

**Recovery Plan For  
Thousand Cankers Disease of Black Walnut  
Caused by *Geosmithia morbida*  
And Vecteded by the  
Walnut Twig Beetle (WTB) *Pityophthorus juglandis***

**Completed August 2011**

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This recovery plan is one of several disease-specific documents produced as part of the National Plant Disease Recovery System (NPDRS) called for in Homeland Security Presidential Directive Number 9 (HSPD-9). The purpose of the NPDRS is to ensure that the tools, infrastructure, communication networks, and capacity required to minimize the impact of high consequence plant disease outbreaks are available so that a reasonable level of crop production is maintained.

Each disease-specific plan is intended to provide a brief primer on the disease, assess the status of critical recovery components, and identify disease management research, extension, and education needs. These documents are not intended to be stand-alone documents that address all of the many and varied aspects of plant disease outbreak and all of the decisions that must be made and actions taken to achieve effective response and recovery. They are, however, documents that will help the USDA to further guide efforts toward plant disease recovery.

## Executive Summary

Widespread branch dieback and mortality of black walnut (*Juglans nigra*) has occurred in Colorado, Idaho, New Mexico Oregon, Utah, and Washington since the mid-1990s. Black walnut is not native to this region, but has been widely planted as an ornamental and nut tree species. Affected trees initially exhibit yellowing and wilting of the foliage followed by progressive branch dieback. Trees are killed within three to four years after initial symptoms develop. Tree mortality is the result of aggressive feeding by the walnut twig beetle, *Pityophthorus juglandis* (WTB) and subsequent canker development surrounding beetle galleries by the fungus *Geosmithia morbida*. The number of cankers formed on branches and the trunk is enormous, hence the name thousand cankers (TCD) to describe the disease. The WTB and *G. morbida* also have been identified in other walnut species including southern and northern California black walnuts (*J. californica* and *J. hindsii* respectively) and Arizona walnut (*J. major*).

Walnuts in the United States have both a nut and timber economic value. Loss of the black walnut timber industry could have a large economic impact as well as significant ecological consequences. Black walnut in the eastern United States has an estimated value of over half a trillion dollars. Although Persian walnut (English walnut) appears not be as susceptible to the disease, TCD could pose a risk to some of the hybrid rootstocks. The Persian walnut crop in California was valued at over \$1 billion in 2010.

In July 2010, TCD was identified in Tennessee and in the native range of black walnut. In 2011, TCD was discovered in Richmond Virginia and Philadelphia, Pennsylvania. It is unlikely these outbreaks can be eradicated. The economic and ecological impact of this disease could be staggering. It is debatable whether there can be a successful 'recovery' plan for TCD. Our best hope is to prevent the rapid spread of the WTB by taking the following action:

- Delineate the current distribution of the WTB and *G. morbida* in North America and then prevent movement of infested logs and firewood into uninfested areas.
- Develop a national educational program on the threat of TCD
- Identify methods to sanitize infested logs so that they may be safely used for commercial purposes
- Identify potential prophylactic treatments (insecticides or fungicides) to preserve high value timber or landscape trees. Identify potential biological control agents.
- Identify potential sources of resistance in black walnut or related walnut species and consider developing a germplasm preservation program

A TCD technical working group, comprised of University research scientists, USDA Forest Service scientists and personnel, state and federal regulatory officials, and representatives of the Walnut Council and the forest lumber industry, convened in 2009 to discuss a national framework for dealing with this disease. The TCD working group is continuing to develop effective management strategies.

**Contributors and Reviewers:**

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## I. Introduction

Black walnut (*Juglans nigra*) is one of the most highly valued timber species in North America (Harlow & Harrar, 1969). The wood is prized for use in cabinetry, gunstocks and other finished wood products. The nuts are also an important nutritional source for wildlife and as a food condiment. Black walnut is native to eastern North America, and is widely distributed on deep alluvial soils from New England and the Appalachian Mountains west to the Great Plains and from the Canadian border south into Texas and the Florida panhandle (Harlow & Harrar, 1969). It has been widely planted outside its native range in the western United States as an ornamental and timber tree, and for nut production.

Widespread morbidity and mortality of black walnut was first observed in the Wasatch Mountains of Utah and areas of the Columbia Gorge and Willamette Valley in Oregon as early as the 1990's. At that time mortality was not linked to a specific cause. The first published report of extensive dieback and death of black walnut was in New Mexico in 2001 (USDA Forest Service 2002). Mortality was reported to be associated with drought conditions and damage by the walnut twig beetle (WTB), *Pityophthorus juglandis* Blackman, (Col. Curculionidae, Scolytinae). By 2003 widespread black walnut mortality was observed in several Colorado municipalities and by 2008 the cause was determined to be the result of aggressive feeding by the WTB and subsequent canker development surrounding beetle galleries caused by a fungal symbiont of the beetle (Tisserat et al. 2009). The number of cankers formed on branches and the trunk is enormous, hence the name thousand cankers (TCD) to describe the disease. The fungus was recently named *Geosmithia morbida* (Kolařík et al. 2010). Since the disease was first described, both the WTB and *G. morbida* have been collected from various *Juglans* species in counties in California, Oregon, Washington, Idaho, Utah, Arizona, New Mexico and Colorado (Figure 1). Extensive mortality of black walnut has occurred wherever TCD has been found (Tisserat et al. 2011).

In July 2010, TCD was confirmed from dying and dead black walnuts in Knoxville TN. The size of this infestation is currently being determined, but hundreds of walnuts with TCD have been identified in at least four TN counties. In 2011, TCD was discovered in Richmond VA and Philadelphia PA. The extent of these outbreaks is still unknown. TCD now is apparently well-established in the native range of black walnut and poses a serious threat to the to this species.

The origin of TCD remains unclear. The WTB was first collected in 1896 in New Mexico (Blackman, 1928). In 1992 its range was reported as Arizona, New Mexico and Chihuahua, Mexico (Wood, 1992). This coincides with the northern native range of the Arizona walnut (*J. major*). In 2008 and 2009, *G. morbida* was consistently isolated from necrotic phloem surrounding WTB galleries in native stands of Arizona walnut in AZ and NM, but the fungus was not causing branch dieback or mortality in this species. This has led to speculation that WTB and its fungal symbiont *G. morbida* are native to the southwestern United States.

Other walnut species are also hosts of the WTB. The beetle was collected from southern California walnut (*J. californica*) in Los Angeles County in 1959 (Bright & Stark, 1973) but curiously was not found, or at least not reported on this species, until recently, from other sites in California. However,

since 2008 the WTB has been widely associated with and collected from declining southern California black walnuts in the foothills and mountains just north of the Los Angeles Basin (Seybold et al. 2010). Similarly, the WTB has recently been associated with widespread dieback of northern California black walnut (*J. hindsii*) in the lower Sacramento Valley as well as in riparian zones along the tributaries to the Sacramento River. It has also been found in northern California black walnuts in isolated locations in central and northern California. *Geosmithia morbida* is consistently isolated from the small cankers surrounding galleries on trees at all of these locations. Because the first collection records in California pre-date those from Mexico and because of the native distributions of walnut in California, Seybold et al. (2010) have speculated that the WTB may be native to at least the southern California black walnut (Seybold et al. 2010). However, the beetle has remained relatively inconspicuous in the collection record in California for approximately 50 years, and only recently has been associated with the dieback of California walnut trees.

California also has large commercial nut plantings of the non-native English walnut (*J. regia*). The WTB and *G. morbida* have been found on scattered trees in orchards, but they currently are not causing significant damage or mortality (approximately 30 cases documented so far). English walnut appears to be moderately to highly resistant to TCD, but most of the commercial trees are now grafted onto a walnut hybrid root stock called Paradox. Paradox is commonly defined as a hybrid between *J. hindsii* and *J. regia* but the black walnut component of the hybrid can include any black walnut (*J. nigra*, *J. californica* or *J. hindsii*) (Potter, Gao, Baggett, McKenna, & McGranahan, 2002). The genetic diversity in the rootstocks can therefore be very high and the resistance to TCD possibly variable. As a result, there have been observations of some Paradox rootstocks with symptoms of TCD.

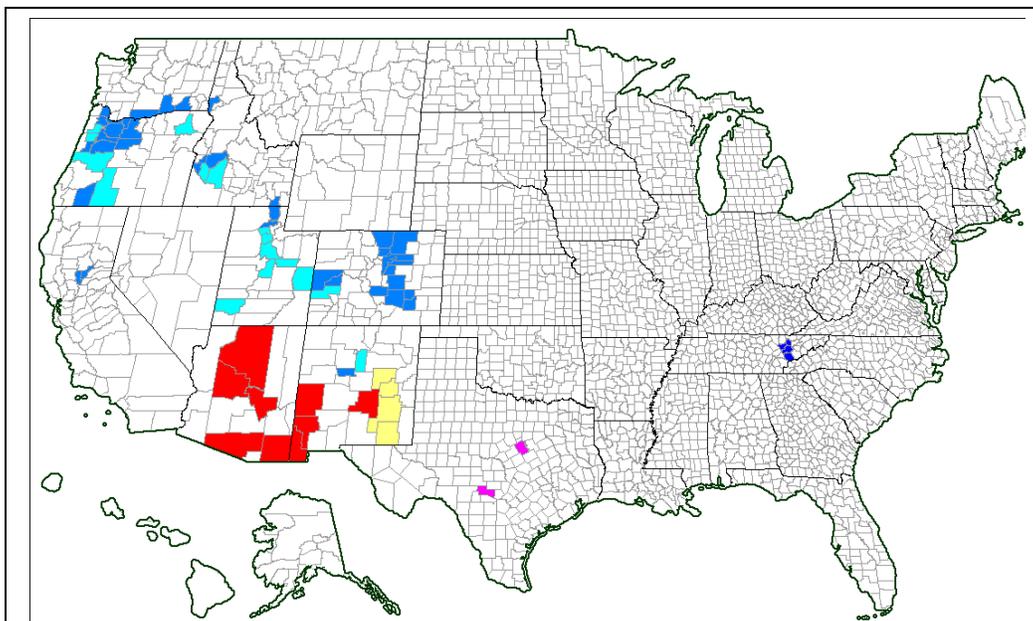


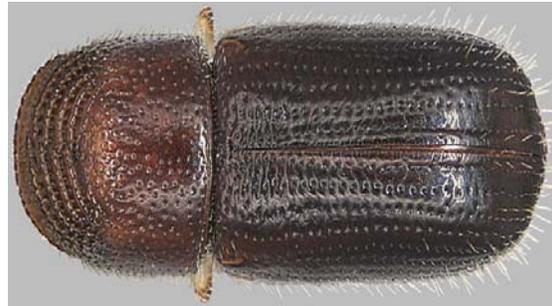
Fig 1. Distribution of the walnut twig beetle and *Geosmithia morbida* on *Juglans* species (excluding the native *J. hindsii* and *J. californica* in California) in the United States as of October, 2010. Counties highlighted in dark blue represent those in which *Geosmithia morbida* has been isolated from symptomatic trees. Counties highlighted in light blue represent those where symptoms of thousand cankers disease were observed or where the walnut twig beetle (WTB) was found, but where isolation of *G. morbida* was not attempted because trees were removed before samples could be collected. Some of the trees sampled for confirmation of *G. morbida* in Oregon are hybrids of *J. nigra* with *Juglans hindsii*. Counties in red represent those in which the WTB and fungus was recovered from *J. hindsii*. The WTB was not observed in isolated pockets of *J. major* in the two Texas counties highlighted in pink or in *J. microcarpa* in New Mexico counties highlighted in yellow

## II. Biology and Symptoms

The WTB is a minute (1.5-2.2 mm) yellowish-brown bark beetle, about 3X as long as it is wide. It is the only *Pityophthorus* species associated with *Juglans* in the western U.S. but can be readily distinguished from other members of the genus by several physical features (Figures 2 and 3). Among these are 4 to 6 concentric rows of asperities on the prothorax, usually broken and overlapping at the median line. The declivity at the end of the wing covers is steep, very shallowly bisulcate, and generally flattened at the apex with small granules.



**Figure 2.** Walnut twig beetle, side view. Photograph by Jim LaBonte, Oregon Department of Agriculture.



**Figure 3.** Walnut twig beetle, top view. Photograph by Jim LaBonte, Oregon Department of Agriculture.

Despite its small size and common name, WTB rarely develops in twigs. Instead tunneling is almost always confined to branches greater than 2 cm diameter. Very large branches and even the trunk can be colonized during advanced stages of TCD.

The life history of the WTB is not completely understood. In areas with cold winters such as Colorado, overwintering is spent primarily, and possibly exclusively, in the adult stage sheltered within cavities excavated in the bark of the trunk. Overwintering may also occur in larval stages, particularly where winters are mild. Adults resume activity by late-April – beginning as early as February in California. Most fly to branches to mate within a chamber under the bark, and females initiate egg gallery tunnels (Figure 4). Larvae feed for 4-6 weeks under the bark in meandering tunnels that run perpendicular to the egg gallery (Figure 5). Pupation occurs at the end of the tunnel and the adults emerge through minute, round exit holes.



**Figure 4.** Walnut twig beetle and associated staining around a tunnel.



**Figure 5.** Walnut twig beetle tunneling under the bark of a large branch.

Adults emerge to produce a second generation in early summer. Peak flight activity of adults occurs from mid-July through late August and declines by early fall as the beetles enter hibernation sites. A small number of beetles produced from eggs laid late in the season may not complete development until November and some larval development may continue throughout winter, particularly in warmer areas.

*Geosmithia* spp. (Ascomycota, Hypocreales) are dry-spored fungi that are almost exclusively found in association with bark beetles and subcortical insects (Kolařík et al., 2004). Although these fungi are generally found sporulating within beetle galleries on both hardwood and coniferous species, they produce hydrophobic conidia common to air borne fungi (Kolařík et al, 2007). The genus contains seven previously described species as well as at least nine operational taxonomic units (OTUs) that are newly described species (Kolařík et al., 2005, Kolařík et al, 2007, 2009). Based on a comparison of the ITS region, as well as morphological observations, *G. morbida* from *Juglans* species do not fit any previously described species. Morphological identification and ITS region (ITS1-5.8S-ITS2) rDNA sequences have confirmed that this is a new species named *G. morbida* (Kolařík et al., 2011).

Commonly, *Geosmithia* species sporulate on the surface of bark where both wind and water could be effective means of transmission of the fungi. However, these *Geosmithia* spp. are found in complex communities that could not be maintained by simple random dispersal by environmental factors. This suggests an insect vector is necessary for effective transmission (Kolařík et al., 2007). The new species of *Geosmithia* causing cankers on black walnuts is the first in this genus to be pathogenic (Čížková, et al., 2005). Although *G. morbida* is the only known *Geosmithia* species to be directly pathogenic, an unknown *Geosmithia* sp. was recovered from an elm tree that was infected with dutch elm disease (DED). The isolate produced cerato-ulmin (CU). CU is a protein produced by *Ophiostoma* fungi that cause DED and is thought to be a pathogenicity factor and key for isolate fitness (Scala et al., 2007). Neither the CU protein or the gene has been isolated from any other *Geosmithia* spp. isolates leading to the hypothesis that horizontal gene transfer is responsible for the CU production.

Initially infected walnut trees show symptoms in the upper crown with a yellowing and thinning of leaves leading to twig and branch die-back. Progressively larger branches die and eventually the tree is killed. The total length of time for TCD to kill a mature walnut tree (i.e. from initial beetle infestation to tree death) is not known, but trees generally die within four years after symptoms develop. Galleries of *P. juglandis* are only visible after the outer bark is removed. They are surrounded by diffuse brown to black cankers that extend beyond beetle galleries in the phloem and only in late stages into the cambium. Infection with *G. morbida* is not systemic, as cankers remain localized to the areas within approximately 4 cm beyond beetle galleries. Although symptoms initially present themselves in small diameter branches of the upper crown, removal of the outer bark reveals galleries and cankers in twigs, branches and the trunk and are not confined to small diameter branches or weakened branches typical of twig beetle attack (Figs 6-9). After beetle colonization, numerous cankers occur every 2 to 5 cm at each gallery or entrance hole. The cankers eventually coalesce, leading to girdling of limbs (Tisserat et al., 2009).



Fig 6. Large, oval shaped cankers in bark. Walnut twig beetle tunnels are present in the center of each canker.



Fig 7. Shallow tunnels produced by the walnut twig beetle can usually be seen in the center of cankers.



Fig 8. Outer bark removed to expose coalescing cankers in phloem that eventually girdle branches.



Fig. 9. Bark completely removed to show discoloration of sapwood during advanced stages of the disease. Note the white, dusty appearance of *Geosmithia morbida* at the canker margin

### **III. Spread**

The greatest threat of movement of the WTB into the native range of black walnut is from the sales and movement of raw logs. Black walnut wood is highly prized for both lumber and veneer logs. This wood is often sold on small scale by woodworkers for musical instruments, gun stocks and furniture. Black walnut standing wood prices range from \$200 to 4,000 per thousand board feet and \$500 to 6,000 per thousand board feet depending on quality and suitability for veneer wood to mills in Illinois (ILDNR,

2008). These values are representative of prices throughout the United States (Hoover, 1995). As well as intact logs, burls also have a high value for veneer wood and are shipped to east coast mills from the west with intact bark on a regular basis (Newton et al., 2009). These long distance human mediated events could potentially introduce the TCD complex into the native range of black walnut from which it could spread by natural dispersal. The movement of trees from the western to eastern United States by individuals is not well documented but internet searches show many instances of walnut logs for sale to individuals (Newton et al., 2009).

Although black walnut wood is a high value timber, many logs are also used for firewood when they are not suitable for woodworking or mill wood. The risk of movement of WTB infested firewood long distances from the western United States to the eastern range of black walnut is probably low because firewood is generally not shipped and sold over great distances (Newton et al., 2009). However, campers are known to move firewood over several states which could lead to introduction of the WTB into campgrounds containing walnut trees. A small survey of campgrounds by the Kansas Department of Agriculture found that campers had brought firewood in from states as far as California, indicating that introduction of WTB by firewood is possible (KDF, 2007). The risk of moving the WTB in infested wood from areas where TCD is established is very high. For example, the WTB has been found in black walnut firewood sold along the front range of Colorado (Jacobi, personal communication). Firewood movement also poses a significant threat in areas of Tennessee.

The risk of introduction of the WTB or *G. morbida* into new areas by movement of nuts is low. *Geosmithia morbida* is not systemic, it is not a seed borne pathogen and the WTB doesn't feed on the nuts. The possibility of moving the WTB in pallets is low because walnut wood is valuable and not likely used in the manufacturing of pallets. Another possible pathway for interstate movement is movement of infected nursery stock. More research on the suitability of young trees as hosts for the WTB is needed.

The estimated longest flight distance of the WTB is 2 miles, limiting the distance of natural dispersal of the TCD complex (Newton et al., 2009). Although the Great Plains could provide a natural barrier between areas of native black walnut forests and areas of confirmed TCD, several bridges may be present. The WTB is small and may be carried longer distances by weather events and possibly to susceptible hosts. Long distance travel between disparate hosts is not likely based solely on insect dispersal. However, spread along riparian areas such as the South Platte and Arkansas rivers is a potential concern and these areas should be monitored. As well as spread on black walnuts, the range of little walnut (*J. microcarpa*) overlaps with the native range of black walnut and may provide a natural bridge for infected WTB. However, all of these concerns may be moot now that the WTB has become established in Tennessee.

#### **IV. Monitoring and Detection**

Survey and monitoring of TCD has primarily been coordinated at the state level with the assistance, in some cases, of federal agencies. Surveys were conducted in late summer and fall of 2010 in Tennessee and were primarily targeted in Knox and adjacent counties looking for evidence of branch dieback or mortality associated with TCD. Further surveys are critical to ascertain the distribution of the disease in Tennessee for management and regulatory decisions. This is necessary to limit the spread through

movement of diseased wood as well as natural pathways.

A detailed survey of black walnut trees in eastern Colorado (Cranshaw) and western Kansas (Kansas Department of Agriculture) was conducted in 2009. A follow-up survey is planned for 2011. A survey of the distribution of the WTB on several walnut species in California has been conducted. However, there is no current coordinated survey plan to identify the distribution of TCD on black walnut outside the native range of this species

The WTB and *G. morbida* were widely collected on Arizona walnut in Arizona and New Mexico during surveys in 2009 and 2010 (Cranshaw and Leatherman, personal communication). No decline or mortality was observed on infested trees. The farthest east that the beetle and fungus were found on this species was in Lincoln County, NM. TCD was not observed in little walnut (*J. microcarpa*) in a survey of Eastern New Mexico in 2010 (Leatherman, personal communication) and in eastern New Mexico and Texas in 2011 (A.D. Graves, personal communication). Additional surveys of Arizona and little walnut in their extreme eastern ranges (Texas) are planned for 2011.

The WTB is not attracted to ethanol-baited, or colored sticky traps. Therefore efforts to monitor insect movement have been unsuccessful. Continued research is needed to better develop trapping methods to effectively monitor the WTB's presence. Development of pheromone traps would allow monitoring in locations along the western front of the native range of black walnuts and in Tennessee.

A Standard Operating Procedure (SOP) for NPDN diagnostic labs is under development (Snover-Clift, 2010). The SOP contains information on isolation techniques for *G. morbida* and characteristics for morphological identification. Molecular confirmation of *G. morbida* is performed by sequencing the rDNA ITS region by PCR.

## **V. Response**

A TCD technical working group comprised of University research scientists, USDA forest Personnel, state and federal regulatory officials, and representatives of the Walnut Council and the forest lumber industry convened in 2009 to discuss a national framework for dealing with this disease. The TCD working group is continuing to develop management strategies.

In July 2010, prior to the discovery of the WTB in Tennessee, USDA APHIS PPQ decided not to impose a federal quarantine on TCD. Therefore, individual states are responsible for establishing their own quarantines. Many states including Kansas, Nebraska, Iowa, Minnesota, and Missouri have imposed external quarantines to prevent movement of black walnut wood from states known to have TCD from entering their state. This would include Colorado and all states to the west of Colorado, and Tennessee. Tennessee has also imposed an internal quarantine designed to slow the spread of WTB between counties and maintain marketability of Tennessee walnut products. Of great concern is the impact of quarantines, internal and external, on the marketability and commercial value of black walnut in Tennessee.

## **VI. USDA Pathogen Permits**

Plant Protection Act of 2000 (codified at 7 CFR Part 330) regulates registration and permit requirements for USDA, APHIS and PPQ permits. A PPQ 526 Permit is required for laboratories receiving suspect infected plant materials and or plant pests from out-of-state regardless of the quarantine status of the suspect organism. A PPQ 526 permit is required for interstate movement and importation of infected plant material, vectors, pure cultures and diagnostic samples. Permit information can be found at the PPQ permit website (<http://www.aphis.usda.gov/ppq/permits/>), the PPQ permit services (301-734-0841 or 866-524-5421) or by email ( [Pest.Permits@aphis.usda.gov](mailto:Pest.Permits@aphis.usda.gov)).

## **VII. Economic and Ecological Impact**

Loss of the black walnut timber industry could have a large economic impact as well as significant ecological consequences. Black walnut in the eastern United States has an estimated value of over half a trillion dollars (Newton et al., 2009). The impact of TCD on the walnut timber industry in Kansas alone showed losses of over \$9.5 million annually to landowners, loggers and mills, as well as indirect losses to the economy and 46 jobs. The nut industry in Kansas is worth approximately \$600 thousand a year. A third loss to the state is the cost to remove infected urban and park trees and their replacement which is valued at over \$65 million for the state (Treiman et al., 2010). Other states in the native range of black walnut may experience similar economic losses if TCD becomes established in these areas.

Walnuts in the United States have both a nut and timber economic value. California walnuts were valued at over \$527 million in 2008 (USDA-NASS, 2009). English walnut and the Paradox root stocks most commercially grown walnuts are grown on may or may not be susceptible. If TCD infects these walnut species, the results could be devastating and potentially eliminate the industry in California. The value of black walnut wood is estimated at over \$41 million and is exported to over 67 countries world wide.

## **VIII. Mitigation and Disease Management**

### *Exclusion*

The response and mitigation of TCD is dependent on the walnut species affected. On black walnut, there are no known effective control measures once TCD becomes established. Thus, exclusion should be considered the only means to prevent introduction of the WTB and subsequent development of TCD. Surveys to delineate the current distribution of TCD as well as regulations to control the movement of WTB-infested walnut logs to non-infested areas are the highest priority. Mitigation efforts may slow, but probably not stop, TCD progression in black walnut, but may have more positive effects in other walnut species.

### *Surveys*

Since exclusion of TCD from a community or forest is the only means to effectively manage this disease, it is critical to determine the current distribution of TCD. Exclusion is no longer an option where TCD is already present. Nevertheless, if the distribution of the disease can be determined, and

then contained, then the ultimate course of TCD may be limited to the destruction of walnut trees within communities where the disease has already become established.

An intensive visual survey should continue in Tennessee to determine the current extent of the outbreak in that state. Trees suspected of TCD should be confirmed by identifying the WTB and associated cankers caused by *G. morbida*. Verification of TCD by culturing is not necessary if the WTB is present except in the case of new county or state records since it can be assumed that all WTB are infested with *G. morbida*.

Surveys should be conducted throughout the native range of black walnut. The most likely source of introduction of the WTB is on logs and firewood. This is likely how the beetle was introduced into the Knoxville, Tennessee area. Therefore, surveys should initially be focused in urban areas and near sawmills where satellite infections are most likely to occur. These are locations where early detection might be easier.

Surveys of nearby forests adjacent to TCD outbreaks should be conducted periodically (Yearly). Examinations may begin with landowners or other non-professionals and escalate to site visits by foresters or others trained to take tree samples if the situation dictates. When infested trees are removed, periodic monitoring of nearby forests is warranted.

Surveys should also intensify in the Western United States. The WTB continues to spread in Colorado, Idaho and Washington, yet there are no formal surveys being conducted in many of these states.

### *Education*

An intensive education program is needed to inform arborists, foresters, and tree owners on the identification of TCD symptoms. It is also critical that education materials be developed to stress the importance of proper handling of infested wood to prevent spread to new locations. If the disease is widespread and *Juglans* plantings occur throughout the municipality, there is little chance to stop the course of the disease by tree removals. Education and proper handling of TCD-infective wood should be the primary emphasis.

### *Sanitation and Eradication*

Freshly cut wood is highly attractive to the WTB and can support its development. Successful larval development will require wood of sufficient moisture, and drying ultimately will make wood an unsuitable habitat. Because of the small size of the beetles, development may continue in small pockets within logs. Where drying is slow, logs may remain suitable for breeding for 2 or 3 years after felling.

Preemptive harvesting of black walnut in the forest or plantations is not recommended except to contain a known infestation. Removal of infested and potentially infested black walnut within the stand or on the same property is advised. Sanitation harvests, partial harvests or clear-cuts are appropriate methods of treatment. Walnut tree tops should be chipped and left in the woods or burned. Walnut logs should be separated from other logs when loaded for hauling. Walnut logs or products with bark intact in a quarantined county or buffer county should not be taken outside the quarantine area.

In an urban situation, sanitation will have a modest role in management of TCD. This is largely due to two factors: 1) the long lag time between tree infestation and TCD symptom expression that allow for undetected local spread; and 2) the consistent association of the pathogen with essentially all bark beetles. Because of this, once TCD has become established in a city, eradication is unlikely without clear cut although some slowing of spread may be realized. The removal and destruction of WTB-infested wood can potentially reduce the accidental spread to other cities.

Chipping diseased trees will hasten bark drying and beetle destruction, but not completely, so that chipped infested wood should also be handled with care. During warm periods, active beetles potentially may be dispersed from cut wood as it is moved from the site. Therefore, care should be given in routing trucks hauling TCD-infected wood to avoid areas of healthy, uninfected walnut.

Because of the very high value of black walnut logs, salvage often will be attempted. If logs cut from TCD-infected trees are recovered, they should be handled to prevent beetle dispersal until the wood no longer supports walnut twig beetle development. Until sufficiently dried, logs should be isolated. Isolation can be achieved by stockpiling wood in a site that is distant from healthy walnuts, particularly walnuts located downwind. Storage of logs in buildings can achieve beetle containment. Tarping logs with clear plastic also may contain beetles within logs. Tarping to achieve solarization may be a means to kill developing beetles.

#### *Protection of trees with insecticides*

Trunk/branch insecticide sprays (e.g., permethrin, bifenthrin) typically used for bark beetle control do not appear to be effective in preventing TCD, although detailed experiments have not been performed. The large number of WTB present over an extended period (May-September) and the large areas of the tree that may be attacked are all significant impediments to effective coverage. It is possible that late summer trunk sprays directed at beetles seeking overwintering shelter in the trunk may be useful in reducing populations. This may have some value in slowing TCD development and spread; however, this has not been demonstrated.

The value of systemic insecticides in TCD management has not been evaluated. Limited observations indicate that imidacloprid (i.e., Merit, Marathon, Touchstone, etc.) is ineffective after symptoms have developed. Anecdotal accounts suggest that disease progress may be slowed by imidacloprid if applications are made before extensive cankers have been formed; however, it is unlikely that currently available systemic insecticides can prevent TCD. Successful inoculations of *G. morbida* likely can occur even if the walnut twig beetle is subsequently killed. Cankers resulting from infection will produce pockets within the tree where future movement of systemic insecticides will be limited and allow successful development of twig beetles at these sites. Areas under the bark where beetles will be protected from systemic insecticides will increase with time as cankers expand and new cankers are initiated. The more water soluble insecticide dinotefuran (Safari) may provide improved coverage; however, it has not been evaluated.

Pesticide label use restrictions will be an important limitation to the use of systemic insecticides in most walnuts. Any pesticide (insecticide, fungicide) considered in TCD management must comply with use restrictions for walnuts grown for nut-crops. At present, there are food tolerances for

imidacloprid in walnut meat since this insecticide (Provado formulation) is used in commercial nut production. Dinotefuran currently has no established tolerance in walnut meat and no formulations are labeled for this crop.

### *Resistance*

There currently are no known sources of resistance to TCD in black walnut. Although surviving black walnut trees in TCD-affected regions in Colorado have been identified, they have not been evaluated for resistance to *G. morbida* or the WTB. There is also no coordinated effort to identify and preserved these putatively resistant trees. An efficient screening method needs to be developed. Some other walnut species appear to have moderate to high levels of resistance to *G. morbida* and may be useful in future breeding programs.

### *Germplasm preservation*

There are several plantings for walnut germplasm preservation and development. These include facilities at the University of Missouri (primarily for nut germplasm), the USDA - Forest Service HTIRC facility at Purdue University (primarily for black walnut and butternut timber germplasm), the National Center for Germplasm Resources at UC Davis (NCGR facility primarily for *Juglans* species other than black walnut), and the Improving Perennial Plants for Food and Bioenergy (IPPFB) in Richmond Utah (primarily black walnut collections from the western United States). TCD has been found in the NCGR and IPPFB plantings and will be difficult, if not impossible to eradicate at these locations. The best course of action may be to let the disease run its course and identify resistance in surviving trees. TCD has not been observed in trees at the University of Missouri or HTIRC in Indiana. These plantings contain improved timber and nut genotypes. Every effort should be made to protect and preserve the germplasm in these plantings. Unfortunately, these resources are located within the native range of black walnut, and could potentially be impacted by TCD in the future. It may be feasible to graft scion material from these important germplasm resources and relocate them to a region outside the native ranges of all North American species of walnuts and isolated from any infestation of the WTB. This would require committed long-term funding and a coordinated effort among various organizations throughout the nation.

There are current efforts to store walnut germplasm by cryopreservation of scion material (Mark Coggeshall, Univ. Missouri, personal communication). This research is in its infancy and will be expensive and labor intensive on a large scale.

Nut collection and storage may provide some short-term germplasm preservation. Nuts can be stored for at least four years without significant loss in germination (Williams, 1971). This may not be a viable long-term strategy.

## **IX. Infrastructure and Experts**

### *Vector*

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### *Thousand Canker Working Team*

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- **Phil Cannon**, FHP Regional Forest Pathologist, Pacific Southwest Region R5
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- **Whitney Cranshaw**, Professor & Extension Specialist, Colorado State University
- **Dennis Haugen**, Entomologist, Forest Health Protection, USDA Forest Service
- **Robert Lawrence**, Forest Entomologist, Missouri Department of Conservation
- **Phil Marshall**, Division Director, Indiana Department of Natural Resources
- **Jim McKenna** USDA Forest Service, Purdue University
- **Jay Pscheidt**, Professor, Oregon State University
- **Steven Seybold**, Research Entomologist, Pacific Southwest Research Station, USDA Forest Service
- **Eric Smith**, Program Manager, Forest Health Technology Enterprise Team, USDA Forest Service
- **Carla Thomas**, Associate Director, Western Plant Diagnostic Network
- **Sharon Dobesh**, Great Plains Diagnostic Network, Kansas State University
- **Ned Tisserat**, Professor & Extension Specialist, Colorado State University
- **Jerry Van Sambeek**, Cooperative Associate Professor, USDA Forest Service
- **Collin Wamsley**, State Entomologist, Missouri Department of Agriculture
- **Yun Wu**, Forest Health Technology Enterprise Team, USDA Forest Service

## **X. Research, Extension and Education Priorities**

### **Research Priorities**

Research is needed in many areas of this new disease including aspects of the WTB, *G. morbida* and the Juglans host and interactions between all three. The following key priorities have been identified as research goals.

- Investigate the life history and physiology of the WTB: number of generations per year, flight times, host range, tolerance to temperature extremes and temperature requirements for development.
- Isolate and identify WTB aggregation pheromones for monitoring behavior and trapping WTB. This includes identifying behaviorally active compounds, synthesizing these compounds and testing them in field and laboratory trials.
- Develop genetic markers for screening *G. morbida* populations throughout the western United States and Mexico to determine the origin and population structure of the pathogen and assist in identifying strains differing in pathogenicity or other features key to development of the disease.
- Develop genetic markers to determine the population structure and origin of WTB, especially in non-native plantings of *Juglans* species.
- Identify long-term methods for germplasm preservation. This may include establishment of new germplasm orchards outside TCD-affected areas, cryopreservation techniques, or long term storage of nuts
- Determine the host range for the WTB. Observe WTB colonization of various hosts in areas where many species are planted such as the National Clonal Germplasm Repository in Winters CA as well as field observations where multiple hosts occur.
- Determine means of disinfestation of wood products to permit salvaging diseased wood for safe transport throughout the United States.
- Investigate control measures such as chemical controls (fungicides and insecticides), biological controls, and measures to eradicate the complex from newly infected areas.
- Determine the host range of *G. morbida* and screen susceptible hosts for possible individual resistance for breeding purposes. Initial screening can be done in the greenhouse but this work should be followed by field testing.
- Determine the epidemiology of the disease including a timeline of disease progression and factors such as effects of stress level on disease transmission

### **Education and Extension Priorities**

- Expansion of training for early detectors of TCD to include: master gardeners, foresters, extension specialists, walnut producers and arborists.
- Preparation of training materials for identification and diagnostic procedures to include: WTB identification, *G. morbida* culture procedures and identification criteria.
- Preparation and distribution of educational materials for woodworkers and members of the timber industry.
- Develop Best Management Practices (BMP) for both urban and forested landscapes.

## **XI. Timeline for Recovery**

Recovery is unlikely to be accomplished in one year.

Disease resiliency factors: pathogen and vector are present on much of the range of the host, management of vector and pathogen are presently poorly understood, and we do not even know the present range of the vector or pathogen.

The current distribution of the WTB and *G. morbida* in North America needs to be delineated and then movement of infested logs and firewood needs to be prevented from infesting non infested areas. A national educational program on the threat of TCD needs to be developed and implemented. Methods need to be identified to sanitize infested logs so that they may be safely used for commercial purposes and prophylactic treatments (insecticides or fungicides) to preserve high value timber or landscape trees needs development. Management methods need to be developed for the biological control of WTB and resistance in black walnut or related walnut species to *G. morbida*. These projected approaches will take several years to implement in order to achieve a reasonable level of our former production of black walnut.

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## Web Resources

- Thousand Cankers Disease website hosted by Colorado State University: includes disease information, publications, images and contacts:
  - <http://www.colostate.edu/Depts/bspm/extension%20and%20outreach/thousand%20cankers.html> (site can be accessed through Thousandcankersdisease.org, thousandcankersdisease.com)
- Thousand cankers Wikipedia
  - [http://en.wikipedia.org/wiki/Thousand\\_cankers\\_disease](http://en.wikipedia.org/wiki/Thousand_cankers_disease)
- Thousand cankers disease website – Missouri
  - <http://mda.mo.gov/plants/pests/thousandcankers.php>