The Proceedings of the 2nd National Oak Wilt Symposium

Edited by:

Ronald F. Billings
David N. Appel

Sponsored by

International Society of Arboriculture – Texas Chapter

Cooperators

Texas Forest Service
Texas AgriLife Extension Service
The Nature Conservancy of Texas
Lady Bird Johnson Wildflower Center
USDA Forest Service, Forest Health Protection

2009

THE TEXAS COOPERATIVE OAK WILT SUPPRESSION PROJECT: LESSONS LEARNED IN THE FIRST TWENTY YEARS

Ronald F. Billings
Forest Pest Management
Texas Forest Service
College Station, TX 77840
Email: rbillings@tfs.tamu.edu

ABSTRACT

Live oaks (*Quercus virginiana* and *Q. fusiformis*), prized in central Texas for their stately beauty and welcomed shade, are being threatened by a destructive disease – oak wilt, caused by *Ceratocystis fagacearum*. In 1988, the Texas Forest Service (TFS), the USDA Forest Service, Forest Health Protection (USFS/FHP) and others initiated the Texas Cooperative Oak Wilt Suppression Project. For twenty years, this project has been managing the oak wilt problem through unique partnerships and local cooperation. Goals of the Suppression Project have focused on increasing public awareness about oak wilt, identifying and mapping active oak wilt infection centers, and partnering with landowners to contain oak wilt spread. More than 2 million dollars of federal cost shares have been delivered to participating landowners since 1988 as an incentive to treat expanding oak wilt centers. To date, the Suppression Project has installed more than 3.4 million feet (648 miles) of trenches to control 2,466 oak wilt centers. Of these , 2,156 centers (87%) were cost shared with $2.1 million of federal funds. An economic analysis has documented that the $9.2 million of federal, state, city, and private funds invested in the Suppression Project have yielded an average benefit:cost ratio of 6:1 and saved Texas communities an estimated $55 million in tree removal, replanting, and fungicide costs. Achievements in public awareness also have been substantial. An Internet web page devoted to oak wilt management in Texas (www.texasoakwilt.org) has been developed, representing a partnership among various stakeholders. In an on-going effort, specialists with TFS and Texas AgriLife Extension Service have trained various groups of Master Gardeners/Master Naturalists and International Society of Arboriculture-certified arborists on the basics of oak wilt identification and management. These accomplishments and lessons learned in the last 20 years concerning operational management of oak wilt in Texas are summarized.

Key words: *Ceratocystis fagacearum,* disease management, propiconazole

Live oak trees *(Quercus virginiana* and *Q. fusiformis*) comprise a major component of rural and urban landscapes in central Texas and are highly regarded for their beauty, shade, and forage for wildlife. Widespread mortality of live oaks in central Texas has been recognized for many years (Taubenhaus 1934, Dunlap and Harrison 1949) and oak wilt, caused by *Ceratocystis fagacearum* (Bretz) Hunt, was officially diagnosed in Dallas in 1961 (Dooling 1961). But it was not until the late 1970s that this widespread mortality of oaks in central Texas was attributed to the oak wilt pathogen (Lewis and Oliveria 1979, Appel 1995). This realization sparked interest in research on this disease in Texas (Appel and Maggio 1984, Appel and Lewis 1985, Appel et al. 1989, Appel and Kurdyla 1992) and provided the impetus for two important cooperative projects initiated in the 1980s: the Texas Oak Wilt Demonstration Project (1982-1987) and the Texas Oak Wilt Suppression Project (1988-present) (Cameron and Billings 1995, Billings et al. 2001).

Conditions in central Texas have changed since the Suppression Project began. An increasing number of large ranches are being subdivided into 5-100 acre "ranchettes" as more people take up residence in this region of the state. Their presence not only increases property values but also increases the incidence and economic impact of oak wilt (see Rooni, this proceedings). Some 25 years of experience combating oak wilt in Texas have given the Texas Forest Service (TFS) a unique perspective on how to effectively manage this destructive pest problem.

DEVELOPMENT OF THE TEXAS OAK WILT SUPPRESSION PROJECT

Project Proposal

During the final year of the Texas Oak Wilt Demonstration Project, the TFS Forest Pest Control Section (now Forest Pest Management) developed an Oak Wilt Suppression Project proposal and submitted it to the USDA Forest Service, Forest Pest Management (now Forest Health Protection (USFS/FHP)) in September 1987 (see Cameron and Billings 1995 for details). The Suppression Project was initiated in June, 1988.

Technical Advisory Board

To provide project guidance and direction, a Technical Advisory Board was formed, consisting of key administrators and specialists with the USFS/FHP, TFS, Texas Agricultural Experiment Station (now Texas AgriLife Research), Texas Agricultural Extension Service (now Texas AgriLife Extension Service), the cities of Austin, Lakeway, Cedar Park and Round Rock, and a private tree care company. This advisory board first met in December 1987 to discuss the Project proposal and implementation process. Since then, membership has increased from 10 to 16 members and the board has met annually to review Project accomplishments and provide long-term direction.

Objectives

The primary goal of the Texas Oak Wilt Suppression Project is to minimize the spread of oak wilt in rural and urban areas of central Texas. Initially, objectives of the Project were to: 1) initiate and accelerate public awareness campaigns to educate urban and rural landowners of the oak wilt threat as well as prevention and suppression alternatives, 2) identify oak wilt centers in selected suppression areas using aerial surveys and contacts with local landowners, 3) assist with implementation of control treatments by providing technical assistance and federal cost-share funds for approved treatments, 4) conduct post-suppression evaluations to record the frequency of re-infections (breakouts) and assist with retreatments if necessary, and 5) develop and refine a computerized record-keeping system for cataloguing and summarizing detection, ground evaluation, and control information (Cameron and Billings 1995).

In recent years, additional objectives have been added. These include an economic analysis of SuppressionProject benefits and costs, conducting systematic aerial detection surveys over the most severely-infected counties, organizing and conducting the first National Oak Wilt Symposium (Appel and Billings 1995), offering field tours to highlight the economic impact of oak wilt and showcase Project accomplishments, initiating a webpage devoted to oak wilt management in Texas, and developing a long-range strategic plan for oak wilt management in Texas. During the last decade, in response to increasing public demands, Suppression Project

efforts have been expanded from three initially-targeted counties (Hood, Travis, Kendall) to more than 40 counties covering most of central Texas.

Organization

Cameron and Billings (1995) described the development and initial organizational structure of the Texas Oak Wilt Suppression Project. The Suppression Project currently is led by a project director at the Texas Forest Service headquarters in College Station, Texas. He is assisted by an administrative coordinator with TFS Forest Pest Management in College Station and a technical coordinator based in Austin. Field personnel gradually have been added to the project to carry out specific project objectives and to address increasing numbers of requests for assistance in key counties.

The seven oak wilt foresters currently involved in the Project devote 40-80% of their time to oak wilt and the remainder to coordinating and implementing other federal and state programs (forest stewardship, urban forestry, fire suppression). Four TFS urban foresters contribute 5 to 10% of their time toward implementing the Suppression Project. TFS secretarial staff members in Lufkin and College Station provide administrative support to field personnel. In addition, the city of Austin has one full-time oak wilt forester and two technicians to implement project objectives within the city limits and the city of Lakeway has employed an oak wilt forester since 2001. Both positions were initiated with support from Suppression Project partnership grants.

Funding

The USFS/FHP, Atlanta, GA provides federal funding (40% since 2006) for this cooperative suppression project while TFS (37%), city partners (3%), and private landowners in central Texas (20%) provide required matching funds. Federal suppression funds allocated annually for this project have ranged from $168,000 in FY 1988 to a high of $595,000 in FY 1995. In recent years, federal funds have leveled off at $400,000 to $500,000 per year. Each federal dollar is matched by cooperating agencies or private landowners. Thus, the total expenditure for this suppression project currently averages $1 MM to $1. 2 MM per year, including the State, City of Austin, and private landowner contributions. In recent years, federal suppression dollars for oak wilt have become increasingly difficult to capture, due to the longevity of the project (federal suppression projects seldom are funded for more than five consecutive years) and to competition for shrinking funds to address oak wilt in other regions and other major forest pests (e.g., southern pine beetle, gypsy moth, Asian longhorned beetle, emerald ash borer, etc.).

Control Tactics

The Texas Oak Wilt Suppression Project has a two-faceted approach to oak wilt management - prevention and direct control. Prevention is promoted through public education on proper timing of pruning and treating wounds on oak trees (Appel, Anderson and Lewis 1986, Camilli, Appel and Watson, this proceedings), elimination of potential fungal inoculum by destroying diseased red oaks, proper handling of firewood, use of propiconazole fungicide, and planting diverse and resistant tree species. Direct control procedures include detection, field evaluation, and control of expanding oak wilt centers (Cameron and Billings 1995). Project foresters work with individual landowners or neighborhood groups to identify the location of oak wilt center boundaries. If the infection center is well defined and considered containable, and the landowner is willing to implement the suggested control treatment, the Project forester conducts a cultural resource survey (Billings et al. 2001) and prepares a written oak wilt suppression plan. The plan,

together with an estimate of costs and a request for cost shares, is submitted for approval to the Project Director. Upon approval, the treatment is installed under supervision of the Project forester. After the treatment is completed, the landowner or neighborhood organization is reimbursed with federal funds for up to 40% of the treatment costs, not to exceed $1000 per single landowner or $5,000 per oak wilt center with multiple landowners.

Currently, the primary cost-shared control procedure involves installation of trenches, at least 4 feet deep, to prevent continual tree-to-tree spread of the fungus through interconnected live oak root systems. A variety of equipment has been used to install trenches, including rotary rock saws, belt trenchers, back hoes, and ripper bars. Rock saws and back hoes are most often used in urban areas. Ripper bars pulled by bulldozers were commonly used in rural areas prior to 1999, but were replaced by rock saws when the depth requirements were increased from 3 to 4 feet. Trenches should completely encircle the center or tie into natural barriers or recently-dug utility trenches. The trench is placed 100 feet in front of symptomatic trees; at least one apparently healthy "buffer" tree should be included between symptomatic trees and the trench. Trenches are refilled with soil immediately after installation. Trench inserts (Wilson, this proceedings) are available, but are not recommended due to the additional expense nor are they cost shared.

Whenever practical, especially in rural areas, it is recommended to up-root and dispose of diseased and apparently healthy trees inside the trenched area. This practice is seldom applied in residential areas, where fungicide injection of trees within the trench is a preferred option. Cost-share funds also can be used for the removal and disposal of symptomatic red oak trees to prevent fungal mat formation and to remove diseased live oaks in urban areas.

Root-flare injections with the fungicide propiconazole prevents many trees from developing severe disease symptoms, but this treatment does not prevent the oak wilt fungus from moving through the untreated root systems and spreading the disease through a stand of live oaks (Appel and Kurdyla 1992). Also, retreatments may be necessary because the effectiveness of the fungicide apparently does not last for more than two years. Therefore, the primary justification for incorporating propiconazole treatments in the Texas Oak Wilt Suppression Project from FY 1990 to 1996 was to provide landowners an incentive to incorporate fungicides in trenching operations designed to stop the spread of the disease. Cost-share funds or donations of free propiconazole (Alamo®) were applied solely to high-value non-symptomatic trees inside cost-shared trenches. Beginning in FY 1997, fungicides were no longer cost-shared by the Project or provided free by the manufacturer.

Oak Wilt Information System

To track Project activities and accomplishments, TFS designed and implemented a computerized record-keeping system (Texas Oak Wilt Information System or TOWIS) in 1988 (Cameron and Billings 1995). This record-keeping system was written in D-Base III for IBM-compatible microcomputers. Project personnel entered data on personal computers at each field station. They could access their records at any time to keep track of landowner names and addresses, treatment status, and detailed treatment information on individual infection centers. Current data were periodically sent from each field station via electronic mail or diskette to the TFS headquarters in College Station where the master records are maintained.

In 2003, TFS staff members created the new database Central Texas Geographic Information System (CTexGIS) which has replaced TOWIS. CTexGIS now houses the databases for oak wilt, the Forest Stewardship Program (FSP) and the Forest Land Enhancement Program (FLEP). This database is linked to the geographic information system ArcGIS® 9.2 to provide a seamless

integration of the temporal and spatial data. All staff foresters in central Texas were given training in use of both CTexGIS and ArcGIS® 9.2. Oak wilt data sets for a given forester are "checked out" periodically by the forester, added to or updated and "checked in" to the general database housed on a server in College Station. Through a series of queries or pre-programmed reports, project administrators and field foresters alike have ready access to data summaries for use in periodic reports, post-suppression and personnel performance evaluations, and economic analyses.

Digital Orthophoto Imagery

In FY 1997, implementation of Suppression Project objectives was greatly facilitated by purchase of digital color infra-red imagery (scale 1:40,000) of much of central Texas from EISYS, Austin, Texas. The imagery is provided on compact discs covering individual USGS 7 ½ minute quadrangles. The CDs will operate on microcomputers running Microsoft Windows 3.1, MS Windows 95, or MS Windows NT. With this resource, Project foresters have access to fairly recent (1995/1996) imagery with 1 m resolution. This digital imagery allows them to generate accurate treatment maps and to delineate the spatial distribution and abundance of available hosts in the treatment area. The CIR treatment maps are prepared with Arc-View software to highlight location of infected trees, planned trenches, existing roads and barriers, etc. These maps also are useful during post-suppression revisits to treatment sites as a means to accurately relocate old trenches. This imagery, now more than ten years old, is to be updated at the first available opportunity.

PROJECT IMPLEMENTATION AND ACCOMPLISHMENTS

Public Awareness of Oak Wilt

Suppression Project personnel are continually involved in efforts to make central Texas landowners aware of the oak wilt problem and available methods of diagnosis, control, and prevention. These efforts can be categorized as public presentations on oak wilt, media events, responses to daily telephone calls from concerned property owners, and individual on-site assists (Billings et al. 2001). Recently, a webpage specific to oak wilt in Texas (www.texasoakwilt.org) was initiated. This web page has been developed and is maintained as a partnership among the TFS, USFS/FHP (Region 8), Lady Bird Johnson Wildflower Center, National Biological Information Infrastructure, Houston Advanced Research Center and the International Society of Arboriculture, Texas Chapter (ISAT). This web page is becoming increasingly popular as a source of oak wilt information. For example, in a single month (March 2007), the web site received 79,000 hits and 19,000 page views. With success of the oak wilt webpage, the oak wilt telephone hot line, established in 1990 with support of the Lower Colorado River Authority (Billings et al. 2001), was discontinued in 2005.

To further promote public awareness of oak wilt and the Suppression Project, three illustrated circulars were published and widely distributed to interested landowners and neighborhood groups. These are titled *How to Identify and Manage Oak Wilt in Texas* (Appel, Filer and Cameron 1990, Appel et al. 2005), *Save Our Shade - A Guide to Cost-Sharing for Oak Wilt Control in Texas* (Texas Forest Service 1990), and *Partnerships and Cooperation Combat Oak Wilt in Texas* (Texas Forest Service 1999). A fourth circular entitled *Oak Wilt: A Guide to Identification and Management* (City of Austin 1994) was published by the City of Austin and

distributed by Project personnel. Also, a MS Power Point presentation and a portable photo display describing oak wilt and Project activities have been prepared for public presentations.

Project personnel, in cooperation with Dr. David Appel, Texas A&M University, organized and hosted the 1992 National Oak Wilt Symposium in Austin (Appel and Billings 1995) and the 1996 North American Forest Insect Work Conference in San Antonio (Billings and Nebeker 1996). In 2007, Project personnel assisted the ISAT with organizing and hosting the 2nd National Oak Wilt Symposium. The impact of oak wilt and Project accomplishments were highlighted in Symposium and Conference presentations and field trips.

Identification and Confirmation of Oak Wilt Centers

To date, oak wilt has been confirmed in six counties in west Texas and 55 counties in central Texas. The latter are located primarily along the Interstate-35 corridor from Dallas-Fort Worth to San Antonio (see Rooni, these proceedings). Detection of oak wilt centers by Project personnel is achieved by conducting aerial survey flights over predetermined areas or by responding to landowner inquiries (see Billings et al. 2001).

Control Accomplishments

Since the Suppression Project began in 1988, a total of 2,466 oak wilt centers have been treated with trenches extending for 3.42 million feet (648 miles or 1,037 km). Of these, 2156 centers (87%) involving 3.22 million feet of trench have been cost shared with federal funds; the remainder involved technical assistance from Project staff without cost shares. Based on feet of trench installed with Project cost shares since 1988, the top 10 counties receiving federal assistance to halt oak wilt spread have been Bosque, Gillespie, Travis, Bandera, Kendall, Williamson, Hays, Hood, Bell, and Kerr County (Table 1). Average cost per foot of trench over this 20-year period among these ten counties ranged from $0.50/foot in Bosque County (mostly rural centers) to $4.13/foot in Travis County (mostly suburban and urban centers). Interestingly, the average cost to install trenches has tripled since 1990, increasing from $1.34/foot for the period 1988-1990 up to $4.11/foot in 2007 for all land-use categories combined.

The cost of installing trenches to suppress oak wilt continues to increase (see McKinney and Billings (1995) for initial treatment costs) and varies markedly with land use classification. In FY 1998, for example, trenching costs ranged from an average of $0.60/ft in rural non-residential sites to $10/ft in urban sites. In suburban and rural residential sites, average trench costs were $2.68/ft and $1.11/ft, respectively (Billings et al. 2001). In comparison, the cost of installing trenches to suppress oak wilt in FY 2006 ranged from an average of $1.65/ft in rural non-residential sites to $22.45/ft in urban sites. In suburban and rural residential sites, average trench costs were $3.32/ft and $4.14/ft, respectively. The average cost of trench installation has increased in all land use categories but particularly in urban areas, where trench costs increased by more than $12/foot. The high cost to trench in urban sites reflects the inherent expenses and liability associated with underground utilities and street repairs.

Much of this increased cost was borne by participating urban landowners, since maximum cost shares paid per center were capped at $1,000 for single landowners and $5,000 for four or more landowners and the federal match was reduced to 40% to cover a state-mandated increase from 10.5% to 26% for indirect costs in FY 2005.

Annual accomplishments, based solely on centers treated and amount of trench installed, steadily increased through the first eight years as the Suppression Project grew in personnel and experience (Fig. 1). Since 1995, the annual amount of trenches installed by the Project has

declined to ca. 150,000 feet/yr (46,154 m/yr), due to various factors. These include reduced levels of cost share funds, increasing costs per foot of trench, increased government restrictions (i.e., cultural resources), shifting of Project emphasis to other objectives (post-suppression evaluations, aerial detection surveys, public awareness), and other demands on Project personnel (stewardship, fire suppression, urban forestry). Also, many of the small, accessible, and easily controlled centers have already been treated.

Through September 30, 2007, $2.5 million of federal cost shares had been reimbursed to participating landowners, representing 40% of the total costs of oak wilt treatments. The majority (80%) of these funds have been used for trenching, the primary means of halting the local spread of individual oak wilt centers in live oak stands. Other treatments receiving cost share funds include tree cutting (6%), uprooting trenches within the trenched area (4%), infected tree removal (6%), and fungicide treatments (4%).

Efficacy of Project Trenches

Procedures for conducting the post-suppression evaluation of Project trenches have been described previously (Gehring 1995). This evaluation has become an annual event to document efficacy of trenches, but is now limited primarily to those installed during the previous 3 years. In the fall of 1998, for example, Project personnel revisited oak wilt sites treated with cost-share funds from 1995 through 1997. The occurrence and frequency of breakouts on 571 oak wilt centers were evaluated in relation to feet of trench, month of installation, equipment type, and months since trench installation.

Results reveal that, on average, 76% of all trenches installed from 1994 to 1997 had no breakouts. Of 690 trenches installed between 1991 and 1994, 67% have had no breakouts. Breakouts, when they do occur, are most likely to become visible within 18-30 months after installation. Interestingly, frequency of breakouts did not seem to be related to month of installation or to equipment type. Breakouts were most often attributed to insufficient trench depth (e.g., roots present beneath the trench), rather than to roots reattaching or growing back across the trench. In the winter of 2008, a random sample of 121 trenches out of 356 trenches (34% sample) installed from 2002 – 2005 were revisited. Twenty-six breakouts were observed for a success rate of 79%. This is the first PSE where all trenches visited were at least 48” in depth and the increase in success is attributable to this increased depth (up to 5 feet (1.5 m) with rock saws and 12 feet (3.7 m) with back hoes) and the experience gained over the years in correct trench placement.

Partnerships

The Suppression Project has promoted and benefited from various partnerships. The City of Austin was a major partner in the Project from its initiation in 1988 until 2000, when city budget reductions caused the city to end its participation. In FY 1998, the council converted two temporary oak wilt positions to permanent ones, increasing the oak wilt staff to four persons. In 2006, the city hired an oak wilt forester and resumed participation in the Suppression Project. During the years the City of Austin served as a partner, the Project reimbursed Austin's Parks and Recreation Department (PARD) $25,000-30,000 for their staff's participation in the Project. Also, Austin's neighborhood associations and citizens were reimbursed up to 50% of their suppression costs for approved trenching projects and diseased tree removal. In 2007, the city opted to finance their oak wilt program entirely with city funds.

From 1989 through 2005, the City of Lakeway and Texas Forest Service personnel worked with 170 Lakeway property owners to install over 34,000 feet (10,462 m) of urban trenches. The

city hired its first forester in February 2001, with a partnership grant from the Suppression Project. During the five years that the city was a partner, nine trenches were installed with 95 cooperators totaling almost 18,000 feet (5,538 m). The grants gave Lakeway officials incentive to tackle the oak wilt problem head-on. The city council stepped up to the plate by increasing funding for oak wilt suppression every year despite rapidly rising costs. Feedback on the oak wilt program has been overwhelmingly positive. Many citizens have expressed the belief that they benefit directly from Lakeway's forestry program. After FY 2005, the city declined further partnership grants, opting to continue funding their oak wilt program entirely with city funds.

As described above, partnership grants also have been provided to the Lady Bird Johnson Wildflower Center and the Houston Advanced Research Center primarily to develop the Texas oak wilt web page (www.texasoakwilt.org).

Master Gardener/Master Naturalist/ISA Certified Arborist Training

In recent years, TFS Project foresters in central Texas have become overwhelmed with phone calls and inquiries concerning oak wilt, many of which do not result in cost-shared treatments. In recognition of this fact, a new approach was taken beginning in FY 2005 to increase the availability of volunteers trained in oak wilt detection, prevention, and control. Training sessions were offered to interested Master Gardeners and Master Naturalists as a means to increase public awareness and to serve as an interface between the public and TFS foresters. In FY 2006 and 2007, TFS staff foresters, in cooperation with Dr. David N. Appel, a recognized authority on oak wilt in Texas, continued these training sessions various locations throughout central Texas.

In other training sessions, several dozen certified arborists with the International Society of Arboriculture were trained in oak wilt diagnosis, prevention, and suppression procedures. Again, Dr. Appel, with the Texas AgriLife Extension Service, and various TFS Project foresters served as instructors for classroom and field training sessions for the certified arborist training. Upon successful completion of this intensive 2-day course, each participant is certified as a "Specialist in Oak Wilt."

It is anticipated that these volunteers will assist TFS Project foresters in screening oak wilt-related phone calls and verifying the presence of oak wilt via on-site visits. It is envisioned that such a cooperative partnership with Master Gardeners, Master Naturalists, and ISA Certified Arborists will facilitate the suppression project by reducing the time TFS foresters now spend responding to inquiries from the general public and local property owners.

Economic Analysis of the Project

In FY 1997, an economic analysis of the Texas Oak Wilt Suppresion Project was independently conducted by J. T. Gunter, previously a forest economist from Mississippi State University. Input information consisted of Project accomplishments (specifically trenching, tree removal, and fungicide injection treatments) and Project costs (salaries, benefits, operating expenses, contracts, cost shares, administrative expenses, and indirect costs) for the period FY 1990 through 1996. Rates and extent of spread, host densities, and average tree diameter data were taken from a previous economic analysis of the Project (McKinney and Billings 1995). Project efforts were divided into four different land use categories (urban, suburban, rural residential, and rural non-residential) as previously defined (McKinney and Billings 1995).

Benefits were computed based solely and conservatively on the basis of those dead tree removal and replanting costs avoided when oak wilt spread was halted in individual centers for 5 years by 1) trenching and diseased tree removal or 2) trenching, fungicide injection of trees

within the trench, and diseased tree removal. For each treated center, benefits were defined as the monies saved by a landowner by cooperating with the TFS to suppress the spread of oak wilt. In turn, costs were defined as the actual cost incurred by the Suppression Project to prevent further spread of the disease center, and incorporated Project operating and administrative costs.

No attempt was made to assess or include the value of the trees saved, as was done in an earlier analysis (McKinney and Billings 1995) or additional benefits (protecting real estate values, reducing air conditioning costs, etc.). Assumptions were that, if no trench was installed, oak wilt would continue to spread at 75 feet per year for 5 years, killing 85% of the oaks in the direction of spread (defined for purposes of this analysis as 50% (urban sites) to 75% (rural sites) of the circumference of the oak wilt center).

Based solely on dead tree removal and replanting costs avoided by halting oak wilt spread for 5 years, the average benefit cost ratios were 6, 14, 8 and 4:1 for urban, suburban, rural residential, and rural-non-residential sites, respectively. Based on fungicide injection, dead tree removal, and replanting costs avoided for five years with Project activities, benefit:cost ratios averaged 6, 16, 8 and 4 :1 for the same land use categories. The average benefit cost ratio for both scenarios was 6:1. This suggests that the Texas Oak Wilt Suppression Project is economically efficient. In other words, the $9.2 million of federal, state, local, and private funds invested in oak wilt suppression since 1988 has saved Texas landowners over $55 million in tree removal and replacement costs, exclusive of the many other benefits derived from keeping existing live oaks alive in the central Texas landscape.

LESSONS LEARNED

The Texas Cooperative Oak Wilt Suppression Project is unique among pest suppression projects in that it was initiated by the USFSW/FHP and the TFS in a region where neither agency previously had a strong presence. In the 20 years since the Project began, a professional staff has been established to assist private landowners over an extensive and expanding area in central Texas with education on oak wilt, detection and evaluation of infection centers, and implementation of control treatments with the assistance of cost-share funds. Through the dedicated efforts of numerous cooperating agencies, communities and individual landowners, central Texans are gradually learning to cope with this devastating disease. Furthermore, lessons the TFS and its cooperators have learned about managing oak wilt should benefit other states faced with this disease or other destructive pests affecting multiple ownerships.

Among the lessons the TFS has learned, both about the disease as it expresses itself in central Texas and about its management, are the following. Despite increased suppression, oak wilt may well be having a greater impact now in central Texas than it was having twenty years ago. This is due to the rapid increase in human population, property fragmentation, urban sprawl, increasing property values, and heightened value property owners now place on live oaks (see Rooni, this proceedings). Foresters working with the disease have learned that there is no typical oak wilt center. Each is unique, involves a different set of landowners with different values and resources, and may spread at widely different rates, thus complicating suppression.

Trench depth, placement, and tree removal within the trenched area are keys to successful suppression. Experience has shown that properly-placed trenches dug at least 4-feet (1.2 m) deep are usually effective for halting oak wilt spread, although failure (breakouts) somewhere along the trench is always a possibility and can be expected to occur in a third of the trenches. Most breakouts occur within two years, indicating poor placement or insufficient depth rather

than root grafting across the trench. Seldom do breakouts signify a complete trench failure – just a weak point that can be addressed with a follow-up trench around the breakout area.

Management of oak wilt is equivalent to management of people, since oak wilt is as much a people problem as it is a disease problem. Public education is essential and never ending. New residents, unfamiliar with oak wilt, continually move to the area and their activities often incite the disease (i.e., pruning in the spring, not painting pruning wounds, storing infected red oaks, not diagnosing the disease in early stages, etc.). The loss of prized shade trees to oak wilt often elicits the standard grief steps in affected property owners: shock, denial, guilt, anger, depression, resignation, acceptance, and finally, hope. TFS foresters have learned to help clients through these various stages, offering reforestation with diverse tree species as hope. A holistic stewardship approach to land management has proven most successful.

The Texas Forest Service, in cooperation with the USDA Forest Service and the Texas AgriLife Extension Service, has learned that partnerships are the key to addressing this forest health problem, be it through the oak wilt web page, Master Gardner/Master Naturalist training, or cooperation with arborists and oak wilt venders. Once enlightened about oak wilt, neighborhoods have taken amazing and myriad steps to seek cooperation, fund suppression, and address the problem.

Finally, sufficient and sustained program funding has been critical. Indeed, oak wilt suppression without money is just conversation. With the proper staff, dedication, resources, partnerships, knowledge, and long-term commitment, anything is possible. The Texas Cooperative Oak Wilt Suppression Project is proof of that.

ACKNOWLEDGEMENTS

The author expresses his gratitude to the many people and organizations which have generously contributed their time, energies, and resources toward making this suppression project a success. I especially thank the USDA Forest Service, the cities of Austin and Lakeway, and the Texas Forest Service for their continued support in obtaining and providing funding for this project; the USDA Agriculture Research Service for providing office facilities; the Texas AgriLife Extension Service and Texas AgriLife Research for their continued technical support, and the Lady Bird Johnson Wildflower Center, National Biological Information Infrastructure/Houston Advanced Research Center, and the International Society of Arboriculture, Texas Chapter for supporting the oak wilt web page. The highly qualified and motivated field and office staffs of the Texas Forest Service and the cities of Austin and Lakeway deserve special recognition and thanks. Finally, I wish to acknowledge the many private individuals who have contributed countless hours and personal resources toward extending public education efforts and establishing the numerous control treatments credited to the Suppression Project.

LITERATURE CITED

Appel, D.N. 1995. The oak wilt enigma: Perspectives from the Texas epidemic. Annual Review of Phytopathology 33: 103-118.

Appel, D.N., and R.F. Billings, eds. 1995. Oak Wilt Perspectives: The Proceedings of the National Oak Wilt Symposium, June 22-25, 1992. Austin, TX. Information Development, Houston, TX. 217 pp.

Appel, D.N., and T. Kurdyla. 1992. Intravascular injection with propiconazole in live oak for oak wilt control. Plant Disease 76: 1120-1124.

Appel, D.N., and R.L. Lewis, Jr. 1985. Prospects for oak wilt control in Texas, Pp. 60-68. *In*: R.A. Goyer and J.P. Jones (eds.), Insects and Diseases of Southern Forests. 34th Annual Forestry Symposium., Lousiana Agricultural Experiment Station., Louisiana State University, Baton Rouge, LA.

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

Appel, D.N., K. Anderson, and R. Lewis, Jr. 1986. Occurrence of nitidulid beetles (Coleoptera: Nitidulidae) in Texas oak wilt centers. Journal of Economic Entomology 79: 1276-1279.

Appel, D.N., T.H. Filer, Jr., and R.S. Cameron. 1990. How to identify and manage oak wilt in Texas. USDA Forest Service Southern Forest Experiment Station, New Orleans, LA. 2 pp.

Appel, D.N., R.C. Maggio, E.L. Nelson, and M.J. Jeger. 1989. Measurement of expanding oak wilt centers in live oak. Phytotopathology 79: 1318-1322.

Appel, D.N., R.S. Cameron, A.D. Wilson, and J.D. Johnson. 2005. How to identify and manage oak wilt in Texas. USDA Forest Service How-To SR-1, Southern Research Station, New Orleans, LA. 2 pp.

Billings, R.F., and E.T. Nebeker, eds. 1996. Proceedings: North American Forest Insect Work Conference. Texas Forest Service Publication 160. San Antonio, TX, April 8-12, 1996. 228 pp.

Billings, R.F., E.H.Gehring, R.S. Cameron, and J.T. Gunter. 2001. Current practices in managing oak wilt: Federal cost share programs, trenching, chemical injection, and the Texas Suppression Program, Pp. 117 – 129. *In*: C. L. Ash (ed.), Shade Tree Wilt Diseases: Proceedings fromWilt Diseases of Shade Trees: A National Conference. August 25-28, 1999, APS Press, St. Paul, MN.

Cameron, R.S., and R.F. Billings. 1995. The Texas Oak Wilt Suppression Project: Development, implementation, and progress to date, pp. 139-146. *In*: D.N. Appel and R.F. Billings (eds.), Oak Wilt Perspectives: The Proceedings of the National Oak Wilt Symposium, June 22-25, 1992. Austin, TX. Information Development, Houston, TX.

City of Austin. 1994. Oak wilt: A guide to identification and management. Austin Parks and Recreation circular, Austin, TX. 2 pp.

Dooling, O.J. 1961. Oak wilt identified in Texas. Plant Disease Reporter 45: 749.

Dunlap, A.A., and A.L. Harrison. 1949. Dying of live oaks in Texas. Phytopathology 39: 715-717.

Gehring, E.H. 1995. Evaluation of suppression project treatments, Pp. 147-154. *In*: D.N. Appel and R.F. Billings (eds.), Oak Wilt Perspectives: The Proceedings of the National Oak Wilt Symposium, June 22-25, 1992. Austin, TX. Information Development, Houston, TX.

Lewis, R., Jr., and F.L. Oliveria. 1979. Live oak decline in Texas. Journal of Arboriculture 5: 241 -244.

McKinney, C., and R.F. Billings. 1995. Economic analysis of oak wilt suppression in Texas, Pp. 155-160. *In*: D.N. Appel and R.F. Billings (eds.), Oak Wilt Perspectives: The Proceedings of the National Oak Wilt Symposium, June 22-25, 1992. Austin, TX. Information Development, Houston, TX.

Taubenhaus, J.J. 1934. Live oak disease at Austin. Texas Agricultural Experiment Station. Annual Report 47: 97-98.

Texas Forest Service. 1990. Save our shade, a guide to cost-sharing for oak wilt control in Texas. Texas Forest Service Circular 281. College Station, TX. 2 pp.

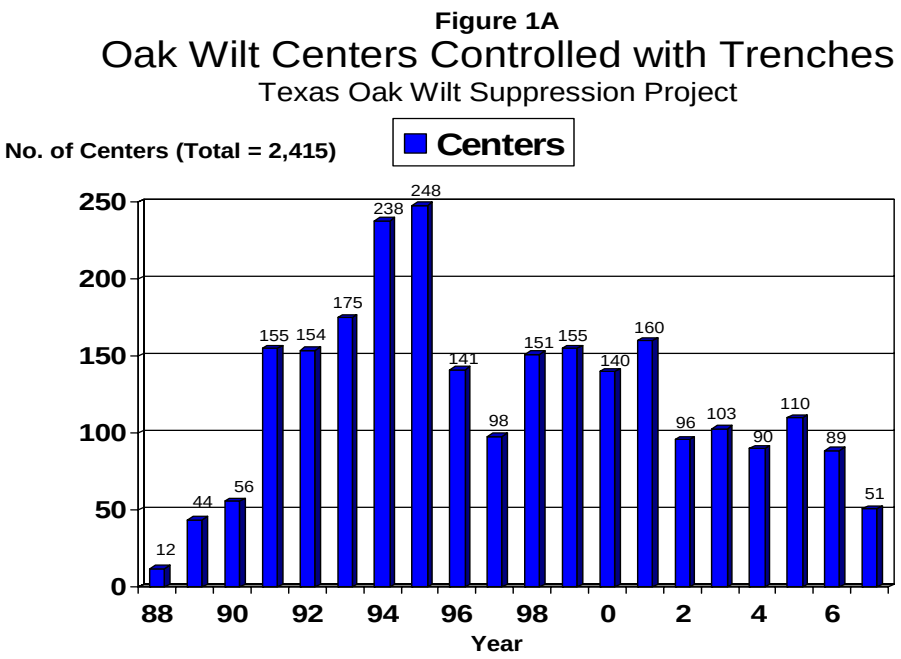
Texas Forest Service. 1999. Partnerships and cooperation combat oak wilt in Texas. Texas Forest Service Circular 303. College Station, TX. 2 pp.

Table 1: Summary of oak wilt cost-shared trenches by county in central Texas: 1988 – 2007.

County	Centers	Feet	Cost shares	Total costs	Cost/foot
Bandera	197	272,942	$82,260	$211,285	$0.77
Bell	67	102,265	$66,110	$147,309	$1.44
Bexar	22	36,068	$54,431	$165,676	$4.59
Blanco	39	63,432	$45,419	$113,303	$1.79
Bosque	291	368,951	$88,753	$185,313	$0.50
Burnet	34	75,677	$57,592	$154,104	$2.04
Caldwell	1	3,000	$2,500	$5,000	$1.67
Colorado	8	23,835	$14,301	$34,843	$1.46
Comal	12	32,912	$11,539	$20,613	$0.63
Comanche	15	23,625	$14,178	$31,070	$1.32
Coryell	67	81,560	$32,917	$69,034	$0.85
Dallas	1	675	$1,753	$3,505	$5.19
Erath	69	99,015	$23,638	$48,784	$0.49
Falls	3	4,900	$5,400	$12,200	$2.49
Fayette	12	22,310	$18,692	$38,769	$1.74
Gillespie	216	342,929	$132,694	$342,675	$1.00
Guadalupe	1	3,000	$4,500	$9,000	$3.00
Hamilton	42	48,740	$23,720	$48,823	$1.00
Hays	121	217,948	$246,949	$599,255	$2.75
Hill	1	500	$330	$826	$1.65
Hood	96	158,961	$59,609	$130,477	$0.82
Johnson	1	1,000	$675	$1,350	$1.35
Karnes	1	5,300	$2,500	$10,600	$2.00
Kendall	178	257,690	$165,207	$457,391	$1.77
Kerr	67	100,872	$51,749	$155,841	$1.54
Kimble	6	10,675	$7,350	$20,725	$1.94
Lampasas	30	44,785	$27,662	$64,302	$1.44
Lavaca	5	17,130	$7,709	$15,419	$0.90
Llano	1	1,000	$1,165	$2,330	$2.33
McClennan	37	30,095	$31,104	$58,175	$1.93
Mason	3	5,312	$5,236	$10,472	$1.97
Medina	10	15,898	$5,968	$13,782	$0.87
Mills	38	67,509	$21,207	$45,808	$0.68
Palo Pinto	2	2,800	$580	$1,160	$0.41
Parker	26	36,470	$14,755	$30,208	$0.83
Parmer	20	14,131	$19,304	$40,734	$2.88
Somervell	75	90,505	$25,629	$54,908	$0.61
Tarrant	5	5,840	$2,775	$4,450	$0.76
Travis	187	287,320	$455,416	$1,185,942	$4.13
Uvalde	2	6,000	$5,255	$20,075	$3.35

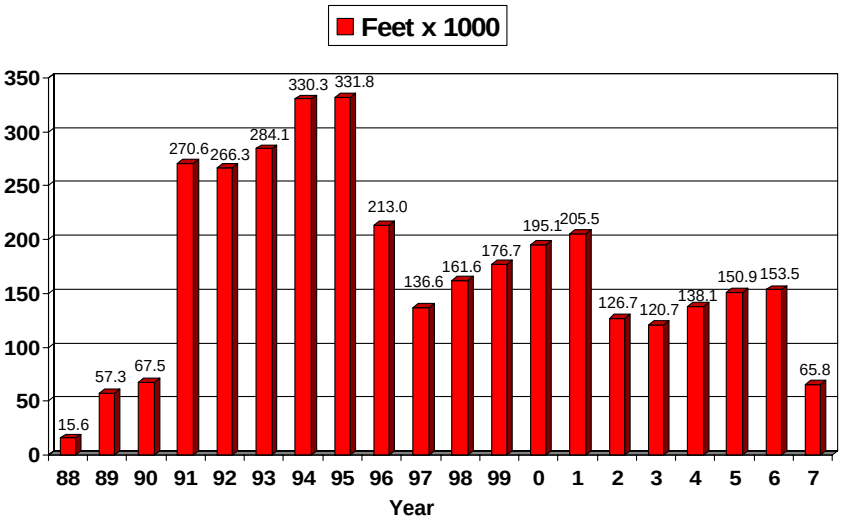
Washington	1	4,678	$2,500	$5,000	$1.07
Williamson	145	234,626	$273,883	$598,888	$2.55
Wise	1	800	$300	$713	$0.89
Total (43 counties)	2156	3,223,681	$2,115,214	$5,170,137	$1.60

Figure 1A



(includes non-cost shared trenches)

Figure 1B



Total = 3.42 million feet or 648 miles

Figure 1: Trenching accomplishments of the Texas Oak Wilt Suppression Project showing oak wilt centers treated (1A) and feet of trench installed (1B) with federal cost shares and/or technical assistance of Project personnel by federal fiscal year.