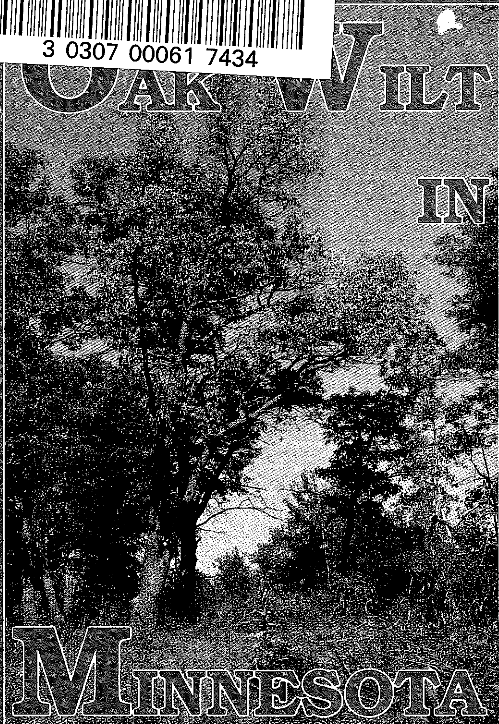
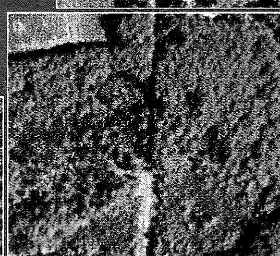
Oak Wilt in Minnesota

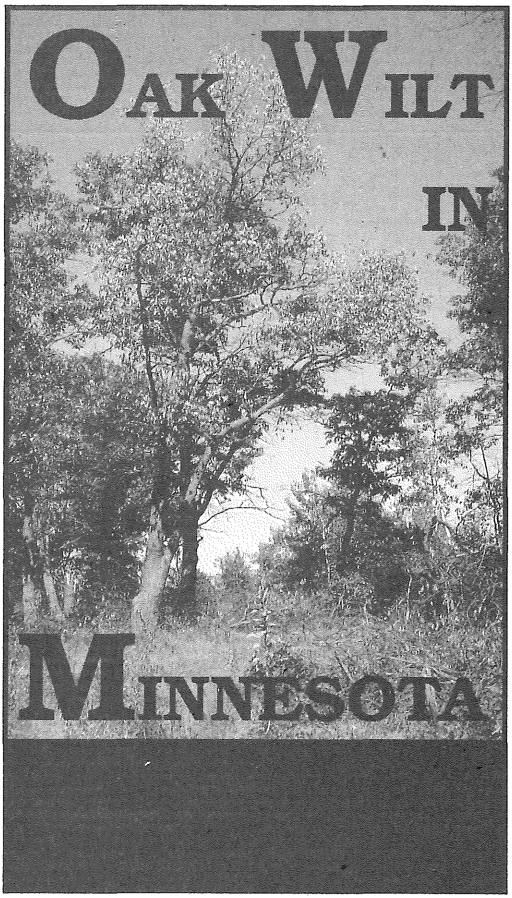




Minnesota Department of Natural Resources
Division of Forestry

Cover Photo

Aerial view of oak wilt. Aerial photographed in 1988 and area photographed in 1989 (because of the drought the latter may have to be done again in 1990).



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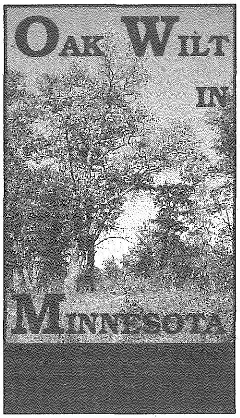
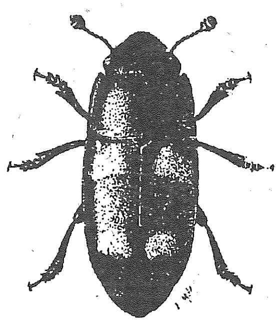


BACKGROUND

Cause and Spread of Oak Wilt

Oak wilt is caused by a fungus related to the Dutch elm disease fungus. These fungi, once in the vascular system of a tree, cause the tree to become plugged. This stops the flow of water to the crown, resulting in rather rapid wilting and dying of red oaks. Once infected, red oaks wilt in two to three weeks and will not recover. White oaks are much more resistant, but will decline over one to several years.

The fungus commonly spreads through grafted roots between infected and healthy oaks, moving about 15-20 feet in every direction from the diseased tree. To make control more difficult, the fungus can be carried to healthy trees by picnic beetles. These insects are attracted to diseased trees by the odor the fungus produces from spore mats formed under the bark. The beetles become well covered with spores when they feed on these mats. They may then find their way to a nearby healthy oak, possibly depositing spores if a fresh

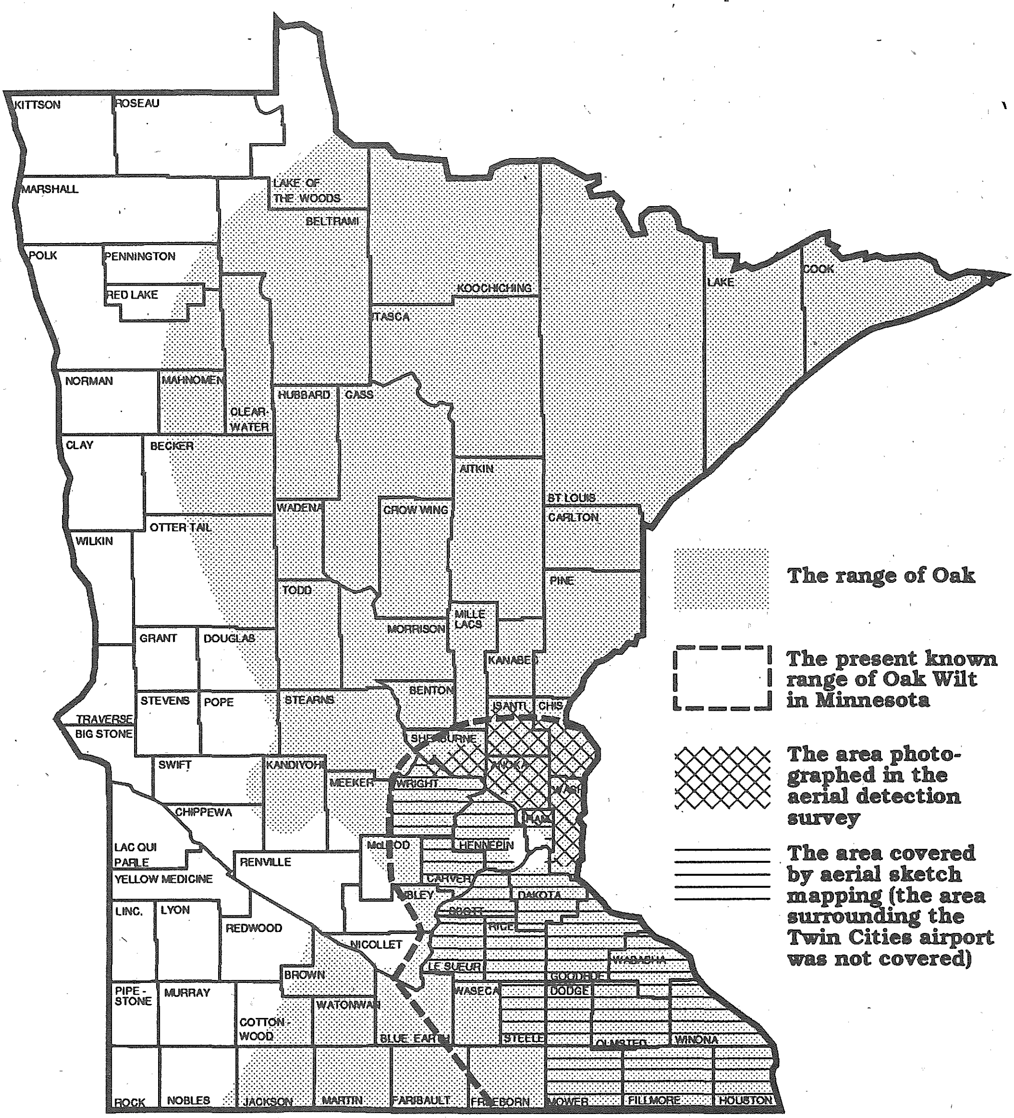


wound is present. Fortunately this system is not perfect. These beetles, called *Nitidulidae* or picnic beetles, are not able to wound trees and or efficiently find oak trees. The wounds on oaks have to be made by something else (pruning, wind, etc.) and must be fresh, possibly not more than a day or so old. Infection occurs for a short period in spring from 15 May - 15 June. If oaks are not wounded during this period, infection will not result. If wounds are painted, infection will not occur. We have some advantages in dealing with this fungus and should be encouraged to take advantage of our opportunities.

Distribution of the Oak Species in Minnesota

Of the six or more species of oaks in Minnesota the most important species are the northern red, northern pin, bur, and white (Fig. 1). Other species include the biocolor oak and the eastern pin oak. Eastern pin oak is not native to Minnesota, but both of these latter two species are being grown and sold by commercial nurseries. The northern red oak and northern pin oak are widely distributed in Minnesota. Northern pin oak is the dominant species in areas north of the Twin Cities where sandy soils predominate and where oak wilt is common. The bur oak is found throughout the state and is able to survive on poor sites. The biocolor oak, native to southeastern Minnesota, is being planted but is not a major species. The white oak is found

Figure 1. Distribution of oak, oak wilt, and areas surveyed in Minnesota.



on better sites in southeastern and central Minnesota. Black and scarlet oaks found in southeastern Minnesota are not common.

The Value of Oaks

Without question, oaks are Minnesota's most valuable shade trees with approximately 234 million red and white oaks in the state. If the value of trees by species could be calculated, the value of oak would be far in excess of all other shade trees. Commercially, oak is used by 400 firms in Minnesota and contributes an estimated $1 billion to the state's economy. Oaks are reasonably free of pests except for oak wilt, are able to tolerate a wide range of soils, and are surprising performers on marginal sites where most other hardwoods such as maples, lindens, and others would not survive.

Not only are oaks valuable as shade trees but they supply an important wood products industry. Oaks are also valuable as veneer logs. Many are shipped overseas to be sliced into thin veneer which is then glued over less attractive cheaper woods. There is a major wood industry in Minnesota that is dependent on oaks for raw material.

If we do not control oak wilt, property values will be drastically reduced and the wood industry will sustain substantial losses.

Oak Wilt History in Minnesota

From observations of various pathologists, oak wilt was present in Minnesota, in the vicinity of the Twin Cities, since early in this century. Based on a report in Wisconsin, it was present in this part of the United States in the 1880s. It is reasonable to assume that oak wilt has been present in the north-central United States for well over a century.

In 1988, the first intensive and systematic survey for oak wilt was attempted as a pilot project funded by the Minnesota Legislature. A 44 township area north of the Twin Cities was photographed with IR color film by the Department of Natural Resources (DNR) and ground-truthed by a University of Minnesota graduate student working with DNR. The southeastern part of the state was checked using direct aerial observation by DNR staff. This survey has not been ground checked due to funding limitations.

Prior to the 1988 surveys, the distribution of oak wilt was poorly known on the basis of detection as we traveled the state for other purposes. A reasonable amount of oak wilt was known from the Rochester area plus a few trees in and near Mankato. The area south of Mankato was surveyed from the roads down to the Iowa border. Although there were dead and dying oaks, none were confirmed as cases of oak wilt. Oak wilt was found on the hills along the Mississippi River in the Lake City and Wabasha areas and from there north, in several locations.

Oak wilt has been common in the Twin Cities area east to the St. Croix River and on into Wisconsin. The disease extends west of the cities for several miles involving much of Hennepin County. The southern suburbs such as Burnsville and Eagan, have had major problems with oak wilt.

For many years after first finding oak wilt in the late 1940s the disease had been identified as far north as North Branch and west toward St. Cloud but not in St. Cloud or further west. Recently oak wilt has been causing tree losses near Cambridge and was reported from Mora in 1988. As of 1989, we assume the disease in Minnesota extends from

Wisconsin west to the St. Cloud area, south to Iowa, and north to Mora. The incidence is very restricted north of Highway 95 at this time.

Oak wilt has been present outside of the above described area but in most of these outlying areas, the disease has disappeared or has not been observed in recent years. Oak wilt was found in the City of Brainerd and the fungus was isolated from a tree near Brainerd in the 1950s. Based on the assumption that oak wilt was present in that part of Minnesota, the fungus was used as a way of clearing red oaks from a red pine plantation near Brainerd. The fungus was highly efficient in clearing the unwanted oaks and did not spread from the inoculated trees.

The fungus was used also as a means of eradicating undesirable oak stands in Chisago County, where oak wilt was already commonly present. It has also been successfully used as a selective silvicide in several other locations. In all cases, the fungus killed the undesirable trees and did not spread.

More recently in Aitkin County an infection center of oak wilt was found involving 64 oaks. All of these trees died and no oak wilt has been found in the last few years even though many oaks were present nearby. In this case it was confirmed that the fungus was introduced on firewood brought from the Twin Cities, obviously from oak wilt infected trees, undoubtedly containing fresh mats of the fungus. This is similar to what presumably happened in the Upper Peninsula of Michigan. Firewood was hauled from the Milwaukee area to a recreation area of the Upper Peninsula, west of Stephenson, resulting in more than 20 separate infection centers. Apparently the many centers occurred because firewood with the oak wilt fungus was offered to several neighbors.

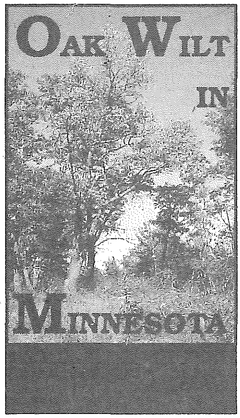
Over the years there have been reports of oak wilt in other parts of Minnesota, however, none were confirmed. At one time extensive oak mortality occurred in Cass County and surrounding counties. When investigated, there was no evidence of oak wilt. Based on circumstantial evidence, the mortality was ascribed to insect damage caused by walking sticks and at least two other insects which consumed oak foliage.

The fact that oak wilt has not spread when brought to more northerly areas of Minnesota suggests that possibly the vectors of the fungus are not able to transmit the fungus. Another explanation is that fresh wounds were not available in these areas. This is doubtful because oaks are commonly pruned at the time when spread could occur. The picnic beetles *(Nitidulidae)* occur throughout Minnesota, but their activity may not be coordinated with the availability of spores produced by the fungus. The oak wilt fungus does survive and sporulate in northern Minnesota, but does not spread as in areas to the south. We know little about grafting of oaks in northern Minnesota, but it is reasonable to question whether this is a factor because most trees become infected via common roots between infected and adjacent trees.

Even though oak wilt seems unable to cause continuing losses in oak stands in northern Minnesota, we should take steps to prevent the introduction or spread of the fungus in that direction. Also, based on what we now know, we should be able to eradicate oak wilt and prevent its spread northward.

As a result of drought conditions, there was extensive mortality of oaks in 1977. In the area south of New Ulm, many oaks died and were dying during the summer months. Most of the mortality occurred where the soil conditions were poor, mainly clay and gravel. The two-lined chestnut borer was commonly present but we found no evidence of oak wilt.

Thousands of oaks died in Minnesota as a result of the 1988 drought. Many people assumed oak wilt was involved because many of these oaks were located in areas where oak wilt was active. Although oak wilt was a factor, it was minor compared to secondary pests encouraged by the drought. Oaks which had been pruned to clear power lines were especially vulnerable to drought. In some locations, almost every tree on the north side of these cleared lines had either been killed or severely damaged due to increased exposure. In the Brainerd area, as much as 50% of oak in thinned stands died in 1989. Most of this damage was caused by the two lined chestnut borer.



Oak Wilt Survey

Need for the Oak Wilt Survey

It is important to know where oak wilt presently exists if we are planning an effort to limit this disease to an inconsequential factor in urban and timber forests of the state. It is critical that we document its present distribution and in future years be able to monitor its spread. Eradication of diseased trees in non-historic locations would greatly reduce the chance of oak wilt spreading still further north. It is also important, through an education program, to limit spread by people unknowingly carrying inoculum into new regions. Gradually all outlying infection centers can be eliminated, thus reducing the threat of spread to healthy stands.

With up-to-date, reasonably accurate information on where oak wilt exists, it will be possible to design a control program that will maximize the results. Isolated infection centers with potential for further spread because of the availability of susceptible hosts should have high priority. Also, outlying infection centers should be controlled to keep the fungus confined more to southeastern Minnesota, essentially in and around the Twin Cities.

Aerial Photography

Between July 5 and July 27, 1988, an area approximately 1,620 square miles in size lying east to northwest of Minneapolis and St. Paul was aerially photographed for the detection of oak wilt. The area, comprised of 44 geographic townships[1], includes northern Ramsey County, central and northern Washington County, portions of southern and western Chisago County, all but the southwestern corner of Anoka County (from the southern portion of the city of Anoka to Columbia Heights), southern and central Isanti County, southeastern Sherburne County, and a small portion of northern Wright County. The photography was taken by the Minnesota Department of Natural Resources Division of Forestry using a 35 mm Nikon F3 with Kodak 2443 color infrared film and a Tiffen 15 filter. Photo scale was 1:15,840, with a photo format of 5 x 7 inches.

The photography was interpreted by Westfield Aerial Photography (Walker, Minnesota) with the objective of locating every oak wilt infection center

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[1]A geographic township, as defined by the U.S. Public Land Survey System, is a 36-square-mile area denoted by township and range numbers; e.g., T.33N., R.24W. This differs from the definition of a township as a political unit which, like a city or a village, has a local governing body and a name; e.g. Oak Grove Township. The boundaries of a political township may correspond with those of a geographic township, as Oak Grove Township corresponds with T.33N., R.24W. This is not always the case; T.34N., R.24W., for example, is comprised of portions of the city of St. Francis in Anoka County and Stanford and Athens Townships in Isanti County. The distinction between geographic and political townships should be kept in mind when reading the Results section of this report.

consisting of three or more trees. Depending on exposure, a healthy tree in the photographs appeared dark-red to pink while a stressed tree was yellow to white and a dead tree greenish-to-bluish-gray[2].

Infection centers were characterized by location, size (measured to 0.1 acre with 1.0 acre being the smallest infection center for which size was recorded), and number of dead and dying trees. The interpretive criteria for determining if a group of dead or dying trees should be attributed to oak wilt included the following:

1) Were the trees oaks? Oak identification was reasonably easy in areas dominated by pure or mixed stands of oak; however, identification in areas where oaks were not the dominant cover type was more difficult.

2) Was the tree mortality caused by high water levels? The period from 1982 to 1986 was characterized by higher-than-normal precipitation[3], dead trees on the perimeter of a low area were assumed to have been the result of flooding.

3) Did the site have the characteristics of an oak wilt infection center? Because the fungus causing oak wilt is primarily transmitted through root grafts, infection centers are somewhat circular, with dead trees in the center and wilting trees around the perimeter.

4) Were other infection centers nearby? Overland transmission of the fungus, particularly by Nitidulid beetles, results in the creation of new infection centers in the vicinity of existing centers.

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[2] Westfield, L. M. Personal Communication.

[3] Unpublished report on file at Borlaug Hall, University of Minnesota, State Climatology Office, St. Paul, Minnesota.

Maximum Nitidulid flight range has been estimated to be 5 miles, but most beetles will not move that far.

The 35 mm slides with suspected infection centers were projected on the USGS topographic maps where the infection centers, now re-scaled (to match the map scale), were recorded. From October 22, 1988 to March 30, 1989 findings were ground truthed by the University of Minnesota in portions of southern and northwestern Anoka County, southwestern Isanti County, and northern Wright County as representative of the total area photographed in 1988. Results of the field checks, including errors of commission and omission as well as actual number of diseased trees in infection centers of 1.0 acre or less, were provided to the interpreter to enhance subsequent survey accuracy.

After interpretation, the information was digitized using Arc Info software. Use of this software results in accurate calculation of infection center size. It also permits great flexibility in handling the data, including scaling the output to any desired scale, highlighting any number of infection centers (including number of trees, area of center and legal description of location down to a quarter of a quarter section), and generating output according to various political or organizational boundaries. Arc Info is presently the standard digital software used in Minnesota, which will permit exchange of the data with a number of public and private organizations.

Results

The aerial photography identified a total of 3,012 oak wilt infection centers containing 91,821 trees (Table 1). Of the total infection centers 1,055

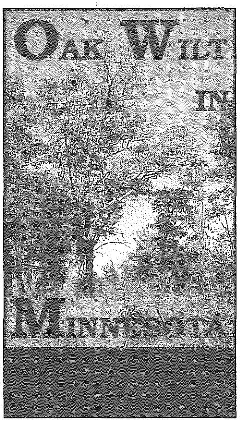
TABLE 1. Oak Wilt Statistics by County from the 1988 Minnesota DNR Aerial Photo Survey.

COUNTY	NUMBER OF INFECTION CENTERS	TOTAL ACREAGE	NUMBER OF TREES
ANOKA	1,351	2,816.0	62,357
CHISAGO	257	253.2	4,265
ISANTI	258	448.8	7,288
RAMSEY	87	38.4	783
SHERBURNE	508	980.0	11,309
WASHINGTON	551	469.8	5,819
WRIGHT	0	0.0	0
TOTALS	**3,012**	**5,006.2**	**91,821**

(approximately 35% of the total) covered an area of 1.0 acre or more, and totaled 5,006.2 acres, or approximately 7.8 square miles. This is slightly over one-fifth of a geographic township in size and accounts for 0.48% of the total surveyed area. The remaining 1,957 infection centers were less than 1.0 acre in area and their actual sizes were not recorded. The largest identified infection center (99.4 acres) is located on the eastern shore of Long Lake in Bradford Township, Isanti County.

Among counties, Anoka has the most infection centers (1,351) as well as having the greatest number of diseased trees (62,327) and the largest affected total area (2,816 acres) Table 1. No infection centers were found in Wright County where portions of 3 political townships comprise the relatively small area included in the survey.

Among units of local government (cities, villages, and political townships), as well as among geographic townships, Oak Grove Township in Anoka County leads in all categories: most infection centers (381), greatest number of diseased trees (27,230), and largest affected total area (1,306.0 acres) (Table 2 on page 23, and Table 3 on page 26). In addition to the area in Wright County, no infection centers were detected in 3 of the 4 geographic townships along the northern tier of the surveyed area (these areas correspond with the political townships of Wyanett and Cambridge in Isanti County and Fish Lake in Chisago County.



DISCUSSION

Survey Accuracy

The field check of Coon Lake Beach quadrangle, which included portions of East Bethel, Ham Lake, Linwood Township and Columbus Township, all in Anoka County, were still in progress when the interpretation phase of the project ended. Results of this field check were not used by the interpreter and provide the best means, at present, by which to evaluate survey accuracy.

The photo interpretation identified 75 infection centers in the Coon Lake Beach quadrangle. Of the 71 centers checked on the ground, 57 (80%) were confirmed as oak wilt and 14 were errors of commission (areas incorrectly identified as oak wilt). Commission errors resulted from cases of storm damage, oaks with symptoms of stress, dead or stressed tree of other species, and, in one instance, misinterpretation of the roof of a house. Field checks of other quadrangles also yielded commission errors resulting from Dutch elm disease and tree damage due to high water levels.

Nineteen errors of omission (infection centers confirmed on the ground that were not identified by photo interpretation) were located, some by chance and others by a careful reexamination of the photographs under direct sunlight. It should be noted that the latter approach led to additional errors of commission. Slightly over 25% of the omission errors were the result of instances in which most or all of the diseased trees in an infection center had been removed. Infection centers of this nature appear as open areas on an aerial photograph, and were most often found around single homes or in housing developments. Several other omission errors located in mixed forest stands consisted of diseased red oak and healthy white oak.

Infection centers less than 1.0 acre in size also were checked to compare the number of affected trees estimated by photo interpretation and number of trees counted on the ground. For example, 7 infection centers were identified by photo interpretation as consisting of 5 trees each. Field checks of these sites counted 4,5,5,5,9,13 and 75 trees (the latter being an instance of an infection center in which almost all of the trees had been removed). Six infection centers were identified on photos as containing 20 trees each, while a field check of these areas counted 5,10,16,20,20, and 31 trees.

In summary, photo interpretation of the Coon Lake Beach quadrangle identified 75 infection centers containing 1,140 trees, involving 58 acres. Taking into account errors of commission and omission, the ground check located 80 infection centers consisting of 2,343 trees covering 68 acres. Even these revised figures should be viewed as conservative estimates of the extent of oak wilt in this quadrangle, for neither the photo interpretation nor the field check attempted to locate younger infection centers consisting of only 1 or 2 trees. The field check, without doubt, also failed to locate some of the older and larger infection centers, particularly those in which many or all of the trees had been removed.

The Impact of Home Construction on the Spread of Oak Wilt

There is little doubt that a major cause of the proliferation of oak wilt in some parts of the surveyed area (portions of Anoka and Sherburne Counties, in particular) is the continuing population increase in these areas. New infection centers result from oaks being wounded in May and June during home construction, clearance for utility lines, road construction, yard maintenance, and recreation activities.

Home construction, with work often beginning in early spring, has become a recent focus of concern and speculation regarding the magnitude of its contribution to the spread of the disease. In an attempt to address this issue, evaluations were made of the probable origins of infection centers in portions of Blaine, Ham Lake, and East Bethel. Of 190 centers, 74 (39%) were judged as having a reasonable likelihood of resulting from construction activity.

This conclusion should be treated cautiously. It was reached by initially considering all infection centers that adjoined the boundary of a home or a yard. In a number of these cases, one or more other possibilities may explain the presence of oak wilt. These include tree pruning or wounding, the possibility that the home or development was built in an existing center[4] and the possibility that a nearby infection center expanded to the property where the home was located. In such instances, a judgement had to be made, often with insufficient evidence, regarding the most likely explanation of how the center started. Some of the infection centers initially attributed to home construction were dropped from consideration and perhaps others should have been. On the other hand, it was difficult to identify infection centers around homes where most or all of the trees had been removed.

Conclusions

Based on the results, aerial photography provides a reasonably accurate summary of the distribution and incidence of oak wilt. In years with more normal weather the accuracy of photographic detection would be greater. Also with the same personnel interpreting the photography, accuracy will increase. The errors of omission and commission are minimal and can be corrected by field personnel responsible for the actual program of control. The aerial photography provides a great deal of valuable information with minimal cost and time involved. Aerial photography would be espe-

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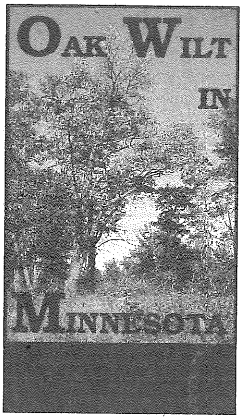
[4]Such an instance was observed on 2 occasions during the field check; once when a single home and the other time when homes were being built in an area that appeared on the photos as an infection center. In the case of the single home, all the trees had been removed and the resident had no knowledge of the presence of oak wilt on the site. In the latter, only scattered groups of dead trees remained on the perimeter of the infection center. In either case, without this knowledge, an evaluation of the site several years from now might well conclude that the oak wilt was the result of construction activity.

cially helpful in detecting new infection centers which threaten healthy stands of oak.

It is quite evident that photography needs to be done in early July before there is any change in foliage as a result of unfavorable weather or early senescence of the foliage. The oak wilt fungus moves slowly so photography can be done every five years.

Thus there is a system of detecting oak wilt and the next step is to establish a long range plan to reduce losses to oak wilt. It should be clear where the maximum advantage can be gained by concentrating control programs. Over a period of years subsequent surveys should demonstrate the reduction in losses to oak wilt. The ultimate goal, which is attainable, is to reduce oak wilt to an inconsequential factor in the oak forests of Minnesota.



Oak Wilt Distribution in Southeastern Minnesota Based on Aerial Sketch Mapping

Area Surveyed

In 1987 and 1988 southeastern Minnesota was aerially sketch mapped for oak wilt. In 1987 the southeast counties of Olmsted, Fillmore, Houston, Winona and Wabasha were mapped. In 1988 most of the 1987 lines flown over the memorial hardwood forest in the five southeast counties were rechecked for further verification and the remaining western and northern counties were surveyed. The additional counties added in the 1988 survey were

Mower, Dodge, Steele, Goodhue, Rice, Le Sueur, Dakota, Scott, Carver, Hennepin, Wright, southern Washington, and the eastern wooded areas of Nicollet, Sibley, McLeod, and Meeker counties.

The detection and mapping of oak wilt was accomplished from a Cessna aircraft flying at 1,500 feet above ground level on three mile flight lines. Two sketch mappers were used in the aircraft, each surveying and mapping for 1.5 miles north and 1.5 miles south over each flight line. Single wilting trees were not mapped. Suspect oak wilt centers consisted of two or more wilting trees associated with a pocket of existing mortality.

Survey Results

The total number of oak wilt infections across the southeast region is estimated to be 400-550 (Table 4, page 22). This is an estimate since not every mortality center mapped is expected to be oak wilt nor was every existing center detected. In Dakota County where the estimate is from 50 to 150 centers, the area mapped did not include Burnsville, Eagan, Apple Valley, and Inver Grove Heights. The commercial air traffic limited access and the disturbance is such that the cover type maps are no longer adequate, however numerous oak wilt infection centers in these areas were observed.

Throughout the southeastern region the highest concentrations of oak wilt are associated with northern pin oak forests on sandy sites with urban development. In Olmsted County, where 62 centers were detected, the majority were located in the greater Rochester area. Just southeast of Rochester, in southern Marion township, over 30 tentative centers were detected. This is an area of extensive pin oak on sandy soils with a recent history of urban development. This area is very similar to small areas across the southeast where one or more active centers were found. Throughout the more remote areas of the hardwood forest the incidence of oak wilt appears low in comparison.

TABLE 4. Incidence of Oak Mortality Centers in Southeastern Minnesota Counties 1987 & 1988 Aerial Survey.

County	Number of Oak Mortality Centers	
Carver	10	
Dakota	50-150?	Not including Burnsville, Eagan, Apple Valley and Inver Grove Heights
Dodge	3	
Fillmore	19	
Goodhue	29	
Hennepin	19	From Lake Minnetonka west, excluding eastern portion of county
Houston	32	
Le Sueur	6	
Mower	6	
Nicollet	3	
Olmsted	62	
Rice	19	
Scott	17	All located in eastern third of the county
Steele	1	
Wabasha	52	
Washington	18	South of 1988 aerial photography
Winona	50	
Wright	14	
Total Infection Ctr. 400-550		

TABLE 2. Oak Wilt Statistics by Municipality or Political Township from the 1988 Minnesota DNR Aerial Photo Survey.

COUNTY	MUNICIPALITY OR POLITICAL TOWNSHIP	NUMBER OF INFECTION CENTERS	TOTAL ACREAGE	NUMBER OF TREES
Anoka				
	Andover	257	457.3	9,734
	Anoka*	3	0.0	33
	Bethel	1	1.5	25
	Blaine	76	53.8	2,026
	Burnsville Twp	20	33.6	881
	Centerville	0	0.0	0
	Circle Pines	1	0.0	10
	Columbus Twp	39	21.2	769
	East Bethel	152	288.3	4,269
	Ham Lake	84	77.6	2,069
	Lexington	0	0.0	0
	Lino Lakes	28	19.7	741
	Linwood Twp	105	127.6	2,231
	Oak Grove Twp	381	1,306.0	27,230
	Ramsey	118	193.7	6,004
	St. Francis	86	235.7	6,335
Chisago				
	Branch	103	128.9	2,510
	Center City	0	0.0	0
	Chisago City	0	0.0	0
	Chisago Lake Twp	14	9.9	152
	Fish Lake	0	0.0	0
	Franconia Twp*	4	0.0	14
	Lent Twp	79	61.3	984
	North Branch	0	0.0	0
	Stacy	0	0.0	0
	Wyoming	9	0.0	62
	Wyoming Twp	48	53.1	543

TABLE 2. (continued)

COUNTY	MUNICIPALITY OR POLITICAL TOWNSHIP	NUMBER OF INFECTION CENTERS	TOTAL ACREAGE	NUMBER OF TREES
Isanti				
	Athens Twp	58	43.6	1,668
	Bradford Twp	72	160.2	1,766
	Cambridge	0	0.0	0
	Cambridge Twp	0	0.0	0
	Isanti	0	0.0	0
	Isanti Twp	7	15.7	410
	North Branch Twp	20	23.0	437
	Oxford Twp	11	15.1	185
	Spencer Brook Twp	6	73.8	170
	Springvale Twp	4	1.1	60
	Stanford Twp	80	116.3	2,592
Ramsey				
	Arden Hills	8	15.2	122
	Gem Lake	5	3.5	53
	Little Canada*	1	0.0	5
	Mounds View	3	0.0	18
	New Brighton	3	0.0	23
	North Oaks	35	14.2	277
	Shoreview	13	2.3	95
	Vadnais Heights	12	1.7	138
	White Bear Lake	5	1.5	39
	White Bear Twp	2	0.0	13
Sherburne				
	Becker*	0	0.0	0
	Becker Twp*	1	1.1	20
	Big Lake	2	0.0	15
	Big Lake Twp	175	410.0	4,409
	Elk River	207	326.2	3,523
	Livonia Twp	35	24.6	470
	Orrock Twp	86	217.6	2,859
	Zimmerman	2	0.0	13

TABLE 2. (continued)

COUNTY	MUNICIPALITY OR POLITICAL TOWNSHIP	NUMBER OF INFECTION CENTERS	TOTAL ACREAGE	NUMBER OF TREES
Washington				
	Afton	18	18.0	233
	Bayport	0	0.0	0
	Bayport Twp	14	5.5	144
	Dellwood	5	0.0	19
	Forest Lake	1	0.0	5
	Forest Lake Twp	24	41.2	367
	Grant Twp	68	22.4	521
	Hugo	55	39.5	657
	Lake Elmo	41	34.3	407
	Lakeland	0	0.0	0
	Lakeland Shores	0	0.0	0
	Lake St. Croix Beach	2	1.3	30
	Mahtomedi	19	13.4	170
	Marine on St. Croix*	12	6.3	76
	May Twp*	134	168.0	1,753
	New Scandia Twp*	42	22.0	302
	Oakdale	5	1.0	30
	Oak Park Heights	1	0.0	5
	Stillwater	1	0.0	4
	Stillwater Twp	52	73.3	595
	St. Mary's Point	0	0.0	0
	West Lakeland Twp	16	9.1	134
	Willernie	1	0.0	3
	Woodbury	35	12.9	332
Wright				
	Clearwater Twp*	0	0.0	0
	Monticello*	0	0.0	0
	Monticello Twp*	0	0.0	0
	Silver Creek Twp*	0	0.0	0

*Entire Municipality or political township was not surveyed.

TABLE 3. Distribution of oak wilt infection centers among the 44 geographical townships (ordered according to number of infection centers).

Location	Number of Infection Centers	Total Acreage	Number of Trees
T.33N., R.24W. **(Oak Grove Twp.)**	381	1,306.0	27,230
T.32N., R.24W. **(Andover Twp.)**	249	449.2	9,425
T.33N., R.26W. **(Elk River)**	207	326.2	3,523
T.34N., R.24W. **(St. Francis/Standford Twp./Athens Twp.)**	195	350.2	9,501
T.31N., R.20W. **(May Twp.)**	144	172.2	1,809
T.33N., R.27W **(Big Lake Twp.)**	140	360.1	3,396
T.32N., R.25W. **(Ramsey)**	129	201.8	6,346
T.33N., R.23W. **(East Bethel)**	116	145.2	3,065
T.35N., R.21W. **(Branch Twp.)**	103	128.9	2,510
T.30N., R.21W **(Grant Twp.)**	96	37.4	734
T.34N., R.27W. **(Orrock Twp.)**	86	217.6	2,859
T.32N., R.23W. **(Ham Lake)**	84	77.6	2,069
T.34N., R.21W. **(Lent Twp.)**	79	61.3	984
T.34N., R.22W. **(Linwood Twp./Oxford Twp.)**	77	116.9	1,901
T.31N., R.23W. **(Blaine)**	77	53.8	2,036

TABLE 3. (continued)

Location	Number of Infection Centers	Total Acreage	Number of Trees
T.35N.,R.24W. (Bradford Twp.)	72	160.2	1,766
T.34N., R.23W. (East Bethel/Athens Twp.)	59	157.1	1,780
T.33N, R.21W. (Wyoming Twp.)	57	53.1	605
T.31N., R.21W. (Hugo)	55	39.5	657
T.30N., R.20W. (Stillwater)	54	73.3	604
T.30N., R22W. (Northwestern Ramsey Co.)	49	15.4	430
T.29N., R21W. (Lake Elmo)	48	35.3	448
T.32N., R.20W (New Scandia Twp.)	44	24.1	322
T.33N., R.22W. (Linwood Twp./Columbus Twp.)	41	25.8	535
T.33N., R.28W. (Becker Twp./Monticello/Monticello Twp.)	38	51.5	1,048
T.30N., R.23W. (Northeastern Ramsey Co.)	38	23.0	353
T.34N., R.26W. (Livonia Twp.)	37	24.6	483
T.32N., R.22W. (Columbus Twp.)	37	21.2	749
T.28N., R.21W. (Woodbury)	35	12.9	332
T.29N., R.20W. (Baytown Twp./West Lakeland Twp.)	30	14.6	278

TABLE 3. (continued)

Location	Number of Infection Centers	Total Acreage	Number of Trees
T.31N., R.22W (Lino Lakes)	28	19.7	741
T.32N., R.21W. (Forest Lake Twp.)	25	41.2	372
T.33N., R.25W (Burns Twp.)	20	33.6	881
T.35N., R.22W. (North Branch Twp.)	20	23.0	437
T.28N., R.20W. (Afton)	20	19.3	263
T.34N., R.20W (Chisago Lake Twp.- North)	9	6.2	87
T.33N., R.20W. (Chisago Lake - South/Franconia Twps.)	9	3.7	79
T.34N., R.25W. (St. Francis/Stanford Twp.)	7	32.9	543
T.35N., R.23W. (Isanti Twp.)	7	15.7	410
T.35., R.25W. (Spencer Brook Twp.)	6	73.8	170
T.36N., R.24W. (Springvale Twp.)	0	0.0	0
T.33N., R.29W. (Becker/Silver Creek/Clearwater Twps.)	0	0.0	0
T.36N., R.25W. (Wyanett Twp.)	0	0.0	0
T.36N., R.23W. (Cambridge Twp.)	0	0.0	0
T.36N., R.22W. (Fish Lake Twp.)	0	0.0	0