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**PLANT PATHOLOGY**

# *Detecting Oak Wilt by False Color Infrared Aerial Photography*

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ABSTRACT — An aerial survey using false-color infrared film at scales of 1:9,600 and 1:12,000 located 93.7% of the oak wilt infection centers in the 1,500-acre study area. The ground survey of the same area also located 93.7% of the infection centers but half of those found by this method were difficult to relocate because they were not correctly mapped. Whereas aerial survey usually missed only trees of small diameter, the ground survey missed trees as large as eight inches in diameter.

Oak wilt, caused by *Ceratocystis fagacearum* (Bretz) Hunt, is a long-established and widely distributed tree disease in the Upper Midwest. It causes widespread depreciation of property values, particularly in suburban areas where red oaks are often the primary shade tree species. Red oaks are killed rapidly by this fungus, dying within a few months after symptoms become evident. The fungus also can kill white oaks, although these species may survive for a year or longer after symptoms appear.

Present control methods require one or more complete ground surveys each summer so that all of the infected red oaks can be detected and removed before spores are produced the following spring to cause new infections. The spores are produced on mycelial mats which develop between the wood and bark. Although a detection and removal program does not eradicate the disease, it does reduce annual losses and helps to provide time for introduction of other tree species as replacements for the oaks. Complete ground coverage is, of course, slow and expensive. If ground crews are not well versed in the use of maps, given locations are often erroneous and the diseased trees are not eradicated. Also, since the disease first becomes apparent in the very top of the tree, observation from the ground may miss trees which are just beginning to wilt.

## Comparison of survey methods

A portion of the Village of North Oaks, a suburb of St. Paul, was selected for comparison of aerial survey with inspection from the ground as a means of detecting infected trees. This community is well suited to such a comparison because of the large number of oaks (approximately 75,000) and the incidence of oak wilt, which has ranged from 236 to 284 infected red oaks annually since 1963.

Stereoscopic aerial protographs were taken, using Kodak Ektachrome Infrared Aero Film, Type 8443, a Zeiss RMK A 15/23 9x9-inch format camera, and a Wratten 12 filter, at scales of 1:9,600 (1″ = 800′) and 1:12,000 (1″ = 1,000′). Two survey flights were made over the area by Mark Hurd Aerial Surveys during the first week of August, 1967. The developed film strips were viewed over a light table with a scanning stereoscope, and the suspected diseased trees were marked on acetate overlays placed over the color transparencies. Two photo interpreters, without prior ground experience in the study area, each examined both the 1:9,600 and the 1:12,000 scale photography for a total of four interpretations of the community. Once the annotation of the acetate overlays was complete, a black and white internegative was made from each color exposure so that regular black and white contact prints could be produced. A photo mosaic was then prepared from black and white contact prints and the locations of suspected trees were transferred from the acetate overlays to the mosaic for use in checking the trees from the ground.

The essential part of the system is the film and filter combination. This false-color, reversal type film, when used with a minus-blue filter, is sensitive to the green, red, and near-infrared portions of the spectrum. Healthy vegetation, having a high reflectivity in the infrared wave

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TABLE 1 — Percentages of infection centers correctly located, those missed, and those incorrectly located.

| Method of survey | Correctly located (%) | Completely missed (%) | Incorrectly located (%) |
|---|---|---|---|
| GROUND SURVEY | 43.7 | 6.3 | 50.0 |
| AERIAL SURVEY* | | | |
| Photo interpretation I (1:9,600) | 60.7 | 39.3 | |
| Photo interpretation II (1:9,600) | 75.9 | 24.1 | |
| Photo interpretation III (1:12,000) | 70.5 | 29.5 | |
| Photo interpretation IV (1:12,000) | 58.0 | 42.0 | |
| Combined results of the four photo interpretations | 93.7 | 6.3 | |

* Each photo interpretation represents the analysis of one scale of photography by one of the two photo interpreters.

lengths, appears red. Leaves under water stress (as in oak wilt) have lost most of their infrared reflectivity. Consequently, such leaves appear in various shades of green. All such trees were marked for checking on the ground.

The ground survey was completed between 21 August and 4 September so as to include as many of those trees infected during 1967 as possible, without involving a second survey. The survey was accomplished by four men, trained in detecting oak wilt, but having no knowledge of the results of the aerial survey. Once the ground survey was completed, results of the two were compared. Where differences were noted, both aerial and ground survey personnel made ground inspections.

The ground crew spent 118 man hours completing the regular survey. Each of the four photo interpretations took approximately 6 hours. Verification of the photo interpretations consumed about 60 hours. The two photography flights and the photo mosaic for the study area cost about $400.

### Relative accuracy of the surveys

The percentage of infected trees detected and the accuracy of their location as determined by both survey methods are in Table 1. The ground survey missed 7 infection centers (6.3 per cent) and, because of inadequate mapping procedures, incorrectly located 56 infection centers or 50 per cent of the total. Aerial survey, when the results of the four interpretations are combined, located 105 or 93.7 per cent of the infection centers correctly. Of the 305 points marked on the photographs as possibly being infected with the oak wilt fungus, 200 or 65.6 per cent were either some species other than red oak or had been damaged by some other agent (Table 2).

### Analysis and Conclusions

These results indicate that oaks dying of oak wilt can be detected by aerial photography using false-color infrared film and a scale of 1:12,000. Although the individual interpreters on any one trial located only 58 to 76 per cent of the infection centers, all but 6.3 per cent were

TABLE 2 — Percentages of various phenomena identified on the photographs as possible oak wilt infected trees.

| Percentage by category | | Totals |
|---|---|---|
| Red oak infected with oak wilt | 34.4 | 34.4 |
| Storm damaged trees | 17.1 | |
| Trees dead more than one year | 18.0[a] | |
| Other species | 13.4[b] | 65.6 |
| Construction damage | 4.3 | |
| Unknown | 12.8 | |
| | | 100.0 |

[a] Red oak dead more than one year will not have mycelial mats produced on them and thus need not be eradicated.

[b] Other species includes white oak and burr oak, on which mycelial mats are not produced.

correctly identified and located by the combined efforts of two interpreters, each interpreting once, each scale of photography. Equal or better success should be attainable with only one interpreter and one scale of photography as experience is gained in looking for oak wilt. The trees which were missed were usually small understory trees (some less than 1 inch in diameter). Few spores are likely to be produced on these, and they represent less infection hazard than large trees. Generally, these small infected trees occur with larger trees which can be more easily detected. By coincidence, the ground survey crews missed exactly the same percentage of known infection centers (6.3 per cent) although several of these contained larger trees up to 8 inches in diameter.

The advantage of aerial photography in locating diseased trees (virtually to the exact tree or group of trees) is demonstrated by the fact that some 50 per cent of the original ground locations were inaccurate, so much so that is was often difficult to relocate them.

As indicated in Table 2, several other phenomena were marked on the photographs as possible diseased trees. Some 65.6 per cent of the suspected trees proved not to be wilted red oak, but with experience it should be possible to separate oak wilt from most of these other phenomena most of the time.

The effect of differences in scale of photography on interpretation success was small in this study. As indicated in Table 1, the success between interpreters varied considerably more than the success between scales of photography. Other scales need to be evaluated, but it appears clear that a scale of approximately 1:12,000 can be used successfully. Alternate filter systems also may enhance the efficiency of detecting oak wilt.

The usefulness of any such technique depends, of course, on its ability to produce equal results for a lower cost or better results at an equal cost. In a pilot study of this sort the cost figures are not too meaningful, particularly with respect to the photo coverage. In an operational system, however, a single interpretation should be adequate, and verification cost should be sharply reduced. Nevertheless, the cost figures for this aerial survey compare quite favorably with cost of the ground survey, indicating that the aerial method will probably find increasing use.