results. Chief among these was the segregation of treatments. The Pennsylvania method was applied only to plots in Pennsylvania, the West Virginia method only to plots in West Virginia; and the majority of the check plots were located in western Maryland between the other two States.

A second study has now been made, with several revisions in design, to refine the estimates of control-program effectiveness and the rate of fungus spread in untreated areas. The appraisal was made on 2.9-acre circular plots, each centered on an oak wilt infection center. An oak wilt infection center is a wilt-infected or wilt-killed tree, or a group of such trees, any one of which is not more than 50 feet from another wilt tree. A wilting tree more than 50 feet from other wilt trees is in a separate infection center.

These plots were selected to meet certain specifications so that a degree of uniformity between study areas was assured. The appraisal plot specifications were:

- The plot to be circular, 400 feet in diameter, and centered on an oak wilt infection center.
- The infection center to consist of not more than five wilting or wilt-killed trees, at least one of which is of the red oak group, 6 inches d.b.h. or larger, wilting at the time the plot is established.
- At least five healthy oaks of the red oak group, 2 inches d.b.h. or larger, to be within 50 feet of the diseased oaks, with similar oak stocking on the remainder of the plot.
- Each plot center to be at least 300 feet away from any other known wilt center or dead wilt suspect.
- Partial plots to be acceptable if their inclusion is essential to obtaining the specified number of plots. Partial plots are those in which a field, powerline clearing, road, stream, or nonoak timber type infringe on the plot. Such infringement to be at least 50 feet from the plot center.

Table 1.—Number of control appraisal plots by location and treatment

Plot location	Control method		
	Pennsylvania method	West Virginia method	No control
	No.	*No.*	*No.*
A. NEW PLOTS, ESTABLISHED 1964-66			
Pennsylvania	26	24	24
West Virginia	36	36	35
Subtotal	62	60	59
B. OLD PLOTS, ESTABLISHED 1958-61			
Pennsylvania	41		3
West Virginia		52	24
Maryland			5
Subtotal	41	52	32
Total	103	112	91

Seventy-four plots were established in Pennsylvania and 107 plots in West Virginia in 1964–66 (table 1A). One of three treatments—the Pennsylvania method, the West Virginia method, or no treatment—was assigned in rotation to each plot when it was established. Trees wilting when the plot was established were treated by the method assigned to the plot. Each plot was carefully examined twice each summer through 1968, and the wilting trees found by these examinations were treated by the assigned method. Thus each of the three control treatments was applied to approximately one-third of the plots in each State. Oak wilt spread was recorded from the time of plot establishment through 1968—from 2 to 4 years.

In addition, 125 plots from the old appraisal study met the new standards in 1964, and were maintained through 1968 as an adjunct to the main study (table 1B). Control treatment applied on these plots remained the same as originally assigned. The schedule for examination and treatment and the data recorded were the same for these old plots as for the new plots. Oak wilt spread on these plots was recorded for 7 to 10 years.

RESULTS AND DISCUSSION

The effects of control treatments were appraised by comparing incidence of oak wilt infection on control and check plots. Oak wilt incidence was determined as the number of infected trees and also as the number of active infection centers per plot per year. (An "active infection center" was one with a currently wilting tree.) The data were grouped and compared by years of plot age, measured from the time of establishment. Since plots were established over a period of several years, they become the same age in different calendar years, so this grouping of data tended to average the "normal" year-to-year fluctuation of wilt incidence. Disease incidence on treated and check plots was also compared for the entire period of the study. Some plots were destroyed by fire or cutting

before the study was completed. The data for such plots were included, however, for so long as they met specifications. There were approximately the same number of partial plots among the control and check plots. Results determined with and without partial plots were essentially identical, so data from partial plots were included without special identification.

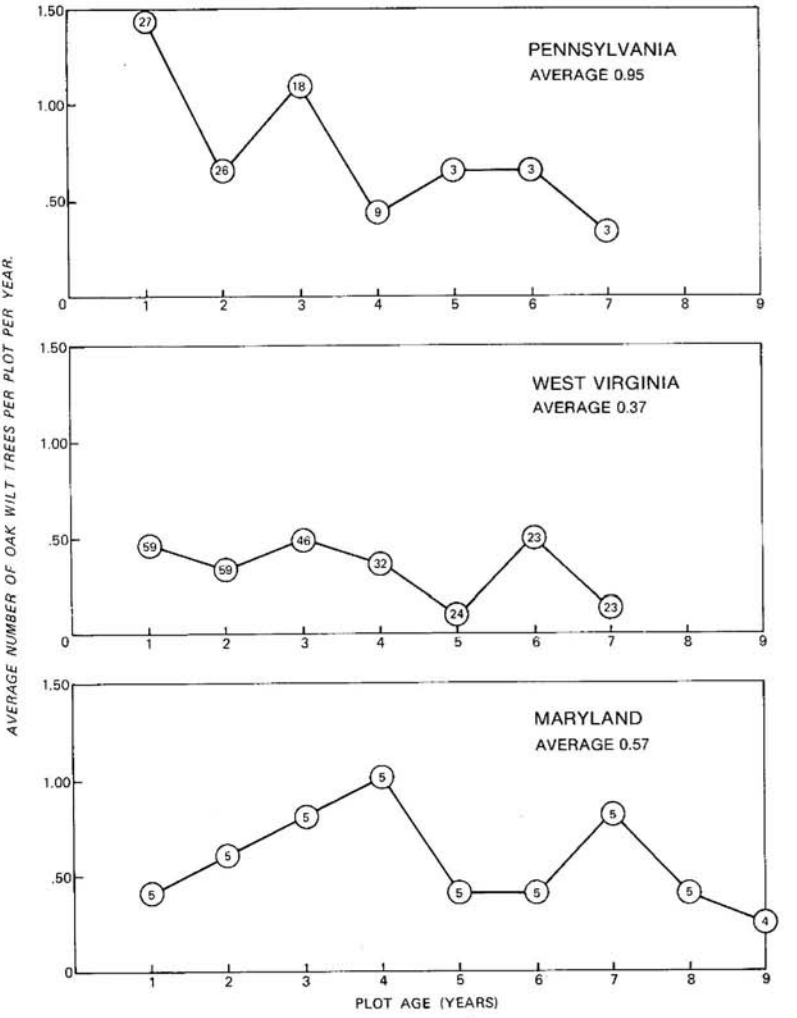
Check Plots

The annual levels of oak wilt infection on check plots were determined from the combined data from both the old and new study (fig. 1). At least two significant conclusions may be drawn. First, the tendency for rate of oak wilt spread to increase with time, as suggested by results of the first study alone, was not substantiated by these combined data. No clear-cut trend was apparent, but there were indications that infection centers tend to become less active rather than more active as time passes. Second, frequency of fungus transmission, at least within 200 feet of existing infection centers, was greatest in Pennsylvania (0.95 trees per plot per year), somewhat lower in Maryland (0.57 trees per plot per year), and still lower in West Virginia (0.37 trees per plot per year).

The relation between incidence of infection and distance from previously diseased trees on check plots in this study (fig. 2), confirmed the spread pattern reported for the first appraisal study and those for West Virginia and North Carolina discussed by True *et al.* (*1960*). Most wilt infections within our plots occurred very close to the apparent source of inoculum. Of the 295 trees that became infected on check plots subsequent to their establishment, 13 percent were within 10 feet of a previously diseased tree, 47 percent within 20 feet, 66 percent within 30 feet, 81 percent within 40 feet, and 88 percent within 50 feet. The remaining 12 percent or 37 trees were scattered, apparently at random, 50 to 200 feet from previously diseased trees.

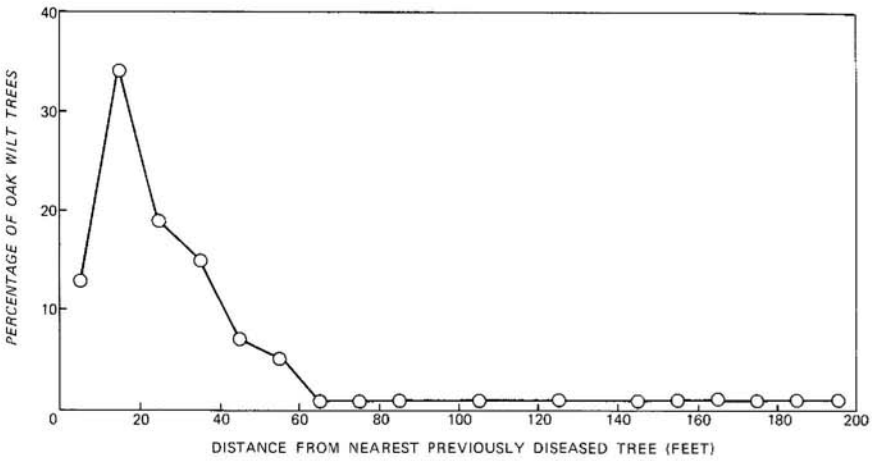
Although oak wilt spread that could be measured on these plots was heavily concentrated within 50 feet of previously diseased trees, spread over greater distances does readily

Figure 1.—Number of oak wilt trees per plot per year by plot age on check plots in Pennsylvania, Maryland, and West Virginia. The encircled numbers indicate number of plots on which average was based.



occur. In 1969, for example, 23 percent of the active infection centers in Pennsylvania and 50 percent of the active infection centers in West Virginia were new centers resulting from spread of the fungus for more—often very much more—than 50 feet from previously diseased trees (*Jeffery and Tressler 1969; anonymous 1969*).

Figure 2.—Frequency distribution of oak wilt trees by distance from nearest previously diseased tree on check plots in Pennsylvania, Maryland, and West Virginia.



It is evident that this study should provide a satisfactory measure of the effect of the control treatments on local spread of the fungus. ("Local spread" is spread of the fungus to trees within 50 feet of previously diseased trees.) It was initially believed that comparing wilt incidence on check and control plots from 50 out to 200 feet from plot infection centers would also provide a measure of the effect of control treatments on long-distance spread of the fungus. ("Long-distance spread" is spread of the fungus to trees more than 50 feet from a previously diseased tree.) However, very few wilt infections occurred in this area on the check plots—an average of only 0.06 trees per plot per year in Pennsylvania, and 0.09 trees per plot per year in West Virginia. So the sampled areas were too small for adequate appraisal of control of this kind of spread.

The Pennsylvania Control Method

With the Pennsylvania control method, fungus spread was reduced on plots in Pennsylvania, northeastern West Virginia, and southern West Virginia by 90 percent, 100 percent, and

97 percent, respectively (table 2). Only 9 trees became infected on the 62 plots receiving this treatment as opposed to 98 new wilt trees on the 59 check plots. The degrees of control by this method, based on the number of active infection centers rather than the number of wilting trees, were 84 percent, 100 percent, and 93 percent, respectively.

In the Pennsylvania method, all healthy oaks within the local spread zone and of the same species group as the diseased tree are cut. Therefore, local spread of the fungus can occur only between trees of different species groups or to trees of the same species group left standing due to oversight in applying

Table 2.—PENNSYLVANIA CONTROL METHOD: Number of wilt trees per plot by plot age for plots established 1964-66

Plot age (years since establishment)	Control			No control		
	Plots	Wilt trees	Wilt trees per plot	Plots	Wilt trees	Wilt trees per plot
			PENNSYLVANIA			
1	26	4	0.15	24	32	1.33
2	26	2	.08	23	14	.61
3	17	1	.06	15	18	1.20
4	10	1	.10	6	2	.33
Average per year	19.7	2.0	0.10	17.0	16.5	0.97
			Control = 90 percent			
			NORTHEASTERN WEST VIRGINIA			
1	17	0	0	16	4	0.25
2	17	0	0	16	5	.31
3	11	0	0	9	4	.44
4	5	0	0	4	1	.25
Average per year	12.5	0	0	11.2	3.5	0.31
			Control = 100 percent			
			SOUTHERN WEST VIRGINIA			
1	19	1	0.02	19	3	0.16
2	19	0	0	19	5	.26
3	14	0	0	13	9	.69
4	11	0	0	4	1	.25
Average per year	15.7	0.2	0.01	13.7	4.5	0.33
			Control = 97 percent			

Table 3.—PENNSYLVANIA CONTROL METHOD: Number of wilt trees per plot by plot age for plots established 1958-61 in Pennsylvania

Plot age (years since establishment)	Control			No control		
	Plots	Wilt trees	Wilt trees per plot	Plots	Wilt trees	Wilt trees per plot
1	41	7	0.17	3	7	2.33
2	41	6	.15	3	3	1.00
3	41	4	.10	3	2	.67
4	40	5	.12	3	2	.67
5	40	3	.07	3	2	.67
6	39	3	.08	3	2	.67
7	39	4	.10	3	1	.33
Average per year	40.1	4.6	0.11	3.0	2.7	0.90
	Control = 88 percent					
8	30	0	0	—	—	—
9	19	0	0	—	—	—
10	7	0	0	—	—	—
Average per year	33.7	3.2	0.09	—	—	—

the control treatment. Of the nine new wilt trees on plots so treated, two resulted from long-distance spread, one from apparent local spread from a red oak to a chestnut oak, and the other six from apparent local spread from infected red oaks to red oaks that were missed in application of the control measures.

The results obtained over a period of 10 years with the Pennsylvania control method on the old appraisal plots are shown in table 3. Only three check plots met specifications for 7 years of this period, so a good comparison between control and no control is not possible. Nonetheless, the indicated degree of control—88 percent—and the annual incidence of wilt on control and check plots agree very closely with corresponding values from the more recent study and so contribute to our confidence in the reliability of the results reported.

The West Virginia Control Method

With the West Virginia control method, fungus spread was reduced in Pennsylvania, northeastern West Virginia, and southern West Virginia by 39 percent, 0 percent, and 79 percent, respectively (table 4). Comparable values based on number of active infection centers rather than number of wilting trees were 26 percent, 3 percent, and 83 percent.

Table 4.—WEST VIRGINIA CONTROL METHOD: Number of wilt trees per plot by plot age for plots established 1964-66

Plot age (years since establishment)	Control			No control		
	Plots	Wilt trees	Wilt trees per plot	Plots	Wilt trees	Wilt trees per plot
PENNSYLVANIA						
1	24	18	0.75	24	32	1.33
2	24	19	.79	23	14	.61
3	15	5	.33	15	18	1.20
4	8	0	0	6	2	.33
Average per year	17.7	10.5	0.59	17.0	16.5	0.97
	Control = 39 percent					
NORTHEASTERN WEST VIRGINIA						
1	17	10	0.59	16	4	0.25
2	17	7	.41	16	5	.31
3	11	5	.45	9	4	.44
4	5	1	.20	4	1	.25
Average per year	12.5	5.7	0.46	11.2	3.5	0.31
	Control = none					
SOUTHERN WEST VIRGINIA						
1	19	0	0.00	19	3	0.16
2	18	2	.11	19	7	.26
3	13	1	.08	13	7	.69
4	5	1	.20	4	1	.25
Average per year	13.7	0.5	0.07	13.7	4.5	0.33
	Control = 79 percent					

There is no clear reason for the variation in results with this method in the three test areas. Oak wilt infection centers are far more numerous in northeastern West Virginia than in the southern part of that State or in Pennsylvania. On the other hand, the rate of fungus spread immediately around known infection centers on check plots was nearly identical for the

Table 5.—WEST VIRGINIA CONTROL METHOD: Number of wilt trees per plot by plot age for plots established 1958-61

Plot age (years since establishment)	Control			No control		
	Plots	Wilt trees	Wilt trees per plot	Plots	Wilt trees	Wilt trees per plot
NORTHEASTERN WEST VIRGINIA						
1	21	21	1.00	24	20	0.83
2	21	8	.38	24	10	.42
3	21	6	.29	24	9	.37
4	21	13	.62	24	10	.42
5	21	6	.29	24	2	.08
6	21	10	.48	24	11	.48
7	21	14	.67	23	3	.13
Average per year	21.0	11.1	0.53	24.0	9.3	0.39
	Control = none					
8	21	10	.48	—	—	—
9	17	6	.29	—	—	—
10	4	0	0	—	—	—
Average per year	18.9	9.4	0.50	—	—	—
SOUTHERN WEST VIRGINIA						
1	31	9	0.29	—	—	—
2	31	6	.19	—	—	—
3	31	5	.16	—	—	—
4	31	6	.19	—	—	—
5	31	7	.23	—	—	—
6	31	8	.26	—	—	—
7	31	9	.29	—	—	—
8	31	6	.19	—	—	—
9	19	1	.05	—	—	—
10	7	1	.05	—	—	—
Average per year	27.4	5.8	0.21	—	—	—

two areas in West Virginia but was much higher in Pennsylvania. The unknown factors responsible for these significant but seemingly inconsistent differences may well be involved in the variable responses to the West Virginia control method.

The results obtained over a period of 10 years with the West Virginia control method on the old appraisal plots are shown in table 5. Sufficient data are available to compare oak wilt incidence on control and check plots in northeastern West Virginia for 7 of those 10 years. These data confirm the conclusion drawn from the more recent study that this control method is ineffective against local spread in the northeastern part of the State. A similar comparison cannot be made for southern West Virginia because none of the check plots in the old study was located there. It can be noted that in this area the number of wilt trees per plot per year on treated plots in the recent study has been held to 0.07 (table 4) as compared with a corresponding value of 0.21 for treated plots in the old study.

CONCLUSIONS

The Pennsylvania control method prevented nearly all spread of the oak wilt fungus to trees in the immediate vicinity of treated infection centers. It was about equally effective in all test areas from Pennsylvania to southern West Virginia. Instances of spread after treatment were rare, and two-thirds of these could be accounted for by incomplete application of the control measures. However, these excellent results were accomplished at a high—and perhaps unacceptable—cost in healthy trees destroyed. About seven healthy trees were cut for each infected tree treated; and this may be more than would be lost to local spread of the pathogen if no control were attempted.

The West Virginia control method was less effective in suppressing local oak wilt spread than the Pennsylvania method in all areas. However, it is much cheaper to apply and does not destroy healthy trees. In southern West Virginia this method provided a high degree of control, and considering its lower

costs for labor and impact on healthy trees, it would appear to be the better method for that part of the State. The performance of this control measure in Pennsylvania was marginal at best, and there was no evidence that it reduced local spread of the fungus in northeastern West Virginia.

The results of this study have provided reliable and well-documented information about the local spread potential of the oak wilt pathogen in Pennsylvania and West Virginia. We can now predict, with a high degree of confidence, what future losses will be in the immediate vicinity of existing and new infection centers if they are not controlled. We know how much these losses can be reduced by applying either of the two control practices.

But these studies failed to measure the amount and importance of long-distance spread of the wilt fungus that results in new infection centers. Nor have we learned how effective either control measure is in reducing this type of spread. These were important objectives of the study that were not attained because of major differences between anticipated and actual study results.

The annual numbers of active infection centers in all of Pennsylvania for the period 1964–68 were 281, 271, 294, 279, and 261. Analogous figures for West Virginia were 3,011, 2,472, 2,047, 2,228, and 2,406. Yearly variations in these figures reflect the effect of weather, other natural phenomenon, financing, and the number and experience of available personnel on survey efficiency as well as real differences in oak wilt incidence; so the oak wilt situation in both States for this 5-year period can be characterized as relatively stable. We know that disease losses in both States would be greater were it not for the control programs, but we have only a partial basis for estimating how much greater.

A new study to provide this information was started in 1969 and is scheduled for completion in 1973. It is specifically designed to measure uncontrolled long-distance spread of the wilt fungus and the effectiveness of the Pennsylvania and West Virginia control programs in suppressing such spread. Infection center multiplication is a vital factor in the disease complex,

so a complete and valid appraisal of the oak wilt threat in these States and realistic biologic and economic evaluation of the control programs must await the outcome of that study.

LITERATURE REFERENCES

Anonymous.
1969. THE 1969 OAK WILT PROGRAM. West Va. Dep. Agr. Spec. Surv. Rep. 69-1, 65 pp., 1969.

Jeffery, Arthur R., and Randall K. Tressler.
1969. OAK WILT IN PENNSYLVANIA. THE 1969 PROGRAM. Penn. Dep. Agr. Bur. Plant Indust., 9 pp.

Jones, T. W.
1965. AN APPRAISAL OF OAK WILT CONTROL PROGRAMS IN EASTERN UNITED STATES. USDA Forest Serv. Res. Paper CS-19, 24 pp.

True, R. P., H. L. Barnett, C. K. Dorsey, and J. G. Leach.
1960. OAK WILT IN WEST VIRGINIA. West Va. Univ. Agr. Exp. Sta. Bull. 448T, 119 pp.

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