M.L. 2018 Project Abstract
For the Period Ending June 30, 2024

PROJECT TITLE: Minnesota Invasive Terrestrial Plants and Pests Center
PROJECT MANAGER: Robert Venette
AFFILIATION: University of Minnesota & USDA Forest Service
MAILING ADDRESS: 1992 Folwell Ave.
CITY/STATE/ZIP: St. Paul, MN 55108
PHONE: 612-301-1405
E-MAIL: venet001@umn.edu & Robert.C.Venette@usda.gov
WEBSITE: https://mitppc.umn.edu/
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 06a as extended by M.L 2023, Chapter 60, Article 2, Sec. 2. Subd. 18

APPROPRIATION AMOUNT: $3,500,000
AMOUNT SPENT: $3,405,451
AMOUNT REMAINING: $94,549

Sound bite of Project Outcomes and Results
The Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC) funded 12 research sub-projects through this appropriation to help protect Minnesota lands from 16 priority invasive species, such as buckthorn, corn tar spot, Dutch elm disease, and non-native Phragmites. Discoveries improved detection methods and generated new management options.

Overall Project Outcome and Results
MITPPC funded 12 research sub-projects through this appropriation to help protect Minnesota's lands from 16 high priority terrestrial invasive species: Annosum root rot, ash dieback, common buckthorn, corn tar spot, Dutch elm disease, emerald ash borer, glossy buckthorn, hybrid barberry, Japanese knotweed, Japanese oak wilt, non-native Phragmites, oak wilt, soybean aphid, sudden oak death, thousand cankers disease, and wild parsnip.

Four sub-projects are highlighted as examples:

- Detection of forest pathogens (Robert Blanchette, lead). This team refined and used tools for the early detection of invasive tree pathogens in Minnesota. Fourteen species in the genus *Phytophthora* (translation "plant destroyer") were found in Minnesota for the first time. An extensive spore trapping network collected higher than expected concentrations of the fungus that causes Annosum root rot, a major disease of red pine. Minnesota Departments of Agriculture and Natural Resources are using these results to proactively manage forest diseases across Minnesota.
- Remote detection of non-native Phragmites (Joseph Knight, lead). This team demonstrated that digital images collected by drones, LiDar, or fixed-wing aircraft can be analyzed to reliably map known Phragmites stands with high accuracy and to detect previously unknown Phragmites patches. Object-Based Image Analysis and machine learning algorithms produced state-of-the-art maps. Methods developed from this project are being incorporated into statewide efforts to manage this major threat to wetlands.
- Rust fungi as biocontrol agents for buckthorn (Pablo Olivera Firpo and Yue Jin, leads). This team confirmed that the fungal rust pathogen, *Puccinia coronata* var *coronata* is a potential biological control agent of glossy buckthorn. The distribution of the pathogen was confirmed across Minnesota and the northeastern United States. Oat, barley, rye, triticale, durum wheat, and bread wheat are resistant to the pathogen. Thirteen grass species in five genera and three native buckthorn species are susceptible. Under controlled conditions, the pathogen significantly reduced biomass of glossy buckthorn seedlings. Work is now underway to operationalize the use of the fungus to manage glossy buckthorn in the field.

- Distribution and management of corn tar spot (Dean Malvick, leads). This team documented a substantial expansion of the area impacted by corn tar spot, now in 25 counties in southern and central Minnesota. The team prepared and published a diagnostic guide in the journal Plant Health Progress to help growers and crop consultants accurately identify the disease. They also developed a DNA-based assay to confirm the pathogen that causes corn tar spot. Environmental conditions favorable for tar spot development were identified. They discovered a novel method to reliably inoculate corn in greenhouse conditions. Results are being used by growers to accurately diagnose the disease and refine treatment recommendations.

Project Results Use and Dissemination

MITPPC teams published results in 24 peer-reviewed articles in prestigious journals such as The Proceedings of the National Academy of Sciences, Plant Disease, Remote Sensing of Environment, Journal of Integrated Pest Management, Frontiers in Insect Science, and PhytoFrontiers. Researchers promoted their work through more than 115 presentations including conferences, webinars, and podcasts. MITPPC and the University of Minnesota amplified the reach through internal communications, websites, and social media. As a result, the research was featured in at least 75 media stories including local and national media such as Star Tribune, Kare 11, WCCO, US National Science Foundation, HGTV, and BBC.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2018 ENRTF Final Work Plan

Today's Date: August 2, 2024 [for work completed June 30, 2024] REVISED October 30, 2024

Final report

Date of Work Plan Approval: June 5, 2018

Project Completion Date: June 30, 2023; June 30, 2024 for Subprojects 1 and 7

Does this submission include an amendment request: Yes

PROJECT TITLE: Minnesota Invasive Terrestrial Plants and Pests Center: Phase 4

Project Manager: Robert Venette

Organization: Regents of the University of Minnesota

College/Department/Division: College of Food, Agriculture, and Natural Resource Sciences

Mailing Address: 1992 Folwell Ave.

City/State/Zip Code: St. Paul, MN 55108

Telephone Number: 612-301-1405

Email Address: venet001@umn.edu

Web Address: www.mitppc.umn.edu

Location: Statewide

Total Project Budget:	**$3,500,000**
Amount Spent:	**$3,405,451**
Balance:	**$ 94,549**

Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 06a as extended by M.L 2023, Chapter 60, Article 2, Sec. 2. Subd. 18

Appropriation Language: $3,500,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for high-priority research at the Invasive Terrestrial Plants and Pests Center to protect Minnesota's natural and agricultural resources from terrestrial invasive plants, pathogens, and pests as identified through the center's strategic prioritization process. This appropriation is available until June 30, 2023, by which time the project must be completed and final products delivered.

M.L. 2023 - Sec. 2. Carryforward; Extensions [to June 30, 2024]

I. PROJECT STATEMENT:

Funding is requested to accelerate priority research that will protect Minnesota's prairies, wetlands, forests, and agricultural resources from terrestrial invasive plants and pests, including non-native weeds, pathogens, and insects. The Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC) leads research that will provide new tools and techniques to:

- predict and prevent the arrival of new terrestrial invasive threats (e.g., mountain pine beetle)
- detect and rapidly respond to new pests (e.g., brown marmorated stinkbug and Palmer amaranth)
- mitigate impacts from well-established threats (e.g., soybean aphid, buckthorn, and oak wilt);
- minimize impacts from measures to control invasive threats;

This proposal funds the work of an additional 4 graduate students and 7 post-docs and their faculty advisors. A new generation of scientists with this expertise is needed in Minnesota to address future invasive threats.

The MITPPC was established at the University of Minnesota under ML 2014, Chapter 312, Article 13, Section 44. The MITPPC is administratively located in the College of Food, Agricultural, and Natural Resources Sciences and is guided by a 15-member Center Advisory Board. Activities of the Center are conducted in close collaboration with state, federal, local and tribal governments, nongovernmental agencies, the private sector, Extension, and other colleges and universities.

The MITPPC relies on a strategic prioritization process to set its research direction. Financial resources are directed towards research that addresses the invasive terrestrial plants and pests which pose the greatest threat to Minnesota and has the greatest potential to substantially improve management. A white paper, "Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research," describes the invasive species that pose the greatest threats to Minnesota's forests, prairies, wetlands, and agricultural resources and provides guidance for rationing limited research funds. The prioritization is revisited at least bi-annually to scan for new threats to the state. For example, when the invasive plant, Palmer amaranth was detected in Minnesota, prioritization methodology allowed the Center to reassess the threat of this species with relevant new information, and the species moved from #20 in 2016 to #15 in 2017 of the top invasive plants in Minnesota.

The MITPPC has had great success in soliciting proposals from University of Minnesota faculty in each of its Requests for Proposals. To date, the MITPPC has funded 16 research projects, totaling almost $6 million from ML 2014 and 2015 ENRTF appropriations. The Center and associated research projects have leveraged an additional $4.86 million in state and non-state funds.

Each successful proposal has had extensive vetting by internal and external reviewers by leaders in invasion biology. Proposals are carefully considered and evaluated on a number of criteria, including urgency, extent of impact, contribution to the field, and innovation. The value-added benefits of the center approach extend to administrative and technical support, facilitating research team development, and convening stakeholders on terrestrial invasive species topics, particularly on issues that affect both the agricultural and natural resource sectors. Partnerships with land managers remain an important part of the success of the research program and MITPPC staff and principal investigators communicate regularly with state and federal agencies, nonprofits, and commodity groups.

II. OVERALL PROJECT STATUS UPDATES:

First Update January 31, 2019 – Submitted May 9, 2019

Preparatory work was completed on the development of the ML 2018 Request for Proposals, which will be open from January through April 2019. The MITPPC RFP runs concurrently with the ENRTF RFP, with the goal to streamline and clarify the appropriate funding process for terrestrial invasive species.

Second Update June 30, 2019:

A request for proposals was open from January through April 2019. Twenty-two eligible project pre-proposals, totaling $8.66 million, were received. Those proposals were sent out to 10 UMN researchers from throughout

the university system for review. Ten sub-projects, totaling $3.47 million, were rated sufficiently high to be invited to submit full research proposals. Those full proposals are currently being developed (due July 31, 2019) and will be reviewed in the coming months by qualified researchers outside the University of Minnesota. We anticipate the appropriation to be fully encumbered at the end of this review process.

During this reporting period, the MITPPC was asked to comment on MITPPC eligibility of project proposals received by LCCMR. Of those projects, only one request to LCCMR was eligible for funding and the Principal Investigator declined to submit the proposal to MITPPC.

Amendment Request (7/16/2019)
MITPPC requests to change the reporting dates to align with other appropriations by reporting by July 31 and January 31 of each year. Additionally, the time for final reporting is requested to change by one month subsequent to current dates.

Amendment approved (8/7/2019)

Amendment Request (10/30/2019)
Based upon a thorough internal and external review of research proposals submitted this year, MITPPC requests the addition of eight research sub-projects to this workplan. The table below summarizes these projects:

Project Manager	**Research Project**	**Amount Funded**	**Species Addressed**
Robert Blanchette	MITPPC sub-project 1: Early detection of invasive tree pathogens using molecular tools for prevention and to mitigate damage	$384,165	Various pathogens, including *Heterobasidion irregular* (Annosum root rot)*, Hymenoscyphus fraxineus* (ash dieback), *Raffaelea quercivora* (Japanese oak wilt), *Geosmithia morbida* (thousand cankers disease), *Phytophthora ramorum* (sudden oak death)
Jeannine Cavender-Bares	MITPPC sub-project 2: Accurate detection of oak wilt from tree to landscape scales for enhanced forest management	$301,993	*Ceratocystis fagacearum* (Oak wilt)
Ben Held	MITPPC sub-project 3: Winning the Dutch elm disease battle: developing resistant elms for MN	$233,924	*Ophiostomoa novo-ulmi* (Dutch elm disease)
Joe Knight	MITPPC sub-project 4: Detection and monitoring of invasive *Phragmites*	$203,781	*Phragmites australis ssp. Australis* (European common reed)
Rebecca Montgomery	MITPPC sub-project 5: Improve invasive plant treatment efficacy using climate based phenology models	$346,213	*Polygonum cuspidatum* (Japanese knotweed), *Pastinaca sativa* (wild parsnip)
Pablo Olivera	MITPPC sub-project 6: Biology and biocontrol potential of a rust fungus	$206,783	*Frangula alnus,*(glossy buckthorn), *Phalaris*

Project Manager	Research Project	Amount Funded	Species Addressed
	infecting *Phalaris arundinacea* and *Frangula alnus*		*arundinacea* (reed canary grass)
Peter Reich	MITPPC sub-project 7: Managing buckthorn with trees: diversity, density, and practicality	$499,734	*Rhamnus cathartica* (common buckthorn)
Ingrid Schneider	MITPPC sub-project 8: Integrated emerald ash borer management: testing a novel approach to assess stakeholder perceptions	$450,000	*Agrilus planipennis* (emerald ash borer)
TOTAL		**$2,626,591**	

With LCCMR's approval, this amendment would allocate $2,626,591 leaving an appropriation balance of $873,409. This balance will be allocated in the January 2020 Call for Proposals process.

These amended research projects will have a start date of January 1, 2020. As such, we request an exemption for the January 31, 2020 report on this appropriation. This change in the reporting deadlines have been made throughout this document.

Amendment approved: November 18, 2019

Third Update, July 31, 2020

All sub-projects had been making solid progress during the first half of this reporting period. These sub-projects were approved to begin on January 1, 2020, so initial activities primarily focused on staffing and preparing for the upcoming field season. COVID-19 affected all sub-projects, some more than others. No sub-projects were slated to achieve outcomes by July 2020. Most sub-project managers feel confident that they can compensate for any lost time.

Some early results are intriguing. For example, *Sub-Project 4* has already developed initial computer routines to detect *Phragmites australis* from satellite imagery. In addition, *Sub-Project 5* launched Pesky Plant Trackers to engage community scientists in the study of the distribution and phenology of Japanese knotweed and wild parsnip. The effort has already attracted significant media attention. Other activities of all sub-projects are described below.

Amendment request (08/03/2020)

Some sub-projects have requested timeline changes as a result of COVID-19 impacts. None of the changes affect outcomes nor are beyond the terms of the appropriation. Sub-projects that are requesting minor timeline changes include: 1, 4, and 5.

We request the following specific amendments:
Sub-project 1: timeline changes (extension of Activity 2 – Outcome 1 from December 30, 2020 to December 30, 2021 and Activity 3 – Outcome 1 from August 30, 2020 to December 30, 2020)

Sub-project 4: timeline changes (extension of Activity 1 – Outcome 2 from June 30, 2020 to December 31, 2020)

Sub-project 5: timeline changes (extension of Activity 1 – Outcome 1 from September 30, 2020 to July 30, 2021 and Activity 1 – Outcome 2 from March 30, 2021 to September 30, 2021)

Amendment approved (12/01/2020)

Interim Update, December 21, 2020

This interim update is submitted in advance of regular reporting that would normally be due on January 31, 2021. Since July 31, 2020, MITPPC has completed evaluations of full sub-project proposals. Each proposal was reviewed by 2-3 subject matter experts outside Minnesota. All reviews were conducted through an on-line grant management system developed for MITPPC. Four sub-projects were recommended for funding.

Amendment request (12/18/2020)

Based upon a thorough internal and external review of research proposals submitted this year, MITPPC requests the addition of four research sub-projects to this workplan. The table below summarizes all current sub-projects (#1-8) and the four proposed new sub-projects (#9-12):

Project Manager	Research Project	Amount Funded	Species Addressed
Robert Blanchette	MITPPC sub-project 1: Early detection of invasive tree pathogens using molecular tools for prevention and to mitigate damage	$384,165	Various pathogens, including *Heterobasidion irregular* (Annosum root rot), *Hymenoscyphus fraxineus* (ash dieback), *Raffaelea quercivora* (Japanese oak wilt), *Geosmithia morbida* (thousand cankers disease), *Phytophthora ramorum* (sudden oak death)
Jeannine Cavender-Bares	MITPPC sub-project 2: Accurate detection of oak wilt from tree to landscape scales for enhanced forest management	$301,993	*Ceratocystis fagacearum* (Oak wilt)
Ben Held	MITPPC sub-project 3: Winning the Dutch elm disease battle: developing resistant elms for MN	$233,924	*Ophiostomoa novo-ulmi* (Dutch elm disease)
Joe Knight	MITPPC sub-project 4: Detection and monitoring of invasive *Phragmites*	$203,781	*Phragmites australis ssp. australis* (European common reed)
Rebecca Montgomery	MITPPC sub-project 5: Improve invasive plant treatment efficacy using climate based phenology models	$346,213	*Polygonum cuspidatum* (Japanese knotweed), *Pastinaca sativa* (wild parsnip)
Pablo Olivera	MITPPC sub-project 6: Biology and biocontrol potential of a rust fungus infecting *Phalaris arundinacea* and *Frangula alnus*	$206,783	*Frangula alnus,*(glossy buckthorn), *Phalaris arundinacea* (reed canary grass)
Peter Reich	MITPPC sub-project 7: Managing buckthorn with	$499,734	*Rhamnus cathartica* (common buckthorn)

Project Manager	Research Project	Amount Funded	Species Addressed
	trees: diversity, density, and practicality		
Ingrid Schneider	MITPPC sub-project 8: Integrated emerald ash borer management: testing a novel approach to assess stakeholder perceptions	$450,000	*Agrilus planipennis* (emerald ash borer)
Dean Malvick	MITPPC sub-project 9: Distribution, Risks, and Management of *Phyllachora maydis*, the Causal Agent of Corn Tar Spot	$185,106	*Phyllacora maydis* (corn tar spot)
Pablo Olivera	MITPPC sub-project 10: Detecting hybrid barberry and investigating its role in rust epidemiology	$247,507	*Berberis x ottawenis* (hybrid barberry)
Robert Koch	MITPPC sub-project 11: Confronting soybean aphid with advanced plant breeding and remote sensing	$295,593	*Aphis glycines* (soybean aphid)
Amy Morey	MITPPC sub-project 12: Expanding and Strengthening the Prioritization of Terrestrial Invasive Species in Minnesota	$151,601	Multiple plants, pests, and pathogens
TOTAL		**$3,500,000**	

With the addition of these four sub-projects, the appropriation is fully encumbered (i.e., the budget reserve goes from $873,407 to $0). Each of the new sub-projects is described in greater detail below. The proposed administrative start date for these sub-projects is January 1, 2021. If approved, the first sub-project updates will be due on August 31, 2021 to coincide with the fifth overall project update. Only modest progress (largely recruiting appropriate staff and organizing project logistics) would be expected for the new sub-projects between the approval date and the February 28, 2021 reporting date.

In addition, we request modifications to reporting dates for this appropriation. Reporting dates are shifted by one month to alleviate administrative burdens within MITPPC and LCCMR associated with the preparation and review of multiple update reports from MITPPC (different appropriation years) at the same time. Note the final update is adjusted to coincide with the end of the appropriation.

Amendment approved (12/29/2020)

Fourth Update, February 28, 2021

The realities of conducting research under COVID-19 became increasingly transparent during the previous six months. Faced with numerous safety concerns/requirements, projects were forced to adjust by limiting the number of people in research facilities at a time, reducing the duration of time researchers spend in facilities, limiting transportation to field sites to one passenger per vehicle, and maintaining proper social distancing and proper PPE in all work environments. In addition, efforts to work from home have been complicated by numerous personal (e.g., distance education for children) and professional (e.g., lack of access to resources) obstacles. As a result, several sub-project managers have acknowledged that research is not progressing as efficiently as originally planned.

Nevertheless, all established sub-project teams have made steady progress despite these unprecedented circumstances. We highlight particularly noteworthy accomplishments here. *Sub-project #2* found that eight spectral bands (i.e., ranges of light wavelengths) seemed particularly useful to detect oak wilt; a customized drone with sensors for oak wilt detection was developed by an industry partner and tested in initial flights. *Sub-project #3* planted several elms with resistance to Dutch elm disease in Nerstrand Big Woods State Park; survival of previously planted elms was high, a promising result, suggesting that resistance to this invasive disease is stable. *Sub-project #4* demonstrated the feasibility of detecting non-native Phragmites though remote sensing and found that methods were greatly improved when methods to account for vegetation height were added (non-native Phragmites is taller than many native plants but shorter than many trees). *Sub-project #5* continues to cultivate a vast and diverse network of citizen scientists across Minnesota to collect detailed phenological data on Japanese knotweed and wild parsnip. *Sub-project #6* revealed that a rust fungus is present across the range of glossy buckthorn in Minnesota; infections by this rust fungus decrease growth and fruit production of glossy buckthorn. More detailed updates on all sub-projects are provided in III. Project Activities and Outcomes.

Amendment request (2/26/2021)

We request amendments to four sub-projects.

Sub-project 1: timeline changes

We request an extension of the completion dates for Activity 1, outcomes 1 and 2 from 12/31/2020 to 06/30/2021. More time is requested to analyze the spore collections to-date. COVID-19 increased the time required to collect air samples in the state. The extension does not affect other outcomes or the timing for completion of the sub-project.

Sub-project 2: budget changes

We request to decrease personnel by $4,643 from $220,593 to $215,950 and increase the capital expenditures by $574 from $17,000 to $17,574 and increase repairs/maintenance to equipment by $4,069 from $2,400 to $6,469. The increase in capital expenditures is due to the need to include a reference in the sensor to calculate the spectral reflectance values accurately. The Sentera sensor is specific to the project and was designed specifically for oak wilt detection. The increase in repairs/maintenance is needed to maintain usable and accurate spectroscopic equipment on the unmanned aerial system specific to the project. COVID-19 has complicated the use of undergraduate student support. So, we anticipate reducing salaries in this area. The postdoc, graduate student, and lab tech will be assigned additional responsibilities to complete the work on time.

Sub-project 5: budget changes

We request to decrease 'other' (i.e., user fees for greenhouse and growth chamber access) by $1,300 from $15,600 to $14,300 and increase field and documentary supplies by same from $3,100 to $4,400 to cover additional costs of iButton sensors. These devices are used to record temperature, humidity, and moisture in the field or in potted plants. Preliminary work on the project quickly revealed that weather stations near field sites and on-board recorders in growth chambers would not be sufficient. The biological events that are being monitored are sensitive to local environmental conditions. Less greenhouse space is needed than was originally estimated.

Sub-project 6: timeline changes

We ask that the deadline for Activity 2, outcome 1 be extended from 06/30/2020 to 05/31/2021 due to additional time needed to test for pathogen susceptibility. The change does not affect other outcomes or the timing for completion of the sub-project.

Amendment Approved (03/03/2021)

Fifth Update, August 31, 2021

All projects continue to make good to excellent progress towards achieving stated outcomes. In general, teams have found strategies for routine work under COVID. Non-routine work, especially the recruitment of new students/staff has been adversely impacted. Sub-project #9 (led by Malvick) was particularly delayed; fewer students/staff/post docs seem to be applying for open positions.

A few accomplishments over the previous six months are particularly notable. Sub-project #1 (Blanchette) is finding promising results with the use of a modified windsock (similar to those seen at airports) to collect air-borne spores from invasive fungi. The team was able to recover many spores of the invasive fungus that causes the devastating pine disease Annosum root rot in Wisconsin, where the disease is well established; few spores were collected in MN where the disease is not known to occur. Sub-project #3 (Held) identified six new elms from across Minnesota that may be resistant to Dutch elm disease. Cuttings from these trees have been vegetatively propagated to create small, rooted trees to bring into the breeding program. Tests started in the summer of 2020 are confirming that many trees thought to be resistant to Dutch elm disease showed limited to no symptoms when intentionally infected with the fungus that causes the disease. Sub-project #5 (Montgomery) has recruited and trained 73 volunteers for the Pesky Plant Trackers citizen science program. Sub-project #6 (Olivera Firpo) has found after screening nearly 1000 oat varieties that more than 99% are resistant to a rust fungus that might be used as biological control agent for reed canarygrass and glossy buckthorn. This information is an essential part of the safety testing before a wider biocontrol effort with the fungus could begin.

Amendment request (08/31/2021)

Sub-project 4 (Knight) requests more time to make up for COVID-caused delays in field work and to compensate for the time PhD student Connor Anderson spent in his internship with NASA in the summer of 2020. Replacement staff could not be found to work on the sub-project during Mr. Anderson's internship. One-year extensions are requested for Activity 1, outcome 3 (from 12/31/2021 to 12/31/2022) and outcome 4 (from 6/30/2022 to 6/30/2023) and Activity 2, outcome 2 (from 6/30/2021 to 6/30/2022) and outcomes 3 and 4 (from 9/30/2021 to 9/30/2022).

In addition, we are asking to modify the first reporting dates for sub-projects #9 (Malvick), #10 (Olivera Firpo), #11 (Koch), and #12 (Morey). Each of the projects was approved earlier this year, so progress to date has been modest, primarily focused on recruiting students, staff, and post docs. First reporting dates were errantly set to begin this reporting period. This change is consistent with previous reporting timelines that have been approved by LCCMR staff. Reporting on these sub-projects will begin with the sixth update on February 28, 2022.

Amendment approved (09/27/2021)

Sixth Update, February 28, 2022

All sub-project teams supported by this appropriation continue to make good to excellent progress towards achieving research outcomes. Most research teams were gathering data over the previous 6 months and are now in the process of analyzing and interpreting results. Five projects had particularly noteworthy results, which are described here in brief. – Additional details may be found later in the report. – Sub-project #3 (led by Dr. Ben Held) confirmed robust resistance to Dutch elm disease in commercially-available elm trees that were selected for resistance to the disease. The team has identified nine new selections with resistance to Dutch elm disease and planted them in Three Rivers Park as part of a forest restoration initiative. Sub-project #4 (led by Dr. Joseph Knight) published significant new findings in the peer-reviewed journal *Remote Sensing* showing that imagery from unmanned aerial vehicles (UAVs, aka "drones") and satellites can be used to detect and delimit patches of Phragmites. UAVs provide more accurate images that satellites. The classification of areas as having Phragmites

or not were much more accurate when information about canopy (or vegetation) height was included. Sub-project #5 (led by Dr. Rebecca Montgomery) includes a citizen science component that has grown to over 93 volunteers, collecting data on the seasonal development of wild parsnip or Japanese knotweed from 81 sites across Minnesota. These data are helping to demonstrate the robustness of results from common garden experiments conducted at most University of Minnesota Research and Outreach Centers across the state. Sub-project #6 (led by Dr. Pablo Olivera-Firpo) used precise genetic techniques to confirm that a rust fungus that infects reed canary grass and glossy buckthorn in Minnesota is *Puccinia coronata* var *coronata*, a non-native species that was first detected in North America in 2016. The rust reduced the biomass of reed canary grass by 25% in greenhouse trials. Finally, Sub-project #9 (led by Dr. Dean Malvick) found that corn tar spot spread to nine new counties during the 2021 field season, a concerning, but not unexpected, finding.

Seventh Update, August 31, 2022

All twelve sub-projects funded under this appropriation remain active. Progress toward achieving stated outcomes over the previous six months has been very good. All teams are gathering new data or analyzing/interpreting previously collected information. Four sub-projects had particularly noteworthy accomplishments. Sub-project #1 (led by Dr. Robert Blanchette) was surprised to trap spores of the invasive fungus *Heterobasidion irregulare* in Minnesota as no active areas of infection were thought to occur in the state. This invasive fungus causes a devastating disease of pines. The detections have triggered intensive searches for potentially infected trees near where spores were trapped. This same team also discovered six *Phytophthora* species that had never been reported in Minnesota in commercial, horticultural nurseries. The species that were discovered are not known to cause severe plant diseases, but closely related species can cause widespread plant mortality. Sub-project #5 (led by Dr. Rebecca Montgomery) participated in a statewide, invasive species conference, coordinated by the College of Food, Agricultural, and Natural Resource Sciences at the University of Minnesota. Dr. Montgomery's presentation on the importance of phenology for management of invasive weeds was simulcast to the ten Research and Outreach Centers around Minnesota (Cloquet, Grand Rapids, Crookston, Waseca, Lamberton, Morris, Rosemount, Chaska, Becker, and Ely). Sub-project #9 (led by Dr. Dean Malvick) worked with colleagues at Michigan State University to improve a quantitative polymerase chain reaction (qPCR) test for the fungus that causes corn tar spot. The refinements improve the ability to reliably detect the pathogen in field, greenhouse, and laboratory studies. The refined test should accelerate research on the pathogen in Minnesota and nationally. Finally, sub-project #11 (led by Dr. Robert Koch) increased two-lines of soybean with natural resistance to soybean aphid, a critical step towards commercialization and widespread adoption of the tool.

Amendment request:

- Sub-project #2 (Cavender-Bares) requests a budget amendment. The request is to decrease personnel by $10,269 From $215,950 to $205,681; to increase supplies and equipment by $5,269 from $9,000 to $14,269; and to create a line item for equipment rental (for a hydroexcavator) for $5,000. The request to increase supplies is needed partially for the custom-built UAV (drone). Battery life on the unit has become a major limitation to our 2022 field work. The team also needs to update the sensor on the drone. Furthermore, Anna Yang's doctoral work on oak wilt retention time in roots requires supplies and equipment rental. A hydroexcavator provides an efficient way to dig oak roots, and renting a unit is the affordable option. Slightly less salary is needed than originally estimated due to the departure of Dr. Gerard Sapes for another position.
- Sub-project # 5 requests a minor budget amendment for an overage on greenhouse rental. We request to decrease personnel expenses by $3,251 from $321,993 to $318,682 and increasing the other line for greenhouse fees by the same amount, from $14,300 to $17,551.
- Sub-project #6 (Olivera Firpo) requests a no-cost timeline extension from December 31, 2022 to March 31, 2023 for completion of Activity 3, Outcome 4. Reporting dates are modified accordingly. This request is to ensure the team has sufficient time to publish and disseminate findings from the final phase of the project. Salary savings were incurred when the PhD student on the project received a fellowship to study international agriculture.

- Sub-project #9 (Malvick) requests a budget amendment to decrease professional services by $3,800 from $6,400 to $2,600 and decrease travel by $3,200 from $7,900 to $4,700 and increase supplies by $7,000 from $5,600 to $12,600. Professional services were used to a lesser amount than estimated due to dry weather that decreased tar spot development and sample submissions in 2021 as well as increased capability for diagnosis of tar spot in the Malvick lab, all which reduced the need for assistance with sample analysis in a service laboratory. Similarly, travel/mileage was overestimated due to a decreased need for sample collection and travel due to dry weather and COVID restrictions. The budget needed for lab/medical supplies was underestimated due to revision of methods and supplies needed to complete the planned work and significant increases in cost of materials and supplies over the past two years.
- Sub-project #10 (Olivera Firpo) requests a no-cost extension for the completion of Activity 1, Outcome 3 and Activity 2, Outcomes 1 and 2 from November 30, 2022 to June 30, 2023 to accommodate the difficulty in recruiting a qualified postdoctoral scientist to accomplish the objectives proposed in the research project. Reporting dates are modified accordingly. The delay in hiring caused a significant salary savings.
- Sub-project #12 (Morey) requests a no-cost extension for the completion of Activity 2, Outcome 3 from December 30, 2022 to March 30, 2023. Reporting dates are modified accordingly. A computer malfunction during the previous reporting period caused an unexpected delay to the project. A replacement computer with appropriate analytical capabilities was purchased (not with LCCMR funds) and progress has resumed.

Amendment Approved (11/02/2023)

Eighth Update, February 28, 2023

All sub-project teams have made very good to excellent progress towards the completion of outcomes. Accomplishments by each sub-project team are described below, but five achievements are particularly noteworthy. Sub-project #1 (Blanchette) confirmed the presence of *Heterobasidion* spores in their spore trapping network. The spores are from the fungus of Heterobasidion root disease, considered one of the world's worst diseases of pines in northern latitudes but generally thought not to occur in Minnesota. The team is working with the MN Department of Natural Resources (MN-DNR) to identify potential infection centers in the state and coordinate a rapid response. Sub-project #2 (Cavender-Bares) reported success with the analysis of satellite imagery to detection oak wilt. This new approach will allow for broader areas of the state to be monitored for the presence of the fungus. Sub-project #4 (Knight) advanced techniques to used unmanned aerial systems (UAS, aka "drones") and machine learning to detect and map invasive *Phragmites* in wetlands; a research paper that describes the success of the method is in review. This sub-project team is sharing findings with the MN-DNR and the University of Minnesota (Minnesota Aquatic Invasives Species Research Center) who are working collectively towards the targeted control of invasive *Phragmites*. Sub-project #9 (Malvick) made a major break-through discovery with the development a technique to artificially infect corn with the pathogen that causes corn tar spot. This new method creates major opportunities to screen corn varieties for resistance to the fungus, test fungicides for efficacy against the disease, and explore more precisely how this fungus affects the physiology of corn plants. Lastly, sub-project #11 (Koch) advanced multiple soybean lines with resistance to soybean aphid in the soybean-breeding pipeline; two new lines are nearing commercial release.

Within the last six months, MITPPC staff were surprised to learn of some challenges associated with the analysis, interpretation, and communication (i.e., publication) of near-final project findings. These difficulties apparently started during the pandemic due to the disrupted interactions among team members but were not evident given the significant progress being made with field, greenhouse, and laboratory studies. Peer-reviewed publication of research findings is a critical part of science communication because it provides a "seal-of-approval" on the rigor of the methods and the interpretation of results. As a result, we a requesting a one-year extension to this appropriation and to extend sub-projects #1 (Blanchette) and #7 (Reich)to May 15, 2024. (The requested extension is currently included in House File 172 and Senate File 442.) Both teams have multiple publications planned but need additional time to complete them.

Amendment request #1:

We are requesting several amendments to this appropriation. The first set of amendments corrects inconsistencies between sub-project end dates reported in this work plan and the associated budget spreadsheet. The following sub-projects request corrections:

- Sub-project #4: change work plan end date (Activity 2, Outcome 4) from 9/30/23 to 6/30/23.
- Sub-project #5: change work plan end date (Activity 3, Outcome 2) from 9/30/22 to 6/30/23.
- Sub-project #6: change work plan end date (Activity 3, Outcome 4) from 12/31/22 to 6/30/23.
- Sub-project #9: change work plan end date (Activity 3, Outcome 2) from 4/30/23 to 6/30/23.
- Sub-project #10: change work plan end dates (Activity 1, Outcome 3; Activity 2, Outcomes 1 and 2) from 11/30/22 to 6/30/23 and Activity 2, Outcome 3 from 4/30/22 to 6/30/23.
- Sub-project #11: change work plan end date (Activity 2, Outcome 3) from 12/30/22 to 6/30/23.
- Sub-project #12: change budget (6/30/22) and work plan (Activity 2, Outcome 3) end dates (12/30/22) to 6/30/23.

Additional reporting periods are added where necessary.

Secondly, we request a series of minor budget amendments to accommodate actual expenses incurred vs initial budget estimates as sub-project begin to wrap up their work:

- Sub-project #2 (Cavender-Bares) requests to increase personnel by $65,074 from $205,681 to $270,755 decrease professional services by $47,766 from $50,000 to $2,234, decrease equipment/tools/supplies by $9,977 from $14,269 to $4,292, decrease travel expenses in Minnesota (mileage) by $3,000 from $3,000 to 0, increase repairs to equipment by $669 from $6,469 to $7,138, and decrease in rental equipment by $5,000 from $5,000 to $0. More staff time was needed than originally anticipated for image analysis. Unforeseen changes in the project due to COVID19 resulted in a lower than expected contracted services for tree removal. Long distance travel to field sites was not feasible under COVID restrictions.
- Sub-project #5 (Montgomery) requests to decrease personnel by $1,644 from $318,682 to $317,038 and a commensurate increase in greenhouse fees from $17,551 to $19,195 due to an increase in greenhouse user fees. Slightly less time was needed for a volunteer coordinator than originally estimated.
- Sub-project #7 (Reich) requests to decrease equipment/tools/supplies by $863 from $30,990 to $30,127 and increase travel by same from $9,744 to $10,607. Slightly fewer field supplies were needed for field site preparation than originally estimated. Slightly more travel to research sites was needed, partly a reflection of team members needing to travel in separate vehicles.
- Sub-project #8 (Schneider) requests to decrease personnel by $8,300 from $388,130 to $379,830; to increase professional services by $2,986 from $24,200 to $27,186, and to create a new professional services line item for $8,300 to contract for statistical support. The increase in professional services is needed to archive virtual-reality and other project elements in the UMN Digital Media Center and to produce a short video to disseminate project findings. They also ask to reduce facilitation expenses by $2,986 from $6,000 to $3,014 because fewer people participated in in-person focus groups due to COVID. They also ask to increase printing by $15,000 from $1,000 to $16,000 and decrease travel by $15,000 from $30,670 to $15,670. These changes are due to less travel than anticipated due to COVID19 and a desire to provide open access for three journal articles.
- Sub-project #11 (Koch) requests to decrease equipment, tools, and supplies by $821 from $4,000 to $3,179 and a commensurate increase in greenhouse user fees from $7,000 to $7,821 due to an increase in greenhouse user fees.

Amendment #1 Approved by LCCMR 4/10/2023.

Amendment request #2:

Finally, we have requested a legislative appropriation extension of one year to June 30, 2024 to accommodate programs impacted by COVID19. The one-year extension will allow for additional analysis and project write-up.

Specifically, we intend for sub-projects #1 (Blanchette) and #7 (Reich) to utilize this additional time. For sub-project #1, we request an amendment to the end date listed on the sub-project budget spreadsheet from 06/30/23 to 05/15/2024 and changes of Activity 2, Outcome 4 and Activity 3, Outcome 3 in this work plan from 06/30/2023 to 05/15/2024. For sub-project #7, we request a similar amendment to the end date in the sub-project budget spreadsheet from 06/30/23 to 05/15/2024 and changes of Activity 1, Outcome 3 and Activity 2, Outcomes 2-4 from 06/30/2024 to 05/15/2024. This will extend approximately $200,000 in funding.

Amendment #2 pending further LCCMR and legislative action as of 4/10/2023.

Amendment #2 approved by the Legislature and signed into law 5/24/23

Ninth Update, August 31, 2023

Twelve research sub-projects were active at the start of this reporting period. Ten sub-projects completed their work on or before June 30, 2023. Legislative action provided an additional fiscal year to complete two remaining sub-projects (#1 Blanchette and #7 Reich.) Final updates for completed sub-projects are provided within this report. Separate final abstracts for each of the 12 sub-projects will be provided with the final overall report at the close of the appropriation.

Most sub-projects have made excellent progress over the previous six months as described in the updates that are provided below. Highlights from just four of those projects are given here as examples. First, sub-project #1 (Blanchette) has demonstrated the utility of spore traps and baiting techniques for the early detection of Heterobasidion (the causal agent of Annosum root rot in pines) and Phytophthora (the cause of diverse root rots and blights of many plants), respectively. Detection of unexpectedly high concentrations of Heterobasidion in this project has triggered intense searches with the Department of Natural Resources for infected trees, likely in Winona county and elsewhere in southeastern MN. The early detection and rapid response for Heterobasidion would not have been possible without this project. Second, sub-project #2 (Cavender-Bares) has drafted a high resolution map of the distribution of oak wilt in Minnesota. The map is derived from analyses of satellite imagery. The map is currently being validated. If demonstrated to be accurate, it will provide a powerful tool to focus management efforts and slow the spread of the disease, particularly into central Minnesota. Third, sub-project #4 (Knight) developed powerful tools to reliably detect the presence of Phragmites, a highly invasive plant in wetlands, in images collected by unmanned aerial systems (aka drones). The sub-project has provided maps and techniques that strongly support on-going efforts in Minnesota to prevent and reduce wetland damage from Phragmites. Fourth, sub-project #6 (Olivera Firpo) made major progress to demonstrate the feasibility and safety of a rust fungus, *Puccinia coronata var. coronata*, to provide biological control of glossy buckthorn (and potentially reed canarygrass). Rigorous testing has demonstrated that the fungus reduces growth of both plants but does not infect commercially grown crops, especially oats.

Amendment request (8-31-2023)

Amendments are requested for 11 sub-projects, largely as a result of their closing. Throughout this report, we modify the reporting date of June 30, 2023 to August 31, 2023 (as confirmed by LCCMR staff). We also insert two reporting dates for sub-projects #1 and #7. Budget amendments for subprojects #2-#6 and #8-#12 reflect actual costs incurred through June 30, 2023, not estimates.

- Sub-project #2 (Cavender-Bares) requests that personnel expenses be decreased by $10,722 from $270,755 to $260,033; that professional services be increased by $3,557 from $2,234 to $5,791; equipment/tools/supplies by increased by $3,354 from $4,292 to $7,646; and repairs increased by $930 from $7,138 to $8,068. This activity returns $2,881 to the reserve.
- Sub-project #3 (Held) requests to decrease personnel expenses by $2,719 from $211,924 to $209,205; to increase equipment/tools/supplies by $1,242 from $12,000 to $13,242; to increase travel by $61 from $2,000 to $2,061; and increase other expenses by $1,416 from $8,000 to $9,416. These changes do not affect the total funding allocated to the sub-project.

- Sub-project #4 (Knight) requests to increase personnel by $12,133 from $189,531 to $201,664; to decrease professional services by $1,800 from $3,000 to $1,200; and to decrease travel by $10,333 from $11,250 to $917. These changes do not affect the total funding allocated to the sub-project.
- Sub-project #5 (Montgomery) requests to increase personnel by $853 from $317,038 to $317,891; decrease equipment by $202 from $6,500 to $6,298; decrease travel by $684 from $3,480 to $2,796; and to increase other by $31 from $19,195 to $19,226. This activity returns $2 to the reserve.
- Sub-project #6 (Olivera) requests to increase personnel by $13,781 from $163,283 to $177,064; to decrease equipment by $496 from $18,000 to $17,504; decrease travel by $12,461 from $16,500 to $4,039; and decrease other by $824 from $9,000 to $8,176. These changes do not affect the total funding allocated to the sub-project.
- Sub-project #7 (Reich) requests to decrease personnel by $697 from $432,000 to $431,303 ; and increase travel by the same from $10,607 to $11,304.
- Sub-project #8 (Schneider) requests to decrease personnel by $4,055 from $379,830 to $375,775; increase professional services by $12,514 from $35,486 to $48,000; decrease equipment/tools/supplies by $1,054 from $3,104 to $2,050; decrease printing by $15,279 from $16,000 to $721; and decrease travel by $5,416 from $15,670 to $10,254. This activity returns $13,200 to the reserve.
- Sub-project #9 (Malvick) requests to decrease personnel by $22,049 from $152,006 to $129,957; to decrease professional services by $1,835 from $2,600 to $765; decrease equipment/tools/supplies by $3,569 from $12,600 to $9,031; decrease travel by $834 from $4,700 to $3,866; and increase other by $2,288 from $6,800 to $9,088. This activity returns $25,999 to the reserve.
- Sub-project #10 (Olivera) requests to decrease personnel by $30,109 from $181,907 to $151,798; decrease professional services by $14,589 from $21,700 to $7,111; decreasing equipment/tools/supplies by $577 from $32,800 to $32,223; decreasing travel expenses by $4,043 from $7,100 to $2,957; and decreasing other by $2,354 from $4,000 to $1,646. This activity returns $51,772 to the reserve.
- Sub-project #11 (Koch) requests to increase personnel by $2,432 from $271,893 to $274,325; decrease professional services by $3,073 from $5,700 to $2,627; decrease equipment/tools/supplies by $2,800 from $3,179 to $379; decrease travel by $3,847 from $7,000 to $3,513 ; and increase other by $3,827 from $7,821 to $11,648. This activity returns $3,101 to the reserve.
- Sub-project #12 (Morey) requests an addition to the total budget from the reserve by increasing personnel by $4,187 from $151,601 to $155,788. The increase is necessary due the closure of a similar project under ML 2015 and an increase in salary and benefits during this appropriation. This amendment takes $4,187 from the reserve, but is well within the funding limits of the overall appropriation.

Amendment Approved (1-31-2024)

Tenth Update, March 1, 2024

Two research sub-projects remain active under this appropriation. Both continue to make solid progress towards the final completion of project outcomes. Both projects completed field work for 2023 in the previous six months. Teams continue to process samples in the laboratory, analyze data, and prepare summary reports. Both teams are on track for final project completion per the modified project timelines.

Our last update, submitted August 31, 2023, triggered questions from LCCMR staff. MITPPC received those questions on January 31, 2024. Most questions pertained to forthcoming final abstracts, so those will not be addressed at this time. LCCMR staff noted an issue with the previous update for sub-project #8 and asked for clearer summaries of work over the previous six months. Similarly, staff asked for more information about revenues generated by sub-project #11. Reponses are provided using underline formatting in the updates submitted on August 31, 2023 for sub-projects #8 and #11 below.

Amendment Request (3-1-2024)

Budget amendments are requested for sub-projects #1 and #7:

- Sub-project #1 (Blanchette) requests to amend its budget as follows**:** Increase equipment and tools by $12,232 from $29,800 to $42,032; decrease travel by $12,232 from $18,400 to $6,168. More equipment, tools and supplies were needed for processing samples than first estimated, partly a result of more samples being collected by partners and given to the research team than first imagined. A previously undescribed *Phytophthora* species has been found, as well as other new fungi on woody materials, also requiring the need for additional lab supplies. Less travel was needed than estimated due to the efforts of partners.
- Sub-project #7 (Reich) requests to amend its budget as follows: Increase personnel by $18,840 from $431,303 to $450,143; decrease professional services by $14,475 from $27,000 to $12,525; decrease equipment and supplies by $5,517 from $30,127 to $24,610; and to increase travel by $1,152 from $11,304 to $12,456. Contracts for professional services (vegetation management) at the research sites were less than first estimated. Research teams were able to reuse more materials than first estimated to allow for the reduction in equipment and supplies. Decreasing unspent funds in professional services and equipment and supplies and increasing the personnel budget allows additional time for the research team to monitor its sites. The increase in the travel budget was because research sites were visited more frequently than first estimated.

Final Update, August 2, 2024

The two research projects (sub-projects #1 and #7) that were extended under ML 2023, Sec 2, Carryforwards have completed their work. With the time extension, sub-project #1 (Blanchette) expanded surveys for non-native forest pathogens in Minnesota. In total, the team found 14 species of the pathogen *Phytophthora* that had never been reported from the state. Findings have been shared with the Minnesota Department of Agriculture. The team also trapped more spores than expected from the fungus that causes Annosum root rot in red pine. The results strongly suggest the presence of infection centers in Minnesota, a surprise finding. The team continues to work with the Forestry Division in the Department of Natural Resources to locate these infection centers in the field and prepare an appropriate management response. Research findings from sub-project #1 were published in a PhD thesis with individual chapters soon to be published in peer-reviewed journals.

Sub-project #7 (Reich) used the additional time to complete field observations on the impact of planting trees and shrubs on the growth and survival of buckthorn seedlings. The work builds on the idea, established earlier by this research team, that dense shade created by native plants can kill or stunt small buckthorn plants, hence the phrase “Cover It Up.” Trees and shrubs can take 10-20 years to reach maturity, so benefits of planting these species may not be fully realized within the relatively short timeframe of this research project. The team intends to work with its implementation partners from Ramsey County, Washington County, and Three Rivers Park District to continue monitoring the plots into the future. The team has two papers summarizing keys results for peer-reviewed journals. The team also prepared “A guide to forest understory revegetation to help manage buckthorn and other invasive plants” (Available at: https://z.umn.edu/buckthorn-revegetation-guide-2024). This document provides managers with practical guidance for more effective buckthorn management.

Amendment Request (8-2-2024)

We request budget amendments to four sub-projects to reflect actual expenses incurred, not estimates. All expenses were incurred within the performance period for each sub-project and are less than or equal to the funding originally allocated to each.

- Sub-project #1 closed during this period and now requests to reconcile its budget as follows: decrease personnel by $15,450 from $316,965 to $301,515; increase equipment, tools, and supplies by $26,713 from $42,032 to $68,745; decrease travel by $2,889 from $6,168 to $3,279; and decrease other expenses by $8,674 from $19,000 to $10,326. The final budget total is $383,865, ~~resulting in a return to the reserve of $300.~~ The PhD student supported by the project received a fellowship from the University of Minnesota, resulting in savings on personnel. “Equipment, tools, and supplies” was increased to accommodate the additional samples that were processed in the final year of the project; more samples were processed than first estimated. Implementation partners collected several soil samples for the

project, reducing the need for the research team to travel to field sites. The team elected to perform several laboratory analyses themselves (for example, genetic sequencing), rather than contract the work to a private lab, a choice that resulted in savings of "other" expenses.

- Sub-project # 2 has a minor final budget adjustment: an increase in personnel of $2,825 from $260,033 to $262,858; and an increase to equipment and tools of $4 from $7,646 to $7,650. These legitimate project expenses had been errantly charged to other accounts at the University, an oversight that was not discovered until final budget reconciliation with the close of the appropriation. The revised final budget total is $301,941, which remains less than the $301,993 that was originally allocated to the sub-project. ~~With this final closing, the sub-project returns $52 to the reserve.~~
- Sub-project # 8 has a minor final budget adjustment: a decrease in personnel of $728 from $375,775 to $375,047. A small portion of a University employee's time had been mistakenly charged to the sub-project; the oversight was discovered with the final budget reconciliation. The final project total is $436,072. ~~With this final closing, the sub-project returns an additional $728 to the reserve, bringing the total return to the reserve for this sub-project to $13,928 (relative to the $450,000 that was originally allocated to the sub-project)~~.
- Sub-project #9 has a minor final budget adjustment: an increase in travel by $291 from $3,866 to $4,157; and an increase of other expenses (i.e., greenhouse fees) by $314 from $9,088 to $9,402. These legitimate project expenses had been mistakenly charged to other accounts at the University. The oversight was not discovered until final budget reconciliation. The final project total is $153,312.~~, which remains less than the $178,706 that was originally allocated to the sub-project.~~

All of the above changes are reflected in the attached budget spreadsheet and in this work plan.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Accelerate research on high priority, terrestrial invasive species

Description:
MITPPC will accelerate research on invasive species that pose the greatest threat to Minnesota. The overall goal of this research is to prevent or minimize the damage caused by terrestrial invasive species across the state. Research projects will focus on the development of strategies for prediction and prevention of threats that are not yet in the state and on tools and techniques for early detection and rapid response for new terrestrial threats to Minnesota's resources. Some management options for well -established species range from containment, to slowing the spread, to Integrated Pest Management (IPM). IPM, the reliance on multiple, compatible strategies to keep plants or pests below damaging levels, may also include new biological control efforts. New tools, technology, and strategies are needed to support these efforts. Training experts in invasive species remains a common, vital goal, so funding for graduate students to work with existing faculty remains a core component of these projects.

Outcome	Completion Date
1. New tools and technologies developed to detect and characterize the distribution of invasive species.	06/30/2023
2. New, effective prevention and management alternatives developed and tested.	06/30/2023
3. Predictive tools created to account for invasive species issues under future conditions.	06/30/2023
4. Socio-economic analyses completed to better gauge impacts from, and responses to, terrestrial invasive species.	06/30/2023

ENRTF BUDGET: $3,500,000

First Update January 31, 2019 – Submitted May 9, 2019
No activity has been undertaken during this reporting period beyond the preparation of the ML 2018 Request for Proposals.

Second Update June 30, 2019:
A request for proposal was open for four months during this period and 22 eligible pre-proposals were received and vetted. Currently, 10 of those proposals are being developed into full research proposals. We anticipate that the selection process will be completed by the next reporting period and that the appropriation will be fully encumbered.

Third Update, July 31, 2020

We strategically chose not to allocate all funds from this appropriation in 2019 to ensure a modest pool of funding was available for another request for proposals in 2020. A second request for proposals under this appropriation was released in January 2020 and open for a four-month solicitation period. Of the nineteen pre-proposals received, six have been invited to continue with full proposal development. Decisions regarding full proposals will be completed by the next reporting period.

Fourth Update, February 28, 2021

In response to the call for proposals that was issued in January 2020, and after internal and external review, four sub-projects were selected for funding. These sub-projects, #9-#12, were presented to LCCMR staff in an interim update, provided on December 21, 2020. Staff reviewed and approved the addition of those projects on December 29, 2020, allowing for work to begin in early January 2021. To date, most effort around the new sub-projects has related to the establishment of financial accounts and initial staffing of projects. Per previous agreement with LCCMR staff, no additional updates will be provided for the four new sub-projects at this time.

MITPPC sub-project 1: Early detection of invasive tree pathogens using molecular tools for prevention and to mitigate damage

Project manager: Robert Blanchette

Description: This project will monitor invasive tree pathogens using molecular biosurveillance methodology and manage them before they become widespread problems. A focus will be on *Heterobasidion* Root Disease (HRD) since the pathogen causing the disease poses an immediate threat to Minnesota's red pine and white pine resource. However, the monitoring will also detect other important pathogens on the MITPPC prioritized pathogen list. Monitoring will be conducted with efficient and sensitive spore samplers and for the various exotic *Phytophthora* species, plant and water samples will be used. Detection will involve the development of real-time PCR using specific DNA primers for each pathogen, high-throughput sequencing and other molecular assays. Different spore samplers and collection methodology will also be tested. Early monitoring of HRD and other invasive pathogens will address socio-economic concerns by using early-detection surveys to identify new introductions and apply the best management options before the disease becomes widespread and enormously costly to control. Many reports have noted the importance to begin biosurveillance in the US for detecting invasive tree pathogens. The need is great if we are to prevent future ecological disasters and economic losses from invasive pathogens. This proposal allows work to begin using new methods of monitoring for pathogens on the top 15 pathogen list as well as many others in the top 120 list. It will also serve as a model for other states and federal agencies to follow in the future.

Summary budget information ENRTF budget: $~~384,165~~ $383,865

Outcome	Completion Date
ACTIVITY 1: **Testing for efficient and accurate spore trap systems**	
1. Determine the most effective spore samplers	6/30/2021
2. Determine if other air samples routinely collected by the state can be used	6/30/2021
3. Develop primers for all invasive fungi to be surveyed and determine the best protocols for DNA detection	12/31/2021
ACTIVITY 2: **Detection of invasive terrestrial tree pathogens including *Heterobasidion irregulare***	
1. Evaluate monitoring used for *Heterobasidion* in different regions of Minnesota	12/30/2021
2. Monitor for *Heterobasidion* and other exotic invasive tree pathogens	06/30/2023
3. Complete high-throughput sequencing of samples from first year	12/30/2020
4. Complete annual high-throughput sequencing of samples	05/15/2024
ACTIVITY 3: **Detection of invasive *Phytophthora* species**	
1. Obtain and test *Phytophthora* primers for qPCR and evaluate effectiveness of sampling protocols	12/30/2020
2. Monitor for exotic *Phytophthora* species in different regions of Minnesota	06/30/2023
3. Complete high-throughput sequencing annually of samples	05/15/2024

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

Work on this project has included getting personnel hired, purchasing spore trapping equipment, setting up sampling protocols and identifying sampling sites with the MN Department of Natural Resources. All is on schedule for our field sampling to take place this field season. Although restrictions apply for all University field research work, we have received approval and will be able to carry out all our planned activities for 2020 and sampling has started. Sampling is underway to identify the exotic Phytophthora species in Minnesota during June and July and sampling for *Heterobasidion irregulare* and other invasive tree pathogens in August to October as spores from these pathogens begin to be disseminated.

Fourth Update, February 28, 2021

Good progress has been made on the project. Three different spore samplers (Roto-Rod, Burkard, and windsocks) were deployed in the field to test efficiency for detecting *Heterobasidion* spores at a site in WI with active disease centers. Samplers were deployed for two weeks at a time, in early and late fall. DNA has been extracted from samples and is currently being processed for QPCR analysis. Detection surveys throughout south-eastern Minnesota in counties near positive *Heterobasidion* infection sites in Wisconsin have been initiated. Three detection systems were used at the sites near Weaver and Whitewater State Park. Windsocks fitted with Vaseline coated slides were also deployed near Minneiska, Lake City, and Hay Creek. Spore collections from all of these locations are being processed using selected primers that have been found to work successfully. Additional sampling at several locations and in Minnesota nurseries for *Phytophthora* species was carried out

from plant material, soil, and baits placed in water reservoirs. Partners at the MN DNR have also sent samples from different areas of the state with soil from around trees suspected being infected with *Phythophthora*. Immunological tests, culturing and identification by DNA sequencing are being completed on the samples and cultures obtained. Confirmation of species is also being done using metabarcoding high throughput sequencing.

Fifth Update, August 31, 2021

Excellent progress has been made and all activities are on track to be completed as expected. The Burkard, RotoRod and windsock spore samples from 2020 collected from Burr Oak, Wisconsin, Weaver, Whitewater, Minneiska, Lake City and Hay Creek, Minnesota as well as other sites have been processed successfully and analyzed using qPCR. Heterobasidion spore concentrations have been calculated for each location and show low levels of airborne spores are arriving in Minnesota at locations adjacent to the Wisconsin border. All of the soil that was collected or received from the Minnesota Department of Natural Resources or other collaborators from around the state has been processed and sequenced to determine the *Phytophthora* species that are present. *Phytophthora* sequencing was run with COXII primers and additional genes were used to further characterize the isolates. In addition, amplicon sequencing was done using selected spore collections and was successful in confirming other detection methods. Additional studies are underway in 2021 to deploy more spore traps along the Minnesota-Wisconsin border to further quantify spores present in locations where high numbers of spores were found. Windsock and RotoRod spore traps will also be deployed in central and northern Minnesota. For Phytophthora, we are resampling locations around the state that revealed noteworthy species in 2020 to get a better understanding of where these pathogens are located and how well established they are. In addition to soil samples, we are sampling nursery stock and irrigation water from woody plant nurseries around the state.

Sixth Update, February 28, 2022

Excellent progress has been made and all activities are on track to be completed as expected.

Burkard, RotoRod and windsock spore traps were deployed at strategic locations in Minnesota and Wisconsin this fall. Sampling locations included all areas from last year (Burr Oak, Wisconsin, Weaver, Whitewater, Minneiska, and Lake City) with several additional locations in Minnesota and Wisconsin to increase our screening efforts for Heterobasidion. Soil samples were collected with the help of The Minnesota Department of Natural Resources at locations where Phytophthora isolates of interest were identified in Minnesota forests. Sampling from Minnesota forests was also carried out by members of the project. In addition to soil samples from the Minnesota DNR, plant and soil samples were taken from three large production nurseries in Minnesota as well as from the University of Minnesota Horticultural Research Center and Landscape Arboretum to screen for potentially invasive Phytophthora species. The soil and plant material collected has been screened for Phytophthora and cultures obtained were sequenced with COXII primers. Tasks for the upcoming season include processing samples collected from the spore traps and quantifying the spores present via qPCR. Phytophthora samples that matched more than one species are being studied with additional primers to confirm identity. We are also scheduled to get air filters from the Minnesota Pollution Control Agency to screen for invasive pathogens.

Seventh Update, August 31, 2022

All aspects of the project have been progressing very well and activities are on track to be completed as expected. Samples from the fall collection materials have been extracted and analyzed. Five locations had detectable amounts of *Heterobasidion* spores. Two sites were in Minnesota (locations near Weaver and Stillwater). In Wisconsin, detectable spores came from Cylon State Park, Perrot State Park and Burr Oak (our positive control site). In locations in Minnesota where average to high numbers of spores were present, the surrounding areas are being searched for locations where *Heterobasidion* root rot centers are located. Over the past two years, nearly 200 samples yielded *Phytophthora* species including 6 species that appear not to have been reported in the state. *Phytophthora* sampling this spring in underway at all of the same nurseries that were sampled last year as well as at the University of Minnesota Arboretum and many other locations including 35

other nursery and Christmas tree growing locations. Soil, plant, or water bait samples have been taken at each location. Sample collection from the nurseries and Christmas tree plantations around the state were collected in collaboration with the Minnesota Department of Agriculture and their nursery inspectors. We also have received forest soil samples from the Minnesota Department of Natural Resources. Isolations to obtain pure cultures and rDNA sequencing is underway to identify the *Phytophthora* species in the state. *Phytophthora* sampling is also being done at metropolitan parks and waterways where trees and other plants are declining.

Eighth Update, February 28, 2023

Good progress has been made on the project and all activities are to be completed as expected. Burkard, RotoRod and windsock spore traps were deployed around Minnesota and Wisconsin during the field season. Locations this year were similar to the past sampling periods with a focus on locations that have had moderate to high amounts of *Heterobasidion* spores. The locations were near Weaver, Minnesota and Burr Oak, Wisconsin. In addition, four windsock spore traps were also deployed at Itasca State Park. The inclusion of Itasca State Park is to survey for the Heterobasidion species that was reported there in the 1970's. Aerial surveys using google maps and ground surveys have begun to find infection centers near Weaver, Minnesota with our laboratory and the Minnesota Department of Natural Resources. Over 450 samples of *Phytophthora* have been processed with a total 12 new species to the state. Nurseries, the UMN Arboretum, and Horticulture Research Center and various water ways were baited for *Phytophthora* using pear and rhododendron leaves. Two collections of 35 samples from nurseries and Christmas tree farms were also processed. The Minnesota Department of Natural Resources also provided samples from declining forest stands. This winter we will be extracting all of the spore sampling material and quantifying spores present at each location. *Phytophthora* isolates are also continuing to be processed and sequenced.

Ninth Update, August 31, 2023

Excellent progress is being made on the project and milestones have been met. Spore collections from Burkard, Roto Rod, and Windsock spore traps from fall 2022 have all been extracted and processed. Each collection method was extracted separately by location to prevent the possibility of contamination. Spores from each location around the state have been analyzed and the spores for *Heterobasidion* quantified. Our results suggest there is one or possibly several new positive locations in the Winona County area of Minnesota and there is a possibility of other positive locations in other areas of southeastern Minnesota. Nursery and forest stand *Phytophthora* samples from last summer and fall have all been processed and the *Phytophthora* species identified. Additionally, soil samples received from the Minnesota Department of Agriculture that were collected from 35 different nurseries and Christmas tree plantations have been processed and sequenced. Since the beginning of the project, over 1000 samples have been processed and sequenced. For species of *Phytophthora*, over 500 *Phytophthora* isolates were obtained and 13 species that have not been reported from Minnesota were identified. Samples from collections made in the 2022 sampling year are currently being prepared and analyzed for Oxford Nanopore sequencing. Summer and fall activities will focus on sampling for *Phytophthora* at large nurseries around the state as well as sampling local parks and forest systems. *Heterobasidion* sampling will occur at similar locations that were used in previous years and on ground scouting of infection sites will be completed.

Tenth Update, February 28, 2024

The overall progress of the project and each of the objectives has been excellent and all activities are to be completed on time as expected. Sets of spore traps- Burkard, Roto Rod and windsocks were placed at different locations in Wisconsin and Minnesota in 2023. Sampling locations this year were similar to the previous three years with the addition of four windsocks being deployed around Itasca State Park. Our efforts were mainly concentrated on areas of southeastern Minnesota and Wisconsin where we have previously trapped moderate to high amounts of *Heterobasidion* spores. We have been collaborating with the Minnesota Department of Natural resources to look at aerial maps of conifer/pine stands that have been thinned or harvested in the past 15 years. Aerial and on foot surveys for *Heterobasidion* infection sites and fruiting bodies will continue into 2024. We are also planning to deploy windsock spore traps at positive locations in Wisconsin this winter to

assess how long spores persist in the environment during the year. To date over 500 samples of *Phytophthora* have been processed with a total of 14 new to the state species identified from the past four years of sampling. Sampling this year took place at several production and retail woody plant nurseries, Christmas tree plantations, UMN Arboretum and Horticulture Research Center. Two collections of 35 soil samples from nurseries and Christmas tree farms from around the state were submitted to our lab by the Minnesota Department of Agriculture. Processing of the remaining soil and plant material from the fall field season is continuing. Spore collections from this fall will also be processed and spores quantified during the winter months. Sequencing of 2022 samples using Oxford Nanopore was successfully completed and produced copious data (i.e., 6.56 million genetic reads comprised of 3.96 gigabases) that are being analyzed.

Final Update, June 30, 2024

All soil samples from the nurseries and the 35 locations that the Minnesota Department of Agriculture (MDA) provided to us have been processed. Our project has processed over 1500 samples since we began in 2020. We detected 14 previously undetected species of *Phytophthora* present in Minnesota. A manuscript with our findings from the past four years of sampling has been written and will be submitted for publication in early Summer 2024.

All spore collections of Heterobasidion from spore samplers including windsocks, Roto Rods, and Burkards, from Fall 2023 have been extracted and analyzed via qPCR. Our results are consistent with the previous three years, indicating a high probability of an infection center in or near Winona County, Minnesota. We intend to work this summer and fall (beyond the life of this project) with the Department of Natural Resources, one of our implementation partners, to find these infection centers on foot and through aerial imaging.

Nanopore sequencing was successfully initiated beginning with fall ’22 samples. Heterobasidion was successfully detected in samples where qPCR was positive along with many undescribed fungal species. It may be a useful tool going forward in order to detect other top 20 threats to forests and beyond.

MITPPC sub-project 2: Accurate detection of oak wilt from tree to landscape scales for enhanced forest management

Project manager: Jeannine Cavender-Bares

Description: The oak genus (*Quercus*) is a functionally critical and wide-spread tree genus, that is abundant in the upper Midwestern US. Oak wilt, caused by the invasive fungus *Bretziella fagacearum*, is one of several diseases severely impacting oak species. Over the last sixty years, oak wilt has become increasingly destructive and currently represents a major threat to forest health. Infection, which in most cases is followed by death, represents a critical loss of ecosystem services provided by oak trees, including carbon storage, erosion control and wildlife provisioning. To effectively prevent the spread of oak wilt, it is important to accurately detect and monitor the disease over large areas. We have successfully been using hyperspectral data at the leaf level as well as airborne imaging spectroscopy to detect oak wilt symptoms and differentiate it from other stress factors, including drought, bur oak blight. We now propose 1) to develop a method for detecting and predicting mortality in trees due to oak wilt and 2) to scale up spectral detection of the disease—and differentiation from drought+two-lined chestnut borer, bur oak blight and insect defoliation—by coupling UAV, airborne and satellite data, including the Japanese-US HISUI hyperspectral sensor on the International Space Station. We will also evaluate the efficacy of contrasting oak wilt management strategies and examine the ecological impacts and dynamics of forest change in forests experiencing oak wilt damage. Our goal is to provide a choice of several readily usable methodologies that can be applied by natural resource managers across a range of spatial scales at the county, state and sub-regional levels.

Summary budget information ENRTF budget: ~~$301,993~~ $301,941

Outcomes	Completion Date
ACTIVITY 1. **Scale oak wilt detection from canopies to landscapes using spectral data from the leaf and canopy level, UAV platforms, airborne hyperspectral imagery, and spaceborne satellite imagery.**	
1. Determination of physiological basis of oak wilt spectral signatures at the canopy, stand and regional level	06/30/2023
2. Airborne testing of oak wilt detection models and candidate spectral band	09/30/2022
3. Custom designed UAV sensor developed, deployed and tested	12/31/2023
4. Development of pipeline for mapping of oak wilt across Minnesota and the Upper Midwest using satellite imagery and delivered to DNR and forest Managers	05/30/2023
5. Online report of findings published	06/30/2023
6. Two workshops offered through the SFEC and one at the STSC on using hyperspectral tools in oak wilt detection	06/30/2023
ACTIVITY 2. **Evaluate the efficacy of contrasting oak wilt management strategies**	
1. Twenty oak wilt centers treated and evaluated	06/30/2023
2. Recommendations to managers on efficacy of double vibratory plow control method and its economic costs	06/30/2023
3. Field demonstration of the two-pass system to stakeholders	05/30/2023

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

We have finished gathering and preprocessing all the 2018 AVIRIS airborne data acquired by NASA and tree coordinates necessary to obtain hyperspectral data for northern pin oak (*Quercus ellipsoidalis*), northern red oak (*Q. rubra*)—both species are in the red oaks lineage—and bur oak (*Q. macrocarpa*) in the white oak lineage for healthy, infected and dead oaks specifically. This data covers the five different sites where collaborator Juzwik is assessing oak wilt management strategies. We are in the process of building PLSDA models and spectral indexes that are applicable across sites. We have also completed discussions with Sentera to design a custom UAV capable of measuring wavelengths sensitive to oak wilt based on our previous findings. The UAV is now under construction. Finally, we have initiated communications with our collaborators at NASA to obtain the spaceborne satellite imagery that we will use to scale oak wilt detection models and spectral indices from canopies to landscapes.

Since January 1, 2020 we have completed updating all electronic geospatial and other data files for 1) 2019 field season monitoring, 2) three new (and final) oak wilt sites treated in 2019, and 3) several sites requiring minor vibratory plow re-treatment. In the past month, needed maintenance/clearing was completed along plow treatment lines on several sites. Lastly, the first monitoring period of all 20 sites for the 2020 growing season began in late June.

Key stakeholders are interested in comparing results of vibratory plow use for controlling root graft transmission of the oak wilt fungus (this project) to similar, multi-year operational trials conducted using either “girdle-herbicide only” or to “root rupture” treatment approaches in Wisconsin. We anticipate preparing our project report in a manner to best allow for this comparison.

Fourth Update, February 28, 2021

We have analyzed hyperspectral aerial imagery from AVIRIS NG and AISA imaging spectrometers, covering the wavelength ranges of 400 – 2400 nm and 400 – 1000 nm, respectively, at the Cedar Creek Ecosystem Science Reserve. The detection accuracy was improved by first classifying the oaks separately from other trees and then by classifying the red oak lineage, which is killed by the fungus. We called this the ”phylogenetic approach”, which is part of our framework for maximizing the accuracy of the statistical models in detecting oak wilt (Sapes et al. below).

Based on airborne image analysis, we identified eight candidate spectral bands for detecting and monitoring of oak wilt based on airborne data from Cedar Creek and physiological data from our outdoor field experiment. We worked with our industry partner, Sentera (www.sentera.com), to develop a light-weight multispectral sensor to detect oak wilt under field settings. With Covid19, the sensor was not completed until late October 2020. We were able to test the sensor and fly the drone twice for testing during the fall of 2020. During these test flights, hardware and software issues were worked out, and the sensor was able to capture a series of images during two test flights in fall 2020.

We accessed a total of 174 hyperspectral images from the DESIS satellite sensor since its launch between the months of August and September. Our approach is to derive models starting with airborne imagery collected over oak wilt sites and adapt these models to satellite imagery separately in deciduous and mixed forests at broad spatial extents.

Fifth Update, August 31, 2021

Our efforts to date for accurate detection of oak wilt across scales using spectral reflectance have focused on 1) establishing and monitoring a drought x oak wilt sapling experiment with red oak, 2) flying our custom-designed multispectral drone over the experiment and over forest sites that we are monitoring for oak wilt or that are known to have oak wilt, 3) revising a manuscript demonstrating our modeling approach using airborne remote sensing with spectroscopic data, 4) gathering airborne canopy spectral reflectance data across sites in Minnesota to develop landscape-level models capable of pre-visual oak wilt detection, and 5) advancing data assembly efforts for the use of satellite data. Our team has presented at a scientific meeting and in graduate and undergraduate classrooms and has involved landowners and managers in site-level data collection campaigns.

Sixth Update, February 28, 2022

We have completed the work for the oak wilt x drought experiment and the first phase of the airborne spectroscopy study to understand the physiological basis of the disease and advance airborne detection. In the most recent reporting period, we have focused our primary efforts on the UAV and satellite image processing and pipeline development.

Seventh Update, August 31, 2022

We have continued our activities and foresee a successful close to the project in the coming year with all proposed activities complete. We have completed the leaf and canopy level detection work using aircraft, unmanned aerial vehicles (UAVs) and hand-held spectroscopic instrumentation. A manuscript has been published on the airborne detection of the oak wilt pathogen *Bretziella fagacearum* using hyperspectral imagery and a phylogenetic modeling approach (based on Phase 1 of this project). A second manuscript using the UAV multispectral sensor we had custom built is in progress that integrates physiological symptoms of disease and

drought progression in experimental red oaks. A standardized, automated analytical method that uses satellite data, ground-truthed with images from the National Agriculture Imagery Program (NAIP) and UAV data, has been developed for regional-scale oak wilt detection in forests. In the forest sites we managed for oak wilt experimentally using a vibratory plow, monitoring and documentation of oak wilt symptomatic red oaks was completed during two visits to each field site (n = 24) between early July and early September 2021. Containment of belowground spread of the oak wilt pathogen was attempted on each site using either a single pass or a double pass of a vibratory plow along a path delineated by an experienced oak wilt management forester.

Eighth Update, February 28, 2023

Our most recent work shows that phenological changes in pigments and photosynthetic activity of oak trees due to oak wilt can be tracked using phenological metrics derived from the Chlorophyll/Carotenoid Index (CCI) from satellite observations. We evaluated an approach in conjunction with high resolution aerial observations of symptomatic trees in pockets of disease from Central Minnesota. This study highlights the use of phenological-base metrics from frequent and continuous spaceborne observations for mapping oak wilt disease at large scale. We also used drone imagery to detect physiological symptoms of oak wilt and differentiate oak-wilt infected seedlings from droughted seedlings in an outdoor experiment. Two manuscripts are in progress.

Final Update, August 31, 2023

In the past six months, we have completed a workflow using satellite data to detect oak wilt across Minnesota. Our work demonstrates that phenological metrics derived from the Chlorophyll/Carotenoid Index (CCI) from spaceborne sensors show high accuracy in detecting oak wilt and differentiating healthy, symptomatic, and dead trees in Minnesota and the Upper Midwest. We integrated high-resolution airborne imagery in multiple locations to select pixels (n = 3,872) from healthy, symptomatic, and dead oak trees. These pixels were used to train an iterative Partial Least Square Discriminant (PLSD) model and derive the probability of an oak tree in one of these conditions and the associated uncertainty. We assessed these models spatially and temporally on testing datasets revealing that it is feasible to discriminate among the three health conditions with overall accuracy between 80-82%. Within conditions, our models suggest that spatial variations among three CCI-derived LSP metrics can predict healthy (Area Under the Curve (AUC) = 0.98), symptomatic (AUC = 0.89), and dead (AUC = 0.94) oak trees with low false positive rates. The model performance was robust across different years. The predictive maps were used to guide local stakeholders in locating disease hotspots for ground verification and subsequent decision-making for treatment. Our results highlight the capabilities of phenological metrics from spaceborne observations to map diseases at large scales. A manuscript is in review in Remote Sensing and Environment. A second manuscript on the outdoor drought and oak wilt experiment is in the final stages of preparation before submission.

MITPPC sub-project 3: Winning the Dutch elm disease battle: developing resistant elms for MN

Project manager: Ben Held

Description: For nearly 10 decades, the invasive pathogen *Ophiostoma novo-ulmi* has been decimating American elm (*Ulmus americana*) in Minnesota. There was good reason for the once widespread use of elm, since it has elegant form, tolerance to the harsh urban environment and is a premier canopy species. American, along with red (*U. rubra*) and rock (*U. thomasii*) elm, also provide critical benefits to wildlife, insects, and native forest ecosystems. Control measures so far have relied on sanitation and chemical control, which are both expensive. Varied disease resistance has been identified in a small number of elms but lack of good form and winter hardiness are problems along with a need for more genetic diversity.

This is a critical time for the American elm and new urban trees are also desperately needed to replace ash losses from the emerald ash borer and maples from *Verticillium* and the new invasive *Rhytisma* leaf disease. This proposal builds on previous research that has focused on natural disease resistance found in survivor elms. Through inoculation trials using clonally propagated material from trees identified across the state, we aim to thoroughly test and establish disease resistant American, red, and rock elm for use in Minnesota and also return

them back into the Minnesota landscape through a planting program. We will also determine how varying inoculum dose and tree age contributes to disease severity

Summary budget information ENRTF budget: $233,924

Outcomes	Completion Date
ACTIVITY 1**: Inoculate and evaluate putative resistant elm selections in the field**	
1. Determine comparative DED resistance of commercially available elm selections	08/31/2021
2. Determine effect of inoculum dose on disease development	08/31/2022
3. Determine one season resistance of elm selections from MN	06/30/2023
4. Determine influence of age and dose on DED resistance of commercially available elm selections	06/30/2023
ACTIVITY 2: **Select and Propagate resistant elms**	
1. Propagation of resistant elm selections for use in park and natural area plantings	12/31/2022
2. Identify and propagate 20 elm selections from underrepresented geographical areas	06/30/2023
3. Determine effectiveness of refined methods for elm propagation	06/30/2023
ACTIVITY 3: **Reintroduction of elm selections to state parks and other natural areas**	
1. Plant additional putative disease resistant elms in Nerstrand Big Woods State Park	12/31/2020
2. Plant disease resistant elms in four additional Minnesota State Parks or SNAs	06/30/2023
3. Ensure establishment of planted elms by maintenance and determine performance	06/30/2023

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

Excellent progress has been made since the start of this project. Despite COVID-19, we are still on track to meet the next activity outcome dates. The winter months were busy propagating putatively resistant selections for future studies and out planting in parks and natural areas. This also included propagation studies aimed at improving success and efficiency. Planning has begun with cooperators with the MN DNR and Three Rivers Park District about planting selections from our program in their managed lands. This is an excellent opportunity to reestablish elm in these areas and provide long term testing. Specific areas have been identified for planting and a fall planting has been scheduled. An inoculation trial was initiated on June 12 in which three commercially available resistant elm selection (Valley Forge, Jefferson and Prairie Expedition) were inoculated with three different doses with different concentrations of the pathogen in liquid form. The goal is to optimize inoculum load in order to achieve the appropriate dose so as not to overload resistance that would perform well in natural settings. Trees will be rated two weeks post inoculation and four weeks thereafter. One year ratings of last year's inoculation will also be completed at the two week post inoculation. Preliminary results from last year show that several selections have survived and are showing moderate resistance. Several videos of propagation, soil testing, inoculation and other aspects of the UMESP have been produced during this period for outreach

purposes and can be reached on our YouTube page:
https://www.youtube.com/channel/UCOzfgUDMfQ10on_PuqhfL6w

Fourth Update, February 28, 2021

Good progress has been made on the project and milestones for activities are being met. Following a successful inoculation of commercially available DED resistant elm selections using varying doses, rating and monitoring of these trees was carried out until early September. Ratings show limited disease progression in inoculated trees. This study is providing important data on refinements on inoculation methods as well as additional data on resistance of the selections. Ratings will continue in the next growing season. Rooted cutting studies were carried out and showed promising results that will improve this method of propagation. Developing a more efficient rooted cutting propagation method would greatly improve propagation processes. Maintenance of grafts that were made earlier in the year was also done during this time by moving them outdoors in the nursery. These selections will be used in future studies. In our partnership with the MN DNR, additional planting of elm selections was done in Nerstrand Big Woods State Park in areas of prior tree mortality. Assessments of elm that had been planted previously revealed very good survival rates. Maintenance was also done on seedlings in the planting. We were excited about two outreach pieces in newspaper articles that explained our research and the importance of elm in the Star Tribune and The Minnesota Daily. A presentation was also made at the Upper Midwest Invasive Species Conference on our research in November.

Fifth Update, August 31, 2021

Significant progress has been made during this period and all milestones are being met in each activity. Much of the work during this period during the winter months was focused on collection of new putatively resistant selections in the landscape and propagation. Six new selections were identified from which scion material was collected for grafting. Propagation also continued to replicate various selections for future inoculation trials. Progress was also made in clonal cutting propagation methods in order to increase success with that method. Ratings continued in early June from the inoculation trial initiated one year ago. Initial findings are hopeful and show that many selections had limited wilting continuing in this growing season while a smaller number showed limited to moderate wilting. Dose effect is not yet clear and will be determined as trees stop wilting. Trees will be continually monitored and rated over the growing season. Maintenance of field plots was done which included pruning, culling of dead trees and planting additional selections for future trials. Propagation and planning also continued for planting in parks and natural areas, with plans to plant additional trees in the fall.

Sixth Update, February 28, 2022

Progress on all activities has met or exceeded goals for this period. Ratings from the 2020 inoculation dose study does not appear to show a relationship between inoculum dose and wilt symptoms. The three commercially available DED resistant selections performed well overall having average wilt symptoms below 3.5, out of a 0-11 scale where 0 = no wilt and 11 = complete wilt. An additional set of trees in this plot will be inoculated in the spring to test age. Growing propagated trees from grafting activities in the winter continued by planting in field plots on campus as well as at a Three Rivers Park. This included nine new selections. We also began to grow trees from seed, which is presumable enriched as it was collected from St. Croix, a resistant selection that is growing in the nursery. We will use a portion of these trees for rootstock for grafting scion material from new selections. A planting was carried out at Elm Creek Park, in the Three Rivers Park District in Maple Grove. The site was ideal location because prior plantings had largely failed due to site conditions and elm has been a component in the past, which many have succumbed to DED. The planting consisted of 25 DED resistant selections which were staked, tubed and GPS located.

Seventh Update, August 31, 2022

Progress on the project is on schedule and goals are being met in all activities during this period. The majority of the work during this period focused on propagation of newly selected material from putatively resistant

selections in addition to grafting previous genotypes for planting in parks. Ten genotypes were grafted onto resistant selection St. Croix and wild type root stock. Five of these selections will be used for planting in outplantings and another five are new selections that will undergo disease resistance screening in the future. Rooting studies also continued with softwood cuttings and will continue into the growing season. Also during this period an inoculation was carried out on new selections that were planted in the field plots in 2018 in addition to an additional set of commercially available resistant selections, Valley Forge, Prairie Expedition, and Jefferson. Ratings of these selections will be done throughout the growing season.

Eighth Update, February 28, 2023

It was a productive summer season for the elm project and progress in on schedule. Inoculations took place in mid June where new Minnesota elm selections were challenged in addition to an additional set of commercially available resistant selections (Valley Forge, Jefferson, and Prairie Expedition) to compare with a similar inoculation 2 years ago. Two month wilt ratings for Minnesota selections and the commercially available selections showed limited wilt. Propagation studies continued with trials investigating timing of hormone application and use of soluble fertilizer to promote cutting health. Two planting sites in Minnetonka have been identified and a fall installation was planned however drought conditions and schedules caused this planting to be shifted until the spring. An additional planting project was also identified and is planned for spring 2023 with Green Crew youth at Izaak Walton League.

Final Update, August 31, 2023

Progress on the project is on schedule and goals are being met in all activities during this period. Much of the effort during this time was focused on propagation of newly selected material from putatively resistant selections in addition to grafting previous genotypes for planting in parks. Preparations were also made for seedlings prepared last year for field plantings this spring. A field planting took place at the Izaak Walton League, MN Valley Chapter in Bloomington, which was done in cooperation with the Green Crew, a youth-led environmental action program. Ratings were also completed from the inoculations last year in two plots showing that wilt was limited in most of the new selections and very limited in the commercially available resistant cultivars.

MITPPC sub-project 4: Detection and monitoring of invasive *Phragmites*

Project manager: Joe Knight

Description: Information about the location and extent of *Phragmites* is required for proper management of this invasive plant. However, there is no existing method that can detect and monitor *Phragmites* with high accuracy and at high resolution. The proposed research would develop an approach to detect and monitor invasive *Phragmites* using remote sensing data and methods. We propose two Specific Aims: 1) To assess the accuracy with which *Phragmites* can be detected using state-of-the-art remote sensing approaches, and 2) To assess the potential for using remotely-sensed data to monitor *Phragmites* throughout Minnesota and the Great Lakes Basin. This research would use high spatial resolution stereo satellite imagery and Synthetic Aperture Radar to identify spectral, structural, and textural attributes of *Phragmites*. These attributes will be used to detect and monitor *Phragmites* on the landscape. Our team has collaborated on numerous projects focused on wetland habitat monitoring and characterization, including multiple current and concluded Great Lakes Restoration Initiative projects.

Summary budget information ENRTF budget: $203,781

Outcomes	Completion Date
ACTIVITY 1: **Assess the accuracy with which *Phragmites* can be detected and mapped using state-of-the-art remote sensing methods and data**	

Outcomes	Completion Date
1. Study sites selected to evaluate mapping approaches	03/31/2020
2. Compile remotely sensed data for selected sites	12/31/2020
3. Evaluate the accuracy of remotely sensed data for mapping *Phragmites*	12/31/2022
4.Statistically robust validation	06/30/2023
ACTIVITY 2: **Assess the potential for using remotely-sensed data to monitor *Phragmites* throughout Minnesota and the Great Lakes Basin**	
1. Modify LandTrendr code for pre-processing of all image data	02/28/2020
2. Customize LandTrendr code in GEE to track known *Phragmite*s patches	06/30/2022
3. Validation	09/30/2022
4. Distribution of code/tools to stakeholders for testing.	6/30/2023

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

We have made strong overall progress in securing the geospatial data to be used, identifying field sites for training and validation, and developing analysis methods for identifying and monitoring phragmites on the landscape. We experienced a minor disruption to our field work due to COVID-associated travel and work restrictions. This resulted in a delay in acquiring field data. We anticipate being back on schedule at some point this year. Other project deliverables and deadlines are on schedule. Our preliminary work so far is important for stakeholders because it indicates that geospatial methods are likely to provide important additional information to improve the "picture" of the status of phragmites in Minnesota. We plan to present our work at the upcoming online Upper Midwest Invasive Species Conference (UMISC). We had planned to present at the MN GIS/LIS conference, but it was canceled due to COVID. The only other important disruption is that the primary scientist working on the project, graduate student Connor Anderson, will be doing an internship with NASA this summer. This will take him away from the project for approximately three months. At this point, we do not anticipate changes to our deliverable dates because of his absence. We have one manuscript in preparation at this point: 20%. We do not yet have a working title.

Fourth Update, February 28, 2021

We have made strong overall progress in securing the geospatial data to be used, identifying field sites for training and validation, and developing analysis methods for identifying and monitoring phragmites on the landscape. We experienced a minor disruption to our field work due to COVID-associated travel and work restrictions. This resulted in a delay in acquiring field data. We anticipate being back on schedule at some point this year. Other project deliverables and deadlines are on schedule. Our preliminary work so far is important for stakeholders because it indicates that geospatial methods are likely to provide important additional information to improve the "picture" of the status of phragmites in Minnesota. We presented our work at the 2020 Upper Midwest Invasive Species Conference (UMISC; online). We had planned to present at the MN GIS/LIS conference, but it was canceled due to COVID. The only other important disruption is that the primary scientist working on the project, graduate student Connor Anderson, will be doing an internship with NASA this summer. This will take him away from the project for approximately three months. At this point, we do not anticipate changes to our deliverable dates because of his absence. We have one manuscript in preparation at this point: 20% complete. We do not yet have a working title.

Fifth Update, August 31, 2021

Overall progress has been strong during this reporting period. After some disruption to field work due to COVID in prior reporting periods, we are currently collecting UAS image data for multiple pilot areas in Minnesota, including Swan Lake and Delano, with several more planned fights. Most of these areas are within two hours drive of the Metro, but we plan to expand to more outlying areas in the near future. We have one manuscript describing the initial stages of this project in revision in the journal "Remote Sensing". Its title is "Mapping Invasive Phragmites australis Using Unoccupied Aircraft System Imagery, Canopy Height Models, and Synthetic Aperture Radar." We remain optimistic that our work will benefit stakeholders through the demonstration that geospatial methods are likely to provide important additional information to improve the "picture" of the status of phragmites in Minnesota.

Sixth Update, February 28, 2022

Overall progress has been strong during this reporting period. We have flown with UAS several areas containing invasive phragmites. Most of these areas are within two hours drive of the Metro, but we plan to expand to more outlying areas in the near future. We have one manuscript describing the initial stages of this project published in the journal "Remote Sensing". Its title is "Mapping Invasive Phragmites australis Using Unoccupied Aircraft System Imagery, Canopy Height Models, and Synthetic Aperture Radar." The DOI for the paper is https://doi.org/10.3390/rs13163303. We remain optimistic that our work will benefit stakeholders through the demonstration that geospatial methods are likely to provide important additional information to improve the "picture" of the status of phragmites in Minnesota.

Seventh Update, August 31, 2022

We continue to make good progress on this sub-project. Connor Anderson, doctoral graduate student and the primary technician on this project, has made excellent progress in developing geospatial mapping methods for Phragmites. Our results so far using UAS imagery, lidar point clouds, and image-derived surface models in an Object-Oriented Image Analysis (OBIA) framework perform very well. Similarly, processing these data using the RandomForest machine learning algorithm are very good for identification of Phragmites. We are currently working to expand our approach to more and larger areas and additional data types. Specifically, we are using National Agricultural Imagery Program data and Sentinel-2 satellite imagery to assess their potential for mapping Phragmites throughout the Great Lakes Basin. We have identified several hundred Phragmites patches throughout Minnesota and Wisconsin to use for testing and training of our machine learning algorithms. Results so far using NAIP and Sentinel are encouraging but at this point we do not expect to be able to develop a broadly applicable method using these data types during the period of this project. We anticipate that this work will serve as preliminary results for a potential MITPPC-funded extension of this project.

Eighth Update, February 28, 2023

Overall progress continues to be strong during this reporting period. In addition to the previously report paper that describes mapping invasive Phragmites with UAS imagery in an OBIA context (https://doi.org/10.3390/rs13163303), we have a follow-on paper in review. This new paper describes mapping Phragmites using UAS and machine learning algorithms. During this reporting period we have been working on expanding our methods to larger/more areas using additional aerial and satellite imagery. We remain optimistic that our work will benefit stakeholders through the demonstration that geospatial methods are likely to provide important additional information to improve the "picture" of the status of Phragmites in Minnesota.

Final Update, August 31, 2023

Overall progress was strong during this reporting period. In the last report, we listed a manuscript in review describing mapping Phragmites using UAS and machine learning algorithms. That paper has now been published in the journal Remote Sensing (DOI: 10.3390/rs15040989) as "Improving Machine Learning Classifications of *Phragmites australis* Using Object-Based Image Analysis." We have another manuscript in review, which has the proposed title "Using Voting-Based Ensemble Classifiers to Map Invasive *Phragmites australis*." The initial peer

review comments are positive, so we expect the work to be published soon. All Activities of this project are complete at this time.

MITPPC sub-project 5: Improve invasive plant treatment efficacy using climate based phenology models
Project manager: Rebecca Montgomery

Description: The management and control of invasive species depends strongly on applying effective management strategies timed to appropriate life cycle stages. For example, mowing after seed maturation potentially contributes to spread whereas mowing during early flowering phases can prevent seed development and maturation. However, there is often a paucity of data on life history and timing of key life cycle events (i.e., phenology) for species in their introduced ranges. Currently, management activities tend to use calendar days for predicting phenology and timing of management. However, phenology is strongly regulated by temperature. Thus, scheduling management using temperature-based predictions of phenology could be more effective. The goal of the proposed research is to develop better information on the timing of life cycle events and how they relate to temperature on two of the top 15 prioritized plants of the Minnesota Terrestrial Plants and Pest Center (wild parsnip, *Pastinaca sativa* and Japanese knotweed, *Polygonum cuspidatum*). We will achieve our goals through three specific activities: we will develop climate-based models of phenology (e.g. degree-day models) using citizen science and common garden data. We will examine temperature and photoperiod sensitivity of growth and flowering phenology using greenhouse and growth chamber experiments. We will integrate models into a simple interface for accessing real-time degree-day data and phenology model predictions for scheduling treatments. Results of our project will enable land managers to correctly time management activities to improve outcomes on a statewide level.

Summary budget information ENRTF budget: ~~$346,213~~ $346,211

Outcomes	Completion Date
ACTIVITY 1: **Develop phenology models for two plant species**	
1. Phenology data on two key species of concern	07/31/2021
2. Phenology models that predict timing of critical phenophases from climate data	09/30/2021
3. Active citizen science campaign generating new data completed	09/30/2022
ACTIVITY 2: **Examine temperature sensitivity of growth and flowering phenology**	
1. Key model parameters tested through experiments	09/30/2021
2. More robust models developed for each species	12/30/2021
ACTIVITY 3: **Integrate results into a simple interface for accessing real-time degree-day data and predicted timing of phenology for scheduling treatments**	
1. Models integrated with the USPEST.org interface	03/30/2022
2. Five manager workshops and webinars	6/30/2023

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

We launched the Pesky Plant Trackers program, citizen science program that will support collection of phenology data on our two focal species. The program includes an online training module and live support from

staff for new observers via online office hours. We currently have 105 people who have registered as interested in participating. Pesky Plant Trackers a national campaign being run by the Nature's Notebook program of the USA-National Phenology Network. At the national level, we have 32 observers participating to date in nine states. In addition, we planted Japanese knotweed and wild parsnip at five sites across Minnesota to serve as a foundational phenology dataset that will complement the citizen science data. The gardens ensure that both species are tracked across a broad temperature gradient (from Waseca in the south to Grand Rapids in the north). We have promoted our project through a number of venues such as Anoka County Master Gardeners, Minnesota Department of Agriculture newsletter, and Grow with KARE program on KARE 11 television station.

Fourth Update, February 28, 2021

Pesky Plant Trackers, a citizen science program that supports collection of phenology data on our two focal species engaged >50 people yielding 8 observers in Minnesota in late summer 2020. Pesky Plant Trackers also has a national campaign being run by the *Nature's Notebook* program of the USA-National Phenology Network. At the national level, we have 18 additional observers participating to date. In summer 2020, we monitored plantings of Japanese knotweed and wild parsnip at five sites across Minnesota providing the beginnings of a foundational phenology dataset that will complement the citizen science data. The gardens ensure that both species are tracked across a broad temperature gradient (from Waseca in the south to Grand Rapids in the north). Finally, we began controlled experiments in growth chambers to determine the sensitivity of knotweed and parsnip phenology to temperature. Plants are grown at nine different temperatures ranging from 2-40°C. These experiments extend our modeling efforts based on field data. We have promoted our project through a number of venues such as the Master Woodland Owner, Naturalist and Gardeners programs and at conferences such as Minnesota Association of Environmental Educators and the Upper Midwest Invasive Species Conference. In addition, we've engaged our volunteers through monthly newsletters and weekly Zoom gatherings (Pesky Plants Tea Tuesday).

Fifth Update, August 31, 2021

Pesky Plant Trackers, a citizen science program, supports collection of phenology data on our two focal species. The project has a total of 73 trained volunteers as of June 24, 2021. This is a 400% increase since the close of 2020. Pesky Plant Trackers also has a national campaign run by the USA-National Phenology Network. Overall, 72 sites (40 in Minnesota, 32 beyond) have observations since 2020. We promoted the project through venues such Extension, the Minnesota Township Insider, KAXE Radio, and CitSciVirtual, a national citizen science conference. We've engaged volunteers through monthly newsletters and weekly Zoom gatherings. From December 2020 through April 2021, the emphasis was on recruiting and training. Starting in March and April, the emphasis transitioned to volunteer support.

In March, we resumed monitoring phenology at five sites across Minnesota. This dataset will complement the citizen science data and ensure that species are tracked across a broad temperature gradient (Waseca in the south to Grand Rapids in the north). Finally, we are conducting controlled experiments in growth chambers to determine the sensitivity of knotweed and parsnip phenology to temperature. The initial set of phenology and seed germination experiments failed owing to excessive light intensities inducing irreversible inhibition of photosynthetic systems. A modified protocol with reduced light intensities is yielding significant promise now. Plants are grown at 9 temperatures ranging from 2-38°C and monitored daily. Seeds are followed in germination trays in the same chambers. These experiments extend our modeling efforts based on field data.

Sixth Update, February 28, 2022

Pesky Plant Trackers, a citizen science program, supports collection of phenology data on two focal species. The project has a total of 93 trained volunteers as of December 9, 2021, a 550% increase since the close of 2020. Pesky Plant Trackers also has a national campaign run by the USA-National Phenology Network. Since 2020, volunteer observations of wild parsnip phenology come from 34 sites in Minnesota plus 10 sites outside of Minnesota. For Japanese knotweed, there are 47 Minnesota sites, plus 36 sites beyond Minnesota. We

promoted the project through Extension, MISAC, the Minnesota Association of County Agricultural Inspectors, Three Rivers Parks District, and other organizations. We've engaged volunteers through monthly newsletters and Zoom gatherings. From April through October 2021, the emphasis was on training and supporting volunteer participation. Starting in November, the emphasis shifted to thanking volunteers for contributions and motivating them to rejoin the effort in 2022.

Working with ROC staff and volunteers, we monitored seasonal (early spring to autumn through summer) phenology of the two plants at 3-to-7-day intervals at five "common garden" sites across Minnesota in 2020 and 2021. This dataset encompasses nearly 125,000 records over 28 phenology attributes across two species. It will complement the citizen science data and ensure that species are tracked across a broad temperature gradient (Waseca in the south to Grand Rapids in the north) across multiple years. Early insights from simple phenology models built from common garden data provide estimates of accumulated growing degree-days necessary to achieve critical phenophases for the two species. Future modeling efforts will examine non-linearity in data to provide improved parameter estimates. Novel vegetative and reproductive phenology data generated under a range of constant thermal scenarios from environmental chambers for the two weed species is promising and awaits completion of data entry and curation for phenology modeling. Preliminary insights suggest no effect of photoperiod on the phenology of two weeds.

Seventh Update, August 31, 2022

Major accomplishments include continued engagement of citizen/community science volunteers at community sites and University of Minnesota Research and Outreach Centers (ROCs) around Minnesota providing critical data for our modeling efforts, completion of growth chamber studies, and development of preliminary growing degree day models. All of these will feed into modeling efforts that will occupy the rest of our grant period. Of 96 volunteers recruited and trained in 2020-21, about 13 wild parsnip observers and 38 knotweed observers remain active in 2022, and an additional eight volunteers monitor plants at ROC field sites, a role requiring high level commitment. 2022 is our third year working with ROC staff and volunteers to monitor seasonal (early spring to autumn through summer) phenology of the two plants at 3-to-7-day intervals at five "common garden" sites across Minnesota. We participated in a ROC-wide invasive species conference that focused on citizen science and highlighted our field sites. We have largely met deadlines though the data modeling component is slightly behind due to slow data entry related to undergraduate staffing. Early insights from simple phenology models built from common garden data provide estimates of accumulated growing degree-days necessary to achieve critical phenophases for the two species.

Eighth Update, February 28, 2023

We completed all data collection, entry and organization. We wrapped up the citizen science program and have been working on thanking our volunteers and pointing them to continued opportunities if they want to keep observing. We are finding non-linear patterns in response to temperature with both species hindered by very low and high temperatures. We are slightly behind on modeling outcomes due to complications with harmonizing Nature's Notebook and experimental data structure. We anticipate 2-3 manuscripts emerging from the work in the next 6 months.

Final Update, August 31, 2023

The project experienced highly-disruptive personnel turnover in the final months of the project. We were able to complete simple growing degree day models for both species and have them in the pipeline for posting on the uspest.org website. Once posted we will work with partners on dissemination and training. We are wrapping up the funded part of the project but expect continued data analysis after the formal project ends. In particular, a new post doc with Montgomery & Peter Reich will be working on other phenology data projects and we've discussed bringing in data from this project to that pipeline.

MITPPC sub-project 6: Biology and biocontrol potential of a rust fungus infecting *Phalaris arundinacea* and *Frangula alnus*

Project manager: Pablo Olivera Firpo

Description: Glossy buckthorn (*Frangula alnus*) and reed canarygrass (*Phalaris arundinacea*) are highly invasive plants of wetlands and riparian areas across Minnesota and northern North America. They are ranked, respectively, the 4th and 13th most important terrestrial plants that threaten Minnesota according to the Minnesota Invasive Terrestrial Plants & Pests Center. Eradication of the plants is difficult and costly, but effective management is imperative to protect Minnesota natural resources. Previously, few pests or pathogens were known to reduce the competitiveness of these naturalized invaders, but in 2017, we observed a rust parasite of *F. alnus* that caused severe infection on leaves, stems, and flowers, thus drastically reducing seed production. Field and laboratory testing identified the grass host as *P. arundinacea,* on which infection could be significant. Our preliminary studies have established that the rust is a form belonging to the crown rust species complex (*Puccinia coronata*). Our project seeks to investigate the biology of the rust and its impact on its two highly invasive hosts. Based on the information generated from this study will be useful in developing novel management strategies for the biological control of *P. arundinacea* and *F. alnus.*

Summary budget information ENRTF budget: $206,783

Outcomes	**Completion Date**
ACTIVITY 1: **Studies on Distribution**	
1. A fact sheet for the disease is developed and disseminated to natural resource professionals and citizen scientists	12/31/2019
2. Disease and distribution in Minnesota is determined through 6+ surveys from land managers and citizen scientists, resulting in a distribution map	08/31/2022
ACTIVITY 2: **Investigation of morphology, host specificity and genetic relationships with other forms in the crown rust complex**	
1. Pathogenicity on cereal crop species is determined based on screening 800+ accessions from GRIN	05/31/2021
2. Host range on other grasses is defined based on the screening of 50+ species of grasses in 20+ genera	06/30/2021
3. Pathogenicity on native vs introduced *P. arundinacea* is determined	06/30/2021
4. Host specificity is determined based on screening of 9+ species of *Rhamnus* and *Frangula*	08/31/2022
5. Assessment of variations in the pathogen is completed using a set of 40-50 pure collections of the rust	08/31/2022
6. Phylogenetic relationships with other crown rust forms is determined by DNA comparison with hundreds of publicly available sequences of other forms of crown rust	8/31/2022
ACTIVITY 3: **Assessment of rust's potential for biological control of *P. arundinacea* and *F. alnus***	

Outcomes	Completion Date
1. Effects of infection on plant biomass of reed canarygrass are quantified through controlled inoculation experiments	10/31/2022
2. Effects of infection on seedling mortality rate and plant biomass at the seedling stage of glossy buckthorn are quantified	10/31/2021
3. Assessment on impact of infection on reproduction of glossy buckthorn	08/31/2022
4. A manuscript of biocontrol potential is produced and submitted; a recommendation on management of glossy buckthorn and reed canary grass is made	06/30/2023

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

As it was detailed in the Outcomes section of the report, we are proposing completing all the research objectives six months prior to the ending date (06/30/2022 instead of 12/31/2022). To accomplish this earlier completion, we are requesting an increase of Pablo Olivera's effort from 5% to 15% for the remaining time of the project. With this increased effort, Olivera will focus on three main research objectives that align to his research expertise: 1) the assessment of virulence and genotypic variations in *Pcc*. Fifty to one hundred *Pcc* isolates will be developed from infected reed canarygrass inoculated with aeciospores from glossy buckthorn. These isolates will be used to conduct a pathogen virulence evaluation on a defined set of reed canarygrass accessions; 2) In addition to participate in rust surveys, Olivera will conduct an identification test of the collected rust from reed canarygrass by testing derived isolates on an identification series that includes grasses and crop species; and 3) evaluate the effects of uredinial infection on plant biomass of reed canarygrass by infecting plants with selected *Pcc* isolates in controlled conditions. These research activities, in particular the generation and increase of pure isolates from rust affecting grasses, are labor intense and require specific skills that Olivera has to guarantee it success. The increase in time dedication for Olivera will also help balancing the workload on Nick Greatens, the MS student that is conducting most of the research in this project.

Fourth Update, February 28, 2021

During the previous reporting period, we have made significant progress in the three main activities proposed in our research plan. Our project is going smoothly and according to schedule. From surveys conducted across Minnesota, we established that *Puccinia coronata* var. *coronata* (*Pcc*) is present across the range of glossy buckthorn, *Frangula alnus*, but reed canarygrass, *P. arundinacea*, outside of this range are commonly observed without rust. Additional evaluations of *Pcc* host specificity on buckthorns and grasses showed that Carolina and California buckthorns, several native *Calamagrostis* species, and the introduced *Apera spica-venti,* in addition to glossy buckthorn and reed canarygrass, are the most susceptible of the species assessed. No apparent threat to cereal grains was observed from the *Pcc* rust. Recent trials have shown that glossy buckthorn seedlings, when exposed to *Pcc*, suffer a 40% loss of leaf area and 18% loss of biomass. Seedling mortality in inoculated plants was also observed at a rate of 6%. The impact of *Pcc* on fruit production was evident, as field observations recorded only 5% of flowers producing fruits in early summer when the rust was present. For comparison, about 35% of flowers produced fruit in late summer. *Pcc* seems to have a strong detrimental effect on reproduction, growth, and viability of glossy buckthorn, making it a good candidate for augmentative biological control of this invasive species. Results from this project were presented by Nick Greatens at the American Phytopathological Society Annual Meeting (poster), the Upper Midwest Invasive Species Conference (oral), and Bell Museum SciPride talks (oral).

Fifth Update, August 31, 2021

We continue making progress in the three main activities proposed in our research plan. Our project is going smoothly and according to schedule. Active correspondence with users of iNaturalist.com allowed us to monitor Pcc in the United States and to receive rust samples from several States. Sequence ID of rust samples from eight States will result in an updated map of the distribution of Pcc in North America. An additional set of ~1,000 oats varieties and wild relatives were evaluated for reaction to Pcc at the seedling stage. From them, only three accessions exhibited a moderately susceptible response. Further studies will be conducted in these susceptible oats accessions to understand the genetics of Pcc susceptibility. Evaluations of Pcc host specificity also detected moderately susceptible reaction on Phalaris platensis and *P. angusta*, a North American native. Pcc also produced aecia on the native buckthorn species *Rhamnus lanceolata*. We continue the evaluation of the effect of Pcc on seed production in glossy buckthorn. This year, we expanded the number of evaluated plants to ~70, all located in Roseville (Metro area). Reed canarygrass plants collected from around Minnesota are being grown in preparation for a greenhouse assay to examine effects of the rust on grass biomass and height. Results from this project were presented at the Department of Plant Pathology Seminar Series and will be presented at the 2021 American Phytopathological Society Annual Meeting (oral).

Sixth Update, February 28, 2022

We continue to make progress in the three activities in our research plan. Our project is going smoothly and according to schedule. Using sequences from four genes, we compared the rust with other crown rust fungi and found results to be consistent with our initial assessment based on ITS: the rust is Puccinia coronata var. coronata (Pcc), a taxon not known in North America prior to 2016. Sequence ID of 23 total rust samples from surveys and many provided by iNaturalist.com users resulted in an updated map of the distribution of Pcc in North America. Since it was introduced, it has already spread across eastern North America across the range of glossy buckthorn from New England west to North Dakota.

We completed the host specificity evaluations on both the grass and buckthorn hosts. Grass host evaluations included five cultivated crop species and 80 wild grasses species from 30 genera. 1,000 additional oat accessions were evaluated against pure isolates of Pcc and results were consistent with previous evaluations that used a bulk, mixed-isolate inoculum. Three accessions exhibited a moderately susceptible reaction to Pcc.

We completed the assessment of the effect of Pcc on reed canarygrass biomass. Forty rust-inoculated plants derived from rhizomes produced 25% less aboveground biomass compared with 40 mock-inoculated plants. Similar results were observed in plants grown from seeds. Results from this project were presented at the 2021 American Phytopathological Society Annual Meeting. Next semester will be focused on the preparation of manuscripts and submission to peer-reviewed journals.

Seventh Update, August 31, 2022

Our project remains mostly on track, and in the next six months, we anticipate the submission of at least three manuscripts on our research findings. Over the past six months, the most significant results have been made in the preparation of manuscripts. The first, to be submitted shortly, will report results from Activity 1, including the distribution of the rust fungus, *Puccinia coronata* var. *coronata* (Pcc), and survey results from across Minnesota, and several results from Activity 2 including the phylogenetic analysis and a disease description. A second paper has been drafted and will report the results of host specificity evaluations on grass and buckthorn hosts and results from screens of six cereal grains for susceptibility. We await the results of some small follow-up assays. Some additional time is requested (see amendment request) to ensure all results are published and shared with Minnesota audiences.

Overall, we are satisfied with the results of our research and are pursuing opportunities to build off the knowledge we have generated. In particular, we are interested: in the diversity of crown rust fungi locally, including those that parasitize common buckthorn and their effects on their buckthorn and grass hosts, including Poa spp.; the potential of crown rust fungi for use in studies of non-host resistance, intragenomic

variation of the ITS region in rust fungi; and, as originally hypothesized, the potential of Pcc as an augmentative biological control agent of reed canarygrass or glossy buckthorn.

Eighth Update, February 28, 2023

The project is now mostly complete, with three months remaining of the three-year plan. Our project remains on track, and in the next three months, we anticipate the submission of the last three manuscripts on our research findings. Over the past six months, the most significant results have been made in the preparation and submission of manuscripts presenting the results from this project. The first one, entitled "*Puccinia coronata* var. *coronata*, a crown rust pathogen of two highly invasive species, is detected across the Midwest and Northeastern United States", has been submitted and accepted for publication in the scientific journal 'Plant Disease'. This manuscript report results of the distribution of Pcc in the US and Minnesota, phylogenetic analysis, and disease description. The second manuscript, reporting the results of host specificity evaluations of Pcc on grass and buckthorn hosts and results from screens of six cereal grains for susceptibility, will be submitted in December 2022. The third manuscript, focused on the effects of Pcc on invasive glossy buckthorn and reed canarygrass in greenhouse trials, is also in preparation and will be submitted in January or February 2023. Finally, a fourth manuscript describing the aecial and telial host specificity of *Puccinia digitaticoronata*, a recently described crown rust pathogen of Kentucky Bluegrass present in North America, will be also submitted in January 2023. Results from this project were presented at the 2022 American Phytopathological Society Annual Meeting (oral presentation) and the 2022 Upper Midwest Invasive Species Conference (two oral presentations).

Final Update, August 31, 2023

The project is now completed, reaching all the objectives proposed in the original proposal. Over the past six months, the most significant results have been made in the preparation and submission of four manuscripts presenting the results from this project. The first one, entitled "*Puccinia coronata var. coronata*, a crown rust pathogen of two highly invasive species, is detected across the Midwest and Northeastern United States", is in press in the journal 'Plant Disease'. This manuscript report results of the distribution of Pcc in the US and Minnesota, phylogenetic analysis, and disease description. The second manuscript, entitled "Aecial and telial host specificity of *Puccinia coronata var. coronat*a, a Eurasian crown rust fungus of two highly invasive wetland species in North America" was also accepted for publication in journal 'Plant Disease'. The third manuscript, focused on the effects of Pcc on invasive glossy buckthorn and reed canarygrass in greenhouse trials, is in preparation and will be submitted in July 2023. Finally, a fourth manuscript entitled "Aecial and telial host specificity of *Puccinia digitati coronata*, a recently observed fungus causing crown rust on Kentucky bluegrass in North America", was also submitted in June 2023. Results from this project were presented at the 2023 North American Rust Workshop (oral presentation), CFANS Research Symposium (2 posters), and at Nick Greatens Ph.D. thesis dissertation seminar.

MITPPC sub-project 7: Managing buckthorn with trees: diversity, density, and practicality

Project manager: Peter Reich

Description: European buckthorn is a common invader of forests in Minnesota and forms monospecific stands in the understory that shade out native plant species, cause reductions in plant diversity, inhibit forest regeneration, and host major agricultural pests. Thus, buckthorn removal is a common management goal, but current methods are both costly and far from being effective in the long run. Here we propose a large-scale proof-of-concept test of the degree and type of revegetation needed, and associated costs, to cultivate sufficiently dense woody vegetation post-buckthorn removal to have decadal-long effects and allow establishment of diverse native, or near-native, communities. Here we propose to test whether planted seedlings of selected tree species and complementary direct seeding can in combination with existing overstory canopies create sufficiently dense shade to effectively slow or stop buckthorn recovery, while creating spatially

and compositionally diverse stands, and be done in a cost-effective fashion at a scale relevant to management. If effective, which we believe is possible given our prior extensive research, the revegetation treatments designed and tested here can serve as a template for woodland and forest managers throughout Minnesota and eastern North America. This will potentially result in a significant cost and labor savings as well as benefiting affected ecosystems by inhibiting the establishment of buckthorn and other invaders, reducing herbicide applications, increasing forest plant diversity and improving wildlife habitat. Ultimately, we will provide a clear template and do so in a cost-effective manner that is ready to use by land managers and can be tailored to many other regions because of its flexibility.

Summary budget information ENRTF budget: $499,734

Outcomes	**Completion Date**
ACTIVITY 1: **Enhanced woody density and diversity to suppress buckthorn regeneration over the long term**	
1. Sites identified and initial buckthorn removal complete	01/01/2021
2. Experimental plots planted	06/01/2021
3. Follow-up herbicide applications completed	05/15/2024
ACTIVITY 2**: Measurement, analysis, interpretation, report preparation and dissemination.**	
1. Measurements of buckthorn performance and native plant establishment completed	06/30/2023
2. Statistical analyses completed	05/15/2024
3. Manuscripts submitted to scientific journals	05/15/2024
4. Management guide completed and made available online	05/15/2024

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

This project started last Spring with the selection and establishment of the first out of three research sites. The first research site was established in collaboration with Lake Elmo Park Reserve, we selected the location for the research late in the winter. The site was prepared by removing buckthorn and other invasive species in early April. After initial buckthorn removal, research plots were delineated and permanently established and planted at the beginning of May. Currently, we are proceeding with initial measurements and are in the process of selecting the remaining two research sites at the Three Rivers Park system in collaboration with their management team. This activity is on track despite some small (primarily logistical) obstacles caused by COVID-19.

Fourth Update, February 28, 2021

This project started last spring with the selection and establishment of the first out of three research sites. The first research site was established in collaboration with Lake Elmo Park Reserve. We have also selected and delineated two additional research sites, one at Hampton Wildlife Management Area and the second at Carver Regional Park. The research site at the Lake Elmo Park Reserve was successfully established in the past spring. During last summer we proceeded with initial and final for the year surveys for survival and growth of planted trees and buckthorn. This activity experienced some delays related to unpredictable occurrence of early frost and snow and sites preparation due to contractor work schedule delays caused by COVID-19.

Fifth Update, August 31, 2021

We continued to make progress in establishing our long-term experimental plots. The first of the three research sites, Lake Elmo Park Reserve (Lake Elmo, MN), had been planted in spring 2020. However, high mortality of fir (due to poor stock) and poplar (due to adverse growing conditions) within research plots required that we replace dead individuals of these species, which we completed this spring. We continued preparation of the second research site at Carver Park (Victoria, MN) by contracting mechanical removal of buckthorn there in anticipation of planting in spring 2022. We also identified a new location for our third experimental site. Formerly, this research site was planned for Hampton WMA (Hampton, MN), but will now be located at Snail Lake Park (Shoreview, MN).

Sixth Update, February 28, 2022

We continued to make progress in establishing our long-term experimental plots. First of the three research sites at Lake Elmo Park Reserve (Lake Elmo, MN) had been planted in spring 2020. However, high mortality of fir (due to poor stock) and poplar (due to adverse growing conditions) within research plots required that we replace dead individuals of these species, which we completed this spring. We continued preparation of the second and third research sites at Carver Park (Victoria, MN) and at Snail Lake Park (Shoreview, MN) by contracting mechanical removal of buckthorn there in anticipation of planting in spring 2022. Both Carver and Snail Lake sites were sprayed with foliar herbicide in September to prepare them for spring planting. At the already-established Lake Elmo site, we weeded resprouting buckthorn, conducted light measurements, and censused research plots at the end of the season.

Seventh Update, August 31, 2022

We planted seed of herbaceous plants at our first site (Lake Elmo Park Reserve) that was started in the spring of 2020. We also delineated and planted our second two sites at Carver Park and Snail Lake Park. Across the two sites, we planted approximately 13,000 seedlings over the course of 5 weeks. We also executed a remedial herbicide application at the Carver Park site due to incomplete treatment the previous fall and conducted an outreach event in which undergraduate students from Hamline University assisted in tree planting.

Eighth Update, February 28, 2023

We continued to make progress in establishing our long-term experimental plots. We implemented herbaceous seeding at the two sites established in 2022 (Snail Lake Park and Carver Park). We also removed buckthorn by hand at all three sites and implemented a new sampling approach suited to long-term monitoring of plots as trees and shrubs mature.

Ninth Update, August 31, 2023

We have made significant progress in both activities of this project within the first six months of 2023. In Activity 1, we continued to maintain and monitor all 3 of our now fully-established sites using the updated protocol developed in 2022. Low efficacy of foliar herbicides applied in 2021 and 2022 necessitated larger investment in plot maintenance than anticipated, and vandalism at one site obstructed plot locations. In Activity 2, we have continued to explore data generated through our sampling as well as how it may complement existing data from earlier MITPPC-funded studies. One manuscript, “Efficacy and Non-target Impacts of Fosamine Ammonium and Triclopyr Choline Use in Controlling Common Buckthorn (*Rhamnus cathartica*) in a Forest Understory Community is under review at Invasive Plant Science and Management.

Tenth Update, February 28, 2024

In Activity 1, we continued to maintain and monitor all 3 of our now fully-established sites using the latest protocols. This was the last complete field season prior to the conclusion of the funding period. As such, we focused on the collection of rigorous data and transitioning plots to long-term monitoring. We are continuing to evaluate these data and how they may complement other data remaining from older MITPPC-funded experiments.

A manuscript presenting data from this experiment and detailing the impacts of native stem density on buckthorn re-establishment will be ready for submission by the end of the project period. This manuscript will

describe one of our major findings: that native stem density (regardless of identity) is a significant predictor of buckthorn re-establishment. These findings support site-specific selection of planted species and encourages land managers to select species that are both economically feasible and ecologically advantageous given environment of their particular site. This manuscript also demonstrates the value of native volunteer species that can significantly bolster stem density beyond what is planted by managers.

A second manuscript, “Efficacy and Non-target Impacts of Fosamine Ammonium and Triclopyr Choline Use in Controlling Common Buckthorn (*Rhamnus cathartica*) in a Forest Understory Community'' is currently under review at Northeastern Naturalist. This manuscript demonstrates comparable efficacy between fosamine ammonium (a foliar herbicide the research team has used extensively in past MITPPC-funded experiments) and triclopyr choline (a more commonly used herbicide) against buckthorn, but that each herbicide affects non-target species differently. This manuscript addresses a major question regarding the interpretation of the findings of this project and others that exist within a context of fosamine ammonium-treated buckthorn removal areas and shows that fosamine ammonium is a viable alternative to the conventional herbicide of choice.

Final Update, June 30, 2024

This is the final six month update for this project. Overall, we have largely achieved our stated goals for the two activities. In Activity 1, we designed and executed a complex field experiment evaluating impacts of woody plant revegetation of varied diversities and densities on buckthorn re-establishment. In the past six months, we have worked with our external partners (namely Washington County, Three Rivers Park District, and Ramsey County) to prepare our sites for long-term study. In Activity 2, we pledged to deliver academic journals conveying our findings and to prepare a publicly-accessible guide to forest revegetation. In the past six months, we have advanced both of these objectives. One manuscript, “Efficacy and Non-target Impacts of Fosamine Ammonium and Triclopyr Choline Use in Controlling Common Buckthorn (*Rhamnus cathartica*) in a Forest Understory Community” is under review. Another manuscript, “Improving understory biotic resistance against invasive buckthorn (*Rhamnus cathartica*) through active revegetation of trees and shrubs,” is near submission. Finally, our guide to revegetation is complete and in press.

MITPPC sub-project 8: Integrated emerald ash borer management: testing a novel approach to assess stakeholder perceptions

Project manager: Ingrid Schneider

Description: This project tests the impact of novel emerald ash borer informational interventions to inform and improve management. The purpose of this project is to test educational interventions and advance effective EAB management by integrating stakeholder perceptions into EAB management strategy selection and related communications. Researchers will: 1) identify and compare the acceptability of select EAB management approaches in forested park areas with varied levels of recreation development; and

2) test the impact of novel EAB informational interventions on management acceptability, landscape preference and potential visitor displacement.

The hypotheses are that as informational intervention engagement increases, acceptability and preferences for EAB management strategies will increase, as will intentions to visit. By merging research on human dimensions and silvicultural strategies, natural resource managers within Minnesota can be more effective and supported on public land invasive species management.

Summary budget information **ENRTF budget: ~~$450,000~~ $436,072**

Outcomes	Completion Date
ACTIVITY 1: **Identify and qualitatively compare the acceptability of select EAB management approaches among the public in forested park areas with varied levels of recreation development**	
1. Photo collection established and key photos of clear cut, group selection with artificial regeneration, group selection with natural regeneration selected for focus group use	04/01/2020
2. Understanding of base level acceptability, preferences and perceptions of select EAB management approaches (clearcut, group selection with artificial regeneration, group selection with natural regeneration) to inform informational intervention.	10/1/2020
3. Understanding of likely displacement and visit changes dues to select EAB management approaches (clearcut, group selection with artificial regeneration, group selection with natural regeneration)	10/1/2020
4. Foundational content and themes for novel informational interventions	10/1/2020
5. Publications and information sharing	12/1/2021
ACTIVITY 2: **Test the impact of novel EAB informational interventions on management acceptability, landscape preference and potential visitor displacement**	
1. Research-based informational interventions developed for augmented reality and virtual reality applications (text, AR and VR)	05/30/2021
2. Quantitative data collected to understand impact of novel information interventions on acceptance and preference for select EAB management strategies (clear cut, group selection with artificial regeneration, group selection with natural regeneration)	10/15/2021
3. Research report, presentations and initial dissemination of informational intervention effectiveness	10/01/2022
4. Publications and information sharing	06/30/2023

The first sub-project update will be provided with the third update for the overall project.

Third Update, July 31, 2020

We made significant and timely progress to understand visitor perceptions of forested landscapes and varied emerald ash borer (EAB) management treatments. As planned, we completed focused discussions with visitors that revealed questions and perceptions of four EAB treatments: doing nothing, clear cuts, group selection with

artificial regeneration, and group selection with natural regeneration. Due to COVID 19 safety issues we transitioned from in-person to online discussions with forested landscape visitors. Our findings will inform the development and testing of informational interventions leading to better public understanding and acceptance of forest management approaches.

Fourth Update, February 28, 2021

We made significant and timely progress to understand visitor perceptions of forested landscapes and varied emerald ash borer (EAB) management treatments. As planned, we completed focused discussions with visitors that revealed questions and perceptions of four EAB treatments: doing nothing, clear cuts, group selection with artificial regeneration, and group selection with natural regeneration. We continue to analyze this data and our findings will inform the development and testing of informational interventions leading to better public understanding and acceptance of forest management approaches.

Fifth Update, August 31, 2021

Overall the project is on track. Since our last report we have created and refined messages for the informational interventions and worked with a multi-media team to translate them into print, augmented reality and virtual reality formats. We have 1) secured approval from UMN and MN State Parks to conduct the research onsite in select Minnesota State Parks, 2) developed questionnaire and are pre-testing them prior to implementation, 3) secured materials for the onsite research and 4) are visiting each research site prior to implementation. Given the uncertainty of face-to-face research, we developed and will implement the baseline questionnaire to an online sample purchased from Qualtrics (as discussed and agreed to in our meeting). This will provide baseline information on Minnesotan's acceptance and familiarity with forest management approaches to emerald ash borer.

Sixth Update, February 28, 2022

We made significant and timely progress to understand visitor perceptions of forested landscapes and varied emerald ash borer (EAB) management treatments. As planned, we created, evaluated and finalized messaging related to EAB treatments. We then transformed these messages into varied informational treatments including photos and text, augmented reality and virtual reality experiences. Onsite data collection commenced July 2021 with select state park visitors and revealed perceived importance of invasive species management, EAB management, and perceptions of four EAB treatments: doing nothing, complete harvest with natural regrowth, group selection with planted trees, and group selection with natural regrowth. In addition, as we were unsure if we would be able to collect in-person data, we collected online 'baseline' data from a sample of Minnesota residents acquired through a purchased sample. We have cleaned all of this data and are working to analyze it. Our findings will shed light on the public acceptance of forest management approaches and assess if and how informational interventions impact acceptance, preference and potential displacement.

Seventh Update, August 31, 2022

The project remains on track. Following data collection summer 2021 and data cleaning through early winter 2022, we are in the process of data analysis and publication planning.

Eighth Update, February 28, 2023

The purpose of this project was to test educational interventions and advance effective forest management in response to emerald ash borer (EAB) by integrating stakeholder perceptions into EAB management strategy selection and related communications. The objectives were to

1) Identify and compare the acceptability of select forest management approaches in response to EAB in forested park areas with varied levels of recreation development, and

2) Test the impact of novel EAB informational interventions on management acceptability, landscape preference and potential visitor displacement.

We developed, implemented and tested the informational interventions among Minnesota state park visitors, performed initial analysis and are currently focused on sharing the information through a variety of outlets.

The project is on track.

Ninth Update, August 31, 2023

Throughout the last six months of the project the project team continued to write and share the results in a variety of settings. Specifically, we worked on three manuscripts: 1) one focused on the methodology that was accepted and published Fall 2023 in the journal Applied Environmental Education & Communication, 2) another focused on analysis that assessed and compared engagement, which is under a review with a second journal, 3) a third focused on comparing perceptions by demographic characteristics which needs to be revised and submitted to another journal. Outreach included creating 1) materials for and staffing an outreach booth during the statewide Extension 'Gathering Partners' conference over two days, 2) a panel presentation submission for a national forestry convention that was accepted and presented Fall 2023, 3) presentation for an invasive species management conference, and 4) scripting, filming, and production for a video about the project that lives on the MITPPC website. We did further assessment on message engagement using novel eye-tracking software that we plan to submit for a presentation in 2024. Finally, we worked with University Library Media services to publish and permanently archive specific photos, videos and sound files for others to use. Thus, our findings focused on integrating stakeholder perceptions into forest management response to EAB reached professional, academic, and lay audiences in print, oral and video formats. The work has inspired local entities to reconsider their communication and forest management selections in response to emerald ash borer (EAB).

Final Update, August 31, 2023

Emerald ash borer (EAB) has invaded several state parks in Minnesota and threatens to invade even more. This highly invasive insect may damage and kill ash trees, diminishing the recreational experience of park visitors. However, management responses to EAB (for example, clearing, logging, or replanting trees) may also interfere with the park experience. This study aimed to compare the acceptability of select forest management approaches in response to EAB in forested park areas with varied levels of recreation development. Surveys of visitors to state parks found that inaction was unacceptable. In other words, visitors expected something to be done about EAB. The visual impacts of most treatment options were generally acceptable. Ironically, the visual effects of replanting young trees (with accompanying tree tubes) were considered an undesirable outcome. The study also found that how the information was shared did not substantially affect management acceptability, landscape preference, or potential visitor displacement. We had suspected that augmented reality or virtual reality might help visitors visualize the effects of EAB treatments and change attitudes about them. This did not seem to be the case. Interviews with park visitors confirmed the need for park managers to provide a clear explanation of what was being done to manage EAB and why. Results have been shared with park managers and other natural resource professionals in Minnesota through a variety of outlets and forums, including an online video. We have two published papers and two others in review. The project ended June 30, 2023.

MITPPC sub-project 9: Distribution, risks, and management of *Phyllachora maydis*, the causal agent of corn tar spot

Project manager: Dean Malvick

Description: Tar spot of corn is a leaf disease caused by the fungus *Phyllachora maydis* that can develop rapidly and cause significant yield loss. This disease is new to the U.S. where it was first detected in 2015 in Illinois and Indiana. Tar spot has since spread to multiple states in the Midwest, including southeastern Minnesota where it was confirmed in September 2019. Thus, tar spot threatens the corn crop, and there is limited information about its distribution, biology, and management that applies to Minnesota. This project proposes to address the information needs via three goals. One is to understand the distribution, detection, and establishment of tar

spot in Minnesota. The second goal is to understand the response of tar spot to future conditions. The final and secondary goal is to determine the efficacy of management options for tar spot. Expected outcomes are as follows. Disease distribution would be documented for Minnesota over time, we would further clarify the host range of the tar spot pathogen to determine if common plant species in Minnesota can harbor the pathogen, and methods for detection of tar spot would be validated and developed as needed. We also expect to identify weather and cropping characteristics that favor tar spot in Minnesota, validate or develop tar spot forecasting tools and inoculation methods, and conduct pilot studies to evaluate fungicides and corn hybrids for managing tar spot. This project will develop a solid basis for research of tar spot and for additional discovery research in the future.

Summary Budget Information **ENRTF Budget: ~~$178,706~~ $153,312**

Outcomes	**Completion Date**
ACTIVITY 1: Detection and distribution of tar spot	
1. Determine distribution, establishment and survival of tar spot	06/30/2023
2. Determine the potential for other common plant species in MN to act as hosts of the tar spot pathogen	04/30/2023
3. Validate and develop (as needed) DNA-based methods (e.g., qPCR and LAMP assays) to detect and confirm tar spot on leaves before and after symptoms develop.	10/31/2022
ACTIVITY 2: Response of tar spot to future conditions	
1. Use data from activity #1 to assess disease risk in Minnesota and to validate and contribute to improvement of tar spot forecasting tools for Minnesota conditions.	03/31/2023
ACTIVITY 3: Effectiveness of management alternatives for tar spot.	
1. Develop or improve inoculation methods and field methods to conduct greenhouse and field studies on hybrid resistance and fungicide efficacy.	06/30/2023
2. Determine the efficacy of fungicides and the relative susceptibility/resistance of corn hybrids adapted to Minnesota to tar spot.	6/30/2023

The first update on this sub-project will be given with the sixth update on the overall project.

Sixth Update, February 28, 2022

Tar spot of corn is a leaf disease caused by the fungus *Phyllachora maydis* that can cause significant yield loss. This disease is new to the U.S. where it was first detected in 2015. It was first detected in Minnesota in 2019. One goal of this project is to understand the distribution of tar spot. We determined that tar spot developed widely in SE Minnesota in 2021 where it was previously established, and spread west and north to at least nine new counties. Another goal is to determine if other plant species in Minnesota can act as hosts of the tar spot pathogen. Research is underway to determine if tar spot found on grasses can infect corn. We have been working to validate DNA-based methods to detect tar spot, and our results suggest that we have a good assay to work with after further optimization. To understand the response of tar spot to environmental conditions, we

are looking at weather records to determine more closely which conditions favor tar spot in Minnesota. The final goal is to determine management options for corn tar spot. A key part of this is to develop research methods to conduct studies on hybrid resistance and fungicide efficacy. We have tested many different methods to inoculate corn and initiate disease, and have made progress in developing reliable methods. In summary, this project is making progress on developing a solid basis and tools for management and research on corn tar spot in Minnesota.

Seventh Update, August 31, 2022

Our recent work on this project has focused on the objectives that can be accomplished in the lab and greenhouse, as well as establishing field projects to be completed in 2022. For Activity 1, we have focused on Objective C: "Validate and develop DNA-based methods to detect and confirm tar spot". We have worked with colleagues at Michigan State University to validate and improve the qPCR assay to detect DNA of the fungus *P. maydis*. This technique will greatly improve our abilities to conduct some of the critical research questions with this disease. For Activity 2, determining the response of tar spot to environmental conditions, we have been working to determine temperature and moisture conditions favorable for tar spot development using experiments in a greenhouse and growth chamber. For Activity 3, we have focused on developing inoculation methods for tar spot to conduct greenhouse and field studies. Progress has been made, but the methods are still not reliable. Work continues. In summary, corn tar spot is a complex disease that is poorly understood, and this project is making progress on developing knowledge and tools for management and research of corn tar spot in Minnesota.

Eighth Update , February 28, 2023

The invasive corn disease called tar spot has become increasingly widespread and damaging in Minnesota. Tar spot is a leaf disease incited by the fungus Phyllachora maydis that can cause significant grain yield loss. This disease and its pathogen were first discovered in the U.S. in 2015 and in Minnesota in 2019, and it has been spreading since then. Our recent progress on this project is summarized below. For Project Activity 1, we continued to work on the distribution and detection of tar spot. Our team along with collaborators confirmed tar spot in 33 MN counties this year, which includes several counties where the disease was not previously known. We also worked with colleagues in other states to test DNA-based methods to detect tar spot. The PCR technique will greatly improve our abilities to conduct critical research, but it appears that improvements are needed before full implementation. We also established a network of spore traps to determine when and where the tar spot pathogen was spreading airborne throughout the summer. For Project Activity 2, we continued working to identify temperature and moisture conditions favorable for tar spot development using experiments in a greenhouse, growth chamber, and in the field. For project Activity 3, significant progress was made in developing a reliable inoculation method for tar spot and we are continuing to evaluate this very promising new technique. In summary, this project is making progress on developing knowledge and tools for research and management of this important and poorly understood disease.

Final Update, August 31, 2023

Corn is the largest crop in Minnesota and contributes greatly to the economy in Minnesota. Leaf diseases were relatively minor problems in Minnesota until tar spot became established in 2019 and became increasingly widespread and damaging. Tar spot is incited by the obligate fungus *Phyllachora maydis* and can cause significant grain yield loss. This disease and its pathogen were first discovered in the U.S. in 2015 and they have continued to spread in the northern U.S. Progress on this project is summarized below for the winter/spring period January – June 2023. For Project Activity 1 we focused on host range studies with the tar spot pathogen and on improving a DNA-based (qPCR) assay to detect *P. maydis*. Greenhouse studies with a range of grass species have been used to study the host range of the pathogen. After much testing and troubleshooting we successfully used the qPCR assay to detect small quantities of the pathogen. For Activity 2, we continued working to identify temperature and moisture conditions favorable for tar spot development using experiments in a greenhouse, growth chamber. For Activity 3, a new reliable inoculation method for tar spot was developed and a manuscript has been submitted to a journal for review. In summary, this project is making progress on

developing knowledge and tools for research and management of corn tar spot, an important and poorly understood disease.

MITPPC sub-project 10: Detecting hybrid barberry and investigating its role in rust epidemiology

Project manager: Pablo Olivera Firpo

Description: Common barberry and Japanese barberry are notorious invasive species that have spread throughout the United States, including Minnesota. Less known is the fact that these two readily hybridize to produce Berberis ×*ottawensis*, a morphologically variable nothospecies that can both invade forests and, like common barberry, host cereal rust diseases that threaten wheat and small grain production. Although B. ×*ottawensis* has been reported in Minnesota, unreliable morphological characterization and misidentification with its parental species has, until now, prevented a definitive survey of this under-researched taxon. Accurate identification of B. ×o*ttawensis* is critical to assessing its distribution and the threat it poses to both agricultural systems and forest health. Although commercially-available Japanese barberry and hybrid cultivars are resistant to cereal rusts, natural interspecific hybridization with the rust-susceptible common barberry and subsequent segregation of rust susceptibility among hybrid progeny raise serious questions about the epidemiological impact of both feral and established commercial cultivars, especially in light of their widespread invasiveness. Such questions will be addressed in this project, in which we propose to build on recent research conducted in New England to develop cost-effective molecular diagnostic tools to identify interspecific barberry hybrids throughout Minnesota. We also propose to evaluate the stem rust susceptibility of identified hybrids to evaluate the potential threat posed by this taxon to our state's small grain producers. Ultimately, by enabling reliable identification of hybrids in the landscape, the molecular taxonomic tool developed in this study will facilitate the development of effective management strategies.

Summary Budget Information. **ENRTF Budget: ~~$247,507~~ $195,735**

Outcomes	**Completion Date**
ACTIVITY 1:	
1. Acquisition of plant material	09/30/2021
2. Identification of diagnostic markers	03/30/2022
3. Development/validation of multi-marker assay	06/30/2023
ACTIVITY 2**:**	
1. Testing of naturalized barberry for stem rust susceptibility	06/30/2023
2. Rust surveillance and identification of forms of rust	06/30/2023
3. Testing ornamental barberry for stem rust susceptibility	06/30/2023

The first update on this sub-project will be given with the sixth update on the overall project.

Sixth Update, February 28, 2022

During the second six months of our project, we have made progress in the two main activities proposed in our research plan. Efforts were made in acquiring plant materials from different sources, including collections made by our team and collaborators. In June-August 2021, we conducted extensive surveys of common, Japanese, and putative hybrid barberries covering the previously reported geographic distribution of the species in Minnesota and locations in four counties in Wisconsin. Over 260 phenotypic observations and plant tissue collections were made obtaining a very good representation of Japanese and putative hybrids distribution in the State of

Minnesota. Molecular markers evaluation of these samples will start in February 2022. In addition, a total of 65 putative hybrid live plants brought from our survey trips are being maintained in our greenhouse facilities and will be evaluated for stem rust reaction in spring 2022. In addition, in November and December, hundreds of seeds were collected from barberry plants growing in the wild in Two Harbors, MN, and Wisconsin. Seedlings will be grown this winter and plants will be evaluated for rust reaction in winter 2022. After actively working on recruiting a new postdoctoral researcher for this project, we recruited a highly qualified candidate that will join the project in February 2022 to lead the research activities.

Seventh Update, August 31, 2022

We continue making progress in the two main activities proposed in our research plan. In June 2022, we started conducting our second-year surveys of common, Japanese, and putative hybrid barberries at locations that we didn't cover in 2022. Over 50 phenotypic observations and plant tissue collections were made at five locations in southeast MN. Surveys will continue in June and July in northeastern and central MN. Given the limited locations where common barberry was observed and sampled in MN, this year, we will expand our survey for this species in the neighboring states of WI and MI. Based on genetic data from a previous study, molecular markers have been developed that are likely to distinguish barberry species and hybrids in Minnesota. After generating an effective DNA extraction protocol for barberry, these markers will be validated in a known hybrid population (created for research purposes) and applied to a local population. No susceptible reaction was observed in the testing of stem rust susceptibility of the 50 putative hybrid plants collected in 2021. However, 30 plants exhibited necrotic spots. Like in 2021, no rust infection was observed in Japanese barberry and putative hybrids. In February 2022, Dr. Jyoti Sharma joined our research team as a postdoctoral fellow. Sharma has rapidly taken the lead in molecular marker development and has actively participated in barberry surveys.

Eighth Update February 28, 2023

We continue making progress in the two main activities proposed in our research plan. In June-July 2022, we conducted our second-year surveys of common, Japanese, and putative hybrid barberries including locations that we didn't cover in 2022. Over 170 phenotypic observations and plant tissue collections were made at eight locations in southeast and central MN. Fifty-eight putative hybrid live plants were also collected and brought to our lab for stem rust evaluation in spring 2023. Based on GBS data from a previous study, 120 PACE SNP genotyping markers have been developed. After validating them on an F1 hybrid population, 95 markers were evaluated on common barberry plants collected in MN and Japanese barberry and known hybrid cultivars from the UMN Landscape Arboretum collection. Forty-two markers that detected the parental and hybrid alleles are being evaluated in the entire tissue sample collection from the 2021 and 2022 surveys. No rust infection was observed in our field survey except for a few plants at Afton State Park that exhibited rust necrotic spots with limited fungal infection. Samples were collected and sequencing will be done in the coming days to confirm the rust species infecting these plants. Results from this project were presented at the 2022 Upper Midwest Invasive Species Conference (oral presentation).

Final Update, August 31, 2023

Reaching the end of our two-year research project, we have completed all the objectives detailed in our proposal. All the research and data collection is completed and we are in the process of writing two manuscripts that will be submitted to scientific journals in the next couple of months.

A set of 33 cost-effective PACE markers that detected the parental and hybrid alleles was obtained and can be adopted by any standard laboratory for hybrid identification. By using these markers and morphological traits, we confirmed the presence of hybrid barberries in MN. Rust evaluations of putative hybrids collected in 2-year surveys shows that, although no sporulation was observed, the presence of necrotic spots occurred in many of the evaluated plants. Rust infection under field conditions was only observed in 2023 at Afton State Park. Rust samples were collected and are currently analyzed for species identification.

Results from this research have been presented at the 2023 North American Rust Workshop (oral), 2023 CFANS Research Symposium (oral), and the 2023 Spring Seminar Series at the Department of Plant Pathology, University of Minnesota.

MITPPC sub-project 11: Confronting soybean aphid with advanced plant breeding and remote sensing

Project manager: Robert Koch

Description: The widespread use of insecticides to protect soybean from soybean aphid (*Aphis glycines*) threatens the economic and environmental sustainability of soybean production. This proposal builds on successes of our previous MITPPC grant to advance two aspects of soybean aphid management (aphid-resistant cultivars and remote sensing) to decrease insecticide inputs for soybean aphid. The goals of the first activity will expand the diversity of aphid-resistant cultivars available to growers. Soybean breeding efforts will advance pyramided aphid-resistant soybean lines currently in the breeding pipeline and develop new pyramided lines with known and novel sources of resistance. In addition, aphid resistance will be expanded into food-type soybean germplasm. The goals of the second activity will advance remote sensing for soybean aphid by taking our patent-pending tool for decision making about insecticide applications for soybean aphid to a broadly applicable, satellite-based platform, which has shown promise in other crop-pest systems. Such a tool could be used to prioritize fields for ground- or drone-based scouting, or enable decision making for individual fields. Actual and simulated spectral data from the Sentinel-2 satellite system will be related to aphid abundance on soybean to develop models to determine when soybean aphid populations have reached the threshold to require insecticide application. This project will directly serve the agricultural community of Minnesota and the resulting decreases in insecticide inputs will reduce adverse economic and environmental impacts of soybean aphid management.

Summary Budget Information. **ENRTF Budget: ~~$295,593~~$292,492**

Outcomes	**Completion Date**
ACTIVITY 1: Aphid resistant soybean	
1. Advance aphid-resistant breeding lines toward commercialization	12/30/2022
2.Perform crosses to develop additional sources of pyramided resistance with three or more resistance genes	08/31/2022
3. Introduce aphid resistance into the food-type soybean germplasm	12/31/2022
ACTIVITY 2: Remote sensing	
1. Retrospective validation of actual Sentinel-2 spectral data for classification of soybean aphid infestations in fields	09/30/2021
2. Experimental validation of simulated Sentinel-2 spectral data for classification of soybean aphid infestations in caged experiment	12/30/2022
3. Experimental validation of actual Sentinel-2 spectral data for classification of soybean aphid infestations in on-farm strip trials	06/30/2023

The first update on this sub-project will be given with the sixth update on the overall project.

Sixth Update, February 28, 2022

For development and release of new aphid-resistant soybean varieties, these past six months consisted of advancing materials in the breeding pipeline in addition to testing and multiplying seeds of some new key advanced aphid-resistant lines. We grew and selected 285 new plant rows that either carried one or two aphid resistance genes (Rag1 and/or Rag2), tested 118 new lines in preliminary yield trials (single-gene and multi-gene stacked lines), and tested 68 lines in advanced yield trials, most of which were multiple gene (3+) stacks. A small number of three- or four-gene stacks performed quite well when compared to checks. The best lines will be advanced to regional testing next year. This past summer, we also had several single-Rag gene (Rag1 or Rag2) lines in regional testing. Seed of the best three lines in regional testing has been purified, and decisions right now are being made on whether we send these lines to Puerto Rico for a winter nursery increase to prepare 2022 for a foundation seed increase. We are currently reaching out to commercial partners to gauge interest in this. The other activity was the biotyping on aphid populations collected from single soybean fields. We have completed this objective and published the findings. The article appeared in print last June, and can be found here: https://doi.org/10.1093/jee/toab058.

Seventh Update, August 31, 2022

This overall project aims to increase the economic and environmental sustainability of soybean production by reducing insecticide inputs for soybean aphid. The first activity focuses on development of aphid-resistant soybean. Numerous soybean lines with aphid resistance were further advanced and tested in the breeding pipeline. Foundation seed is being increased for two advanced lines for possible licensing or variety release as requested by a potential commercial partner. In addition, crosses were made to create soybean lines with multiple genes of aphid resistance and breeding populations are being advanced for both general purpose and food type soybeans that are segregating for multiple Rag/rag genes. The second activity focuses on using satellite-based data to scout for soybean aphid. Field-level retrospective analysis is underway with satellite data being acquired for 636 soybean fields from Minnesota, Wisconsin and North Dakota in 2015 to 2019 with corresponding data on soybean aphid abundance. For further validation, ground-based hyperspectral data collected from caged field experiments from 2021 and several earlier years were analyzed to simulate multispectral satellite-based data and found several of the satellite's wavelengths and calculated vegetation indices to be sensitive to soybean aphid. It was not possible to conduct intended on farm strip-trials using actual satellite data to classify soybean aphid infestations, because the drought conditions of 2021, but this will be tried again in 2022.

Eighth Update February 28, 2023

This overall project aims to increase the economic and environmental sustainability of soybean production by reducing insecticide inputs for soybean aphid. The first activity focuses on development of aphid-resistant soybean. Numerous soybean lines with aphid resistance were further advanced and tested in the breeding pipeline. Foundation seed is being increased for two advanced lines for possible licensing or variety release as requested by a potential commercial partner. In addition, crosses were made to create soybean lines with multiple genes of aphid resistance and breeding populations are being advanced for both general purpose and food type soybeans that are segregating for multiple Rag/rag genes. The second activity focuses on using satellite-based data to scout for soybean aphid. Field-level retrospective analysis is underway with satellite data being acquired for 636 soybean fields from Minnesota, Wisconsin and North Dakota with corresponding data on soybean aphid abundance. Data have been acquired and pre-processed for 2015-2017; data continue to be acquired for 2018 and 2019. For further validation, ground-based hyperspectral data collected from caged field experiments from 2022 will be used to update previous analyses that indicated several of the satellite's wavelengths and calculated vegetation indices to be sensitive to soybean aphid. Data were collected from a farm strip-trial using actual satellite data to classify soybean aphid infestations during the summer of 2022; data is currently being processed.

Final Update, August 31, 2023

This overall project aims to increase the economic and environmental sustainability of soybean production by reducing insecticide inputs for soybean aphid. The first activity focuses on development of aphid-resistant soybean. Numerous soybean lines with aphid resistance were further advanced and planted in corresponding seed increase plots and yield trial plots. We have been working with a company that is interested in licensing two of our new aphid-resistant varieties. ~~as they have licensed two of our new aphid-resistant varieties.~~ We planted large pure seed increases ("breeder's seed") of two new aphid varieties, one of which carried Rag1+Rag2. Yield trials and breeding nurseries were successfully planted and we anticipate another season of successful data collection and generational advancement in the aphid-resistant breeding program. The second activity focuses on using satellite-based data to scout for soybean aphid. The use of satellite data to detect soybean aphid was shown as a real possibility through simulation of satellite data using hyperspectral data from a ground-based sensor. These data, collected from caged field plots showed several wavelengths of reflectance were affected by soybean aphid. Follow up validation using actual satellite-based data showed similar effects of aphids on the canopy reflectance of commercial soybean fields. Finally, a linear support vector machine model was developed to use the actual satellite data to accurately classify commercial soybean fields as being above or below the treatment threshold of 250 aphids/plant. This research is being advanced through a subsequent appropriation. All revenue-generating activities are tracked by the Office of Technology Commercialization and reported back to LCCMR directly by that office on an annual basis, as was the case on Aug 31, 2023 with this project, specifically. OTC has not informed MITPPC of any revenue being generated.

MITPPC sub-project 12: Expanding and strengthening the prioritization of terrestrial invasive species in Minnesota

Project manager: Amy Morey

Description: This project will focus on the prioritization process used by MITPPC to identify terrestrial invasive species (TIS) for funding. First, the project will continue to evaluate TIS submitted for consideration among MITPPC's top prioritized species and conduct the biennial update of the prioritization. Second, the project will develop a more systematic format for stakeholders to suggest TIS for consideration by MITPPC. This format is intended to increase transparency and consistency and encourage engagement with a broader community of stakeholders. Lastly, this project will develop and compare climate suitability models for ~25 TIS across a range of model complexities. Among the decision criteria MITPPC uses to evaluate the risk a TIS may pose to Minnesota is potential climate suitability. The climate in Minnesota can be an important deterrent to many TIS establishing or becoming widespread. There are many different methods for forecasting climate suitability, ranging from those based on simple thresholds (e.g., USDA plant hardiness zones) to those based on more complex algorithms (e.g., statistical correlation, process-oriented, etc.). Evidence is presently lacking to inform whether a certain method(s) may be more useful for risk assessment applications, such as the MITPPC species evaluations. This project will analyze trade-offs between model accuracy and resource investment (e.g., time, required expertise) to recommend the most practical modeling approach for MITPPC evaluations.

Summary Budget Information: **ENRTF Budget: $151,601**

Outcomes	**Completion Date**
ACTIVITY 1: TIS evaluations	
1. Development and implementation of species solicitation method completed	06/30/2021
2. Evaluations of 3 new TIS completed	12/31/2021
3. Biennial update of TIS prioritization completed;	01/30/2022
4. Evaluations of 7 additional TIS completed	12/31/2022

Outcomes	Completion Date
ACTIVITY 2: Evaluate climate suitability models	
1. Threshold models built for TIS	01/30/2022
2. Complex models built or compiled for 10 TIS	09/30/2022
3. Summary report and recommendation of forecasting method for MITPPC evaluations	06/30/2023

The first update on this sub-project will be given with the sixth update on the overall project.

Sixth Update, February 28, 2022

During the June-Dec 2021 reporting period, activities related to maintaining and refining the species prioritization process continued, including the updating of dozens of existing species evaluations. The biennial update of the species prioritized for research proposals was completed and is on track to be released as part of the Jan 2022 Request for Proposals.

Methodology for the second major project activity (climate suitability modeling) is being refined and data necessary for model construction is being collected.

Seventh Update, August 31, 2022

During the Dec 2021-June 2022 reporting period, we drafted assessments for little leaf linden, potato wart, Siberian squill, and whitecrack willow. Documents are awaiting review by other MITPPC staff.

We continue to make steady progress on comparisons of methods to forecast climate suitability from historical distribution records for invasive species. Complex models are complete for 8 of 10 species; models for two more species are in progress. Threshold models are in different stages of completion for 25 invasive species. Our preliminary results show marked differences in the performance of the different modelling strategies, models that are very simple or very complex do not perform as well as models with intermediate complexity. We will be evaluating the robustness of this result as analyses for more species are completed. A computer crash and the time required to purchase a replacement (not with LCCMR funding) caused a delay in the project.

Eighth Update February 28, 2023

Seven new species were evaluated as part of MITPPC's research prioritization process by the end of 2022. A protocol for comparing complex and simple species distribution models have been completed using the northern giant hornet and is guiding the construction of models for eight other insect species.

Final Update, August 31, 2023

Species evaluations were completed during the last update period. Another directed request began in May for public suggestions of new species to evaluate and feedback on existing evaluations.

The activity related to species distribution modeling was completed during this reporting period. Models for eight invasive insects were constructed and compared, with a major goal of better informing modeling decisions when estimating climate suitability in risk assessment applications, such as occurs for MITPPC's species evaluations. We found that, relative to more complex approaches, simple estimates of climate suitability (e.g., plant hardiness zones) appear to be just as accurate but require less effort to construct. Therefore, they are reasonable tools to use for MITPPC's species evaluations.

IV. DISSEMINATION:

Description:
Findings will be shared with agencies and citizen groups so that public information and decision making is based on the best available science. Updates on progress and research results will be disseminated through University of Minnesota, College of Food, Agricultural, and Natural Resource Sciences, and College of Biological Sciences via

websites, social media, and publications. Media releases will also be used when warranted. Additionally, findings will be presented at local and national conferences and via peer-reviewed publication and student theses.

First Update January 31, 2019 – Submitted May 9, 2019
No activity to report during this period.

Second Update June 30, 2019:
No activity to report during this period.

Third Update, July 31, 2020
Sub-project 3:
Presentation:
Chad Giblin presented at the Wisconsin Arborists Association (WAA) annual conference in Green Bay on February 17, 2020. His 90-minute presentation "Elm Cultivars & Dutch Elm Disease Update" was well attended and generated numerous questions and comments from those in the crowd. This is the third time WAA has invited Giblin to speak about elms at their annual conference.

Chad Giblin provided a guest lecture in Urban Studies – The Urban Environment (UrbS 3751) on February 25, 2020. This lecture covered the history of elms and Dutch elm disease in Minneapolis as well as covering the work that the MITPPC research team is conducting and a discussion of future prospects of urban forestry in Minneapolis.

Sub-project 4:
Staff have attended the MNDNR-UMN joint phragmites meetings to network with potential collaborators and learn more about the many efforts related to phragmites in Minnesota. We have not yet completed outreach efforts such as publications or presentations, but those are planned or in-progress.

Sub-project 5:

- Presentation at CitSciMN: A Symposium for Citizen Science Professionals in Minnesota, South St. Paul, MN, Nov 22, 2019
- Minnesota Department of Agriculture newsletter, Weed of the Month, April 30, 2020
- Poster for Distancing Partners virtual conference, May 15-16, 2020
- Zoom presentation to Anoka County Master Gardeners (~75 attendees) on Thursday, May 28, 2020
- Filmed Grow with KARE segment on KARE 11, June 24, 2020 to be aired on July 3 and 4, 2020.

Sub-project 6:

A fact sheet for the disease has been developed and has started being disseminated to natural resources professionals and citizens interested in glossy buckthorn and reed canarygrass. We also had informal communications with naturalist groups and citizen scientists from Minnesota and neighboring states. Results from this research have been presented at SciPride 2020 series at the Bell Museum. Results will be also presented at the American Phytopathological Society Annual Meeting (August, 2020) and the Upper Midwest Invasive Species Conference (November, 2020).

Sub-project 7:
We had some casual discussions with the Lake Elmo park reserve and Three Rivers Park management, Lake Elmo Park Reserve and Washington county STS leaders about the objectives and goals of the project. Those

discussions served as educational and informative outreach to involved parties in establishing of the research sites.

Fourth Update, February 28, 2021
Sub-project 2:

Ecological Society of America, Aug. 3-6, 2020. Spectral reflectance models predict ecophysiological indicators of oak wilt and drought induced tree decline in red oaks. Gerard Sapes (presenter), Lucy Schroeder, Jennifer Juzwik, Rebecca A. Montgomery and Jeannine Cavender-Bares.
Joint Conference of the Upper Midwest Invasive Species Conference and the North American Invasive Species Management Association, Rochester MN, November 2, 2020. "Spectral Reflectance Detects Oak Wilt Decline in Oaks at the Landscape Scale" Gerard Sapes (presenter), Cathleen Lapadat, Jennifer Juzwik, Rebecca Montgomery, Nanfeng Liu, Phillip Townsend, Jeannine Cavender-Bares

American Geophysical Union, December 14, 2020. "Understanding the Evolutionary and Environmental Sources of Spectral Variation within Species, Communities and Across the Plant Tree of Life to enhance biodiversity detection." Jeannine Cavender-Bares (presenter) and collaborators

Media
"UMN researchers say invasive fungus that threatens oak trees is spreading. New research into oak wilt allows for better detection and treatment." *Minnesota Daily*, Sept. 27, 2020
https://mndaily.com/262507/news/tree-d-lightly-umn-researchers-say-invasive-fungus-threatens-oak-trees-is-spreading/

LEVERAGE
Two federal grant proposals were funded leveraging the MITPPC-funded research including:

USDA Forest Service Special Technology Development Program, Accurate Detection of oak wilt for effective management at regional scale. 4/01/2020-3/31/2023, $101,451. J. Cavender-Bares (PI), J. Juzwik (Co-PI), P. Townsend, C. Miller, V. Cervenka (Cooperators).

NASA NNH20ZDA001N-BIODIV Biodiversity, Mapping changes in forest diversity and disease in North American temperate forests. 02/01/2021 - 01/31/2024, $481,933 J. Cavender-Bares (PI), P. Townsend (Co-PI), J. Juzwik, C. Miller G. Sapes, J. Pinto-Ledezma (Collaborators).

Sub-project 3:

Held, B., Giblin, C., Murphy, R., Beier, G, Blanchette, R. 2020. Winning the Dutch Elm Disease Battle by Developing Resistant Elms for Minnesota. Upper Midwest Invasive Species Conference. 2-6, November.

Star Tribune article "Minneapolis woman saves 200-year-old elm destined for chopping block". November 14, 2020.

Sub-project 5:

- Monthly newsletters, 160 recipients (up from 139)
- Monthly USA-NPN newsletters to 79 recipients
- Mentions in other newsletters:

- Master Woodland Owner newsletter – July 14, 2020
- Master Naturalist Weekly Updates
- Master Gardeners newsletter - twice since July
- MITPPC Newsletter - Nov 2020

- Pesky Plants Tea Tuesday Zoom meetings
  - 19 iterations (weekly Jul-Oct, monthly Nov-Feb)
  - 51 unique registrants
- Conferences:
  - 23 attendees on Oct 10 at Minnesota Env. Ed. Association (AWA)
  - 58 attendees on Nov 3 at Upper Midwest Invasive Species Conference (RM)
  - Plus the PPT flyer was available at UMISC exhibit booths, Nov 3-6
- Other:
  - Art-and-science project at Franconia Sculpture Park, collaborating with Christine Baeumler
  - NCROC Virtual Visitors Day (Sep 1, 2020) and video (50 views)

Sub-Project 6:

Results from this project were presented by Nick Greatens at the American Phytopathological Society Annual Meeting in August 2020 (poster), the Upper Midwest Invasive Species Conference in November 2020 (oral presentation), and the Bell Museum SciPride talks (oral presentation).

Sub-project 7:

We had some casual discussions with the Lake Elmo park reserve and Three Rivers Park management, Friends of Mississippi River land managers, Lake Elmo Park Reserve and Washington county STS leaders about the objectives and goals of the project. Those discussions served as educational and informative outreach to involved parties in establishing the research sites.

Fifth Update, August 31, 2021
Sub-project 1:
Rajtar N. 2020. Biosurveillance of invasive tree pathogens in Minnesota. Invited seminar. Department of Plant Pathology, University of Minnesota.

Sub-project 3:
Presentation by Ryan Murphy: Dutch elm disease: history, biology, identification, and management. Presented at Conservation Corps Tree Inspector Workshop. May 14, 2021

Sub-project 4:
Connor Anderson presented this work at multiple conferences during the project period. We continue to be connected with phragmites practitioners throughout the state. We have a journal article in revision, as noted in the Activity 1 description.

Sub-project 5:
- Pesky Plants website: 1.2K users since Jan 1, 2021. Average session: 4 minutes, 26 seconds.
- Monthly newsletter (Mailchimp) to 269 subscribers, >40% open rate. Subscribers up from 164 in January 2021.
- May 13-15, 2021: Virtual table/poster at Gathering Partners Exhibit Hall
- May 5, 2021: Community Science with Noxious Weeds (During a Pandemic and an Uprising). Poster and panel discussion by Abbie Anderson for CitSciVirtual. 33 attendees.
- Feb 25, 2021: Anoka Master Gardeners meeting, spot for Abbie Anderson. 89 attendees.
- Feb 25, 2021: Wild Ones - Arrowhead chapter meeting, spot for Stephan Carlson. 6 attendees.

- Feb 9, 2021: Presented at Washington Co CWMA meeting. 34 attendees.
- Feb 2, 2021 KAXE Interview with host John Latimer. February 2, 2021.
- Feb 2021: Local papers (e.g., Duluth News Tribune) announce volunteer opportunities with PPT
- Feb 2021: Minnesota Township Insider, winter 2021 issue, pages 18-20. Cover article, readership of ~9,000.
- Jan 15, 2021: Presented at Ramsey County CWMA meeting. 17 attendees.
- Jan 13, 2021: Info Session for St. Louis County (co-hosted by Duluth CISMA, City of Duluth, St. Louis County Public Works). 26 attendees.

Sub-project 6:
This semester we expanded our collaboration network including ~40 iNaturalist.com users. This network contributes to the dissemination of our project in Minnesota and other States. Results from this project were presented at the Department of Plant Pathology Seminar Series and will be presented at the 2021 American Phytopathological Society Annual Meeting (oral).

Sub-project 8:
Invited presentation on Activity 1 shared with the USDOI National Park Service. integrated Pest Management Virtual Training. March 17. Presentation link here https://mylearning.nps.gov/training-courses/integrated-pest-management-virtual-training-series/

Sixth Update, February 28, 2022
Sub-project 1:
Two general articles were published:
- Bernhardt C. 2021. Rooted in Research. Minnesota Invasive Terrestrial Plants and Pest Center, University of Minnesota. https://mitppc.umn.edu/news/rooted-research
- Bernhardt C. 2021. Fighting for Minnesota Trees (University of Minnesota Twin Cities Homepage Feature). University of Minnesota. https://twin-cities.umn.edu/news-events/fighting-minnesotas-trees

Sub-project 2:
No activity to report during this period.

Sub-project 3:
No activity to report during this period.

Sub-project 4:
The graduate student has presented this work at multiple conferences during the project period. We continue to be connected with phragmites practitioners throughout the state.

We have one manuscript describing the initial stages of this project published in the journal "Remote Sensing". Its title is "Mapping Invasive Phragmites australis Using Unoccupied Aircraft System Imagery, Canopy Height Models, and Synthetic Aperture Radar." The DOI for the paper is https://doi.org/10.3390/rs13163303 . We are preparing another article for publication.

Sub-project 5:
- May 13-15, 2021: Abbie hosted virtual poster table for Gathering Partners conference
- July 19, 2021: Abbie presented at “Annual Short Course” for Minnesota Association of County Agricultural Inspectors, ~50 attendees
- November 10, 2021: Gratitude Party, 29 attendees
- December 7, 2021: Abbie presented to Open Lands Chicago (11 participants)
- Web traffic (Jan 1 - Dec 8, 2021) on peskyplants.umn.edu: 1.8K users , 3.3K sessions, avg session >4 min
- Community Blog page (new feature) has 244 pageviews since July 1, 2021

- Events page has 308 pageviews since July 1, 2021
- MISAC's 2022 calendar - February features Pesky Plant Trackers photo & program description

Sub-project 6:
This year we expanded our collaboration network including many users of iNaturalist.com, many of whom sent us samples for our project. Numerous collaborators found on iNaturalist were land managers or scientists, and most others were hobbyists. This network contributes to the dissemination of our project in Minnesota and other states. Results from this project were presented at the 2021 American Phytopathological Society Annual Meeting (15-minute presentation).

Sub-project 7:
No activity to report during this period.

Sub-project 8:
No activity to report during this period.

Sub-project: 9
Field Day Workshop in Rosemount, MN September 2021
- Articles for Minnesota Crop News blog
- Posters and slides for CPM Short Course in Minneapolis in December and for other field days and meetings in September, October, and November

Sub-project 10:
This semester we expanded our strong collaboration network with people working in invasive species, natural resources, conservation, and state parks at both State and local levels in Minnesota and Wisconsin. Many of these collaborators have facilitated our survey trips and others have been contributing with plant tissue samples and barberry seeds. This extensive collaboration network allows a strong diffusion of our research and our funding source. In 2021, we contributed to an article at the Department of Plant Pathology publication 'Aurora Sporealis' where MITPPC-funded projects were presented.

Sub-project 11:
No activity to report during this period.

Sub-project 12:
This year we expanded our collaboration network including many users of iNaturalist.com, many of whom sent us samples for our project. Numerous collaborators found on iNaturalist were land managers or scientists, and most others were hobbyists. This network contributes to the dissemination of our project in Minnesota and other states. Results from this project were presented at the 2021 American Phytopathological Society Annual Meeting (15-minute presentation). A research presentation is scheduled to be given on preliminary results associated with the project at the North Central Branch of the Entomological Society of America in the spring of 2022. I gave an invited talk to citizen scientists associated with a MITPPC-funded project (Pesky Plant Trackers) that was focused broadly on the value of species occurrence records in the management of invasive species.

Seventh Update,-August 31, 2022
Sub-project 1:
The Hunt for Invasive Forest Pathogens, Minnesota Department of Natural Resources Forest Health Workshop. February 2022. This presentation reported results on biosurveillance of invasive forest and nursery pathogens to the Minnesota Department of Natural Resources.

Sub-project 3:
Presentation
Still in the Fight: Winning the Dutch Elm Disease Battle with Resistant Elms. Northern Green Expo. Jan 12, 2022.

Article
MITPPC-funded researchers are strategically wrangling the charismatic trees' innate ability to fend off Dutch elm disease. By Caryolyn Bernhardt. MITPPC. March 29, 2022.

Sub-project 4:
Connor continues to present this work at multiple conferences. We continue to interact with Phragmites practitioners throughout the state. We have one journal article published, as noted in the Activity 1 description. We are preparing another article for publication.

sub-project 5:

- Web traffic (Jan 1 - June 27, 2022) on peskyplants.umn.edu: 567 users , 767 sessions, avg session 2:35
- Community Blog page (new feature) has 145 page views since Jan 1, 2022
- Events page has 173 page views since Jan 1, 2022
- MISAC's 2022 calendar - February features Pesky Plant Trackers photo & program description
- May-June 2022: Abbie Anderson mentored 12 Master-Naturalists-in-training who completed phenology-related capstone projects as part of their training
- June 28, 2022: Rebecca Montgomery is keynote speaker for Invasive Species Conference at ROCs. Abbie Anderson and Rebecca Montgomery both give field presentations for conference guests
- In their 2021 Annual Report, USA-NPN featured Pesky Plant Trackers as a project that informs decisions in natural resource management. https://usanpn.org/files/npn/reports/USA-NPN_AnnualReport2021.pdf
- In March, the Pesky Plant Tracker training module was updated to be more helpful to volunteers and be a more self-sustaining resource. The updated training is being used for a campaign in the state of Vermont.

Sub-project 6:
Results from this project will be presented at the upcoming 2022 American Phytopathological Society Annual Meeting in Pittsburgh, Pennsylvania (15-minute presentation) and at the 2022 Upper Midwest Invasive Species Conference in Green Bay, Wisconsin. Additionally, we maintain correspondence with land managers and community scientists who submitted samples and credit them by name in our upcoming publication reporting Pcc distribution. Upon publication, we will disseminate our results through this network as well.

Sub-project 9:
I presented and discussed results from this project to audiences at the following Extension Education events.

- Research Updates: Waseca, MN. January 2022
- Research Updates: Rochester, MN. January 2022
- Research Updates: Lamberton, MN. January 2022
- Research Updates: Wilmar, MN. January 2022
- Research Updates: Morris, MN. January 2022
- Crops and Pesticide Workshop. Rochester, MN Feb 2022
- Crop and Pest Management Update. Cold Spring, MN. March 2022
- Crop and Pest Management Update. Little Falls, MN. March 2022
- Pine-Isanti County Crops Update Meeting. Pine City, MN. March 2022

Sub-project 12:
Outreach related to the species prioritization process (Activity 2)

- An abstract was submitted and accepted for the annual meeting of the North American Invasive Species Management Association in the fall 2022. The presentation will summarize MITPPC's species prioritization process.
- I was interviewed by the University of Minnesota regarding terrestrial invasive species and the species prioritization process used by MITPPC (https://twin-cities.umn.edu/news-events/talking-invasive-species-u-m)
- Individual conversations with stakeholders regarding the prioritized species and evaluation process continue sporadically

Outreach related to species distribution modelling and terrestrial invasive species (Activity 3).

- I gave a research presentation at the North Central Branch of the Entomological Society in the spring of 2022 showing preliminary modeling results for two insect species.
- An abstract was accepted for the 2022 Upper Midwest Invasive Species Conference that will highlight additional modelling progress for the invasive wasp, *Vespa mandarinia*, in fall 2022.
- I co-authored a book chapter on the eradication and management of invasive insects. The draft was submitted to the publisher in Feb 2022.
- I continue to serve on the Board of Directors for the North American Invasive Species Management Association (NAISMA) and the NAISMA Standards and Technology Committee.
- Participation in relationship building activities with state tribal communities concerning invasive species issues
- I am co-author to a paper (in revisions, PNAS) involving modelling of the geographic range of the agricultural insect pest, *Helicoverpa zea*

Eighth Update, February 28, 2023

Sub-project 1:

- Phytophthora on woody plants in Minnesota. Presentation at the University of Minnesota Arboretum, July 6th 2022
- Surveying for Invasive species. Pikes Peak Mycological Society, Colorado Springs, Colorado-August 24th 2022
- From Minnesota Nurseries to Minnesota Forests: The Hunt for Invasive Species. North Central Forest Pest Workshop- September 13th 2022
- Biosurveillance of Invasive Phytophthora species in Minnesota Nurseries and Forests. Upper Midwest Invasive Species Conference, Green Bay Wisconsin- October 27th 2022

Sub-project 2:
We participated in the Minnesota State Fair with an oak wilt exhibit and video that we displayed on three different days in August and September 2022. Our team interacted with hundreds of fairgoers and we received 244 completed surveys on oak wilt knowledge of the general public. People interacted with us about their understanding of tree health, tree disease, and oak wilt infection. This provided an opportunity to transfer knowledge about taking measures to prevent disease spread and how to get trees assessed for oak wilt.

Sub-project 3:Presentation
University of Minnesota Elm Selection Program. UFORE Field Day. Aug 18, 2022.

Sub-project 4:
PhD student Anderson continues to present this work at multiple conferences. We continue to interact with Phragmites practitioners throughout the state. We have one journal article published, as noted in above, another in review, and one in preparation.

Sub-project 5:

- Gratitude Party, December 8, 2022: 20 attendees (Virtual)
- Pesky Plants Newsletter: distributed to 262 subscribers
- Monthly Tea Tuesdays via Zoom: 22 unique attendees
- Website peskyplants.umn.edu: 757 users, 879 sessions, avg duration 1:33 (since July 1, 2022)

Sub-project 6:
Results from this project were presented at the 2022 American Phytopathological Society Annual Meeting in Pittsburgh, Pennsylvania (15-minute oral presentation) and at the 2022 Upper Midwest Invasive Species Conference in Green Bay, Wisconsin (two 15-minute oral presentations). Additionally, we maintain correspondence with land managers and community scientists who submitted samples and credited them by name in our publication reporting Pcc distribution. Upon publication, we will disseminate our results through this network as well.

Sub-project 7:
Media coverage:
October 13, 2022. Mike Schuster appeared on FOX 9 to discuss buckthorn management.
https://www.fox9.com/video/1129883

Sub-project 8:
We have several refereed publications planned from the work. As of Dec 2022, we have plans for publications targeted to Environment Management, Journal of Outdoor Recreation & Tourism, Applied Environmental Communication, Urban Forest & Urban Greening, Managing Biological Invasion and one TBD

To date, we have shared our work at local, state, national and international settings. Specifically
1) we wrote and shared area reports for each of the MnDNR state park project sites,
2) shared results and implications at

a. local conferences hosted by UMN Forestry & Outreach Center (summer 2022)
b. state conferences hosted by the Mn Naturalists Assoc (fall 2022), UMN forestry/wildlife review (winter 2021)
c. national conferences hosted by the National Outdoor Rec Professionals, National Natural Areas, (both fall 2022)
d. regional conference hosted by the Upper Midwest Invasive Species group. (fall 2022)
e. national webinar hosted by the National Park Service on integrated pest management (spring 2021)
f. international conference (virtual) hosted by the International Association of Society & Natural Resources (fall 2022)

Sub-project 9:
Results and outcomes from this project were presented and discussed with audiences at the following outreach events and products in the past 6 months.

- I wrote articles for the on-line newsletter/blog 'Minnesota Crop News'. https://blog-crop-news.extension.umn.edu/2022/09/scout-for-tar-spot-of-corn.html
- I presented results in August via a webinar, as part of an Extension program entitled 'Strategic Farming'
- Results were presented and discussed with a large group (>100) of farmers and crop consultants at an annual crops meeting in Trimont, MN in November.
- Results were shared and discussed with colleagues at the National Corn Disease workers and tar spot meetings in Chicago in early December.
- I brought a group of plant pathology graduate students to view and learn about tar spot in the field and see the fungicide field study in Rosemount, MN in August.

- Results from our tar spot work were presented to a group of regional and national researchers and agronomists with Bayer Crop Science as well as a group of Extension Educators in November in Shakopee, MN.
- Information and results have been shared with U of Minnesota Extension Educators, who have presented it at several meetings (such as the Crop Management Input Seminar in Hutchinson in December).
- Confirmed distribution of tar spot in Minnesota is shared widely on a web page dedicated to this disease: https://corn.ipmpipe.org/tarspot/

Sub-project 10:
Research data was presented at the Upper Midwest Invasive Species Conference in Green Bay, Wisconsin between October 25-27, 2022 (oral presentation).

Sub-project 11:
Scientific publications:

- Ribeiro, A.V., T.M. Cira, I.V. MacRae and R.L. Koch. 2022. Effects of feeding injury from Popillia japonica (Coleoptera: Scarabaeidae) on soybean spectral reflectance and yield. Frontiers in Insect Science 2: article no. 1006092 https://www.frontiersin.org/articles/10.3389/finsc.2022.1006092/full
- Menger, J.P., S.J. Bhusal, R.L. Koch and A.J. Lorenz. 2022. Evaluation of advanced breeding lines for resistance to the soybean aphid (*Aphis glycines* Matsumura), 2022. Arthropod Management Tests XX(X): XXX (in press)

Scientific presentations:

- Koch, R.L. 2022, June. Precision plant protection research: Remote sensing for soybean aphid. 10-minute talk. International Conference on Precision Agriculture, Post-conference tour. St. Paul, MN.
- Ribeiro, A.V., T. Cira, I.V. MacRae and R.L. Koch. 2022, November. Effects of *Popillia japonica* (Coleoptera: Scarabaeidae) defoliation on soybean spectral reflectance and yield. 10-minute presentation. Meeting of the Entomological Society of America. Vancouver, BC, Canada.
- Ribeiro, A.V., T. Cira, I.V. MacRae and R.L. Koch. 2022, October. Impacts of Japanese beetle defoliation on soybean spectral reflectance and yield. Upper Midwest Invasive Species Conference. Green Bay, WI.

Sub-project 12: Morey presented a poster describing the MITPPC prioritization process at the North American Invasive Species Management Association annual meeting in Nov. 2022. The models and results for northern giant hornet were presented at the Upper Midwest Invasive Species Conference in October 2022 and are being prepared for publication.

Ninth Update, August 31, 2023

Sub-project 1:
- University of Minnesota Class Plants Get Sick Too-December 2022
- Invasive Forest Pathogens in Minnesota
- Central Minnesota Christen School- February 6th, 2023
- The Wonderful World of Mushrooms and Protecting our Natural Resources
- CFANS Poster Symposium March 16th, 2023
- Protecting Minnesota's Natural Resources: Biosurveillance for new Phytophthora Diseases
- University of Wisconsin- Madison March 21st, 2023
- Biosurveillance of Invasive Forest Pathogens in Minnesota

Sub-project 2:

We have presented our work at a national meeting of the US Forest Service and to the National Park Service

Sub-project 3:

- Elms were once a staple of Minnesota's tree canopy; this is how researchers hope to bring them back. Star Tribune, April 25, 2023
- A new realm of elms. CFANS Purpose article, April 24, 2023
- Senior video capstone project, Macy Berendsen, St. Thomas University.
- MN group working to end Dutch elm disease. Radio interview WJON radio, May 3, 2023.

Sub-project 4:
Connor Anderson has presented this work at multiple conferences. We continue to interact with Phragmites practitioners throughout the state. We have two journal articles published, as noted in above, and another in review.

Sub-project 6:
Results from this project were presented at the 2023 North American Rust Workshop (oral presentation), CFANS Research Symposium (2 posters), and at Nick Greatens Ph.D. thesis dissertation seminar on May 31st.

Sub-project 8:
We have two refereed publications with two more under review.

We have shared our work at local, state, national and international settings. Specifically
1) we wrote and shared area reports for each of the MnDNR state park project sites,
2) shared results and implications at

a. local conferences hosted by UMN Forestry & Outreach Center (summer 2022)
b. state conferences hosted by the Mn Naturalists Assoc (fall 2022), UMN forestry/wildlife review (winter 2021)
c. national conferences hosted by the National Outdoor Rec Professionals, National Natural Areas, Society of American Foresters (fall 2022, fall 2022 and fall 2023 forthcoming)
d. regional conference hosted by the Upper Midwest Invasive Species group. (fall 2022)
e. national webinar hosted by the National Park Service on integrated pest management (spring 2021) and Don't Move Firewood during EAB Awareness week (spring 2023)
f. international conference (virtual) hosted by the International Association of Society & Natural Resources (fall 2022)

Sub-project 9:
Here are a few more examples from Media:

- https://www.agupdate.com/minnesotafarmguide/news/crop/corn-tar-spot-showed-up-in-stearns-county-in-2022/article_ce576350-8d36-11ed-9c0f-cf2e3398e057.html
- https://www.southernminn.com/faribault_daily_news/news/state/university-of-minnesota-extension-urges-growers-to-scout-for-tar-spot-in-corn/article_708b9864-140e-11ed-8d98-c3aa76f6f577.html
- https://www.hometownsource.com/morrison_county_record/strategic-farming-let-s-talk-tar-spot-of-corn/article_bdb5db76-cd87-11ed-813f-d3d4bdbcb7ae.html

Outreach - Other items available on the internet:

- https://blog-crop-news.extension.umn.edu/2022/07/corn-tar-spot-reported-in-southeastern.html
- https://blog-crop-news.extension.umn.edu/2022/08/strategic-farming-field-notes-focused.html
- https://blog-crop-news.extension.umn.edu/2023/03/strategic-farming-lets-talk-crops_13.html

Information and results from this project have also been presented at in-person Extension education programs in Lamberton, Wilmar, Waseca, Morris, and Bloomington MN and Grand Forks, ND. Information was also presented via a webinar.

Sub-project 10:

- Results from this research have been presented at the 2023 North American Rust Workshop (oral), 2023 CFANS Research Symposium (oral), and the 2023 Spring Seminar Series at the Department of Plant Pathology, University of Minnesota.
- Two manuscripts will be submitted to scientific journals in the next couple of months.

Sub-project 11:
Presentations and publications:

- Koch, R.L. 2023, March. Remote sensing for insect pests. FarmBits Podcast, episode 96. University of Nebraska Extension (60-minute presentation saved as a podcast) https://mediahub.unl.edu/media/20568 https://www.youtube.com/watch?v=YU3Ua6ANr2s
- Ribeiro, A.V., L. Lacerda, M.A. Windmuller-Campione, T.M. Cira, Z.P.D. Marston, T.M. Alves, E.W. Hodgson, I.V. MacRae, D. Mulla and R.L. Koch. Linear support vector machine classification of soybean aphid infestations in soybean fields using Sentinel-2 satellite imagery. Computers and Electronics in Agriculture (submitted)

Tenth Update, February 28, 2024
Sub-project 1:
Research presentation at the University of Minnesota Bell Museum, November 9, 2023
On the front lines: How proactively pinpointing pathogens protects Minnesota trees,
August 14, 2023

Final Update, June 30, 2024
Sub-project 1:

Rajtar, N. N., B.W. Held and R. A. Blanchette. 2024. Surveying Minnesota's Nurseries, Forest Stands and Waterways for Phytophthora. Society of American Foresters Meeting- Grand Rapids, MN. March 20, 2024

Rajtar, N. N. 2024. Hunting for Fungi and Pathogens in Minnesota, Mahtomedi Garden Club- Mahtomedi, MN. April 4, 2024

Sub-project 7:

"Improving understory biotic resistance against invasive buckthorn (*Rhamnus cathartica*) through active revegetation of trees and shrubs," in submission review.

"Efficacy and Non-target Impacts of Fosamine Ammonium and Triclopyr Choline Use in Controlling Common Buckthorn (*Rhamnus cathartica*) in a Forest Understory Community"

V. PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview:
See attached spreadsheet.

Explanation of Capital Expenditures Greater Than $5,000: One capital expenditure is requested for MITPPC sub-project 2: Accurate detection of oak wilt from tree to landscape scales for enhanced forest management (Project Manager: Jeannine Cavender-Bares). The request is for $17,000 for the purchase of a lightweight unmanned-aerial-vehicle (UAV) and ground control software for the UAV (estimated cost of $8,500), and the

construction of a custom photo sensor ($8,500) by Sentera. Much like a camera, the photosensor measures the intensity of Red-Green-Blue (RGB) light and five, custom selected non-visible (hyperspectral) wavelengths of light. Results from previous work will be used to select the wavelengths that indicate changes in chlorophyll and photosynthetic function, changes in water content, and changes in carbohydrates and sugars. Changes in these characters have proven useful to detect oak wilt diseased leaves and trees. Sentera's FieldAgent software is required for autonomous flight of the UAV and data capture. Collectively, these three elements are intended to provide data on the condition of mature oak trees and stands, ultimately yielding tools to better detect oak wilt. The UAV will be flown over multiple sites in each year of the project.

All equipment or other capital assets purchased with this appropriation will continue to be used through its useful life by the Minnesota Invasive Terrestrial Plants and Pests Center at the University of Minnesota for the same program, or, if the use changes, the Environment and Natural Resources Trust Fund will be reimbursed an amount equal to either the cash value received or a residual value approved by the LCCMR director if it is sold.

Explanation of Use of Classified Staff: N/A

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 7FTE

Enter Total Estimated Personnel Hours: 14,560	Divide by 2,080 = TOTAL FTE: 7

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

Enter Total Estimated Personnel Hours:	Divide by 2,080 = TOTAL FTE:

B. Other Funds:

SOURCE OF AND USE OF OTHER FUNDS	Amount Proposed	Amount Spent	Status and Timeframe
Other Non-State $ To Be Applied To Project During Project Period:			
	$	$	
Other State $ To Be Applied To Project During Project Period:			
UMN Indirect rate 54%	$ 1,890,000	$ 0	This is the rate for 2019.
Past and Current ENRTF Appropriation:			
ML 2014, Ch. 312, Art. 12, Sec. 8	$1,460,000	$1,460,00	6/30/2022
ML 2015, Ch. 76, Sec. 2, Subd. 6a	$5,000,000	$4,810,727	6/30/2023
ML 2016, Ch. 186, Sec. 2, Subd. 6a	$3,750,000	$3,121,486	6/30/2023
Other Funding History:			
ML 2014, Ch. 312, Art. 12, Sec. 8	$ 3,400,000	$914,046	6/30/2022

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
University of Minnesota Researchers TBD through competitive RFP process			

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
TBD			

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

The Center's ultimate goal is to eliminate, reduce, mitigate or prevent the introduction, expansion or damage done by terrestrial invasive species in Minnesota. Metrics of success include: threat awareness, response efficiency, control effectiveness, non-target species protection, and mitigation strategies. Ancillary goals include: workforce development, citizen engagement, focused research strategies, improved response time to emerging threats, and improved coordination of efforts.

Success will depend on the ability to marshal multi-disciplinary teams in timely and prioritized ways to deliver results. Funding provided will be used to support additional multi-disciplinary research teams. With adequate funding, the Center's efforts are expected to result in numerous, effective prevention and control methods within an eight year time frame for a significant portion of the species upon which we will focus.

VIII. REPORTING REQUIREMENTS:

- **T**he project is for four years, will begin on July 1, 2019 and end on June 30, 2023. Subproject 1 and 7 will end on June 30, 2024
- Periodic project status update reports will be submitted August 31 and February 28 of each year.
- A final report and associated products will be submitted between July 30 and September 15, 2023; between June 30, 204 and August 15, 2024 for Subprojects 1,7, and the final Overall report.

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Pests and Plants Center-- Sub Project List
Legal Citation: M.L. 2018, Ch. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Robert Venette
Project Title: Minnesota Invasive Terrestrial Plants and Pests Center – Phase III
Organization: Regents of the University of Minnesota
College/Department/Division: College of Food, Agricultural, and Natural Resources Sciences
Project Budget: $3,500,000
Project Length and Completion Date: 5 years; June 30, 2023**;** June 30, 2024 for Sub 1 and 7
Current Date: August 2, 2024

Sub Project #	Sub-Project Title	Species	Sub-Project	LCCMR	Total Budget	Amount Spent	Balance	Status	Original budget	reserve
Reserve										$2
MITPPC sub-project 1	Early detection of invasive tree pathogens using molecular tools for prevention and to mitigate damage	Various pathogens, including *Heterobasidion irregular* (Annosum root rot), *Hymenoscyphus fraxineus* (ash dieback), *Raffaelea quercivora* (Japanese oak wilt), *Geosmithia morbida* (thousand cankers disease), *Phytophthora ramorum* (sudden oak death)	Robert Blanchette	#########	$383,865	$383,865	$0	Complete	$384,165	$300
MITPPC sub-project 2	Accurate detection of oak wilt from tree to lanscape scales for enhanced forest management	*Ceratocystis fagacearum* (Oak wilt)	Jeannine Cavender-Bares	#########	$301,941	$301,941	$0	Complete	$301,993	$52
MITPPC sub-project 3	Winning the Dutch elm disease battle: developing resistant elms for MN	*Ophiostomoa novo-ulmi* (Dutch elm disease)	Ben Held	#########	$233,924	$233,924	$0	Complete	$233,924	$0
MITPP sub-project 4	Detection and monitoring of invasive *Phragmites*	*Phragmites australis ssp. australis* (European common reed)	Joe Knight	#########	$203,781	$203,781	$0	Complete	$203,781	$0
MITPPC sub-project 5	Improve invasive plant treatment efficacy using climate based phenology models	*Polygonum cuspidatum* (Japanse knotweed), *Pastinaca sativa* (wild parsnip	Rebecca Montgomery	#########	$346,211	$346,211	$0	Complete	$346,211	$0
MITPPC sub-project 6	Biology and biocontrol potential of a rust fungus infecting *Phalaris arundinacea* and *Frangula alnus*	*Frangula alnus,* (glossy buckthorn), *Phalaris arundinacea* (reed canary grass)	Pablo Olivera	#########	$206,783	$206,783	$0	Complete	$206,783	$0
MITPPC sub-project 7	Managing buckthorn with trees: diversity, density, and practicality	*Rhamnus cathartica* (common buckthorn)	Peter Reich	#########	$499,734	$499,734	$0	Complete	$499,734	$0
MITPPC sub-project 8	Integrated emerald ash borer management: testing a novel approach to assess stakeholder	*Agrilus planipennis* (emerald ash borer)	Ingrid Schneider	#########	$436,072	$436,072	$0	Complete	$450,000	$13,928
MITPPC sub-project 9	Distribution, Risks, and Management of *Phyllachora maydis* , the Causal Agent of Corn Tar Spot	*Phyllachora maydis (causal agent of corn tar spot)*	Dean Malvick	#########	$153,312	$153,312	$0	Complete	$178,706	$25,394
MITPPC sub-project 10	Detecting hybrid barberry and investigating its role in rust epidemiology	*Berberis x ottawensis*	Pablo Olivera	#########	$195,735	$195,735	$0	Complete	$247,507	$51,772
MITPPC sub-project 11	Confronting soybean aphid with advanced plant breeding and remote sensing	*Aphis glycines*	Robert Koch	#########	$292,492	$292,492	$0	Complete	$295,593	$3,101
MITPPC sub-project 12	Expanding and Strengthening the Prioritization of Terrestrial Invasive Species in Minnesota	*Multiple plants, pests, and pathogens*	Amy Morey	#########	$151,601	$151,601	$0	Complete	$151,601	$0
Notes:	TOTAL				**$3,405,451**	**$3,405,451**	**$0**		**$3,499,998**	**$94,549**

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Robert Blanchette
Sub-project Title: MITPPC sub-project 1: Early detection of invasive tree pathogens using molecular tools for prevention and to mitigate damage
Organization: University of Minnesota
Project Budget: ~~$384,165~~ $383,865
Project Length and Completion Date: 4.5 years June 30, 2024
Current Date: August 2, 2024

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	**Total budget**
BUDGET ITEM	
Personnel (Wages and Benefits)	~~$316,965~~
PhD graduate student (56% salary, 8% benefits, 36% tuition)	
Benjamin Held 12 weeks salary for each year (75% salary, 25%	
Undergraduate Students (100% salary) January 2020 to December 2023. Students to work part time during the academic year and summer taking part in field sample collection and laboratory analyses ($6,000 per year)	
Equipment/Tools/Supplies	
$7450 per year for 4 years. Costs for cyclone spore traps and other trapping devises during the first year, spore collection materials, molecular primers, probes and reagents, petri dishes, culture containers, microbiology diagnostic reagents, sterile bags, pipettes and pipette tips, DNA extraction kits, autoclave bags, culture tubes and other	~~$42,032~~
Travel expenses in Minnesota	
$4600 per year for vehicle travel costs to set up spore samplers and collect samples in different areas of Minnesota and for meals and lodging that take more than one day to	~~$6,168~~
Other	
Lab services, sequencing costs and other molecular analyses	~~$19,000~~
COLUMN TOTAL	$384,165

Returned to reserve $300

Total budget

Revised budget [8-2-2024]	Amount Spent	Balance
$301,515	$301,515	$0
$68,745	$68,745	$0
$3,279	$3,279	$0
$10,326	$10,326	$0
$383,865	$383,865	$0

0.00

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Jeannine Cavender-Bares
Sub-Project Title: MITPPC sub-project 2: Accurate detection of oak wilt disease at
Organization: University of Minnesota
Project Budget: ~~$299,112~~ $301,941
Project Length and Completion Date: 3.5 years June 30, 2023

Current Date: August 2, 2024

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Revised budget [8-2-2024]	Amount Spent
BUDGET ITEM			
Personnel (Wages and Benefits)	~~$260,033~~	$262,858	$262,858
Postdoc: $160,397 (80.5% salary, 19.5% benefits); 100% FTE for years 1 & 2; 50% FTE for year 3			
Graduate Student: $16,722 (86.2% salary, 13.8% benefits); 12.5% FTE for years 1 &2 (summer only)			
Undergraduate Student:$18,730 (100% salary, 0% benefits); 19.3% FTE for years 1-3			
Lab Tech: $24,744 (77.3% salary, 22.7% benefits); 16.7% FTE years 1 & 2; 8.4% FTE year 3			
Professional/Technical/Service Contracts			
Tree removal by outside vendors	$5,791	$5,791	$5,791
Equipment/Tools/Supplies			
Field equipment: including but not limited to tree marking paint, nails, tags, flagging, binoculars, chainsaw and accessories, batteries, Spectralon panels that serve as white references, stepladders, coin envelopes and sample bags, and insect spray	~~$7,646~~	$7,650	$7,650
Capital Expenditures Over $5,000			
Sentera - 1 quant sensors ($8,500) & unmanned aerial vehicle with flight software ($8,500)	$17,574	$17,574	$17,574
Travel expenses in Minnesota			
Mileage for field trips per year for 1-2 people over 3 yrs	$0	$0	$0
Other			
Repairs/Maintenance to equipment	$8,068	$8,068	$8,068
Rental, equipment	$0	$0	$0
COLUMN TOTAL	$299,112	$301,941	$301,941

returned to reserve: $52

Balance
$0
$0
$0
$0
$0
$0
$0
$0
$0

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Ben Held
Sub-Project Title: MITPPC sub-project 3: Early detection of invasive tree pathogens using molecular tools for prevention and to mitigate damage
Organization: University of Minnesota
Project Budget: $233,924
Project Length and Completion Date: 3.5 years June 30, 2023
Current Date: August 31, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$209,205	$209,205	$0
Benjamin Held, Scientist; 12 weeks salary for each year (64% salary, 36% benefits) September 2019-			
Scientist (64% salary, 36% benefits) September 2019- August 2023, 0.15 FTE per year			
Scientist; 8 weeks salary for each year (64% salary, 36% benefits) September 2019- August 2023, 0.15			
Undergraduate Students (100% salary) January 1, 2018 to July 31, 2021. Students to work part time during the academic year and summer.			
Equipment/Tools/Supplies			
innoculation supplies, culture tubes, isolation tools, lab gloves, pots, gloves, etc	$13,242	$13,242	$0
Travel expenses in Minnesota			
Mileage expenses to collect scion material from surviving elms across MN	$2,061	$2,061	$0
Other			
Greenhouse and field plot maintenance costs	$9,416	$9,416	$0
COLUMN TOTAL	$233,924	$233,924	$0

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Joe Knight
Sub-Project Title: MITPPC sub-project 4: Detection and monitoring of invasive *Phragmites*
Organization: University of Minnesota
Project Budget: $203,781
Project Length and Completion Date: 3.5 years June 30, 2023
Current Date: August 31, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$201,664	$201,664	$0
P/A: $20,967 (73% salary, 26% fringe) .033 FTE for 3 yrs			
Graduate research assistant: $168,563 (55% salary, 36 % tuition, 9% fringe) 1 FTE for 3 yrs			
Professional/Technical/Service Contracts			
Remote sensing lab fee	$1,200	$1,200	$0
Travel expenses in Minnesota			
To/From Field sites 5 trips per year (750/trip hotel, mileage, per diem)	$917	$917	$0
COLUMN TOTAL	$203,781	$203,781	$0

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Rebecca Montgomery
Sub-Project Title: MITPPC sub-project 5: Improve invasive plant treatment efficacy using climate based phenology models
Organization: University of Minnesota
Project Budget: $346,211
Project Length and Completion Date: 3 years, June 30, 2023
Current Date: August 31, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Amount Spent
BUDGET ITEM		
Personnel (Wages and Benefits)	$317,891	$317,891
Faculty summer salary: $64,724 (73% salary, 26% fringe) Montgomery, 4% time = 40h		
Post-doc: $213,025 (74% salary, 36% fringe) 1 FTE for 3 yrs		
Undergraduates: $31,200 "Undergraduate Students ($15*20h/week*26 weeks in year 1 and 3 and 52 weeks in year 2)."		
Temporary/Casual: $12,984 (92% salary, 8 % fringe) over 3 yrs ($15/h * 40h/week * 10		
Equipment/Tools/Supplies		
Greenhouse and field supplies (bags, notebooks, planting supplies)	$2,002	$2,002
Field and documentary supplies (data loggers, cameras, laptop). A special request is made for a laptop for on-site, field data collection. Cooperators will be installing and tracking the growth and development of knotweeds and wildparsnip over time with field cameras (a contribution to this project). Imagery from the cameras and data from temperature/moisture data loggers will need to be downloaded in the field. These data are essential to provide consistent, reliable data on plant phenology and local weather conditions. When not being used for field-work, the same computer will be used for other project related work. The computer will be returned to MITPPC for future use after the project is completed.	$4,296	$4,296
Travel expenses in Minnesota		
Mileage, lodging, and per diem for 5 field trips per year for 1-2 people over 3 yrs	$2,796	$2,796
Other		
User fees for greenhouse and growth chamber access at the University of Minnesota over 3	$19,226	$19,226
COLUMN TOTAL	$346,211	$346,211

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Balance
$0
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Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Pablo Olivera
Sub-Project Title: MITPPC sub-project 6: Biology and biocontrol potential of a rust fungus infecting *Phalaris arundinacea* and *Frangula alnus*
Organization: University of Minnesota
Project Budget: $206,783
Project Length and Completion Date: 3.5 years June 30, 2023
Current Date: August 31, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$177,064	$177,064	$0
faculty: $15,345 (73% salary, 27% fringe) .05 FTE for 3yrs			
graduate student: $135,938 (55% salary, 34% tuition, 9% fringe) 1 FTE for 3			
undergraduate student (250 hrs/yr (10 hrs/wk from April to September) for 3 yrs			
Equipment/Tools/Supplies			
Internal transcribed spacer region sequence of rust isolates, full genome sequence of rust isolatesgreenhouse supplies, rust innoclulators, cryovials, trays and pots, labels, liquid nitrogen storage, microscopic slides and dyes	$17,504	$17,504	$0
Travel expenses in Minnesota			
Survey trips to assess distribution of pathogens in MN. 29 trips for 2 researchers. Includes mileage, perdiem, and lodging, $14,700	$4,039	$4,039	$0
Conference costs to present research results: $1800	$0	$0	$0
Other			
Greenhouse rental in Plant Growth Facility at the University of Minnesota	$6,241	$6,241	$0
Publication costs	$1,935	$1,935	$0
COLUMN TOTAL	$206,783	$206,783	$0

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet

Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Managers: Peter Reich
Sub-Project Title: MITPPC sub-project 7: Managing buckthorn with trees: diversity, density, and
Sub-Project Budget: $499,734
Project Length and Completion Date: 4.5 years June 30, 2024
Current Date: August 2, 2024

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
faculty, 1 week summer salary: $13,367 (73.57% salary, 26% fringe)
Post-doctoral associates: $ 381,140 (80.45% salary,19.54% fringe) 1.5 FTE, for 3.5 years
5-10 undergraduates: $37,492 (100% salary) @15/hr * 2,499 hrs/yr over 3.5 yrs
Professional/Technical/Service Contracts
For buckthorn removal and related site prep
Equipment/Tools/Supplies
seedlings and seeds, labels, sample bags, increment borers, plot tags, data sheets, data storage,
Travel expenses in Minnesota
From UMN Twin Cities campus to experimental field sites ≈80 miles round-trip, 0.58/mile,
COLUMN TOTAL

Total budget	Amount Spent	Balance
$450,143	$450,143	$0
$12,525	$12,525	$0
$24,610	$24,610	$0
$12,456	$12,456	$0
$499,734	$499,734	$0

0.00

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Ingrid Schneider
Sub-Project Title: MITPPC sub-project 8: Integrated emerald ash borer management: testing a novel approach to assess stakeholder perceptions
Organization: University of Minnesota
Project Budget: ~~$436,800~~ $436,072
Project Length and Completion Date: 3.5 yrs June 30, 2023
Current Date: August 2, 2024

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Revised budget [8-2-2024]
BUDGET ITEM		
Personnel (Wages and Benefits)	~~$375,775~~	$375,047
Faculty summer salary: $162,674 (74% salary, 26% fringe) .25 FTE for 3 yrs		
Professional staff: $27087 (84% salary, 16% fringe) .10 FTE for 3 yrs		
Graduate research assistant: $180,819 (62% salary,27% tuition, 10% fringe) 1		
Undergraduate 4 @ 15/hr x 20 hrs x 13 weeks + 1 10 hrsx13 weeks summer 1		
Professional/Technical/Service Contracts		
Video and AR production expenses	$38,220	$38,220
Project statistical support	$9,780	$9,780
Equipment/Tools/Supplies		
Facilitiation expenses, focus group incentives, and other incidental expenses,	$2,050	$2,050
Printing		
Article processing charges for publications to be open access	$721	$721
Travel expenses in Minnesota		
2 people per diem for 12 days. Hotel expenses for 6 nights. Focus groups	$10,254	$10,254
COLUMN TOTAL	$436,800	$436,072

Returned to reserve $ 13,928

Amount Spent	Balance
$375,047	$728
$38,220	$0
$9,780	$0
$2,050	$0
$721	$0
$10,254	$0
$436,072	$728

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Dean Malvick
Sub-Project Title: MITPPC sub-project 9: Distribution, Risks, and Management
Organization: University of Minnesota
Project Budget: ~~$152,707~~ $153,312
Project Length and Completion Date: 2.5 yrs June 30, 2023
Current Date: August 2, 2024

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Revised budget [8-2-2024]	Amount Spent	Balance
BUDGET ITEM				
Personnel (Wages and Benefits)				
P&A staff ($11,312 salary; $3,847 fringe) .1 FTE for 2years	$129,957	$129,957	$129,957	$0
Post doc ($99,772 salary; $25,345 fringe) 1 FTE for 2 years				
Undergraduate (ca. 750 hours @ $15.64/hour)				
Professional/Technical/Service Contracts				
Participant payments/fees for sample collecting (ca. 60 samples @ $40/sample) and genetic sequence analysis (ca. 80 samples @ $50/sample) Payments are meant to go to growers or other ag professionals for the time required for surveying suspect fields (estimated at 2 hour of survey effort @ $20/hour). Participants will be selected based on reports of symptoms that are consistent with the disease in a participant's field(s) and possibly a participant's proximity to previously reported infections. Malvick learned from his previous MITPPC project (on sudden death syndrome in soybeans) that few growers will submit samples for analysis without modest compensation for their time and effort. Malvick believes that the approach will be much more cost-efficient and safe (COVID) than driving to locations to collect samples	$765	$765	$765	$0
Equipment/Tools/Supplies				
Misc lab supplies (e.g., culture media, Petri dishes, Ehrlenmeyer flasks, DNA extraction kits, PCR reagents)	$9,031	$9,031	$9,031	$0
Travel expenses in Minnesota				
Scouting expenses around MN (ca. 13,000 miles @ $0.575/mile; 5 nights lodging @ $100/night)	~~$3,866~~	$4,157	$4,157	$0
Other				
Greenhouse fees (ca. $400/month for 17 months)	~~$9,088~~	$9,402	$9,402	$0

COLUMN TOTAL	$152,707	$153,312	$153,312	$0

Returned to reserve $25,394

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Pablo Olivera
Sub-Project Title: MITPPC sub-project 10: Detecting hybrid barberry and
Organization: University of Minnesota
Project Budget: $195,735
Project Length and Completion Date: 2.5 yrs June 30, 2023
Current Date: August 31, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)			
Faculty ($37,602 salary; $13,537 fringe) .25 FTE	$151,798	$151,798	$0
Post doc ($97,901 salary; $24,867 fringe) 1 FTE			
Undergraduate (250 hrs/yr * 2 years @ $16/hour)			
Professional/Technical/Service Contracts			
Genetic sequencing services (estimated 434 samples @ $50/sample)	$7,111	$7,111	$0
Equipment/Tools/Supplies			
Greenhouse, field survey, and molecular supplies (potting mix, plastic pots, mist chamber repair parts, coolers, loppers, DNA extraction kits, DNA prep kits)	$32,223	$32,223	$0
Travel expenses in Minnesota			
Field surveys, professional meeting presentation (ca 9,300 mi of travel @ $0.575/mi; 5 nights of lodging @ $100/night; $852 conference registration; 2 days of lodging and meals @ $200/day)	$2,957	$2,957	$0
Short Term rents			
Greenhouse fees (ca. $400/month for 10 months)	$1,646	$1,646	$0
COLUMN TOTAL	$195,735	$195,735	$0

Returned to reserve $51,772

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Robert Koch
Sub-Project Title: MITPPC sub-project 11: Confronting soybean aphid with
Organization: University of Minnesota
Project Budget: $292,492
Project Length and Completion Date: 2.5 yrs June 30, 2023
Current Date: August 31, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)			
Post doc ($207,919 salary; $52,811 fringe) 2 FTE for 2 yrs	$274,325	$274,325	$0
Undergraduate (750 hours @ $14.88/hour)			
Professional/Technical/Service Contracts			
Drone fees for scouting (Planned contract with Sentera)	$2,627	$2,627	$0
Equipment/Tools/Supplies			
Misc field supplies (2 years @ $2,000/year estimated for lithium batteries, soybean seed, flags, fine nylon mesh, & PVC tubing)	$379	$379	$0
Travel expenses in Minnesota			
Scouting and experiment travel around MN (ca. 11,500 mi. @ $0.575/mi; 4 nights lodging @ $400/night)	$3,513	$3,513	$0
Short rerm rents			
Greenhouse fee (17.5 months @ $400/month)	$11,648	$11,648	$0
COLUMN TOTAL	$292,492	$292,492	$0

Returned to reserve $3,101

Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 6a
Project Manager: Amy Morey
Sub-Project Title: MITPPC sub-project 12: Expanding and Strengthening the
Organization: University of Minnesota
Project Budget: $151,601
Project Length and Completion Date: 2 yrs June 30, 2023
Current Date: August 31, 2023

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Total Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)			
P&A ($82,250 salary; $29,610 benefits) .67 FTE for 2 years	$151,601	$151,601	$0
COLUMN TOTAL	$151,601	$151,601	$0