TITLE: The role of *Phytophthora cinnamomi* in recent oak mortalities in northeastern regions, one of the most destructive invasive forest pathogen.

LOCATION: Delaware, Maryland, New Jersey, Ohio, Pennsylvania, West Virginia

DATE: September 30, 2009

DURATION: Year 1 of 3-year project **FUNDING SOURCE:** Base EM

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FHP SPONSOR/CONTACT: Jim Steinman, USDA Forest Service FHM Regional Manager, Northeast Region, jsteinman@fs.fed.us.

PROJECT OBJECTIVES: The project objectives are as follows:

1) Evaluate the association of *P. cinnamomi* with oak decline in various sites across the northeastern US
2) Determine the current distribution of *P. cinnamomi* by sampling different latitude ranges across the study area
3) Establish a database on the etiology of oak decline in northeastern oak ecosystems with a critical review of data obtained through this study and FHM/FIA data

JUSTIFICATION:

- **a. Linkage:** Forest health monitoring and Forest Inventory reports reveal that oak decline is a significant and continuous threat to forest health throughout the eastern US. FHM surveys during the most recent years including 2009 showed that trees at several sites are declining in various parts of DE, MD, NJ, OH, PA and WV. Red oak decline is among the top five risk agents on the National Insect and Disease Risk Map.
- b. **Significance:** Over the past decade oak declines have led to pockets of elevated levels of standing dead biomass as reported on the inventory data from 2002-2006 in 24 states, including our study area. Oak declines within the study sites are common and possibly many sites will experience decline in following years.
- c. **Biological impact:** Oak trees are one of the most critical components across the study area with important ecological and economical values.
- d. **Scientific Basis/Feasibility:** Our collaborative team has extensive experience working with various forest pathogens, in particular *Phytophthora*. Oak decline was also among the research focuses of the principal investigator and cooperators in the past. By linking information from forest health monitoring network and collaborators in various states we will identify and analyze the association of the pathogens of concern with oak decline incidences.
- e. **Priority Issues**: This proposal explicitly addresses the involvement of **invasive pathogens** in current oak declines occurring across a wide range of stand conditions. It also updates and establishes a baseline database on their occurrence and association with oak decline across multiple states. It also will **fill in the data gaps** on causes of oak decline across multiple states.

DESCRIPTION:

a. Background: Among the various causes of oak decline, one pathogen has received special attention during the last decade, *Phytophthora cinnamomi*. It is among the world's 100 worst invasive alien species. Its host list exceeds thousands of plants and it endangers plant communities in various countries, most notoriously in Australia. It is considered exotic to North America with the suggestion that it was introduced more then a century ago (11,31). Historically it was reported in association with chestnut dieback in the Appalachian mountain range (10,11). However, its role decreased in oak ecosystems after the arrival of the Chestnut blight fungus. *P. cinnamomi* continued to survive and spread into new areas and is now wide-spread and the most common exotic Phytophthora species in the eastern US oak forest (3). *P. cinnamomi* has been implicated as a factor in the littleleaf disease complex of pine trees, with root rot and mortality of sand pine plantations in west Florida, and with the death of American chestnut in the southeastern United States (6,11,27,31). The species also threatens the Christmas tree industry (7,31). *P. cinnamomi* has been reported to be associated with bleeding cankers on *Q. laurifolia* in central Florida (30) and trunk cankers of *Q. agrifolia* and *Q. suber* in California (21). Its impact on oak trees under forest settings was shown in central Mexico on *Q. glaucoides*, *Q. peduncularis*, and *Q. salicifolia* (28) and in Europe on *Q. rubra* and *Q. robur* by its association with ink disease (24) and wide-spread decline of *Q. suber* and *Q. ilex* (8, 22).

Its role in oak decline in northeastern oak ecosystems has been largely underestimated and not studied. One of the possible reasons being its belowground pathology and lack of aboveground 'bleeding cankers' that may be obvious to land managers. Numerous disease examples in forests around the world indicate that *P. cinnamomi* is an aggressive root killing pathogen, which does not became obvious unless isolated from soil or necrotic root system. Seedling and tree trials have repeatedly demonstrated that *P. cinnamomi* is capable of causing substantial damage to oak roots if soil is infested artificially or when conditions are favourable in the field (1,2,4,12,13,16,18,19,20,23,24,25,26,28,29). Cork and Holm oak decline in Portugal and Spain are significant examples of its belowground impact in oak forests (8). Similar to the European oak decline case, in a white oak decline site at Scioto Trail State Forest (STSF) in southern Ross County (project was supported by FHM, see attachment for publication), we were able to demonstrate that *P. cinnamomi* was involved in white oak decline by mainly killing fine roots (5). The disease was particularly severe in moist lower bottomlands that favored the population of this pathogen (5). In this study we also found that infested white oak trees had 2.5 times less fine root than healthy non-infested trees.

White oak decline in STSF provides another example of an oak decline scenario where a root pathogen, a series of unusual environmental events, and a susceptible host resulted in decline or death of trees. Considering the epidemiology of *P. cinnamomi*, its impact is most likely to increase and a greater amount of oak decline should be expected particularly if favorable environmental conditions such as the current and expected unusual climatic events continue (9). The wide-spread occurrence of the exotic pathogen *P. cinnamomi* in eastern US oak forest has been demonstrated in a limited survey previously (3). Thus, whether *P. cinnamomi* is involved in oak decline such as in Ohio, needs to be evaluated throughout the northeastern oak ecosystems, which remained unexplored until now. This information is critical to understand and separate the different causal agents, the contributing and triggering factors in oak decline, which still remains hypothetical in various sites across the oak forests reported in FHM data. This information can be also useful for other efforts such as identifying future chestnut planting sites, particularly because *P. cinnamomi* is causing ca 60% mortality of hybrid blight resistant chestnuts (14). By using an updated map on the occurrence of a well-established exotic *Phytophthora* species, we also will start to develop reliable hazard maps for other potentially damaging *Phytophthora* species in future. The data also can be used for real-time decision support on detection surveys and proper assessment of the possible areas to be favorable for invasion by exotic Phytophthoras.

While we visit multiple sites, we will also collect data on other important pathogens. These will include bacterial leaf scorch, anthracnose, oak wilt and Hypoxylon canker. Recent reports from the state of New York, expended the known range of oak wilt much further beyond the northeastern limit (15). This new incidence suggests that the disease may have continued to expand to new areas due to human activities or maybe due to the climatic abnormalities that may have created conducive condition for its spread. New survey data (oak-wilt-like symptoms were observed in New Jersey and Delaware, FHM surveys, Alan Iskra, pers. communication) support this view, but it needs yet to be determined if oak wilt has reached those states and where the actual range of the disease is. Similarly, recent FHM surveys indicate the presence of bacterial leaf scorch in various oak forests, which may contribute to oak decline.

b. Methods: Study site selection: Study sites will be selected based on acquired information from forest health monitoring database and close collaboration with forest health personnel of various agencies including Department of Agriculture, Department of Natural Resources, USDA-Forest service in multiple northeastern states. Forest Inventory Analysis data will also be used to locate some of the decline sites. We are expecting to conduct the study in ca. 40 decline sites. Each of the sites will be visited and critical site/host data will be documented. Eight sites will be selected in each decline area, four healthy and four declining sites. In each study site, five trees of suspected declining oak species will be selected and processed as described below (40 trees in each decline site and aprox.1600 trees in 40 decline site across the study area).

Isolation of *Phytophthora* and other pathogens: In each study site, declining and healthy suspect oak species will be identified. A well-established soil baiting technique utilizing oak leaflets will be used to isolate *P. cinnamomi* from soil samples (17, 3). Soil samples will be processed in the laboratory as described in Balci et al. (2007). The decline sites will also be evaluated for symptoms characteristic of oak wilt such as wilting, premature leaf casting and bronzing of leaf margins. To isolate *C. fagacearum*, twigs will be removed from symptomatic trees within the decline site. Samples taken from discolored/ spotted vascular tissue will be plated on acidified potato dextrose agar. In each study site, the occurrence and association of Hypoxylon canker (based on fruiting structure), anthracnose (symptoms and fruiting structures) and bacterial leaf scorch (Real-time PCR methodology using *Xylella fastidiosa* specific primers) with healthy and declining trees will be determined.

Distribution of *P. cinnamomi*: In addition to the sampling of decline sites, sites will be randomly selected (Balci et al. 2007) in order to establish data on the occurrence of *P. cinnamomi* on oak forest sites (healthy or declining) above and below the N40 latitude range. In a multi-state survey, limited samples resulted with a landscape pattern for *P. cinnamomi* with N 40 being the upper most latitude range. The distribution also overlapped with the plant hardiness zone maps, thus initial sampling will include different hardiness zones and longitudes to validate this early observation. Based on the findings, we will select additional sites to expand the survey. I n each study site, five randomly chosen, healthy and slightly declining oak trees will be selected and soil samples collected (3). Oak species will include species within the red and white oak groups, which were found to harbor *P. cinnamomi* (3).

Oak decline etiology database: Beside the data generated on the etiology of oak decline during the first two-year field study, an extensive literature search will be conducted during the project duration. All documented oak decline occurrences and the diseases involved will be added in a database including host, geography, site characteristics as well as reported causal agents. This database will include a critical review considering the new research findings, oak decline incidences and causal agents. It can be uploaded to the Forest Health Monitoring web page. This database will be of an enormous resource to diagnose, understand and monitor oak health in the future and can provide baseline information for Forest Health Monitoring personnel.

c. Products:

- Evaluation of involvement of *P. cinnamomi* in oak decline across northeastern US
- A baseline map showing the current distribution of *P. cinnamomi*
- An updated and critically reviewed oak decline database showing all reported incidences and causes of oak decline in northeastern US
- Peer-reviewed publications in journals as well as proceeding posters and papers

d. Schedule of Activities:

Year 1 (2010): Site selection using 2009 reports and FHM data. Start to visit oak decline sites, collect material for pathogen isolation, complete isolation and evaluate first year data. Year 2 (2011): Continue to visit sites to evaluate *P. cinnamomi* association, sample soil in different longitudes above and below the N40 latitude range, complete isolations, evaluate data. Year 3 (2012): Complete any lab work, complete literature review to update oak decline database, prepare manuscripts for publication, attend meetings to present data.

COSTS: Salary includes a stipend for a MSc student including tuition and insurance coverage who will be responsible for the project, and monies for undergraduate student help (hr/$10) for sample processing in the lab. Travel costs are associated with vehicle rental and mileage costs. It also includes accommodation costs. Supplies include growth media, Petri dish, antibiotics, chemicals and costs associated with real-time PCR (disease assessment for bacterial leaf scorch) and facility rental (walk-in cooler to bait soil samples).

	Item	Requested FHM EM Funding	Other-Source Funding	Source
YEAR 2010				
Administration	Salary	$ 35,000	$ 24,000	0.30 UMD
	Fringe		$ 8,400	
	Overhead		$ 8,424	
	Travel	$5,000	$ 5,000	Start-up package
Procurements	Contracting			
	Equipment			
	Supplies	$8,000	$ 4,500	Start-up package
Total		**$ 48,000**	**$ 50,324**	
YEAR 2011				
Administration	Salary	$36,750	$ 24,000	
	Fringe		$ 8,400	
	Overhead		$ 8,424	
	Travel	$5,000	$ 5,000	Start-up package
Procurements	Contracting			
	Equipment			
	Supplies	$8,000	$ 4,500	Start-up package
Total		**$ 49,750**	**$ 50,324**	
YEAR 2012				
Administration	Salary	$ 33,075	$ 24,000	
	Fringe		$ 8,400	
	Overhead		$ 8,424	
	Travel	$8,000		
Procurements	Contracting			
	Equipment			
	Supplies	$2,500		
Total		**$ 43,575**	**$ 40,824**	
Total Budget		$ 141,325	$ 141,472	

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