NATIONAL OAK WILT SYMPOSIUM

JUNE 4-7, 2007 • AUSTIN, TEXAS

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

OAK WILT RESEARCH AT FORT HOOD: INOCULUM SOURCES AT LANDSCAPE SCALE

Thomas A. Greene and **Charlotte M. Reemts**
The Nature Conservancy
P.O. Box 5190
Fort Hood, TX 76544
Email: tgreene@tnc.org

ABSTRACT

Fort Hood Military Reservation supports a large population of the endangered golden-cheeked warbler (*Dendroica chrysoparia*, GCWA). Oak-juniper woodland, dominated by *Juniperus ashei* and various hardwood species, notably Texas red oak (*Quercus buckleyi*), plateau live oak (*Q. fusiformis*), and Texas ash (*Fraxinus texensis*), serves as breeding habitat for this species. Oak wilt (causal agent: *Ceratocystis fagacearum*) infects Texas red oak in central Texas and is considered a threat to the GCWA because of its potential to degrade habitat. We have used and evaluated two methods of controlling oak wilt in GCWA habitat on Fort Hood. We have tested the efficacy of basal girdling of symptomatic Texas red oak stems over a 2-year period on Fort Hood for preventing the formation of new infection centers in GCWA habitat by reducing the formation of fungal mats. Although these efforts have been successful at reducing the numbers of fungal mats in our study areas, no overall reduction in infection rates has been noted. We suspect that most new infections in our study resulted from root-to-root transmission of the pathogen, which is not controlled by basal girdling. Approximately 11.2 km of trenches have been installed over the past 4 years to control oak wilt centers in live oak in and near GCWA habitat on Fort Hood. Trenching, though limited to relatively level sites and to infection centers in live oak, has been successful at controlling the spread of oak wilt in live oak in GCWA habitat. We characterized woody species composition and structure after the passage of an oak wilt disease front and tentatively conclude that Texas red oak regeneration is adequate to replace overstory losses due to oak wilt in the absence of overbrowsing.

Key words: *Ceratocystis fagacearum,* direct control, golden cheeked warbler

Fort Hood is an 87,890-ha U.S. Army installation located in Bell and Coryell counties, Texas. Land use on the installation includes mechanized and dismounted military training as well as grazing and recreation. Fort Hood is home to two armored divisions (1st Cavalry Division and the 4th Infantry Division [Mech]), as well as associated support and aviation units. Approximately 42,000 uniformed personnel are currently assigned to Fort Hood (GlobalSecurity.org 2006). Training activities associated with these units have multiple ecological effects on the installation. Mechanized training activities involving the 2,619 tracked vehicles and 11,932 wheeled vehicles on post, as well as those of visiting units, take place throughout the installation's training areas; however, large scale off-road maneuvering is largely restricted to the West Range training areas because of terrain limitations.

Soil disturbance from vehicle traffic maintains much of the vegetation on West Range and on accessible areas of East Range in early successional stages, and accelerates sediment transport and erosion on slopes. Recovery of vegetation between traffic events is slowed by historical soil loss, compaction, periodic drought, and current grazing practices. Areas which are inaccessible to vehicular traffic and/or are not used for other reasons tend to support later successional

vegetation. These areas include slopes, hilltops, riparian areas, and smaller, more isolated training areas. Ecological effectsof training in these areas are usually caused by dismounted activities including cutting of vegetation, construction of individual fighting positions ("foxholes"), and the like.

Training also greatly influences fire frequency and timing on Fort Hood. Incendiary devices, tracers, smoke generators, and other pyrotechnic training devices provide a near-year-round source of ignition. As a result, fire frequency in this area is almost certainly higher than historical levels. Training-related wildfires are a near-daily occurrence when conditions permit, requiring the allocation of significant resources for fire suppression to protect fire-sensitive endangered species habitat as well as structures and other high-value areas. Large expanses of grassland vegetation predominate in the Live Fire Area and especially in the permanently dudded area (PD94) at its center. Woody vegetation occurs only on relatively fire-sheltered portions of the terrain in this part of Fort Hood. Conversely, areas historically dominated by grassland in the training areas of East and West Fort Hood have fewer, less intense fires because of the effects of vehicle traffic and grazing on fuels. These areas either remain in early successional vegetation (annual weeds) due to frequent disturbance or are invaded by Ashe juniper (*Juniperus ashei*) in areas where disturbance is less frequent or intense.

Fort Hood lies within the Lampasas Cut Plains, a geological region characterized by mesa topography with wide valleys separating uplands capped by limestone (Johnson 2004). Narrow canyons occur on the margins of uplands throughout this region. Vegetation in the region has changed over the past two centuries as a result of land use changes. Presettlement vegetation on Fort Hood was probably characterized by Texas red oak-shin oak-Ashe juniper (*Quercus buckleyi-Q. sinuata* var. *breviloba-Juniperus ashei*) woodlands ("oak-juniper woodland"), oak savannas, and tallgrass prairies. Because of frequent fires, woodlands were restricted to rocky slopes and mesa tops where fine fuels were less abundant (Smeins 1980).

Small inclusions of post oak-blackjack oak (*Q. stellata-Q. marilandica*) woodlands occurred on lighter textured soils atop mesas (Diamond 1997). Valleys were historically dominated by grasslands with narrow forested riparian corridors. Land use changes after settlement by Europeans, notably the expansion of row-crop agriculture, the introduction of domestic animal grazing, systematic fire exclusion, and, most recently, disturbance associated with military training, have increased the cover of woody plants, especially *J. ashei*, at the expense of herbaceous communities (Smeins 1980, Van Auken 1993).

Mature oak-juniper woodlands, dominated by Ashe juniper and a variety of oak species, now cover approximately 24,000 ha on Fort Hood. These woodlands serve as breeding habitat for the federally-listed golden-cheeked warbler (*Dendroica chrysoparia*, GCWA). Fort Hood supports the largest known population of GCWA under a single management regime; current estimates of the population are above 5,000 singing males. GCWA depend on Ashe juniper bark for nest construction material and on hardwoods for foraging substrate (Ladd and Gass 1999). Loss of either of these components makes the habitat unsuitable.

Threats to the Fort Hood GCWA population include habitat loss through land use conversion and through wildfire. Ashe juniper lacks the ability to resprout after a fire, so intense fires have the effect of greatly reducing Ashe juniper cover in these communities. Therefore, although oaks and other hardwoods resprout fairly quickly, recovery of oak-juniper woodland from wildfire to the point where it is usable for golden-cheeked warbler breeding habitat may take several decades (Reemts and Hansen 2008). Oak wilt, caused by *Ceratocystis fagacearum* (Bretz) Hunt, has also been identified as a threat to GCWA because of its potential to degrade breeding habitat

by reducing the density of Texas red oaks. The US Fish and Wildlife Service has stated that oak wilt monitoring, research, and control should be a part of management activities for GCWA on Fort Hood (USFWS 2005). However, the extent and seriousness of this threat is unknown. In areas where excessive herbivory or other factors prevent regeneration of oaks (Van Auken 1993, Russell and Fowler 2002), the loss of mature Texas oaks to oak wilt would appear to present a real threat to habitat quality for GCWA. It is unclear whether oak wilt would similarly threaten GCWA habitat in areas where sufficient oak regeneration is occurring.

Oak wilt infects a broad range of oaks, but red oaks (subgenus *Quercus*, section *Lobatae*), including Texas red oak, are highly susceptible, while white oaks (subgenus *Quercus*, section *Quercus*) are generally more resistant and often recover from infection (Appel 2001). Oak wilt spreads over short distances through xylem connections between trees, either via common root systems or through natural root grafts. From a single infected tree the disease typically spreads through root systems to neighboring trees to form a disease center (Appel 2001). Long-distance transmission of oak wilt occurs primarily by insect-vectored transmission of spores (either conidia or ascospores) from fungal mats which form under the bark of infected, dying red oaks. Fungal mats typically form on a small proportion of red oaks during late winter and early spring which were symptomatic the previous summer. Beetles of the family Nitidulidae have been most commonly implicated as vectors (Appel, Anderson and Lewis 1986, Appel, Kurdyla and Lewis 1990, Juzwick 2001). These beetles are attracted to the fungal mats from which they transport spores to uninfected trees.

Oak wilt is common on Fort Hood, both in Texas red oak and in plateau live oak (*Quercus fusiformis*). Infection centers in both species threaten GCWA habitat, both because plateau live oak is an important component of the vegetation in many areas of GCWA habitat on the installation and because of the possibility that the disease will spread from plateau live oak to Texas red oak through interspecific root grafts. The oak wilt pathogen moves in both species via root connections, producing spreading disease centers which remain active for several years. The conditions on Fort Hood, including the presence of an endangered bird species which depends on susceptible oaks for its survival, as well as the unique mix of land uses that Fort Hood hosts, pose a series of questions for managers of GCWA habitat, and in particular, oak wilt in that habitat.

First, we wanted to know whether recommended methods for controlling and reducing oak wilt in endangered species habitat were effective. Basal girdling has been recommended for control of oak wilt fungal mat formation for many years (Morris 1955, Gillespie, Shigo and True 1957, Texas Oak Wilt Information Partnership 2007). The Nature Conservancy has been applying basal girdling to Texas red oak in GCWA habitat for the past 4 years in an attempt to limit the production of fungal mats in these areas. We tested the efficacy of this practice in Texas red oak populations on Fort Hood (Greene, Reemts and Appel 2009).

Second, at a larger scale, we have attempted to answer the question whether reducing fungal mat numbers actually decreases the amount of oak wilt in a stand in subsequent years. This effort will also be reported in Greene, Reemts and Appel (2009). Together, the answers to these questions will indicate whether oak wilt management on Fort Hood can be effective at preventing GCWA habitat degradation.

Finally, given that oak wilt is common in GCWA habitat on Fort Hood, it is important to characterize the vegetation regeneration after the Texas red oak overstory is removed by oak wilt. Understanding how oak wilt modifies the vegetation will provide insight into whether the

modified vegetation will be suitable habitat for GCWAs. We have made preliminary measurements in an attempt to answer this question.

EFFICACY OF BASAL GIRDLING

To test the efficacy of basal girdling to prevent fungal mat formation in oak wilt-infected, symptomatic Texas red oak stems, we conducted a study over three years in which randomly selected experimental units in three blocks were treated by either tagging and girdling all symptomatic Texas red oaks in two successive late-summer periods (2004 and 2005) or by tagging alone, without girdling. Experimental units ranged in size from 62 to 85 ha in size. We followed treatments with assessments in the early spring of the next growing season to determine presence and number of fungal mats. We tested two hypotheses: 1) that late summer basal girdling of symptomatic Texas oak reduces the formation of fungal mats in the following spring, and 2) that late summer basal girdling reduces the incidence of oak wilt symptom development during late summer of the year following the treatment. Procedures for this study are described in Greene, Reemts and Appel (2009).

Basal girdling significantly reduced the probability that a stem would produce fungal mats. The mechanism by which this treatment works is uncertain; evidence in the literature indicates that removing the bark may cause the dying tree to dry out before mats can form (Wilson 2005), or that mechanical damage to the bark introduces competing fungi (in particular, *Hypoxylon* spp.) which colonize the tree and competitively exclude *C. fagacearum* (Tainter and Gubler 1973, 1974). We also noted that stem diameter had a significant effect on the likelihood that a stem would form a fungal mat. Since smaller stems dry out more quickly, this piece of evidence seems to support Wilson's (2005) theory. However, we also observed abundant *Hypoxylon* fruiting structures on many treated stems and noted that these stems rarely formed *Ceratocystis* fungal mats.

When we surveyed our study areas after 1 and 2 years of treatment, we could not detect any treatment effect on overall incidence of oak wilt at the stand level. We suspect that basal girdling may not appreciably affect subsequent infection rates because of the comparative rarity of insect-mediated, spore transmission (which basal girdling could be expected to control) compared with transmission through root connections (which is not known to be affected by girdling). This finding led us to recommend that basal girdling be used sparingly in Texas red oak and only in conjunction with measures to control root-to-root transmission.

TRENCHING

Trenching with a rock saw to a depth of 1.5 m is widely practiced in the Edwards Plateau and has been demonstrated to be effective at controlling oak wilt infection centers in plateau live oak. However, this method of oak wilt control has some important limitations that restrict its use on Fort Hood. First, because of the machinery required to dig the trench, trenching is only feasible on level and gently sloping areas. Since many of the slopes on which GCWA habitat occurs on Fort Hood are steep and rugged, trenching is not an option there, both because of the machinery's limitations and because soil disturbance on steep slopes has the potential to cause erosion. In addition, trenching is quite expensive, and creates habitat breaks which may degrade habitat quality.

Despite these limitations, we have installed 11.2 km of trenches over the past 4 years at Fort Hood. All of the trenches have been deployed either in or near GCWA habitat around disease centers in plateau live oak. We have tried to keep the trenching machine on existing trails, even

if that meant sacrificing a few more live oaks to the disease center in some cases. Trenches have been largely effective at stopping the spread of *Ceratocystis* in plateau live oak stands; there has been only one breakover during the 4-year history of the program. We were able to enclose the resulting outbreak with a second trench the following year.

REGENERATION IN OAK WILT CENTERS

After passage of an oak wilt disease front in oak-juniper woodland, overstory cover is reduced and woody regeneration is released. This is especially true where fire or human disturbance has previously removed the juniper component, leaving coppice-regenerated hardwoods. Regeneration inside oak wilt centers in these areas is of interest for two reasons. First, successful Texas red oak seedling regeneration would perpetuate this component of the woodland into the next stand. Second, although work is underway to study the effect of fire on oak-juniper woodlands (Reemts and Hansen 2008), it is unknown how fire and oak wilt interact with this vegetation type.

In 2006, we examined vegetation on either side of a moving disease front in stands which consisted largely of Texas red oak sprouts of fire origin. Fire scar and tree ring analysis indicated that the stands originated after a 1988 fire and were thus 18 years old at the time we examined them. We measured overstory and regeneration in 3 pairs of nested plots systematically located behind and just ahead of active oak wilt disease fronts on Fort Hood. We estimated that Texas red oaks in the plots inside the oak wilt centers had died 2 to 4 years before the data were collected, based on the state of decomposition of the snags.

Before disease front passage, the basal area in these stands was 75% Texas red oak; the balance was composed primarily of relatively shade-tolerant understory species. Most common were redbud (*Cercis canadensis* var. *texensis*), Carolina buckthorn (*Frangula caroliniana*), and dogwood (*Cornus drummondii*) (Fig. 1). Overstory canopy cover was nearly 100% Texas red oak. Total basal area was 18.6 m^2/ha. Two to 4 years after passage of the disease front, total basal area had been reduced to 4 m^2/ha, basal area of Texas red oak was reduced to 38% of the total, and small components of Ashe juniper, shin oak, and flameleaf sumac (*Rhus lanceolata*) had reached breast height and thus were contributing to basal area (Fig. 2).

Regeneration of all species was much more abundant 2 to 4 years after disease front passage. In particular, Texas red oak regeneration increased nine-fold from 1,326 stems/ha, all shorter than 30 cm, before disease front passage to 12,335 stems/ha after front passage; 45% of these stems were taller than 30 cm (Fig. 3). This finding is in contrast to that of Russell and Fowler (2002), who reported a dearth of Texas red oak regeneration due to overbrowsing by white-tail deer (*Odocoileus virginianus*). Overbrowsing by deer is not generally observed on Fort Hood because deer populations are maintained at relatively low levels.

Although these data are very preliminary, two observations seem warranted at this time. First, it is apparent that Texas red oak will make up a significant fraction, but probably much less, of the next stand. Second, although the regenerated stand is very young, it appears to be more diverse than the fire-origin coppice-regenerated Texas red oak stand. It remains to be seen whether this increased diversity will be maintained as the stand matures.

MANAGEMENT IMPLICATIONS

Based on the results of our research and our experience with operational oak wilt control measures on Fort Hood, we note the following:

- We have discontinued the use of basal girdling, by itself, as a control measure for oak wilt in Texas red oak in GCWA habitat because it appears not to be effective at reducing infection rates in subsequent years. In cases where root transmission of the oak wilt pathogen is controlled by mechanical or other means, basal girdling may be an effective method of reducing the risk of insect-mediated spread.
- Trenching is useful for containing oak wilt centers on level to gently sloping terrain. Operational concerns limit the use of this method on mesa slopes, where the best GCWA habitat occurs.
- There does not appear to be any shortage of Texas red oak regeneration in oak wilt centers in stands composed mostly of Texas red oak (i.e., where the disease results in the death of most of the overstory). It is likely therefore that Texas red oak will comprise a significant fraction of the resulting stand. We have not studied regeneration in centers where Texas red oak is a small fraction of the overstory, and therefore much of the canopy remains intact after passage of the disease front.

LITERATURE CITED

Appel, D.N. 2001. The basics of oak wilt biology and factors influencing disease incidence and severity, Pp. 71-81. *In*: C.L. Ash (ed.), Shade Tree Wilt Diseases, Proceedings from Wilt Diseases of Shade Trees: A National Conference. APS Press, St. Paul, MN.

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(5): 1276-1279.

Appel, D.N., T. Kurdyla, and R. Lewis, Jr. 1990. Nitidulids as vectors of the oak wilt fungus and other *Ceratocystis* spp. in Texas. European Journal of Forest Pathology 20: 412-417.

Diamond, D.D. 1997. An old-growth definition for western juniper woodlands: Texas Ashe juniper dominated or codominated communities. USDA Forest Service General Technical Report SRS-15. 10 pp.

Gillespie, W.H., A.L. Shigo, and R.P. True. 1957. The degree of mat-production control obtained by girdling oak wilt trees in West Virginia and some factors influencing mat formation in girdled trees. Plant Disease Reporter 41(4): 362-367.

GlobalSecurity.org. 2006. Web page, http://www.globalsecurity.org/military/facility/forthood.htm, viewed 12 October 2006.

Greene, T.A., C.M. Reemts, and D.N. Appel. 2009. Efficacy of basal girdling to control oak wilt in *Quercus buckleyi* in central Texas. Southern Journal of Applied Forestry (In press).

Johnson, E.H. 2004. Grand Prairies and Lampasas Cut Plain. The handbook of Texas online, http://www.tsha.utexas.edu/handbook/online/articles/view/GG/rxg2.html, viewed 16 June 2004.

Juzwik, J. 2001. Overland transmission of *Ceratocystis fagacearum*: Extending our understanding, Pp. 83-92. *In*: C.L. Ash (ed.), Shade Tree Wilt Diseases, Proceedings from Wilt Diseases of Shade Trees: A National Conference. APS Press, St. Paul, MN.

Ladd, C., and L. Gass. 1999. Golden-cheeked warbler (*Dendroica chrysoparia*), Pp. ?? *In*: The Birds of North America, Number 420. Academy of Natural Sciences, Philadelphia, PA and American Ornithologists' Union, Wasington, D.C.

Morris, C.L. 1955. Control of mat formation by the oak wilt fungus by early felling of diseased trees. Plant Disease Reporter 39(3): 258-260.

Reemts, C.M., and L.L. Hansen. 2008. Slow re-colonization of burned oak-juniper woodlands by Ashe juniper (*Juniperus ashei*): Ten years of succession after crown fire. Forest Ecology and Management 255: 1057-1066.

Russell, F.L., and N.L. Fowler. 2002. Failure of adult recruitment in *Quercus buckleyi* populations on the eastern Edwards Plateau, Texas. American Midland Naturalist 148(2): 201-217.

SCS. 1985. Soil survey of Coryell County, Texas. USDA-Soil Conservation Service. 129 pp., 57 maps.

Smeins, F.E. 1980. Natural role of fire on the Edwards Plateau, Pp. 4-16. *In*: L.D. White (ed.), Prescribed Range Burning in the Edwards Plateau of Texas. Texas Agricultural Extension Service, College Station, TX.

Tainter, F.H., and W.D. Gubler. 1973. Natural biological control of oak wilt in Arkansas. Phytopathology 63(8): 1027-1034.

Tainter, F.H., and W.D. Gubler. 1974. Effect of invasion by *Hypoxylon* and other microorganisms on carbohydrate reserves of oak-wilted trees. Forest Science 20(4): 337-342.

Texas Oak Wilt Information Partnership. 2007. How to identify and manage oak wilt in Texas— Disease Management. Available online at: http://www.texasoakwilt.org/About/disease.html.

USFWS. 2005. Biological opinion [Fort Hood]. U.S. Fish and Wildlife Service, Austin, TX.

Van Auken, O.W. 1993. Size distribution patterns and potential population change of some dominant woody species of the Edwards Plateau region of Texas. Texas Journal of Science 45(3): 199-210.

Wilson, A.D. 2005. Recent advances in the control of oak wilt in the United States. Plant Pathology Journal 4(2): 177-191.

OUTSIDE OAK WILT CENTER

Legend:
- CERCAN
- CORDRU
- FORPUB
- FRACAR
- JUNASH
- QUEBUC
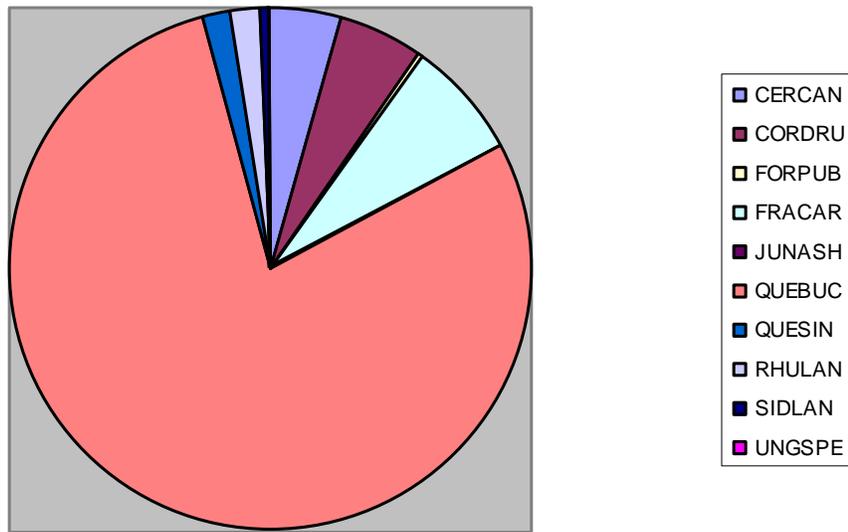- QUESIN
- RHULAN
- SIDLAN
- UNGSPE

Figure 1. Relative basal area of woody stems, by species, on three, 0.01-ha plots outside an oak wilt disease center on Fort Hood, Texas. Species codes are: CERCAN=*Cercis canadensis*; CORDRU=*Cornus drummondii*; FORPUB=*Forestiera pubescens*; FRACAR=*Frangula caroliniana*; JUNASH=*Juniperus ashei*; QUEBUC=*Quercus buckleyi*; QUESIN=*Quercus sinuata*; RHULAN=*Rhus lanceolata*; SIDLAN=*Sideroxylon lanuginosum*; UNGSPE=*Ungnadia speciosa.*
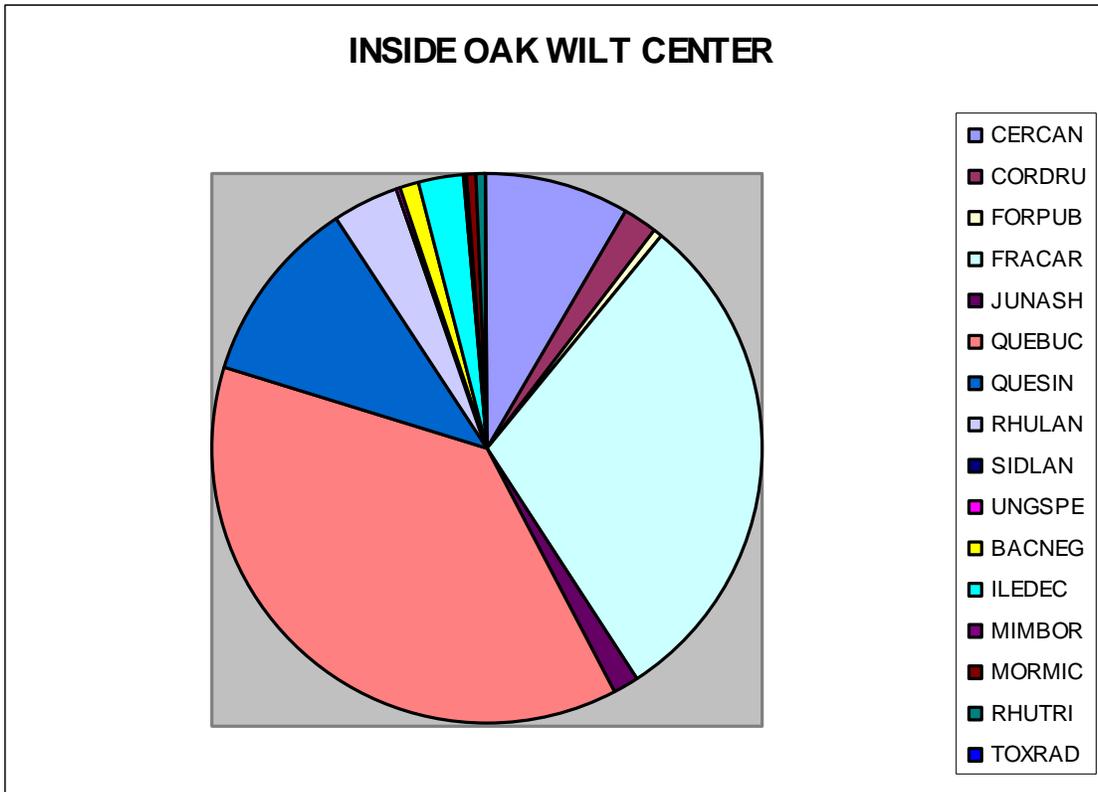
Figure 2. Relative basal area of woody stems, by species, on three, 0.01-ha plots inside an oak wilt disease center on Fort Hood, Texas. Species codes are: CERCAN=*Cercis canadensis*; CORDRU=*Cornus drummondii*; FORPUB=*Forestiera pubescens*; FRACAR=*Frangula caroliniana*; JUNASH=*Juniperus ashei*; QUEBUC=*Quercus buckleyi*; QUESIN=*Quercus sinuata*; RHULAN=*Rhus lanceolata*; SIDLAN=*Sideroxylon lanuginosum*; UNGSPE=*Ungnadia speciosa*; BACNEG=*Baccharis neglecta*; ILEDEC=*Ilex decidua*; MIMBOR=*Mimosa borealis*; MORMIC=*Morus microphylla*; RHUTRI=*Rhus trilobata*; TOXRAD=*Toxicodendron radicans*.
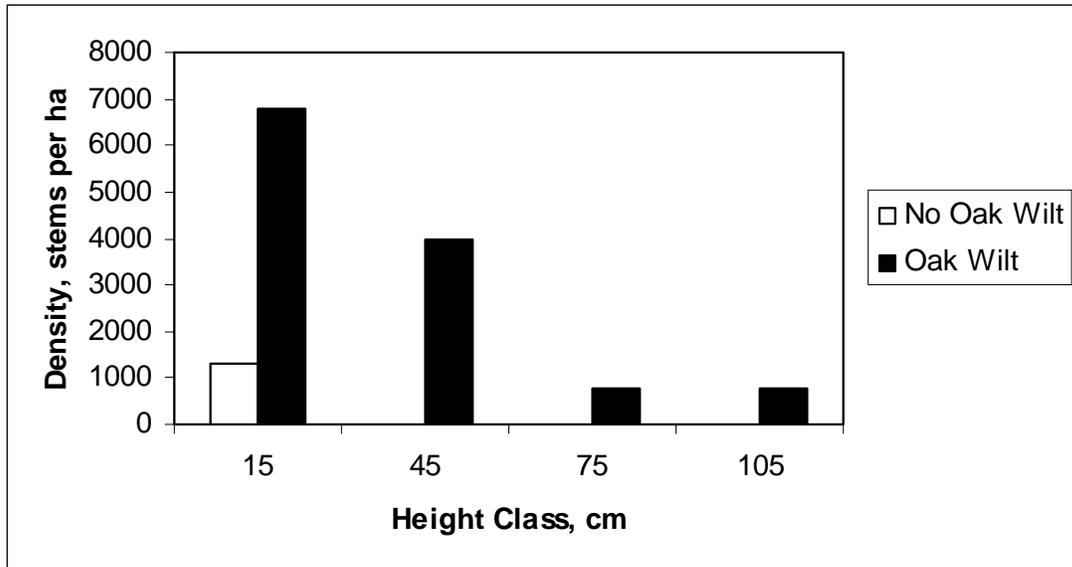
Figure 3. Texas red oak regeneration by 30-cm height class before passage of an oak wilt disease front, and 2-4 years after passage, in oak-juniper woodland on Fort Hood, Texas.