2013 Project Abstract
For the Period Ending June 30, 2016

PROJECT TITLE: Finding Disease Resistant Elm Trees in Minnesota
PROJECT MANAGER: Robert A. Blanchette
AFFILIATION: University of Minnesota
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WEBSITE: http://elms.umn.edu/elm-map
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2013, Chp. 52, Sec. 2, Subd. 03h

APPROPRIATION AMOUNT: $200,000

Overall Project Outcomes and Results

Dutch elm disease is caused by an exotic invasive fungus (*Ophiostoma novo-ulmi*) that was introduced into Minnesota in the 1960's. Since that time the disease has killed millions of elms in urban and forested landscapes across the state. Although most American elms have no resistance to this pathogen, some continue to survive the disease and remain healthy in locations where all other elms have died. To determine if these trees have some tolerance to the disease or just escaped infection, we collected and inoculated a group of selected elms from across Minnesota. These trees were found from surveys with the help of city officials and the general public and they are from metropolitan and rural areas throughout the state. Accomplishments included:

1. Twenty-five trees were selected for testing during the first phase of the project.
2. All trees were successfully propagated to produce clones.
3. Successful inoculation methods were developed.
4. Clones were screened in greenhouse and field for resistance.
5. 600 trees representing different native elm selections have been planted in the elm research nursery at the University of Minnesota for continued testing and evaluation.
6. Over 50 additional selections have been identified and are available for propagation for the future

Results indicate that there is a range of elm genotypes that vary in their tolerance to Dutch elm disease. We are continuing our efforts to find the highest degree of resistance among different genotypes so more Minnesota-hardy elms can be added to our urban and rural landscapes. New elm selections will provide the much needed diversity in these important native species and will provide more options for replanting in communities devastated by the emerald ash borer and other exotic pests and diseases. A Phase II elm project which began on July 1, 2016 with funds from the Minnesota Environment and Natural Resource Trust Fund will allow the testing of more elms, study the mechanisms of resistance found in the trees and continue to field test our selections to ensure trees with the greatest resistance and best growth characteristics are available for planting by the people of Minnesota.

Project Results Use and Dissemination

Over the duration of this project many presentations, magazine articles, and scientific publications have been completed providing information about the project to a large audience of stakeholders including the arborists, nursery managers, foresters, researchers and the general public. We have received a great deal of feedback from the public supporting this project to find hardy Minnesota elms that are resistant to Dutch elm disease. With this information we are closer to our goal of introducing more Minnesota native elms back to our urban and rural landscape. Since the 1960's, Minnesota has lost millions of elms to this disease, changing the landscape. The results from our investigations show that there is hope to obtain resistant elms that are native to Minnesota and these will provide benefits to the environment and people of Minnesota.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2013 Work Plan Final Report

Date of Status Update Report: June 30, 2016
Date of Next Status Update Report: Final Report
Date of Work Plan Approval: June 11, 2013
Project Completion Date: June 30, 2016 **Is this an amendment request?** No

PROJECT TITLE: **Finding Disease Resistant Elm Trees in Minnesota**

Project Manager: Robert A. Blanchette
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Web Address: http://forestpathology.cfans.umn.edu/

Location: Statewide

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$200,000**
	Amount Spent:	**$200,000**
	Balance:	**$0**

Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 03h

Appropriation Language:
$200,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to evaluate and identify native Minnesota elms resistant to Dutch elm disease to assist with limiting the susceptibility of the state's elms to Dutch elm disease. This appropriation is available until June 30, 2016, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Finding Disease Resistant Elm Trees in Minnesota

II. PROJECT STATEMENT:

We propose to find elms [American (*Ulmus americana*), red (*Ulmus rubra*) and rock (*Ulmus thomasii*) elms)] from across Minnesota with resistance to Dutch elm disease, test them rigorously and have a large number of genetically different trees with resistance available so that this magnificent shade tree and important forest species will be brought back to its previous grandeur.

Dutch elm disease (DED) is a vascular wilt caused by two closely related fungi, *Ophiostoma ulmi* and *Ophiostoma novo-ulmi,* and is vectored by several elm bark beetles. This devastating wilt disease has killed millions of elms in Minnesota over the past five decades. So many trees have died people have just about given up hope for this tree. Losses from this invasive and exotic pathogen have been devastating and it has caused an ecological disaster. There is no tree more beautiful or well suited for urban conditions than the elm. They tolerate salt, pollution and other stresses better than other trees. Removing and disposing of diseased trees and other control programs are expensive. Municipal budget constraints over recent years have meant that less funding is available for control and elm mortality has increased steadily. We now find other introduced pests, such as the Emerald Ash Borer, threatening Minnesota ash trees and the need for new trees to be used for replanting in urban areas is greater than ever. Elms also play a vital part in the ecology of Minnesota's forests. Their seed provides important food for wildlife, they are excellent trees for wetlands and add to the biodiversity of a healthy forest (for example, 213 species of moths and butterflies are supported by elms). Elms can also be used for making furniture, boxes, crates and other wood products.

There is new hope for the elm! We have observed that some elms have survived and appear to have special characteristics making them resistant to Dutch elm disease. In our preliminary work, seedlings were grown from these trees and injected with the fungus. Results show some trees survive. Having a large genetic stock of hardy and resistant native Minnesota elms is vital to fight this deadly fungus. Our proposed project would:

1. Survey and identify resistant elm trees. From preliminary research supported by the Minnesota Turf and Grounds Foundation we identified and tested several elms and found 3 with different levels of resistance. We have information from arborists and city foresters about many other candidate elms from throughout Minnesota that appear to be resistant. They survive where all other elms have died. Screening (injecting with the fungus in greenhouse and field trials) will identify which of these trees are truly resistant. Once tree are selected they will be propagated using methods we recently developed.

2. Screen selected trees. To determine if trees are resistant, rigorous testing is needed. This is done by injecting trees with the fungus in greenhouse studies followed by additional field testing. The preliminary data shows that elms resistant to Dutch elm disease exist in Minnesota. Our testing will show which trees are resistant and with state wide screening we expect to find a large number of them.

3. Field testing of elms. Our goal is to obtain a diverse selection of elms from Minnesota that are genetically different but all have resistance. Field testing is essential and will be done on trees from our preliminary research as well as new selections made from this project. Field testing will also be used to identify trees with the best growth and hardiness characteristics.

III. PROJECT STATUS UPDATES:

Project Status as of *(January 2014)*:

Our work on finding disease resistant elm trees in Minnesota has had a successful start and excellent progress has been made over the first 6 months of the project. We have surveyed, identified and begun to propagate elms that have survived the disease in areas where other elms have been killed. An interactive map has been developed showing the location of these trees in Minnesota and is located on the web at: http://elms.umn.edu/elm-map .To evaluate these trees it is necessary to propagate them by making cuttings, grow the seedlings and then inoculate them with the fungus that causes Dutch elm disease. Propagation trials were done to find the most appropriate method for rooting the cuttings. These methods will be used for our winter / spring collections of propagation material from elms that have been identified in our surveys. In 2014,

we will be starting inoculation trials for selected elms and inoculation protocols were developed for seedlings grown in the greenhouse and for larger trees grown in the field. The methods provide for an effected challenge of the trees with virulent isolates of the fungus to assess resistance. To disseminate our results and progress on this project a web site has been developed at the University of Minnesota at elms.umn.edu. Information was also presented to several groups including a large group of urban foresters at the Minnesota Society of Arboriculture's Conference in October 2013 and an article about the project was published in Solutions Magazine and is online at: http://www.cfans.umn.edu/Solutions/Fall2013/ElmStreet/index.htm .

Jeff Gillman, a co PI on the proposal, has left the University of Minnesota for a position in North Carolina. Extension Professor Gary Johnson in the Department of Forest Resources at the University of Minnesota has become the new co-PI. Professor Johnson has extensive experience in urban forestry and is now the director of the tree nursery at the University of Minnesota. Jeff Gillman's contribution to this project was 1 month per year which equaled $36,900. Gary Johnson will now contribute one month per year on the project and this equals $28, 935. One of the research scientist positions listed on the grant has been reclassified from a Civil Service position to a Professional and Academic position and has changed from the Department of Horticulture to the Department of Forest Resources. There is no change in funds requested.

Project Status as of *(September 2014)***:**
In winter and spring of 2014, we successfully collected propagation material from many elms that appear to have resistance to Dutch elm disease. All of these elms were planted in the greenhouse for testing. Although trees have grown well, a preliminary inoculation trial indicated that the stem diameter was not large enough and vessel structure was not sufficient for proper testing. The trees are continuing to increase in size and will be used in our inoculation trials in spring of 2015 when they will be a more appropriate size for the testing protocols. Our outreach activities have continued to be successful to inform natural resource professionals and the general public about our Minnesota elm selection program to fine resistant trees. We have received information on many more prospective elms than we can process in our resistance screening program. Testing all of these trees would be advantageous since many of these trees have survived severe disease pressure and could have resistance. However, due to the limitation on how many elms we can propagate and process, we have been selective in the collections that were made. Notable trees were collected in Otter Tail County, Polk County, and Ramsey County. Additional information was collected on many more trees throughout the state setting the stage for future collections in southwest and southeast Minnesota. Propagation material from many of these trees will made during the winter and early spring of 2014-2015. Over three acres of field plots containing cloned trees have been established at the University of Minnesota in Saint Paul, MN. These trees have been planted for future field inoculation trials.

This work has shown that there are many extraordinary elm trees throughout the state of Minnesota that have resisted Dutch elm disease and it is very apparent that the public is very interested in finding out which trees are truly resistant so they can be used in the future. Expansion of the project appears warranted in future years so more elms can be tested and a larger group of elms with good resistance can be found and made available for planting. Finding new trees for urban landscapes is especially important since many communities are facing the threat from the Emerald ash borer and must plant trees other than ash in the future.

Project Status as of *(March 2015)***:**
Collection, propagation and production of putatively resistant elm selections continued during the past 6 months. Several new collection areas in south central, southeast and southwestern Minnesota were identified and visited during this season. Stems from selected trees surviving Dutch elm disease were used to graft onto established root systems and rooted cuttings have been made. Work continues to develop better and more efficient ways to propagate American, red and rock elms. Many collaborators and partnerships from throughout Minnesota have allowed for identification of potentially resistant elms, aided in collection and resulted in successful propagation of the elms for our upcoming greenhouse and field testing. Inoculation trials are also moving forward and we are currently carrying out inoculations in the greenhouse with a number of new

selections. These clones will be monitored over the coming weeks and disease symptoms assessed. Preparations are also being made to inoculate seedlings in the field this spring about 40 days after bud break. In addition to testing clones in the field we have also been collecting new isolates of the fungus to test a number of inoculation methods as well as to screen the isolates for pathogenicity.

Project Status as of *(September 2015)***:**

Many of the trees collected and propagated during this period of the project have been planted into nursery pots or into field plots for further growth and to get them established so disease inoculations can take place. Work has continued during the summer months to collect more data on auxin conversion rates in native elms and to fine tune collection dates and procedures for softwood cuttings propagation. Inoculation and screening of potential resistant selections has continued. Greenhouse trials in the first round of testing of selections acquired so far have shown several promising selections that have been identified and planted out in field plots for further testing. Inoculation protocols are also being optimized by testing the timing and location (branch vs stem) for the field inoculations. Preparations are now being made for a greenhouse inoculation trial during the winter months with additional elm selections.

Project Status as of *(March 2016)***:**
The project continues without difficulties and good progress has been made. Propagation via grafting has continued from many selections that were made this winter and also to increase the numbers of clones from previous collection. A greenhouse inoculation trial was initiated with 14 different elm selections. Initial results are promising and disease ratings will continue for 10 more weeks. Preparations are also being made to inoculate trees in the field plots in late May/early June. Timing for this inoculation will be dependent on climactic conditions and growth progress of the trees this spring. Expansion of field plots at the Minnesota Landscape Arboretum in Chanhassen, MN will continue this spring, establishing a new location for performance and inoculation trials. We are on target with the budget for the project. However, one category of spending (Greenhouse maintenance fees and service fees for field plots) was slightly more than originally planned. This is primarily due to differences with expense titles in the University accounting system for Lab/Medical Services and expenses were slightly greater than anticipated. Other categories of the budget will have remaining funds to cover this small deficit in the "Other" category in Attachment A Budget detail.

Amendment Request (05/01/2016):
An amendment request is being made for the budget under the budget item listed as "Other". This category was for greenhouse and field nursery costs. Over the past few years the costs in this category were over the expected amount. We had requested $2500 and the amount spent to date is $8308. This makes a deficit of $5808. To cover this deficient, we would like to move funds from other budget categories. The budget for "travel" was less than expected and we have $1828 remaining. We would like to move this amount to the "other "category. To cover the remaining deficit of $3980, we would like to move $3980 from the "personnel" budget item. We have some funds remaining in this category from unused funds for an undergraduate student and some funds in the fringe benefits remaining. This Phase one project is ending June 30, 2016 and we may have a small amount of additional deficit in the "other" category when the accounting is complete. With this amendment we would like to also request a move of funds from the "personnel "category to the "other" category if it is needed. The final budget total will not be greater than our allotted amount of $200,000.
Amendment Approved by LCCMR 5-11-2016

Final Report Summary
Dutch elm disease is caused by an exotic invasive fungus (*Ophiostoma novo-ulmi*) that was introduced into Minnesota in the 1960's. Since that time the disease has killed millions of elms in urban and forested landscapes across the state. Although most American elms have no resistance to this pathogen, some continue to survive the disease and remain healthy in locations where all other elms have died. To determine if these trees have some tolerance to the disease or just escaped infection, we collected and inoculated a group of selected elms

from across Minnesota. These trees were found from surveys with the help of city officials and the general public and they are from metropolitan and rural areas throughout the state. Accomplishments included:

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5. 600 trees representing different native elm selections have been planted in the elm research nursery at the University of Minnesota for continued testing and evaluation.
6. Over 50 additional selections have been identified and are available for propagation for the future

Results indicate that there is a range of elm genotypes that vary in their tolerance to Dutch elm disease. We are continuing our efforts to find the highest degree of resistance among different genotypes so more Minnesota-hardy elms can be added to our urban and rural landscapes. New elm selections will provide the much needed diversity in these important native species and will provide more options for replanting in communities devastated by the emerald ash borer and other exotic pests and diseases. A Phase II elm project which began on July 1, 2016 with funds from the Minnesota Environment and Natural Resource Trust Fund will allow the testing of more elms, study the mechanisms of resistance found in the trees and continue to field test our selections to ensure trees with the greatest resistance and best growth characteristics are available for planting by the people of Minnesota.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1:

Description: Identify and grow resistant Minnesota elms for testing.

With the help of landowners, park and city personnel, arborists, state and national forest managers as well as our surveys of the Minnesota landscape we will identify large, mature elms that have survived heavy pressure from Dutch elm disease. Cuttings will be taken from the growing tips of these trees and rooted and/or grafted in the greenhouse to obtain sufficient numbers of each tree for disease screening. Recently, advances to get elm cuttings to grow by rooting of the branch material have been made and these methods will be used in these investigation. We will use methods developed at the University of Minnesota to propagate elms that appear to have resistance will be selected from diverse locations throughout the state where elms grow. To reduce costs associated with obtaining cuttings from the tops of large elms thought to be resistant, we will solicit the help of city foresters and arborists to get the elm cuttings from the tops of these trees. We expect to obtain propagation material from a minimum of 25 trees. Since the allocated funds were less than the original amount requested, the number of trees that can be screened has been reduced from the original proposal plan. Although this is less than our original goal we should be able to still evaluate a substantial number (25) of trees. As surveys are made, all elm trees with possible resistance will be noted and could be used for possible future propagation work and screenings as additional funds are obtained.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 69,567
Amount Spent: $ 69,567
Balance: 0

Activity Completion Date:

Outcome	Completion Date	Budget
1. *Find and propagate 15 Minnesota elms that appear to have disease resistance*	9/2014	$34,784
2. *Find and propagate 10 additional Minnesota elms that appear to have disease resistance*	9/2015	$34,783

Activity Status as of *(January 2014)*:

The past six months was a productive beginning for the project as we investigated native elms that may have resistance. We have been communicating with a variety of individuals, landowners, city officials, arborists and foresters to identify candidate elms for our program. In total, we identified thirty elms, including American elms along with several red and rock elms. An interactive map has been developed and is on-line to show the locations for the various elms that have been identified around the state of Minnesota. The map can be found at http://elms.umn.edu/elm-map. Detailed information about these trees has been obtained and a few examples of the identified trees are listed below along with a photograph of the tree.

MNT-0356- *Ulmus americana* (American Elm) located in Hennepin County. This tree has been under observation for nearly 20 years and continues to show excellent survival in the midst of extreme pressure from Dutch elm disease. It is now being propagated.

MNT-0357- *Ulmus americana* located in Hennepin County. This tree has undergone decades of observation by trained foresters and has had numerous instances of recovery after obvious infection with Dutch elm disease.

MNT-0359- *Ulmus americana* collected in St. Louis County. An elm remaining after all other elms on the street had been killed by Dutch elm disease.

MNT-0443- *Ulmus rubra* (Red Elm) located in Hennepin County. This is one of two red elms that have survived in the Three Rivers Parks District system and they are the sole surviving red elms from the entire park population. Current stem diameter is over 40 inches.

MNT-0546- *Ulmus thomasii* (Rock Elm) located in Wright County. This tree's estimated height is a stunning 100-107 feet.

MNT-0389- *Ulmus americana* located in Wright County. The tree has an estimated height of 30-35 feet with a 48 inch stem diameter. This unique spreading form is of considerable horticultural interest and it has remained free of disease.

Vegetative Propagation by Stem Cuttings

With the identity of many potentially resistant elms known, cuttings are needed to make clones of the trees for testing. Clones of selected American, red, and rock elms are required to effectively screen them for disease resistance. American elms have a relatively long track record of propagation via stem cuttings, however, there is considerable variability in the success rate of rooting based on the genotype and the timing of collection. Improving predictability and success rate of cloning Minnesota-native elms via stem cuttings is a critical aspect of the selection program as well as their ultimate commercial utilization.

Cuttings are taken from the current year's growth of selected trees and either grafted to wild elm rootstocks or placed in soilless growing media in a carefully controlled greenhouse environment to root. Cloning techniques are being refined to improve production capabilities of the elm cuttings taken from the promising trees selected for study. Propagation by stem cuttings is done by taking tip branches from terminal nodes as well as internodes with three to five buds, and an average length of approximately 15cm. Cuttings are scored at the base and treated with an ethanol-based liquid rooting hormone containing indole-3-butyric acid (IBA) and 1-naphthaleneacetic acid (NAA). The treated cuttings are then planted in a soilless rooting substrate in the greenhouse with average supplemental lighting of 126W per m^2.

Work continues to find and test viable methods for commercial production of potentially resistant elm selections. We will continue to perfect softwood cuttings propagation techniques by exploring optimum collection time and rooting hormone combinations and concentrations as well as stock plant and post-harvest cutting treatments to enhance rooting success and long-term survival. One of the rooted cuttings can be seen in the following photo:

Grafting Activities

While vegetative propagation of selected trees is the desired method to obtain greater numbers of clones (all genetically identical), grafting is also utilized to generate more material for vegetative propagation without having to revisit parent trees. Grafting of desirable elm selections onto wild type American and Siberian Elm rootstocks is done using the cleft graft technique. Grafting selections onto already developed seedling produces faster growth compared to using a cutting propagation technique. The quick growth of the grafted elm selection allows us to propagate more cuttings of the selection without traveling to the parent tree. The process of grafting elm selections onto rootstocks include potting up seedling rootstocks into containers, collecting dormant plant material from the desired elm selection, and finally grafting. The cleft graft method was used on all trees due to the simplicity and high success rate. The cleft graft was done by cutting the rootstock down to 15cm above the soil line and cutting a slit down the center of the stem with a sharp knife. Fifteen cm of new growth cut from a desirable selection (called the scion) was collected from the field. A small narrow wedge was made at the base of the scion that would be placed inside the slit of the rootstock made earlier. The most important step in grafting is making sure the cambium of both the scion and the rootstock touch to ensure a successful union. Once the scion is placed in the rootstock, a rubber band is used to wrap the graft union tightly together. Finally, a small piece of laboratory film is wrapped around the graft union on top of the rubber band to keep the graft union from drying out. Within 4-6 weeks of being in the greenhouse, the scion and the rootstock graft together. It is normal for the freshly grafted elm selection to grow one to three feet in an average growing season. This new growth can then be used in vegetative propagation thereby maintaining clonality with the parent. The

propagation of clones by grafting is underway and good success of the grafted materials has been obtained. The following photo shows a successful graft of a selected potentially resistant elm branch (top of seedling) onto established elm root stock (bottom of the seedling).

Activity Status as of *(September 2014)*:
New elm collection activities during 2014 allowed us to collect and clone an additional 15 new American elms – including 12 specimens from northwestern Minnesota. Collection in this region was focused on the City of Fergus Falls which is home to an incredible population of American elms that is diverse in size and form.

Fergus Falls, MN – Large numbers of elms surviving in Adams Park

In cooperation with Fergus Falls' City Forester, Keith Stafford we identified a prime location in Adams Park, a public park that had significant disease pressure in recent years which resulted in heavy losses to Dutch elm disease. Surveys of this park yielded 10 trees selected for superior form and size. One additional tree was collected from a large surviving boulevard American elm, one of the largest known public boulevard trees in the City.

Fergus Falls, MN – Elm trees near the downtown public library

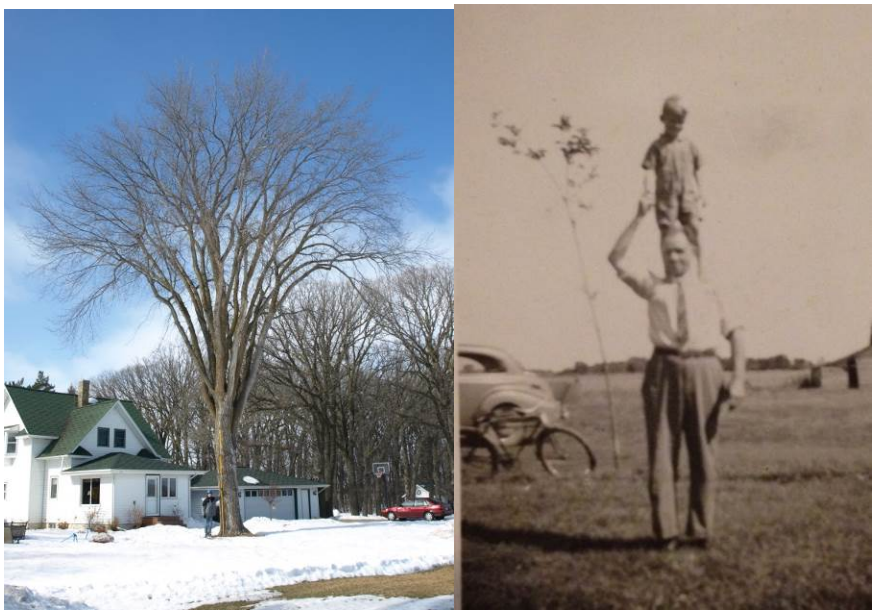
MNT – 0322 – *Ulmus americana* (American elm) located in Otter Tail County. This specimen exhibits a classic vase-shape and is growing in an area under significant disease pressure.

MNT – 0329 – *Ulmus americana* (American elm) located in Otter Tail County. This tree has a dense, upright crown and is growing in a large stand of established American elms in the City of Fergus Falls, MN.

MNT – 0331 – *Ulmus americana* (American elm) located in Otter Tail County. This specimen exhibits the unique "spreading oak" form.

MNT – 0333 – *Ulmus americana* (American elm) located in Otter Tail County. This massive tree is located in a public boulevard in Fergus Falls, MN and continues to thrive under heavy, local disease pressure.

MNT – 0334 – *Ulmus americana* (American elm) located in Polk County. This specimen exhibits the classic vase-shape and is growing in an area that has had a history of significant disease pressure. The property owner indicated that this is the sole survivor of four elms collected locally and planted during the 1940s by his father. This tree showed symptoms of DED and subsequently recovered. Surviving tree (left) and historical photograph of when the tree was planted (right).



MNT – 0307 – *Ulmus americana* (American elm) located in Ramsey County. This large specimen growing in a public boulevard is one of several survivors in an area of heavy disease pressure in Saint Paul, MN.

MNT – 0306 – *Ulmus americana* (American elm) located in Ramsey County.

MNT – 0305 – *Ulmus americana* (American elm) located in Ramsey County.

MNT – 0370 – *Ulmus americana* (American elm) located in Ramsey County.

Vegetative Propagation by Stem Cuttings

Important discoveries examining the role of auxin conversion (the hormone responsible for rooting stem cuttings) were made allowing greater insight into establishing an optimum time frame for cuttings collection and optimized rooting. The results from this study are currently being prepared for publication.

Propagation by Tissue Culture

Exploration of elm propagation using various tissue culture techniques yielded favorable results during the late winter and early spring of 2014. Using protocols previously established, several American, red and rock elm selections were established in tissue culture media. Nearly all clones tested were capable of forming callus tissue in culture giving hope of continuing the work to establish shoots and then roots in culture. Several American elm selections were also rooted in culture tubes giving insight into another method of propagation that may allow almost continuous production of clones for disease screening purposes.

Preparing tissue culture material in a laminar flow hood

Culture tubes with stem sections (left) and tubes with excellent callus development (right)

Grafting Activities

Grafting of selected parent trees continued during this quarter to establish on-campus sources of scion wood and clones for future disease screening. The use of wild-type rootstocks has an incredible effect on growth allowing newly grafted trees to grow several feet in a single growing season. Material for tissue culture and stem cuttings propagation can be harvested from these grafted trees to exponentially increase numbers for future disease screening trials in the greenhouse as well as in University field plots.

Grafted American elm (left) and red elm (right) showing growth during the first growing season

Field Plot Establishment

Over three acres of field plots containing cloned trees have been established at the University of Minnesota in Saint Paul, MN. Through the use of tree tubes and drip irrigation establishment and growth has been exceptional during the 2014 growing season. These trees will be used for disease screening in both the greenhouse and field

One year old elm clones growing in protective tree tubes.

Activity Status as of *(March 2015)***:**
Statewide collections from survivor elms continued during the winter of 2014-2015. Important collaborations were made with Minnesota DNR Parks and Trails staff that allowed identification of several key areas of survivor American and red elms in Lake Shetek State Park (Murray County) and Camden State Park (Lyon County). Additional trees were identified and collected in the following Minnesota counties: St. Louis, Polk, Murray, Lyon, Wabasha, Hennepin, Ramsey, Blue Earth, Nicollet and Le Sueur. This was done with the assistance of local forestry and public works personnel. Trees from all areas mentioned are particularly notable because they are surviving in areas of continuous and heavy pressure from Dutch elm disease.

Ulmus americana **(American elm) located in Wabasha County. This tree is the sole survivor in this area after devastating losses to DED in the early 1980s.**

Collection activities on an *Ulmus americana* (American elm) in Blue Earth County in January 2015

***Ulmus americana* (American elm) located in Ramsey County. This specimen exhibits a unique "crown spreading" form.**

***Ulmus americana* (American elm) located in Lyon County, still healthy after decades of disease pressure and without chemical injections to control Dutch elm disease.**

***Ulmus americana* (American elms) located in Hennepin County. These specimens have survived under very heavy disease pressure.**

***Ulmus americana* (American elm) located in Lyon County. Stem material is being taken for propagation.**

Ulmus americana **(American elm) located in Wabasha County with extraordinary form and has survived when other elms in the area have died.**

Ulmus rubra **(red elm) collected from an island on Lake Shetek in Murray County. This surviving tree is one of just a handful that survived Dutch elm disease in this area.**

Research into propagation using softwood stem cuttings has yielded interesting and valuable results. In cooperation with scientists in the Department of Horticultural Science at the University of Minnesota we were able to identify traits among native American elm that affected their success in propagation using softwood stem cuttings. Timing of collecting softwood cuttings remains a major hurdle for growers wishing to efficiently propagate elm cultivars in commercial nurseries. Continued funding of this work will help establish Growing Degree Day Base 50 (GDD50) requirements and optimum collection times to maximize rooting success in softwood cuttings collected from American, red and hybrid elms. In previous work, rooting success in several American elm genotypes varied from nearly 100% to less than 25% in just a three week period with rooting clearly influenced by auxin conversion (IBA to IAA). Due to differences and seasonal variation in auxin conversion already observed between different American elms, further work is necessary to offer insight into propagation requirements for additional elm genotypes.

Softwood stem cuttings collected from greenhouse clones in March 2015. These stems were treated with rooting hormone and placed in a propagation tray in a mist chamber in the greenhouse.

Successful rooted stem cuttings of an *Ulmus americana* (American elm).

Stems from *Ulmus americana* (American elm) utilized for propagation by layering in a greenhouse mist chamber. Older, woody stems were wounded at nodes and treated with rooting hormone to initiate rooting. This system could more completely and efficiently use collected branch material for propagation.

Work continues to examine micropropagation and tissue culture techniques that will allow us to quickly and continuously produce elm clones from greenhouse stock. Current investigations have examined the effects of shoot forcing as well as different hormone and disinfestation treatments on micropropagation success. Our ultimate goal is to establish efficient and successful micropropagation protocols allowing us to continuously produce American, red and rock elm clones for disease tolerance screening. Our current work in micropropagation differs from previous work in that it will examine propagation methods for a broad range of elm species.

Grafted *Ulmus rubra* (red elm) collected in Lyon County just starting to break bud in the greenhouse.

A fully leafed-out, grafted *Ulmus americana* (American elm) collected in Otter Tail County.

Seed Production and Seedling Nursery Establishment: Seedlings are now growing from seed collected from survivor American and red elms. Older branches collected in the field are forced in the lab to produce flowers and seed for future work with seedlings. Important connections were made in early 2015 that have identified locations in Minnesota for establishment of seedling nurseries and plantations useful for native elm regeneration and breeding. The first proposed site is on a 10 acre parcel at UMN Cloquet Forestry Center (CFC). Due to the isolated nature of this site it is a great opportunity to examine seedlings selected from elite breeding lines with little chance of cross-pollination from native stands. Plans are currently underway to assess this plot for planting in fall of 2015. The elm surveys and collections at Camden State Park and Lake Shetek State Park yielded additional potential for cooperation with Minnesota Department of Natural Resources – Parks and Trails (PAT). Not only were these parks an excellent source of survivor American and red elms, they also present themselves as prime locations for seedling nurseries and varietal trials. Unlike the plot at CFC described above, these parks still have native elms present, but disease pressure is still very high.

Activity Status as of *(September 2015)***:**

Clones from trees propagated during the winter of 2014-2015 were grown at the research nursery at the University of Minnesota and become fully established for greenhouse inoculations and field testing. Production and culture of rootstocks was carried out during the summer of 2015 in preparation for the winter propagation season, producing enough rootstocks to graft several hundred additional trees during the winter of 2015-2016.

American elm rootstocks in gravel bed culture at the University of Minnesota

Propagation of trees in the collection at the University of Minnesota continued through the summer months utilizing softwood stem cuttings. Most commercial nurseries continue to use softwood stem cuttings to propagate American elm and research has continued to identify optimum collection times for this system. Building on work initiated in 2014, a new research project was initiated in June 2015 to acquire additional data. New species were added this year to include both red and rock elm selections in hopes to find new ways to propagate these important, native species.

Final Report Summary:

Propagation of previously identified trees has continued since the last progress report. We have continued to produce elm clones using grafting and stem cutting techniques throughout the late winter and early spring. Propagation using stem cuttings from field grown material commenced in mid-June as well. Research continues to help better understand the relationship between plant hormones and the relative success of using stem cuttings as a propagation method; positive results will benefit the commercialization of disease-resistant elm selections.

During the first phase of this research we successfully surveyed, propagated, and screened 25 unique American, red, and rock elm genotypes from locations throughout Minnesota for Dutch elm disease resistance. All 25 selections have undergone greenhouse and/or field disease screening trials and have been collected from the following Minnesota counties:

- Hennepin
- Kandiyohi
- Murray
- Otter Tail
- Ramsey
- St. Louis
- Washington

New elms selected in 2016: American elm (left) and red elm (right).

More selections from many other counties are planned for inclusion in Phase II of the research.

ACTIVITY 2:

Description: Screen selected elms for resistance

Using previous methods found to be successful, replicated studies using the seedlings obtained from Activity 1 will be grown in the greenhouse and tested for resistance to Dutch elm disease. The Dutch elm disease fungus from Minnesota will be injected into these trees and disease monitored. This screening method provides an excellent way to select the trees with the most potential for resistance. For these studies, the fungus will be grown in the laboratory and a spore suspension obtained. A known quantity of spores will be used to inoculate each seedling. A large number of cloned seedlings are needed for this testing and all experiments will be replicated. To serve as a control, susceptible elm seedlings will also be injected for comparison. Disease progression will be noted over several months and clones that show resistance planted in the field for further testing.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 74,839
Amount Spent: $ 74,839
Balance: $ 0

Activity Completion Date:

Outcome	Completion Date	Budget
1. *Complete disease screening for elms obtained during the first year*	9/2015	$34,284
2. *Complete disease screening for second year elm selections*	3/2016	$34,283

Activity Status as of *(September 2014)***:**

Timing of inoculations on host material is critical. Both the age of the seedling/tree and growth stage play a role in disease development. Due to this, inoculation techniques in the greenhouse were tested and optimized. A specific study was done to determine the age of inoculation. Young seedlings were inoculated in the greenhouse and showed that the susceptible controls failed to show symptoms indicating that sufficient growth was not occurring to cause disease symptoms. Also, in an effort to optimize the evaluation of current year's selections in the greenhouse without waiting one year for rooted seedlings to establish, grafted material was evaluated for greenhouse inoculations. However disease development did not occur on susceptible seedlings (control) as well which indicates that the time of inoculation was too soon after grafting. Adjustments have been made allowing for more growth to occur after grafting.

Preparations are being made to inoculate grafted material that has grown this season in March in the greenhouse to test the current selections.

Selection MN0345 being inoculated in the greenhouse.

Activity Status as of *(March 2015)***:**
Putative resistant American and red elm selections that have been grafted are currently undergoing greenhouse screening. These include 17 unique genotypes collected during the 2012-2013 and 2013-2014 collection seasons. These greenhouse specimens were grafted during the winter of 2013-2014 and have recently been brought out of dormancy to allow a flush of growth in the greenhouse. Inoculation consists of injecting a spore suspension of the pathogen into a small wound in the seedling. After inoculation, seedlings will be kept in the greenhouse to rate symptom development. Symptoms are rated by the amount of wilting that occurs and is compared to susceptible control seedlings. Symptom development typically reaches its peak at 4 weeks post inoculation. Ratings of inoculated grafted clones will be taken into consideration for future trials per given selection.

Selections of elms growing in the greenhouse for inoculations this spring.

Activity Status as of *(September 2015)***:**

Greenhouse inoculations and rating of seedlings that was begun in March have been completed. Ratings of tested seedlings revealed several selections that performed as good or better as current resistant selections. These selections have been planted out in the field for further testing in the next field season.

Elms seedlings being injected with a spore suspension of the Dutch elm disease fungus *Ophiostoma novo-ulmi*


Seedlings in the greenhouse 4 weeks following inoculation with DED pathogen. Left; control seedling on left and inoculated right showing advanced wilt symptoms. Right; control seedling on left and inoculated seedling right showing no symptoms.

Activity Status as of (*March 2016*)

Fourteen putative resistant American, red and rock elm selections that were grafted on wild type rootstock were removed from cold storage in February and inoculated in March. The two week disease severity data shows that disease has progressed in the wild type and is limited in most of the putatively resistant selections. Disease ratings will be taken every two weeks for 10-12 weeks and special consideration will be placed on whether some selections that had initial wilt, recover and re-flush with new growth. The re-flushing of leaves and recovery are characteristics that we have observed in other resistant selections in our trials. The clones that score well will move into field trials.

Grafted elm selections that have been inoculated in the greenhouse and are being rated every two weeks for disease severity

Final Report Summary:

Investigations during this project have developed and perfected inoculation methods that have proved to be successful for the screening of elms with putative resistance to Dutch elm disease. This rapid and efficient method is used to inoculate seedlings in the greenhouse. This provides the first screening of elms to identify trees that may have resistance. Trees surviving these initial inoculations are planted in the field, and after growing for 2-3 years they are once again inoculated under field conditions.

Since our last progress report in March 2016, a final greenhouse trial for these funds was inoculated and trees were rated every two weeks until 10 weeks post inoculation. The results were very positive with 12 of the 13 elm selections showing on average nearly half of the amount of wilt that the wild type elm trees exhibited. Additional studies are being done with these seedlings to examine the internal tree defense mechanisms present. These include morphological and chemical defenses. To monitor the progression of wilt, representative trees were harvested and a dye used to determine differences in functional water conducting tissue as well as defense barriers that form in response to the pathogen. These characteristics indicate how tolerant selections are to the DED pathogen. These investigations are continuing and are part of our Phase II project that was funded on July 1, 2016 by the Environment and Natural Resources Trust Fund. This work will add insight into the mechanisms of resistance that are present within the selected elms. Further inoculations will also continue with these selections that have been planted in the field for long term testing. Currently, we have 16 elm selections that performed well in the greenhouse screening tests and have been planted in the field for monitoring and additional inoculation tests.

Seedlings 10 weeks post inoculation from recent greenhouse trials illustrating the effectiveness of this greenhouse inoculation screening method. Each photo shows two seedlings, a control (left) and inoculated (right). The left photo shows the inoculated seedling with no wilt symptoms and a putative resistant tree while the right photo shows a different selection that was not resistant and it exhibited 100 percent wilt.

ACTIVITY 3: Field testing of selected clones with resistance.

Description:

To confirm that trees showing resistance in greenhouse inoculation trials are truly resistant, it is essential to grow the trees in the field and inoculate under field conditions. Trees selected from the greenhouse experiments that showed high levels of resistance to the inoculations with the Dutch elm disease fungus will be grown in the University of Minnesota tree nursery. Replicated plots of selected trees will be inoculated with a spore suspension of the Dutch elm disease fungus and monitored for symptom development and disease resistance. We anticipate having nine experimental units of each genotype divided into three blocks with three replicates for each block in field experiments. Susceptible elm trees will also be planted in the field and inoculated for comparison. Additional evaluations will be done to determine the tree's growth rate and general growth characteristics to determine their suitability for planting in Minnesota.

Summary Budget Information for Activity 3:

ENRTF Budget:	**$ 55,594**
Amount Spent:	**$ 55,594**
Balance:	**$ 0**

Activity Completion Date:

Outcome	Completion Date	Budget
1. *Field planting of selected elms*	**10/2015**	**$30,933**
2. *Disease screening of elms in the field*	**6/2016**	**$30,933**

Activity Status as of *(March 2015)***:**

Grafted selections made during the winter of 2011-2012 have been planted in the field and are awaiting inoculation. Inoculation will take place 40-50 days after bud break when the tree is actively growing and adding earlywood vessel tissue making it conducive for disease development. During the spring of 2015 six grafted genotypes will be inoculated and assessed for disease tolerance in the field. In addition to the grafted selections we also have an extensive planting of wild type seedlings in the field. We plan to use these seedlings to

investigate different inoculation protocols as well as test different strains of the pathogen. We have been isolating the pathogen from diseased trees from the metro area and greater Minnesota and will use the wild type field planting to test the pathogenicity of the obtained strains. We feel this is an important due to possible changes in the virulence of the pathogen in the recent past. In addition, inoculations have been historically made in the main stem when testing elms for resistance. This, however, is a very aggressive method. This protocol can be used to reveal only the most resistant selections. We want to mimic real world infections and not overlook intermediate resistance that would stand up well in a natural infection scenario. The field grown trees will therefore receive branch inoculations (the location where the beetles that carry the pathogen normally would feed on a tree) with inoculum prepared in the same manner as other inoculations.

Field grown grafted American elm (left) and base of tree trunk showing the healed graft site (right)

Activity Status as of *(September 2015)***:**
Field testing continued in June with an inoculation of wild type American elm to test inoculation methodology. Historically, other studies have used a combination of either stem or branch inoculations. In order to optimize our screening procedure we set up a study to test both methods. We used wild type seedlings and inoculated in the branch or stem and rated disease severity over the season. The results show that while both methods were very effective at causing wilt symptoms, the main difference was the rate at which symptoms developed. The main stem inoculations wilted more rapidly than branch inoculated seedlings. Given these results we plan to move forward with branch inoculations with resistant selections because they are more representative of natural infection process that occurs from beetles and this method appears to be the best way to evaluate the resistant defense mechanisms in trees.

Field inoculation plot of wild elms optimizing inoculation methods

Many new selections obtained during the 2013-2014 and 2014-2015 propagation season were planted in field plots at the University of Minnesota during this periodr. This includes selections of all three native elms (American, red and rock elms). These plantings will provide trees for future inoculation trials and performance evaluations.

Two new elm plots established this season at the University of Minnesota in Saint Paul, MN.

Exceptional rainfall and favorable growing conditions have accelerated the growth of many elms in field plots at the University of Minnesota. Many new selections are now large enough to be inoculated in spring 2016.

Two new American elm genotypes sourced from Greater Minnesota in a field plot at the University of Minnesota. These two specimens are now ready for inoculation trials.

A new plot of elms was also established at the Minnesota Landscape Arboretum in Chanhassen, MN. This plot is adjacent to the Minnesota National Elm Trial plot and provides an excellent opportunity to both trial elm selections and provide field space for inoculation trials. This plot is located on Highway 5, just east of the Arboretum main entrance.

Two views of the new elm plots at the Minnesota Landscape Arboretum.

Activity Status as of *(March 2016)***:**
A field inoculation will take place at the end of May or the beginning of June. Monitoring of field plots has begun to determine when bud break occurs. Timing is crucial and needs to take place as earlywood vessels are forming in order for disease severity to be tested aggressively. This will take place approximately 40 days following bud break, depending on climactic conditions. We are also in the planning stages for inoculation trials at the National Elm Trial plot at the Minnesota Landscape Arboretum in Chanhassen, MN and the elm planting at the WWII Memorial at the Minnesota State Capitol. The National Elm Trial was a 10 year trial designed to track growth characteristics of different elm selections at plots located throughout the United States. Because that portion of

the trial is now complete, we have been given permission to inoculate some of the trees that remain and establish another field plot for resistant elm selection trials. The WWII memorial is home to Princeton elms that have been declining over the past several years which resulted in a decision to replant the area. We have been given permission to inoculate these elms this spring and use it as a trial. This is an excellent opportunity to test large, established Princeton elms (thought to be resistant) in the field, especially when there have been reports nationwide of this tree dying in greater numbers from Dutch elm disease.

Final Report Summary:
Field inoculations have produced valuable results, not only are we closer to identifying hardy Minnesota disease tolerant elm selections, but we are also closer to understanding the mechanisms behind the tolerance. We are hopeful that our selections tested in the greenhouse will continue to show good tolerance to the disease as we conduct longer term studies. In addition, we have also optimized our inoculation procedures which involve timing of inoculation to when trees are usually most susceptible, most appropriate inoculation methods in the field trees (branch vs. main stem inoculation) and amount of inoculum. Historically researchers have used main stem inoculations, however, through a pilot study using wild type susceptible elms and a combination of either branch or main stem inoculations, we concluded that branch inoculations are sufficiently aggressive, while main stem inoculations can be overly aggressive and override resistance in the trees. The branch inoculation methods also mimic the natural process of inoculation when the fungus is transmitted by the elm bark beetle. The timing of inoculation has also been found to be exceedingly important. This must be done when the trees are at a physiological stage where the inoculum is introduced into the rapidly expanding xylem when the larger earlywood vessels have been just formed.

Field inoculations of elm selections in the University of Minnesota elm nursery showing limited symptom development in a resistant selection after inoculation.

During the last few years, seedlings surviving greenhouse inoculation studies have been planted into field test plots for additional testing. This long term process will help ensure that tolerance to Dutch elm disease is long lasting against current strains of the pathogen.

Field plots at the University of Minnesota currently contain nearly 600 elm trees in various stages of development. New plantings that are currently underway or planned for 2016 will bring that number to over 900. Many of these trees will be field tested during Phase II of this research, the first set of inoculation trials will commence in spring 2017 and will include screening of six to eight new genotypes.

V. DISSEMINATION:

Description:
Dissemination of information about this project will begin with a web site to inform the public about the project and statewide survey for elm trees in Minnesota that have survived Dutch elm disease. This web site will be initially set up as a page at: http://forestpathology.cfans.umn.edu/ but will receive its own URL at Minnesota_elms.cfans.umn.edu once the project begins. Presentations will be made at arborists and nursery meetings in Minnesota and documentation of results made in general articles and scientific publications.

Status as of *(January 2014)*:
To disseminate our results and provide information on the progress of this project a web site has been developed at the University of Minnesota (elms.umn.edu), presentations have been given to several groups and a magazine article on the project has been published. The web site contains an interactive map that shows the locations of all of the elms identified to date around the state of Minnesota that appear to have resistance and should be evaluated for resistance. Presentations were made to the Minnesota Shade Tree Advisory Committee in August and to a large group of arborists and urban foresters at the Minnesota Society of Arboriculture's Conference held at the Minnesota Landscape Arboretum in Chanhassen, MN in October 2013. A general article about the project was published in the fall of 2013 in Solutions Magazine and can be viewed online at: http://forestpathology.cfans.umn.edu/pdf/Solutions_Fall2013a.pdf.

Status as of *(September 2014)***:**
Dissemination of results and general information about the project has continued via a number of speaking engagements and displays conducted by University faculty and staff. Presentations and/or displays of elm selections were made at the Minnesota Shade Tree Short Course in Arden Hills, MN (March 2014), Minnesota Turf and Grounds Foundation Field Day in Saint Paul, MN (August 2014), the Minnesota Shade Tree Advisory Committee Forum Presentation in Saint Paul, MN (August 2014) and the Iowa Shade Tree Short Course in Ames, Iowa (February 2014).

A presentation of results was given at the International meeting of the American Phytopathological society in August 2014 and published as: B.W. Held, R.A. Blanchette and C.P. Giblin. 2014. Selecting Minnesota American Elms for Resistance to Dutch Elm Disease. Proceedings of the American Phytopathological Society meeting, Minneapolis, MN p 58.

Information on our website continues to be used widely and updates to include new elms have been added to the statewide map showing collection activities for this project. Additional information on the various activities including propagation and inoculation have also been uploaded and posted to the web site: http://elms.umn.edu/elm-map.

Status as of *(March 2015)***:**
A presentation was given at the Upper Midwest Invasive Species Conference in October 2014 titled 'Selecting Resistant Minnesota Elms to Combat Dutch Elm Disease'. This work described the project that the Minnesota Environment and Natural Resources Trust Fund is supporting in detail. Abstracts for this meeting were published in the proceedings

A poster presentation entitled 'Characterizing the effects of auxin metabolism on adventitious rooting in hazelnut (*Corylus*) and elm (*Ulmus*)' was made by Molly Kreiser in October 2014 at the University of Minnesota Developmental Biology Symposium. This poster highlighted work funded by this project and supported by ENRTF.

A presentation was given at the Northern Green Expo in January 2014 titled 'Pruning Young Trees: Success Stories Start at Planting'. This included a description of the current work supported by ENRTF funding and acknowledgment of the financial support.

A poster entitled 'Commemorating Minnesota's Native Elm Heritage' and accompanying elm clones were displayed at the Minnesota Shade Tree Short Course in March 2015. ENRTF funding was acknowledged on display materials.

Status as of *(September 2015)***:**

A presentation entitled 'The Elms are Back: Exercise Caution' was made at a Minnesota Shade Tree Advisory Committee forum in April 2015 at the Oakdale Discovery Center in Oakdale, MN. This presentation described the elm selection project in detail and covered some of the problems currently faced with American elm selections (Princeton and Valley Forge) that have been selected from outside the state.

A poster entitled 'Commemorating Saint Paul's Native Elm Heritage' and accompanying elm clones were displayed at Linwood Park in Saint Paul for the Arbor Month kickoff event in March 2015. Presentations by project staff were also made at this event to detail our work to find disease resistant native elms and to educate the public on Dutch elm disease. ENRTF funding was acknowledged on display materials.

A presentation entitled 'Pruning Obstreperous Elms' was made at a Minnesota Shade Tree Advisory Committee forum in August 2015 at the University of Minnesota in Saint Paul, MN.

A paper entitled 'Conversion of indole-3-butyric acid to indole-3-acetic acid in shoot tissue of hazelnut (*Corylus*) and elm (*Ulmus*)' was accepted for publication in the *Journal of Plant Growth Regulation*. ENRTF support is acknowledged in the publication.

Status as of *(March 2016)***:**
Presentations were made at Minnesota Licensed Tree Inspector workshops at Brainerd, Morris and Waseca, MN in October 2015. Presentations included information on the ENRTF-supported research and provided general information on elm selection, maintenance and culture to attendees from various communities in Greater Minnesota.

A presentation entitled 'Don't Hate Me for Not Recommending that Tree!' was made at the Minnesota Shade Tree Short Course at Bethel University in March 2016. This presentation discussed the importance species diversity in tree planting selections and discussed the need to broaden the number of native elms available for replanting efforts statewide.

A paper entitled 'Conversion of indole-3-butyric acid to indole-3-acetic acid in shoot tissue of hazelnut (*Corylus*) and elm (*Ulmus*)' was published in the *Journal of Plant Growth Regulation* in February 2016 (. ENRTF support is acknowledged in the publication.

Final Report Summary:

Over the duration of this project many presentations and publications have been completed providing information about the project to a large audience of stakeholders including the general public. We have received a great deal of feedback from the public supporting this project to return majestic elms back into our urban and rural landscapes that are resistant to Dutch elm disease. Since the 1960's, Minnesota has lost millions of elms to this disease. The results from our investigations show that there is hope to obtain resistant elms that are native

to Minnesota. In addition to the numerous presentations and publications listed in our past progress reports an additional report follows that was given after the March 2016 progress report.

A presentation entitled "Minnesota's Native Elms: Threats and Opportunities" was given to the Minnesota Native Plant Society on April 7th 2016.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget:

Budget Category	$ Amount	Explanation
U of M Personnel: Scientist - pathology Scientist –Forest Resources Undergraduate students (3)	 $ 92,000 $ 48,000 $ 40,000	 50% time 71% salary, 29% fringe, for 3 years) 25% time (71% salary, 29% fringe, for 3 years) 100% salary, $5000/year per student. Three students will be involved with the project during years 1 and 2 and two students involved in year 3.
Professional/Technical/Service Contracts:	$	
Equipment/Tools/Supplies: Greenhouse and field supplies Laboratory Supplies	 $6,500 $6,500	 pots, stakes, pruning supplies, fertilizers, container substrates. Supplies are for 3 years. microbiology and inoculation materials, general laboratory materials, fungal genotyping, growth hormone for cuttings, propagation supplies. Supplies are for 3 years.
Travel Expenses in MN:	$4,500	Survey and collection of Resistant Elms
Other: Greenhouse maintenance costs	 $2,500	 Maintenance fees $1000 per year for 2 years
TOTAL ENRTF BUDGET:	**$200,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $3,500: N/A

Number of Full-time Equivalent (FTE) funded with this ENRTF appropriation: 1 FTE per year plus part time students.

Number of Full-time Equivalent (FTE) estimated to be funded through contracts with this ENRTF appropriation: N/A

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Minnesota Turf and Grounds Foundation	$35,000	$35,000	These funds were received in 2013 ($15,000) and in 2014 ($20,000) to support our research efforts .
State			

University of Minnesota University of Minnesota	$41,900 $28,935	Total for both faculty listed = $64,932	Blanchette (co-PI) salary and fringe for one month per year for 3 years Johnson ~~Gillman~~ (co-PI) salary and fringe for one month per year for 3 years
TOTAL OTHER FUNDS:	**$105,835**	**$99,932**	

VII. PROJECT STRATEGY:

A. Project Partners:

Dr. Robert Blanchette (Co-PI, UMN) is a professor and Benjamin Held (UMN) is a research scientist in the Department of Plant Pathology. They will take part in the finding and screening of resistant elms in the greenhouse and field.

Dr. Gary Johnson (Co-PI, UMN) is an extension professor and Chad Giblin (UMN) is a research scientist in the Department of Forest Resources. They will take part in finding, propagating and field planting of resistant elms.

Funds will be utilized evenly in this cooperative project and both partners and their labs using $100,000 each over three years to accomplish the objectives proposed.

B. Project Impact and Long-term Strategy:

The main goal of this research is to identify and propagate resistant elms from Minnesota. Testing for resistance must be rigorous and thorough and field trials are essential. Using our screening methods recently developed, this joint effort between Professors Blanchette and Johnson show great promise in obtaining DED resistant elm cultivars that will grow well in Minnesota and across the northern United States. The results from this work will provide new elms that are native to Minnesota with a high level of resistance and it will return this magnificent tree back into our urban and forest landscapes.

Although some information will be completed from the field trials during the 3 years, it can take 5-6 years for more comprehensive observations. These field trials will continue at the University Research Center after the project has ended. It will also take a few years to propagate the selected trees in sufficient numbers so they are available for release to the nursery industry and the public.

C. Spending History:

Funding Source	**M.L. 2007 or FY08**	**M.L. 2008 or FY09**	**M.L. 2009 or FY10**	**M.L. 2010 or FY11**	**M.L. 2011 or FY12-13**
Minnesota Turf and Grounds Foundation		$20,000	$20,000	$12,000	$15,000

VIII. ACQUISITION/RESTORATION LIST: N/a

IX. MAP(S): N/A

X. RESEARCH ADDENDUM:N/A

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted not later than January 2014, September 2014, March 2015, September 2015, March 2016. A final report and associated products will be submitted between June 30 and August 15, 2016 as requested by the LCCMR.

Attachment A: Budget Detail for M.L. 2013 Environment and Natural Resources Trust Fund Projects

Project Title: Finding Disease Resistant Elm Trees in Minnesota
Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 03h
Project Manager: Robert Blanchette
M.L. 2013 ENRTF Appropriation: $ 200,000
Project Length and Completion Date: June 30, 2016
Date of Update: July 1, 2016

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Balance	Activity 2 03/01/2016	Amount Spent	Balance	Activity 3 03/01/2016	Amount Spent	Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Identify and grow resistant Minnesota elms for testing.***										
Personnel (Wages and Benefits)	61,667	61,667	0	61,667	61,667	0	51,394	51,394	0	174,728	0
Scientist position 1; $92,000, 50% time (71% salary, 29% fringe for 3 years); 50% FTE											
Scientist position 2; $48,000, 25% time (71% salary, 29% fringe for 3 years); 25% FTE											
3 Undergraduate student positions $40,000, 25% time (100% salary, 0% fringe); 75% FTE											
Equipment/Tools/Supplies											
Greenhouse and field supplies: pots, stakes, pruning supplies, fertilizers, container substrates	2,200	2,200	0	2,200	2,200	0	2,100	2,100	0	6,500	0
Laboratory supplies: microbiology and inoculation materials, general laboratory materials, fungal genotyping, growth hormone for cuttings, propagation supplies	2,200	2,200	0	2,200	2,200	0	2,100	2,100	0	6,500	0
Travel expenses in Minnesota: Survey and collection of Resistant Elms Mileage($3200), lodging ($1000), meals ($300)	2,000	2,000	0	672	672	0	0	0	0	2,672	0
Other											
Greenhouse maintence: Maintenance fees are $1500 for the propagation and $1000 for the inoculations	1,500	1,500	0	8,100	8,100	0				9,600	0
COLUMN TOTAL	**$69,567**	**$69,567**	**$0**	**$74,839**	**$74,839**	**$0**	**$55,594**	**$55,594**	**$0**	**$200,000**	**$0**