Aerial Survey for Oak Wilt Incidence at Three Locations in Central Texas

D. N. APPEL, Assistant Professor, Department of Plant Sciences, and R. C. MAGGIO, Assistant Professor, Department of Forest Science, Texas A&M University, College Station 77843

ABSTRACT

Appel, D. N., and Maggio, R. C. 1984. Aerial survey for oak wilt incidence at three locations in central Texas. Plant Disease 68:661-664.

Color-infrared aerial photography was used to survey oak mortality and identify oak wilt centers in central Texas. The highest incidence of oak wilt was found in the 38,850-ha Kerrville-Bandera site, where 1,007 mortality centers comprising 3,749.6 ha of dying or dead oaks were delineated. A random sample of these centers indicated 86% could be attributed to *Ceratocystis fagacearum*. In the 58,559-ha Austin site, 109 mortality centers were found. Of 16 randomly selected centers visited, six in the Austin site were caused by oak wilt. Oak wilt was not found in the 38,870-ha Fredericksburg-Johnson City site. Species affected by oak wilt in central Texas include *Quercus virginiana*, *Q. fusiformis*, *Q. texana*, *Q. marilandica*, *Q. stellata*, *Q. sinuata* var. *breviloba*, and *Q. glaucoides*. Bole sampling for isolation of *C. fagacearum* was consistently more successful than branch sampling. Veinal necrosis and tipburn were the symptoms most reliable for diagnosis of oak wilt on live oaks.

Widespread mortality of live oak (*Quercus virginiana* Mill. and *Q. fusiformis* Small) and Spanish oak (*Q. texana* Buckl.) in central Texas has been a problem periodically since 1934 (14,20). Several pathogens and diseases have been reported responsible, including root rot (15), viruses (5), Hypoxylon canker incited by *Hypoxylon atropunctatum* (Schw. ex Fr.) Cke. (18), oak decline incited by *Cephalosporium* spp. (18,20), and oak wilt incited by *Ceratocystis fagacearum* (Bretz) Hunt (7). Recently, *C. fagacearum* was isolated from diseased trees throughout a large portion of central Texas (1,7,9). No comprehensive surveys have been made to define the incidence of oak wilt in Texas or determine whether *C. fagacearum* is responsible for the widespread oak mortality found there.

Of the various survey methods available, the advantages of vertical color-infrared (CIR) aerial photography (16) make it well suited for detecting oak mortality. Vertical aerial photography can cover large areas in a short time at relatively low cost. Aerial CIR has proven feasible for detecting oak wilt (17). For these reasons, vertical aerial photography was chosen to detect oak mortality and estimate losses in three selected study areas in central Texas. Extensive field and laboratory diagnoses were then conducted to determine the diseases responsible. This paper summarizes the results of that survey.

Accepted for publication 16 April 1984 (submitted for electronic processing).

MATERIALS AND METHODS

Three study sites, comprising a total of 136,279 ha, were chosen for complete coverage with CIR aerial photography. Each site (I, II, and III) is located in or on the edge of the Edwards Plateau region of west central Texas (Fig. 1). The Edwards Plateau is a hilly outcrop composed of vegetation characterized as juniper-oak-mesquite savanna interspersed with short grasses. Oaks of the Edwards Plateau include live oaks, Texas red oak or Spanish oak, post oak (*Q. stellata* Wang.), blackjack oak (*Q. marilandica* Muenchh.), shin oak (*Q. sinuata* var. *breviloba* (Torr.) C. H. Mull.) and Lacey oak (*Q. glaucoides* Marc. & Gal.).

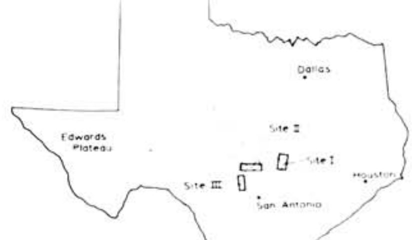

Fig. 1. Map of Texas with aerial survey sites I (Austin), II (Fredericksburg-Johnson City), and III (Kerrville-Bandera) delineated. Site I is 58,559 ha, site II, 38,870 ha, and site III, 38,850 ha.

Photography was done with a model 15/23 RMK Zeiss camera with a 15.24-cm focal-length lens, Wratten No. 89B filter, and Kodak infrared 2443 film. A photographic scale of 1:12,000 on a format of 22.86 × 22.86 cm was used for maximum detection of oaks in urban and rural locations. All photographs were made between 1000 and 1400 hours CST on cloud-free days. Site I (Austin flightline) was photographed on 17 August 1982, site II (Fredericksburg-Johnson City flightline) on 27 July 1982, and site III (Kerrville-Bandera flightline) on 28 July 1982.

The CIR-positive transparencies were interpreted with the unaided eye. Dead oaks were delineated as polygons on frosted acetate overlays, transferred to U.S. Geological Survey topographic maps (scale of 1:24,000), and numbered sequentially. Mortality centers in each site were then randomly selected for diagnosis and visited during February through September 1983.

If the cause of mortality was unknown or oak wilt suspected, samples for laboratory diagnosis were removed from trees. Branch samples greater than 3 cm in diameter and 15–20 cm long were taken from symptomatic limbs on diseased trees. Boles were sampled by removing the bark and chiseling sapwood strips from the tree. All samples were stored in ice chests and refrigerated until processed in the laboratory. Wood chips removed from the samples were soaked in 20% Clorox for 0.5–2 min and placed on potato-dextrose agar (PDA) prepared from fresh potatoes. Plates were retained for 21 days or longer at room temperature and observed for the appearance of suspected pathogens.

Such factors as construction injury and herbicide damage were also considered potential incitants of decline and/or death of trees. Mortality centers were visited a maximum of three times to determine causality. Areas selected for diagnosis but containing no dead oaks were considered errors of commission in photointerpretation.

RESULTS

On the CIR aerial photographs, healthy live oaks appeared dark red (Fig. 2). Initial wilting and partial defoliation caused the tonal signature to change from dark red to reddish gray, whereas totally

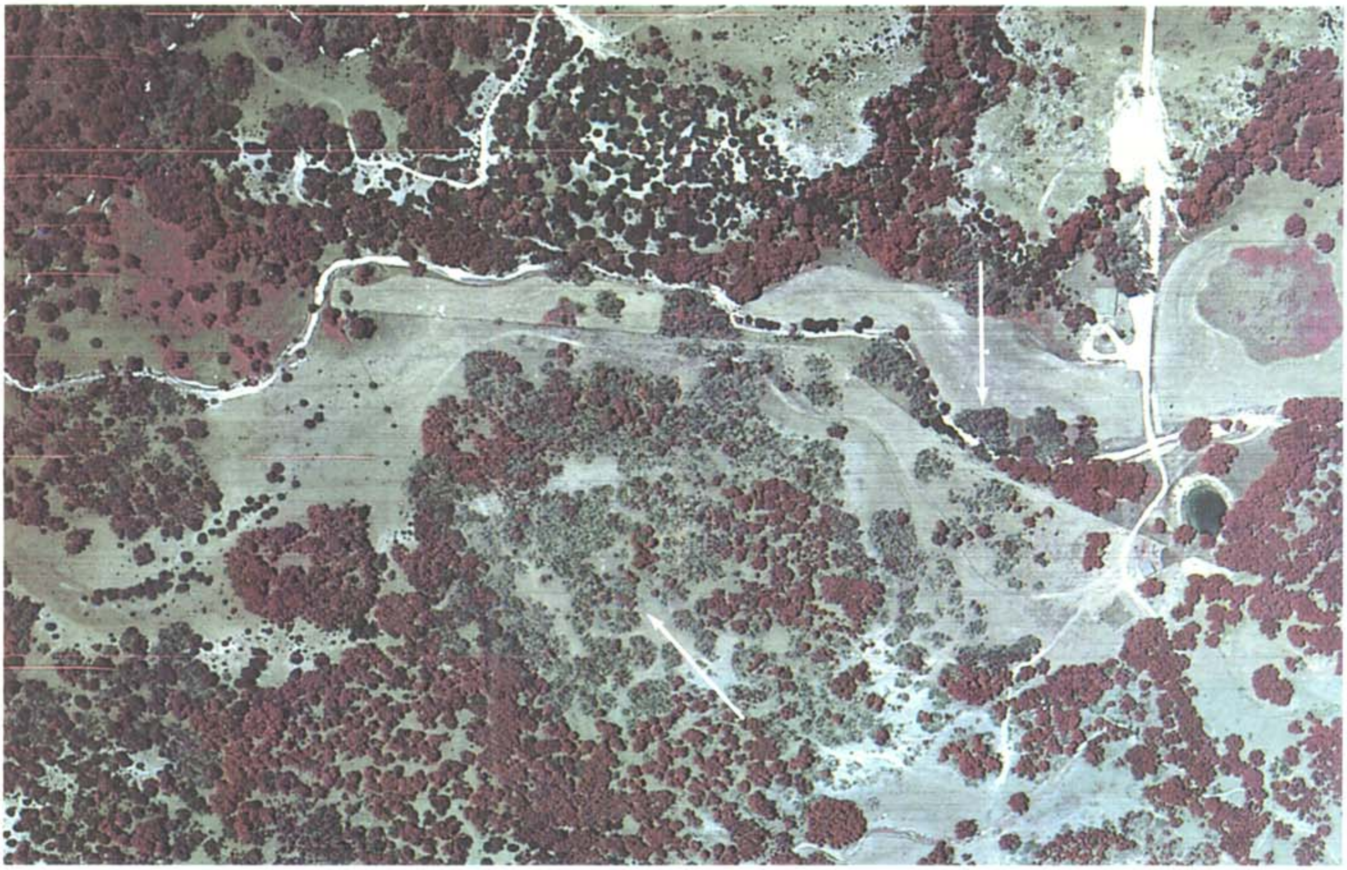

Fig. 2. Color-infrared aerial photograph (original photo 1:12,000) of an oak wilt center near Bandera, TX (site III). Dead, defoliated trees appear gray-green and healthy oaks appear deep red. Arrows show pink trees with current infections and surviving, partially defoliated live oaks in the center of the infection center.

Fig. 3. Common oak wilt symptoms on live oak in Texas. Both **(A)** veinal necrosis and **(B)** tipburn are found, with the former being the most consistent.

defoliated trees appeared gray. Individual polygons were difficult to delineate in large areas of concentrated mortality. Also, the density of susceptible trees was often different from one area of mortality to the next. The total area of mortality, and number and sizes of individual polygons, therefore varied between photo missions.

Mesquite was the tree species most frequently misclassified as dying live oak. Mesquite and cedar cut for range improvement also resembled dead live oaks but could be distinguished by the heights of the downed trees. Individual live oaks were difficult to distinguish because of root sprouting and the clumping habit of the trees.

In total, 1,126 polygons were delineated in the three sites. Site III contained both the greatest combined mortality, comprising 3749.6 ha or 9.6% of the total site (Table 1), and the largest individual mortality polygons. The smallest number of polygons was found in site II, comprising only 0.2% of the total area. In site I, 425.7 ha, or 0.7% of the total area, were delineated as having oak mortality.

Sixteen of the 109 polygons in site I were selected for diagnosis. Six were suspected to be caused by oak wilt and four were confirmed by isolation of *C. fagacearum* (Table 2). Six polygons were either inaccessible or errors of commission, and four were composed of declining trees damaged by construction activities and improper application of herbicides. Forty-three of the 1,009 polygons in site III were visited. Oak wilt was the suspected cause of mortality at 37 polygons, or 86% of the total (Table 2). Twenty-five of these were confirmed by isolation of *C. fagacearum* or the discovery of mat scars on Spanish oak (1). Mats were never found on live oak. Four of the polygons in site III were either errors of commission or inaccessible. At two locations, site disturbances incited tree decline. *Hypoxylon atropunctatum* was a contributing factor at most sites of oak decline and also was commonly found colonizing oaks with oak wilt.

Veinal necrosis and tipburn proved to be the most reliable symptoms for diagnosis of oak wilt in live oak (Fig. 3). Symptoms also included wilting, chlorosis, and leaf mottling. *C. fagacearum* was isolated with greater success from bole samples than from branch samples in February and August (Table 3). During May and July, *C. fagacearum* was isolated with similar frequency from branch and bole samples. The best record for confirmation of oak wilt was during July, when an average of 2.5 samples was removed from each tree and 48% of the trees sampled were confirmed. The lowest confirmation rate was in February, when an average of 1.6 samples were removed from each tree and only 3 of 19 trees were confirmed.

All *Quercus* spp. on the Edwards Plateau showed susceptibility to *C. fagacearum*. Post oak seemed most resistant, whereas live oaks and Spanish oak were most susceptible. Dying post oaks were rarely found in active oak wilt centers. A total of 57 oak wilt centers were found in sites I and III. These centers included randomly selected polygons and intentionally visited locations and ranged from 0.4 to 51.4 ha. No active oak wilt centers were found in site II.

DISCUSSION

The highest oak wilt incidence occurred in the Kerrville-Bandera area (site III). Eighty-six percent of a random sample of mortality selected from the aerial survey of site III was diagnosed in the field as oak wilt (Table 2). Field diagnosis was based on specific foliar symptoms on live oak (10) (Fig. 3) or the occurrence of fungal mat scars on Spanish oak. On the basis of this survey, in 1982, oak wilt was causing mortality in 866 infection centers on 3,244.7 ha in site III. Although these figures could vary with the photointerpreter's system of delineation, they are sufficiently precise to verify that an intense oak wilt epidemic is being sustained in the Kerrville-Bandera area of central Texas.

There is also considerable oak wilt in the urbanized Austin area (site I), although the level is not nearly as high as in site III. Several oak wilt centers in and around Austin have been visited since the original diagnosis and are known to be expanding rapidly. The valuable live oak population in site I warrants continued survey to determine whether an oak wilt epidemic similar to the proportions found in site III has begun. As might be expected in a rapidly growing metropolitan area, construction and site disruption are responsible for much of the oak mortality in site I. Oak wilt was not found in the Fredericksburg-Johnson City area (site II), but its proximity and similarity to site III make it vulnerable to future losses. Large, discreet oak wilt centers have been visited and diagnosed between sites II and III outside the flightlines of the survey (Fig. 1).

Of the 57 oak wilt centers visited in sites I and III, laboratory confirmation was successful for only 38 locations after one or two visits. Similar difficulties in isolating *C. fagacearum* from diseased live oaks have been encountered previously (19). Increasing the number of samples taken from diseased trees improved the chance of isolation in this study (Table 3). Bole sampling also proved more successful than branch sampling for isolation of *C. fagacearum* during February and August. These are the two months of greatest temperature extremes on the Edwards Plateau and *C. fagacearum* may not be able to survive as well in small branches as in the tree bole (3). Lewis (8) found that *C. fagacearum* survived in live oak boles even though the ambient temperature was 37.8 C. Temperatures on the Edwards Plateau often exceed 32 C, a temperature that limited survival of *C. fagacearum* in infected oak seedlings, standing trees, and oak logs (6). It is likely that temperatures higher than 32 C would eradicate the fungus from small branches in the crowns of diseased, defoliated trees.

Besides making isolation difficult, high temperatures might also account for the survival of some apparently susceptible live oaks within active oak wilt centers (Fig. 2). Tainter and Ham (13) reported that high temperatures may debilitate *C. fagacearum* colonizing turkey oaks (*Q. laevis* Walt.) in South Carolina. As a result, tree resistance mechanisms are able to inhibit advanced colonization and the tree survives. Most live oaks in Texas, however, die within 3–12 mo of initial symptom development. Therefore, high temperatures alone are not sufficient to limit the southern spread of *C. fagacearum*. The biocontrol properties of *H. atropunctatum* (12), a common inhabitant of dying oaks in central Texas, also do not appear to significantly limit fungal spread.

Some factors responsible for the oak wilt epidemic in central Texas can be identified. Oak wilt incidence in other states is related to host abundance, especially in areas where frequent root-grafting occurs (11). Large, homogeneous oak stands exist in the Kerrville-Bandera site, probably the result of tree encroachment onto grassland prairies after fire control, overgrazing, and preferential thinning (2,4). Live oak, a predominant tree species in the upland plant communities of the Edwards Plateau (21), readily regenerates via root sprouts. These factors allow for efficient local spread of *C. fagacearum* through

Table 1. Photointerpretation results for survey of oak mortality at sites I (Austin), II (Fredericksburg-Johnson City), and III (Kerrville-Bandera) in Texas

Area	Total size (ha)	Polygons delineated[a]	Hectares delineated	Area delineated (% of size)	Range in size of polygons (ha)
Site I	58,559	109	425.7	0.7	0.12–56.7
Site II	38,870	10	81.3	0.2	0.81–25.0
Site III	38,850	1,007	3,749.6	9.6	0.20–120.0

[a] Polygons consisted of dead and dying oaks delineated on color-infrared aerial photographs.

Table 2. Ground-diagnosis results for survey of oak mortality at sites I (Austin), II (Fredericksburg-Johnson City), and III (Kerrville-Bandera) in Texas

	Site I		Site II		Site III	
	Number	Hectares[a]	Number	Hectares	Number	Hectares
Randomly selected polygons visited	16	35.4	7	47.8	43	156.7
Commission errors and inaccessible polygons	6	12.9	3	12.2	4	11.8
Suspected oak wilt centers	6	14.9	0	0	37	136.0
Confirmed oak wilt centers	4	12.3	0	0	25	119.9
Decline polygons	4	7.6	4	35.6	2	9.0

[a] Polygons consisted of dead and dying oaks delineated on color-infrared aerial photographs.

Table 3. Isolation of *Ceratocystis fagacearum* from branches and boles on symptomatic oaks during 4 mo in Texas

	Month sampled			
	Feb.	May	July	Aug.
No. of trees sampled	19	44	29	14
Avg. no. of samples/tree	1.6	1.4	2.5	3.6
No. of trees positive for *C. fagacearum*	3	10	14	6
Positive isolation ratio, branch samples	0	0.17	0.39	0.13
Positive isolation ratio, bole samples	0.29	0.13	0.44	0.67

common root systems. In addition, Spanish oak forms a significant component of the oak population, and when infected, it supports mat production for insect contamination and long-distance spread. The combination of these factors may have created conditions suitable for intensification of oak wilt.

This is the first report of *C. fagacearum* colonizing *Q. fusiformis, Q.glaucoides,* and *Q.sinuata* var. *breviloba*. There are several oak species in the Trans-Pecos region of western Texas for which the susceptibility to the oak wilt fungus is unknown. Although the spread of *C. fagacearum* has proven erratic, oak wilt still constitutes a serious threat in areas previously considered safe from the disease.

ACKNOWLEDGMENTS

This work is the result of a cooperative cost-share project supported by the USDA Forest Service, Southern Region, Forest Pest Management Group, the Texas Forest Service, and the Texas Agricultural Experiment Station.

LITERATURE CITED

1. Appel, D. N., Fox, T., and Drees, C. F. 1983. The occurrence of oak wilt in Texas. (Abstr.) Phytopathology 73:883.
2. Bray, W. L. 1904. The timber of the Edwards Plateau of Texas; its relation to climate, water supply, and soil. U.S. Dep. Agric. Bur. For. Bull. 49. 30 pp.
3. Bretz, T. W., and Morison, D. W. 1953. Effect of time and temperature on isolation of the oak wilt fungus from infected twig samples. Plant Dis. Rep. 37:162-163.
4. Buechner, H. K. The range vegetation of Kerr County, Texas, in relation to livestock and white-tailed deer. Am. Midl. Nat. 31:697-743.
5. Dunlap, A. A., and Harrison, A. L. 1949. Dying of live oaks in Texas. Phytopathology 34:715-717.
6. Houston, D. R., Drake, C. R., and Kuntz, J. W. 1965. Effects of environment on oak wilt development. Phytopathology 55:1114-1121.
7. Lewis, R. 1977. Oak wilt in central Texas. (Abstr.) Proc. Am. Phytopathol. Soc. 4:225.
8. Lewis, R. 1981. Interior tree temperatures favor *Ceratocystis fagacearum* survival during summer in Texas. (Abstr.) Phytopathology 71:236.
9. Lewis, R., and Oliveria, F. L. 1979. Live oak decline in Texas. J. Arboric. 11:241-244.
10. Lewis, R., Oliveria, F. L., and Walterscheidt, M. J. 1983. How to identify and suppress oak wilt in live oak and Texas red oak. U.S. Dep. Agric. For. Serv. South. For. Exp. Stn., New Orleans. 2 pp.
11. MacDonald, W., and Hindal, D. 1981. Life cycle and epidemiology of *Ceratocystis*. Pages 113-144 in: Wilt Diseases of Plants. M. E. Mace, A. A. Bell, and C. H. Beckman, eds. Academic Press, New York. 640 pp.
12. Schmidt, R. A. 1978. Diseases in forest ecosystems: The importance of functional diversity. Pages 287-315 in: Plant Disease. An Advanced Treatise. Vol. 2. J. G. Horsfall and E. B. Cowling, eds. Academic Press, New York. 436 pp.
13. Tainter, F. H., and Ham, D. L. 1983. The survival of *Ceratocystis fagacearum* in South Carolina. Eur. J. For. Pathol. 13:102-109.
14. Taubenhaus, J. J. 1934. Live oak disease at Austin. Tex. Agric. Exp. Stn. Annu. Rep. 47:97-98.
15. Taubenhaus, J. J. 1935. Live oak disease at Austin. Tex. Agric. Exp. Stn. Annu. Rep. 48:49-50.
16. Toler, R. W., Smith, B. D., and Harlan, J. C. 1981. Use of aerial color infrared photography to evaluate crop disease. Plant Dis. 65:25-31.
17. Ulliman, J. J., and French, D. W. 1977. Detection of oak wilt with color IR aerial photography. Photogramm. Eng. Remote Sens. 43:1267-1272.
18. Van Arsdel, E. P. 1972. Some cankers on oaks in Texas. Plant Dis. Rep. 56:300-304.
19. Van Arsdel, E. P., Bush, D. L., and Kaufman, H. W. 1975. A comparison of *Cephalosporium diospyri* from Texas oaks with *Ceratocystis fagacearum*. (Abstr.) Proc. Am. Phytopathol. Soc. 2:142.
20. Van Arsdel, E. P., and Halliwell, R. S. 1970. Progress in research on live oak decline. Plant Dis. Rep. 54:669-672.
21. Van Auken, O. W., Ford, A. L., Stein, A., and Stein, A. G. 1980. Woody vegetation of upland plant communities in the southern Edwards Plateau. Tex. J. Sci. 32:23-35.