Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2015 Work Plan

Date of Report: July 30, 2019

Date of Next Status Update Report: January 30, 2020

Date of Work Plan Approval: June 25, 2015

Project Completion Date: August 15, 2023

Does this submission include an amendment request? YES

PROJECT TITLE: Minnesota Invasive Terrestrial Plants and Pests Center

Project Manager: Robert Venette

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Location: Statewide

Total Project Budget:	$5,000,000
Amount Spent:	$2,099,040
Balance:	$2,900,962

Legal Citation: M.L. 2015, Chp.76, Sec. 2, Subd. 6a

Appropriation Language:
$5,000,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the Invasive Terrestrial Plants and Pests Center established in Laws 2014, chapter 312, article 13, section 44, to conduct research to prevent, minimize, and mitigate the threats and impacts posed by invasive plants, pathogens, and pests to the state's prairies, forests, wetlands, and agricultural resources. This appropriation is available until June 30, 2023, by which time the project must be completed and final products delivered.

I PROJECT STATEMENT:

The Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC) will serve a lead role in terrestrial invasive species research – coordinating initiatives on prevention of establishment; early detection and rapid response; development of new control methods and technology; integrated pest management; and minimizing non-target impacts of control. The MITPPC mission is to offer science-based solutions to pest invasions that ensure the protection of Minnesota's healthy prairies, forests, wetlands and agricultural resources. The goal is to eliminate, reduce, mitigate and prevent the introduction, expansion, or damage caused by terrestrial invasive species in Minnesota.

The array of terrestrial invasive species (TIS) of high concern for Minnesota are numerous and diverse, and include invasive grasses, trees, shrubs, insects, earthworms, mammals, fungal pathogens, and other microbes. TIS impact every citizen in the State: emerald ash borer damages our forests and urban landscapes; weeds diminish the biodiversity of our prairies and wetlands; and pests and pathogens destroy fruit and grain harvests resulting in significant economic costs. The annual, combined economic impact of plant, animal, and microbial invasives in the U.S. is estimated at $134 billion (Agricultural and Resource Economic Review, 2006). Minnesota's share of this loss is estimated at $3 billion annually, which is typical of the 50 states.

The MITPPC will support priority research on TIS that pose the greatest threats to Minnesota and a take a comprehensive, planned, multi-disciplinary approach to addressing risk. The MITPPC research prioritization process and subsequent lines of research will involve researchers from multiple disciplines, and will address invasives affecting our prairies, forests, agricultural landscapes and wetlands in urban, developing and rural contexts. The Center will identify research priorities for TIS already established in Minnesota and for those that appear likely to arrive and do harm, and develop control methods, management strategies, and policy to achieve effective outcomes. The expert panel working group will establish priorities and present requests for proposals and work-plans to conduct research to address identified priority invasive species. Proposals will be sent out for peer review to ad hoc scientific reviewers in the field of research, which will allow for rapid turnaround of proposals to expedite work to be completed. The ad hoc scientific reviewers will make award recommendations. These specific initiatives selected and their budgets will be provided to LCCMR for review as the selections are made and the work progresses.

The Center will prioritize and support multiple projects by research teams comprised of faculty, students, and staff from one of 10 participating departments. UMN faculty will work with both graduate students and post-doctoral associates on any given project. The scope of each research project will likely vary by species addressed. With this funding, it is expected that over a six-year period the Center will conduct an estimated seven projects and train roughly 14 graduate students and postdocs.

The Center is administratively located in the College of Food, Agricultural and Natural Resource Sciences (CFANS) in coordination with the College of Biological Sciences (CBS). Participating departments within CFANS include Entomology, Plant Pathology, Forest Resources, Agronomy & Plant Genetics, Horticultural Science, Applied Economics, Fisheries, Wildlife and Conservation Biology, and Bioproducts and Biosystems Engineering. Participating departments within CBS include Plant Biology and Ecology, Evolution and Behavior. Additionally, research will be possible on CFANS' eight research and outreach centers located in diverse agro-ecological areas of the State.

II. OVERALL PROJECT STATUS UPDATE:

Amendment Request 1/31/16

Changes have been made to this document to align with amendments adopted into the ML 2014 workplan, including language regarding sub-project approval process, the prioritization process, and the document's internal budget table.

Amendment Approved: February 15, 2016

Project Status as of *January 31, 2016:*
There has been no activity yet under this appropriation. Details on the MITPPC's work to-date, including details of the prioritization process, may be found in the ML 2014 ENRTF workplan and sub-workplans.

Project Status as of *July 31, 2016:*
There has been no activity yet under this appropriation. Details on MITPPC's work to-date, including details of the prioritization process, may be found in the ML 2014 ENRTF workplan and sub-workplans. Funds in this account will be allocated to research projects in response to the Center's next request for proposals (to be issued in August 2016).

Amendment Request (1/30/2017)
We are requesting slight changes to the timeline under Activity 1. The change in dates is to accommodate a later than anticipated start date for the FY 17 RFP. Outcomes remain the same.
Amendment Approved February 6, 2017

Project Status as of *January 31, 2017*:

At its July 12-13, 2016 meeting, the LCCMR directed the MITPPC to fund two projects: "*Alliaria petiolata* biocontrol: ecological host range of biocontrol agents," by Dr. Roger Becker and "Mountain pine beetle, ph. II: protecting Minnesota," by Drs. Kevin Chase and Brian Aukema. Both garlic mustard (*Alliaria petiolata*) and mountain pine beetle were identified as priority species by MITPPC and the research addressed at least one critical theme. The MITPPC and LCCMR agreed that the proposals would undergo external review before final approval. External reviewers raised a number of substantive questions that led to improvements in the scope of work and research protocols for both projects. The review/revision process is complete for Dr. Becker's proposal on garlic mustard. A sub-project work plan is being developed as an amendment to this work plan for review and approval by LCCMR staff. Drs. Chase and Aukema's proposal received several comments; they are currently addressing those comments and modifying the scope of work accordingly. We anticipate that process to be complete within the next several weeks. Both of these projects will be funded from the ML 2015, Ch. 76, Sec. 2, Subd. 6a appropriation.

The FY 17 MITPPC's Request for Proposals was issued on August 4, 2016 and closed on September 30, 2016. The RFP was based upon the document, "Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research." The RFP directed applicants to frame their research in one of four research themes and at least one of the top 15 species from each taxa.

MITPPC received 19 pre-proposals with $7.5 million in requests. In addition, the two LCCMR-directed projects cited above requested $1.085 million in funding, for a total of approximately $8.6 million. The 19 proposals underwent internal review by a panel of University researchers, with an invitation to 12 principal investigators to submit full proposals. Those 12 proposals are currently under external review, with an expected decision being made by the middle of February, 2017.

Other details on MITPPC's work to-date may be found in the updates to the ML 2014 ENRTF workplan and sub-workplans.

Project Status as of *July 31, 2017:*
Eleven projects were funded from the ML 2015 appropriation, totaling $4.65 million. The projects' workplans were approved by LCCMR staff and sub-accounts are currently being established at the University of Minnesota. The projects are preparing their labs and hiring the necessary staff to accomplish their research goals. The funded research projects are listed under Activity 1 below.

Amendment Request 10/27/17
The MITPPC requests the addition of a research project to this appropriation's portfolio, "MITPPC #12: Developing robust identification assays for *Amaranthus palmeri* in seed mixtures." In response to the identification of Palmer amaranth in the state, the MITPPC was approached by the Minnesota Department of Agriculture to assist in the development of a Palmer amaranth mixed seed identification process. Dr. Donald Wyse, an agronomist with the University of Minnesota, working collaboratively with researchers in other parts of the country, have developed a research design that has the potential to be important safeguard for conservation seed mixes used for land restoration coming into Minnesota. The seed identification method will help to safeguard Minnesota's agricultural and natural resources from this dangerous terrestrial invasive plant.

Amendment approved November 9, 2017

Project Status as of January 31, 2018:
Research projects made progress over the last six months and have submitted individual workplan and budget updates, all of which have been approved. This suite of research projects reflect the legislative directive to address the state's most pressing terrestrial invasive species. The MITPPC continues to engage research project staff and land managers in meaningful discussion about the efficacy of the applied research and its ultimate application.

Project Status as of July 31, 2018:
MITPPC staff met with each subproject team. Research projects made progress over the last six months and have submitted individual workplan and budget updates, all of which have been approved by LCCMR. A synopsis of those projects follows in this document. Projects funded under this appropriation have a range of start dates, so the extent of progress varies considerably, as expected. Two accomplishments are particularly noteworthy. First, Mr. Jake Whitman is nearing the completion of his Master's degree with Dr. Brian Aukema (Subproject #9, Characterizing Dispersal of Larval Gypsy Moth to Improve Quarantine Regulations). Preliminary results indicate that larvae may crawl more than 100 m over bare soil. This distance is substantially farther than previous studies had suggested was likely. Second, Dr. Gigi DiGiacomo (applied economist working on Subproject #10, Management Strategies for Spotted Wing Drosophila) has completed a grower survey and preliminary results indicate that this invasive insect is causing an annual losses of $2-6 million annually for Minnesota raspberry producers. Pressures have increased substantially to use insecticides or risk going out of business.

Amendment Request 12/21/2018
The MITPPC has one minor adjustment to make to the dates of reporting, under this appropriation, as agreed to with LCCMR staff. The current dates, July 31 and January 31; the new dates are August 30 and February 28.

We request amendments to this overall work plan to reflect previously approved amendments to subproject work plans that were made since the last progress report. Here we summarize the date the amendment request was made, the nature of the amendment(s), and the official date of approval by LCCMR staff. Amendments are also reflected in the M.L. 2015 Project Budget – Overall Budget of Minnesota Invasive Terrestrial Plants and Pests Center. Modifications to that document are given the current date as projects were amended at various times through July 31, 2018. No amendments are requested beyond what has previously been approved by LCCMR staff. None of the modifications affect the Budget Reserve. Additional details about the amendments may be found in subproject reports.

Activity 1, Sub-project #1 Garlic Mustard Biocontrol: Ecological Host Range of Biocontrol Agents (Becker, project manager). Amendment request submitted (10/30/2018)- The Equipment/Tools/Supplies line item is increased by $428 (from $1,272 to $1,700) with a commensurate decrease in the travel line item (from $8,192 to $7,764). The reduction in travel is achieved through greater ride share to research sites with project cooperators or a one-day reduction in travel to meet with the Technical Advisory Group (preferred option). This request does not impact outcomes nor timeline of the research. Amendment request approved (11/9/2018).

Activity 1, Sub-project #3 Biological Control of the Soybean Aphid by *Aphelinus certus* (Heimpel, project manager). Amendment request submitted (11/3/2018)- Undergraduate labor is reduced in the personnel budget by $250 to compensate for a previously unnoticed typographical error that resulted in an underestimation of the travel budget by $250. This change lowered the Personnel budget from $479,096 to $478,846. Over the life of the project, the impact of this adjustment is negligible and will not affect timelines or outcomes. Amendment request approved (11/16/2018).

Activity 1, Sub-project #5 Optimizing Tree Injections against Emerald Ash Borer (Aukema, project manager). Amendment request submitted (1/19/2018)- The contract line item for azadiracthin treatments is reduced by $9,000 due to a change in vendors, and the supplies line item increases by $9,000 to achieve the same work. These changes do not affect the total budget, activity, nor the research outcomes. Amendment request approved (1/23/2018). It appears to be an oversight that the amendment was not included with the previous overall report for this project.

Activity 1, Sub-project #7 Tools to Distinguish Native from Exotic Reed Canary Grass (Anderson, project manager). Amendment request submitted (10/31/2018)- The equipment/tools/supply (E/T/S) line item is reduced from $61,070 to $31,070, a total of $30,000. A new budget line item for "Professional Services" is established for $30,000. The research team will use the service of a private lab to collect DNA sequences from reed canary grass more quickly and cost-effectively. The postdoc is redirected to devote more of his time to data analysis than data collection (no budget impact). This amendment will not impact outcomes nor timeline for the research project. Amendment request approved (11/9/2018).

Activity 1, Sub-project #8 Accurate Detection and Integrated Treatment of Oak Wilt (*Ceratocystic fagacearum*) in Minnesota (Cavender Bares, project manager). Amendment request submitted (11-2-2018)- a total of $12,500 is transferred from the Equipment/Tools/Supplies line item to the Professional/Technical/Service Contracts line item to correct an error in how the rental of field equipment was budgeted. This amendment request does not impact outcomes nor timelines of the research. Amendment request approved (11/9/2018).

Activity 1, Sub-project #9 Characterizing Dispersal of Larval Gypsy Moth to Improve Quarantine Regulations (Aukema, project manager). Amendment request submitted (11/02/2018)- A total of $307 is moved from capital expenditures (a reduction from $33,500 to $33,193) to Professional/Technical/Service Contracts (an increase from $1,500 to $1,807.) The costs associated with the servosphere were slightly less than anticipated. However, slightly greater use of the quarantine lab space was needed than originally anticipated to complete the work. This amendment zeros out the budget for this sub-project. Amendment request approved (11/16/2018).

Activity 1, Sub-project #10 Management Strategies for Spotted Wing Drosophila (Rogers, project manager). Amendment request submitted (11/01/2018) Professional and technical services are increased by $3,500 (from $40,000 to $43,500) and to decrease equipment and supplies by $3,500 (from $16,410 to $12,910). The need to construct and maintain high tunnels is less than originally estimated as the tunnels are proving to be sturdy. The adjustment directs funds for technical services for rental of a growth chamber for the project to maintain a year-round supply of live spotted wing drosophila for experiments. The team had anticipated using another current growth chamber, but it has become unavailable due to current heavy use by other research teams. Amendment request approved (11/09/2018).

Amendment Approved (1/24/19)

Project Status as of January 31, 2019:
The MITPPC research projects had an overall successful performance in the last six months. Prominent among the highlights was a strong showing of MITPPC research at the Joint Conference of the Upper Midwest Invasive Species Conference and the National Invasive Species Management Association held in Rochester, MN in

October 2018. Twenty-one research project team members made oral or poster presentations at the conference. The UMISC is the largest gathering of applied researchers and land managers in the upper Midwest. All materials presented by MITPPC research teams were branded and included proper attribution to the ENRTF. Once again, our colleagues from other states are impressed with Minnesota's commitment to terrestrial invasive species research.

Amendment Request (4/26/2019)

The MITPPC is requesting to add two projects to this appropriation. The first adds "Sub-Project 13, Terrestrial invasive species prioritization," led by Dr. Amy Morey to the suite of projects under this appropriation. This project will review and update "*Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research*," which has provided guidance on funding MITPPC research projects. This is a six month project will be staffed by a post-doctoral associate with Dr. Robert Venette's lab and is budgeted at $36,125

The second project is to co-fund a new research project with ML 2016 funds ("MITPPC 2016 Sub-project 7 Improved Detection and Future Management of Leafy Spurge and Common Tansy using Remote Sensing, Mechanistic Species Distribution Models, and Landscape Genomics " by Dr. David Moeller and Dr. Ryan Runquist.) Known as MITPPC 2015 Sub-Project 14 under this appropriation, $70,812 would be encumbered from the ML 2015 reserve. Research updates and results will be provided under both appropriations' workplans.

We are also requesting three minor budgetary amendments; the amendments alter allocations among sub-project budgetary line items but do not change the total amount allocated to each sub-project:

MITPPC #1. An amendment is requested due to unanticipated costs for getting and utilizing serpentine soil (respirators, trays, buckets, etc.); shipping containers for insects; additional field pots, trays, nursery modifications when moved to avoid viruses in stock; supplies to get growth chambers to meet project needs (lights, modifying data collectors, etc.).
Decreases salaries by $1200 from $509,971 to $508,771
Increases supplies by $1200 from $1,700 to $2,900.

MITPPC #10**.** An amendment is requested to cover higher than expected high tunnel expenses associated with the research project by decreasing salaries by $2,059 from $419,190 to $417,333 and increasing supplies and materials by $2,059 from $12,910 to $14,969. High tunnel experimentation is crucial to this research project.

MITPPC #12: An amendment is requested to cover slight overage in travel expenses associated with this research project.
Decreases professional services by $263 from $59,220 to $58,957
Increases travel by $263 from $2,230 to $2,493

We are also requesting minor modifications to the names of sub-projects 1 and 2. To each, we insert "MITPPC #1:" and "MITPPC #2:" where needed to maintain consistency with the naming of other sub-projects.

Lastly, pursuant to conversations with LCCMR staff, we are requesting revisions to the current and future reporting procedures to make the process as simple as possible and emphasize achievements of MITPPC-related projects while allowing LCCMR to ensure that the expenditures and outcomes described in the work plan for appropriations funded by the environment and natural resources trust fund are met. Specifically, this document will become the primary vehicle to describe research plans and report significant accomplishments of all sub-projects funded under this appropriation. Here will be found a brief overview of relevant MITPPC-related activities and a table with the current status of each sub-project. Each sub-project will be described with outcomes and activities with corresponding completion dates with enough detail to adequately convey what work is being conducted, why, and the projected impact. A budget for each sub-project will be attached to the overall work plan, however budgets for sub-projects will not report on sub-activities. Separate sub-project work plans will not be required. MITPPC will maintain copies of research addenda for each sub-project and make

them available to LCCMR staff upon request. Dissemination activity will be reported with each sub-project; and overall MITTPC dissemination will be reported in the overall dissemination section of the work plan. MITPPC and LCCMR staff tested these reporting procedures for one year (2018) with appropriation M.L. 2016, Chp. 186, Sec. 2, Subd. 06a. Both parties agreed that the new procedures were more effficient (approximately 85% reduction in adminstrative effort) and conveyed all necessary information.

Because this transition is occurring mid-way through the appropriation and individual work plans for subprojects #1-12 are already on hand, LCCMR and MITPPC have agreed that the very brief descriptions for these subprojects in this document suffice. However, as future subproject are added, additional context and description will be provided in the project description sections.

Amendment Approved (4/29/19)

Project Status as of July 31, 2019:
All sub-projects continue to make good progress. MITPPC staff met with research teams throughout May 2019 to review progress and discuss proposed modifications to research plans or budget allocations, including justifications for any proposed changes. Most projects were on-track to achieve outcomes as originally proposed. Research highlights are reported in the general update for Activity 1. Five sub-projects have made amendment requests.

Amendment Request (7/31/2019)
The MITPPC is requesting five amendments to this appropriation's research projects. Each is described below.

Sub-project 1:
The sub-project requests a decrease in personnel by $32,000 (from $508,771 to $476,771) and increase equipment by $2,000 (from $2,900 to $4,900) and professional services by $30,000 (from $80,565 to $112,565.). The increase in professional services is for an increase in usage fees from the biocontainment facility to accommodate the expansion of *C. constrictus* host range testing and the need to relocate to a make-shift greenhouse space during a renovation of greenhouse space that had been used by the project. The make-shift space is needed for the propagation of plants for host range testing. Additional equipment costs are needed for materials (seeds, soil, pots, fertilizer, etc.) to grow the plants. The project has been able to secure other funding to cover necessary personnel costs. There is no impact to outcomes nor timeline.

Sub-project 3:
This sub-project requests a decrease in professional and technical services by $1,000 (from $66,938 to $65,938) and create a line item for postage for $1,000. This request is due to a change in the nature of work with the Minnesota Department of Agriculture in which UMN will now pay for mailing postage. The Minnesota Department of Agriculture collects samples of soybean leaves with soybean aphids as they scout fields for other agricultural pests. The aphids are inspected at the University of Minnesota to determine the proportion of aphids that have been parasitized by *Aphelinus certus* around the state. In the past, MDA had shipped samples at their own expense, but the cost proved to be prohibitive.

Sub-project 7:
A request is made to amend the rationale, objectives, hypotheses and outcomes of Activity 2. We propose changing Activity 2 to "Collect additional reed canary grass (RCG) specimens from the transportation (highway) corridors and lakes across MN to identify the native vs. exotic status of populations". There would be no change to the budget or timeline of outcomes in Activity 2. The rationale for this change is based on the conclusions from the genetic analysis of RCG sampled from the University of Minnesota herbarium, forage and ornamental cultivars, rivers in MN and the Czech Republic (Activity 1). These results indicated that all RCG from MN rivers and native herbarium samples were a single, genetically-similar population distinct from European types. A native field of RCG from Roseau, MN also clustered these samples (except RCG from Roseau River). In addition, the current Roseau production fields where RCG varieties ('Palaton', 'Venture') are grown commercially and RCG

from the Roseau River are genetically distinct from the remaining MN river populations. Collectively, these results suggest that the vast majority of reed canary grass along MN rivers might qualify as native. At this point, the development of a hand-held device to distinguish between native and exotic RGC seems pointless for MN land managers. Consequently, our new objective for Activity 2 is to collect additional samples along transportation corridors (highways) and lakes to determine the genetic stature of these populations relative to the native MN river populations, using the same genetic markers from Activity 1. This additional work will demonstrate whether RCG populations along the major highways and major lakes are also native.

Sub-project 8:
A request is made to decrease professional and technical services $5,471 ($38,500 to $33,029) and increase equipment and supplies by $5,471(from $9,387 to $14,858). The contractor was able to remove infected trees as part of Activity 3 for less than originally estimated. Supplies (particular laboratory equipment to test for the presence of the oak wilt fungus and to prepare the fungus to inoculate trees) and equipment have proven more costly than originally estimated. Outcomes nor timelines are affected by this budgetary change.

Sub-project 11:
We request a minor budget amendment to decrease equipment/tools/materials line item by $2,600 (from $19,441 to $16,841) and create a new line item at $2,600 for "shipping, data services, plot use fee", to fund shipping services of supplies and samples for analysis; service fees to transmit data from continuous data sensors at remote field sites to central data storage and analysis facilities; and $275 research plot fee at U of M Rosemount Research and Outreach Center (ROC). These changes support the completion of work under Activity 1.

Project Status as of January 31, 2020:
Project Status as of July 31, 2020:
Project Status as of January 31, 2021:
Project Status as of July 31, 2021:
Project Status as of January 31, 2022:
Overall Project Outcomes and Results:

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Launch research on high priority, established terrestrial invasive species and rapid response for the prevention of establishment of new threats.

Description: By using funds from the 2014 General Fund appropriation, the MITPPC conducted a rapid prioritization in the spring of 2015 to identify immediate research needs among state agencies with primary responsibility for the management of terrestrial invasive plants and pests on public and private lands. Initial priority plants are species on the eradicate list, the control list, or the restricted noxious weed list as designated under Minnesota's noxious weed law, and initial priority pests were the brown marmorated stink bug (*Halyomorpha halys*) and oak wilt (caused by the fungal pathogen *Ceratocystis fagacearum*). Initial priority themes for research are:

- invasive species detection and distribution;
- invasive species response to climate change; and
- new approaches to management of invasive species.

These priorities were identified through a consultative process with eight representatives from the Minnesota Board of Water and Soil Resources, Minnesota Department of Agriculture, Minnesota Department of Natural Resources, and Minnesota Department of Transportation. Each agency had generated a list of several dozen potential research themes and topics. From these lists each agency self-selected their top four research priorities. MITPPC advised that a research topic should be considered a priority if it (i) would help the agency achieve its mission more effectively, (ii) would be of benefit to another agency (iii) could be supported by the agency financially or through in-kind contributions, and (iv) could be completed with the capacity at the

University of Minnesota. Agency priorities were vetted during a joint meeting on March 26, 2015. The initial prioritization was complete by April 15, 2015. The prioritization provided the basis for MITPPC's first request for proposals (RFP). After review by LCCMR staff, the RFP was issued on April 30, 2015. The complete request for proposals, including descriptions of priorities and the process by which projects will be selected, is attached as Appendix A to this work plan. The rapid prioritization and associated request for proposals will be used to allocate up to $1.2 million awarded to MITPPC though the M.L. 2014 ENRTF appropriation.

Eight pre-proposals were received on May 22, 2015. Those pre-proposals are currently being reviewed by a five member panel of University faculty who do not have a conflict of interest with the proposals submitted. Their evaluations will be used to determine which research teams will be invited to submit full proposals with the proposed or a modified scope of work. Full proposals will be reviewed by three experts outside of the University for scientific novelty and rigor. Funding recommendations will be reviewed by the Center Advisory Board. The intent is for initial projects funded under the M.L. 2014 ENRTF appropriation to begin by August 15, 2015.

A more expansive research prioritization was initiated in May 2015 to systematically evaluate threats posed by a wider array of terrestrial invasive plants, pathogens, and insects/arthropods than could be completed during the rapid prioritization. The more expansive prioritization will be used to allocate the remaining research funds from the M.L. 2014 ENRTF appropriation and the M.L. 2015 ENRTF appropriation. Twelve panelists were identified, six from the faculty at the University of Minnesota and six program managers with advanced degrees from partner agencies (Minnesota Departments of Natural Resources and Agriculture). In total, these panelists will identify 120 significant invasive plants, pathogens, or insects/arthropods that threaten Minnesota's agriculture, forests, wetlands, or prairies. An Analytical Hierarchy Process (AHP) will be used to rank these threats. AHP is a form of multi-criteria decision analysis that makes the process of selecting the highest priority threats consistent and transparent. AHP has been used by many agencies and organizations to facilitate complex decision making. In brief, the twelve member panel will engage in a facilitated discussion about criteria by which terrestrial invasive plants and pests should be considered a high threat (e.g., spread rate, reproductive rate, and impact potential) and the relative importance of each criterion. Each of the criteria will be applied to the 120 plants, pathogens, and insects/arthropods through reviews of the literature and consultations with relevant experts. National experts will be consulted to identify the greatest research needs for these priority taxa.

Upon the completion of the expansive research prioritization, the expert panel working group will establish priorities and present requests for proposals and work-plans to conduct research to address identified priority invasive species. Proposals will be sent out for peer review to ad hoc scientific reviewers in the field of research, which will allow for rapid turnaround of proposals to expedite work to be completed. The ad hoc scientific reviewers will make final award recommendations.

The Center will initiate and/or accelerate coordinated, applied research according to the prioritized list of pest and plant species that threaten Minnesota's prairies, urban and rural forests, wetlands, and agricultural resources as identified through this assessment process. Depending on the net impacts associated with each species, research may include new control methods including bio-control and technology, development of integrated pest management tools that minimize non-target impacts of control, early detection of and/or rapid response to new threats, and establishment prevention. The Center infrastructure is vital to improving Minnesota's capacity and response time to preventing and limiting introduction of new terrestrial invasive species. All research projects will include an analysis of any consequences related to the management of prioritized species to the State's non-target flora, fauna or our soils, water and climate.

Workforce development and training experts in invasive species management is also critical. A core component of each project will be funding of graduate students and postdoctoral associates to work with existing faculty.

Since University faculty are expected to acquire grants that cover their research salary, existing faculty are accounted for in the budget at 25% time in their role as the project leader. Providing salary through these awards

will secure faculty time and intellectual effort in the projects, assuring that we are attracting the resources to provide project design, effort, and mentoring of the graduate students and post-docs in their research development. We do not anticipate hiring any new faculty for the projects.

The Center will support multiple projects by research teams, each comprised of a UMN faculty member from one of the participating departments, one graduate student and one postdoctoral associate. Estimated funding per project will be $180,000-210,000 per year, for three to four years. We expect this to result approximately seven projects in two separate phases, depending upon the priority identified by the annual risk assessment planning. It is expected that per project expenses for established invasive species will be higher as compared to prevention strategies.

These selected proposals are to be considered sub-projects with respect to this work plan. Detailed sub-project work plans and budgets will be submitted to LCCMR for review and approval. The details about each sub-project work plan will be included as attachments to this document. Regular activity updates and budget updates will be provided by sub-project leaders and MITPPC to LCCMR. This overarching work plan and budget will be updated accordingly to include general progress of the Center and a synopsis of activities completed by each sub-project. The budget updates for this overall work plan will provide summaries of expenditures (by budget line item) for each sub-project. Detailed sub-project reports and associated budget updates will be prepared by investigators in cooperation with the MITPPC Director and Associate Director. MITPPC will provide LCCMR with updates to this overall work plan and each sub-project as a single packet.

Summary Budget Information for Activity 1: **ENRTF Budget: $5,000,000**

Activity Completion Date:

Outcome	Completion Date
1. RFP released for first phase of projects	August 4, 2016
2. First phase research projects selected and launched (est. 4 projects, ranging from 3-4 years each)	March 1, 2017
3. Second phase research projects selected and launched (est. 3 projects, ranging from 3-4 years each)	June 30, 2017
4. Research findings for first phase of projects	May 15, 2020
5. Research findings for second phase of projects	May 15, 2021

Activity Status as of *January 31, 2016:*
There has been no activity yet under this appropriation. Details on the MITPPC's work to-date may be found in the ML 2014 ENRTF workplan and sub-workplans.

Activity Status as of *July 31, 2016:*
There has been no activity yet under this appropriation. Details on MITPPC's work to-date, including details of the prioritization process, may be found in the ML 2015 ENRTF workplan and sub-workplans.

Activity Status as of *January 31, 2017*:
At its July 12-13, 2016 meeting, the LCCMR directed the MITPPC to fund two projects: "*Alliaria petiolata* biocontrol: ecological host range of biocontrol agents," by Dr. Roger Becker and "Mountain pine beetle, ph. II: protecting Minnesota," by Drs. Kevin Chase and Brian Aukema. Both garlic mustard (*Alliaria petiolata*) and mountain pine beetle were identified as priority species by MITPPC and the research addressed at least one critical theme. The MITPPC and LCCMR agreed that the proposals would undergo external review before final approval. External reviewers raised a number of substantive questions that led to improvements in the scope of work and research protocols for both projects. The review/revision process is complete for Dr. Becker's proposal on garlic mustard. A sub-project work plan is being developed as an amendment to this work plan for

review and approval by LCCMR staff. Drs. Chase and Aukema's proposal received several comments; they are currently addressing those comments and modifying the scope of work accordingly. We anticipate that process to be complete within the next several weeks. Both of these projects will be funded from the ML 2015, Ch. 76, Sec. 2, Subd. 6a appropriation.

The FY 17 MITPPC's Request for Proposals was issued on August 4, 2016 and closed on September 30, 2016. The RFP was based upon the document, "Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research." The RFP directed applicants to frame their research in one of four research themes and at least one of the top 15 species from each taxa.

MITPPC received 19 pre-proposals with $7.5 million in requests. In addition, the two LCCMR-directed projects cited above requested $1.085 million in funding, for a total of approximately $8.6 million. The 19 proposals underwent internal review by a panel of University researchers, with an invitation to 12 principal investigators to submit full proposals. Those 12 proposals are currently under external review, with an expected decision being made by the middle of February, 2017.

Other details on MITPPC's work to-date may be found in the updates to the ML 2014 ENRTF workplan and sub-workplans.

Activity Status as of July 31, 2017:
The eleven funded research projects are summarized in the table below and in the following sub-project descriptions.

Lead PI	**Research Project**	**Amount Funded**	**Species Addressed**
Becker	MITPPC #1: Garlic mustard biocontrol: Ecological host range of biocontrol agents	$600,000	*Alliaria petiolata,* garlic mustard, priority plant #15
Aukema	MITPPC # 2: Mountain pine beetle, Phase II: Protecting Minnesota	$456,000	*Dendroctonus ponderosae,* mountain pine beetle, priority insect #1
Heimpel	MITPPC #3: Biological control of the soybean aphid by *Aphelinus certus*	$600,000	*Aphis glycines,* soybean aphid, priority insect #3
Koch	MITPPC #4: Decreasing environmental impacts of soybean aphid management	$570,000	*Aphis glycines,* soybean aphid, priority insect #3
Aukema	MITPPC #5 Optimizing tree injections against emerald ash borer	$320,000	*Agrilus planipennis,* emerald ash borer, priority insect #2
Malvick	MITPPC #6: Distribution and traits of the fungal pathogen *Fusarium virguliforme* that influence current and future risk to soybean and other legumes in Minnesota	$412,000	*Fusarium virguliforme,* soybean sudden death, priority pathogen #13
Anderson	MITPPC # 7 Tools to distinguish native from exotic reed canary grass	$268,000	*Phalaris arundinacea*, reed canary grass, priority plant #12
Cavender-Bares	MITPCC #8: Accurate detection and integrated treatment of oak wilt (*Ceratocystis fagacearum)* in Minnesota	$357,420	*Ceratocystis fagacearum*, oak wilt, priority pathogen #2
Aukema	MITPPC #9 Characterizing dispersal of larval gypsy moth to improve quarantine regulations	$35,000	*Lymantria dispar,* European gypsy moth, priority insect #5

Rogers	MITPPC # 10: Management strategies for the invasive spotted wing drosophila	$505,000	*Drosophila suzukii,* Spotted Wing Drosophila, priority insect #13
Reich	MITPPC #11: Will future weather favor Minnesota's woody invaders?	$526,000	*Lonicera morrowii,* Morrow's honeysuckle, priority plant #3; *Frangula alnus,* glossy buckthorn, priority plant #4*; Lonicera tatarica,* Tatarian honeysuckle, priority plant #6*, Rhamnus cathartica,* European buckthorn, priority plant #7
	Total allocated	**$4,649,420**	

Activity Status as of January 31, 2018:
With the addition of sub-project 12, Developing Robust Identification Assays for Amaranthus palmeri in Seed Mixtures ($208,230), the portfolio of research projects under this appropriation is near completion. A small balance will be held for unforeseen contingencies and/or for funding of smaller research projects. All research projects are underway with staff hired and laboratories prepared. Individual research progress can be found in each sub-project workplan.

Activity Status as of July 31, 2018:
Each of the twelve research projects made significant progress over the reporting period. The activities and outcomes can be found within the individual project descriptions below.

Activity Status as of January 31, 2019:
Each of the twelve research projects made significant progress over the reporting period. Notable accomplishments include: 1) US Fish and Wildlife Service initiated formal review of petition to release biological control agents for garlic mustard; 2) The parasitic wasp, *Aphelinus certus*, was found to be keeping soybean aphid below economically-damaging levels in 10% of soybean fields in Minnesota, and options to increase the number of fields that benefit have been identified; 3) the first soybean line adapted to Minnesota growing conditions with resistance to soybean aphid was made commercially available, more lines will soon follow; 4) the pathogen that causes soybean sudden death was found to be more widely distributed in Minnesota than previously known; 4) studies with a servosphere showed that gypsy moth larvae can walk more than 100 ft over bare ground, raising concerns over the effectiveness of some current safeguards to prevent gypsy moth movement; 5) an economic analysis showed that spotted wing drosophila is costing Minnesota raspberry producers more than $2 million annually and has dramatically increased insecticide use on this high-value commodity. Additional activities and outcomes can be found within the individual project descriptions below.

Activity Status as of July 31, 2019:
All projects have made good to excellent progress towards completing stated outcomes. Notable accomplishments include: [from sub-project 3; Heimpel (Project Manager); biological control of soybean aphid] Activity 2 is now complete. A publication from this project by James Miksanek and George Heimpel in the journal *PLoS One* reports that only 11% parasitism of soybean aphid by the parasitoid *Aphelinus certus* (no common name) is needed to keep populations of soybean aphid in check. *Aphelinus certus* must arrive within 1 month of the arrival of soybean aphid to be effective. Cool summer temperatures improve the performance of

A. certus. [from sub-project 6; Malvick (Project Manager); distribution and activity of soybean sudden death]Analysis of soil samples collected in the fall of 2018 demonstrate that the fungus that causes soybean sudden death is more widely distributed in the state than previously thought. [from sub-project 7; Anderson (Project Manager); genetic testing to distinguish native from invasive reed canarygrass] Preliminary analysis of over 2,000 plant samples collected from herbaria, all major river systems in Minnesota, previously collected plants from the Czech Republic; and a production field near Roseau, MN reveal unexpectedly similar genetic profiles from most samples in the state. (Samples from the Czech Republic were different.) These surprising results raise the possibility that much of the reed canarygrass within the state might actually be native. Additional testing from lakes and roadsides (where mixing of seeds might be more limited than along rivers) is proposed to confirm this result. [from sub-project 12; Wyse (Project Manager); genetic test to identify Palmer amaranth seeds] A testing protocol has been developed that has proven more than 99% accurate. In several hundred test cases, the protocol always correctly identified Palmer amaranth and in <1% of cases, incorrectly classified other *Amaranth* species as Palmer.

Activity Status as of January 31, 2020:
Activity Status as of July 31, 2020:
Activity Status as of January 31, 2021:
Activity Status as of July 31, 2021:
Activity Status as of January 31, 2022:

Activity 1 Sub-Projects

Sub-project 1: MITPPC #1: Garlic mustard biocontrol: Ecological host range of biocontrol agents
Project Manager: Roger Becker
Description: The project's goal is to implement a novel technique to achieve long-term sustainable management of *A. petiolata* by developing a biological control program.

Summary of budget information for sub-project 1 **ENRTF budget**: $600,000

Sub-Project 1

Outcomes, Activity 1	**Completion date**
1. Determine the impact of *C. scrobicollis* feeding, oviposition and larval development on key native plants, with specific studies on the interaction of serpentine soils with *S. glandulosus* spp. *niger* specificity and effects on garlic mustard.	December 31, 2020
2. Find upper and lower development and oviposition threshold for *C. scrobicollis,* the effect of temperature and photoperiod on *C. scrobicollis* diapause, and determine date of flowering and chill units, and vernalization requirements for garlic mustard across North America.	December 31, 2019
Outcomes, Activity 2	
1. Complete host range testing for seed-feeder, *C. constrictus.*	December 31, 2020
2. Use a Species Distribution model to predict the potential distribution of *C. scrobicollis* and *C. constrictus* in North America and develop a composite model using development parameters from Activity 1.	December 31, 2020

Outcomes, Activity 3	
1. Develop and verify a new methodology for monitoring garlic mustard populations.	December 31, 2020

Sub-Project Status as of June 30, 2017:
Seeds have been obtained and plants grown in preparation for the initiation of experiments with *C. scrobicollis* in fall of 2017 and *C. constrictus* in the spring of 2018. Tests for each weevil require phenology of the insects and the unique phenology of each test plant species be in synchrony to permit valid tests. The test plant colonies had been reduced in size and scope due to lack of funding when the project was not funded in the initial MITPPC RFP, and work is underway to re-establish test plant materials. Initial *C. scrobicollis* release sites are being selected for subsequent garlic mustard monitoring. A permit to APHIS PPQ was submitted on April 1, 2017 requesting approval to release *C. scrobicollis*, which begins the process of review by USFWS. We have established contacts with key individuals in USFWS to begin the process to gain approval by USFWS.

Sub-Project Status as of January 30, 2018
The invasive garlic mustard (*Alliaria petiolata*) is present in 37 states and 6 Canadian provinces. The long-term goal of this project is to develop a biological control program with two weevils, *Ceutorhynchus scrobicollis* and *C. constrictus*. To date, we have rebuilt the test plant and insect agent capacities for testing, and have determined the steps necessary to synchronize the phenology of the insects with the unique phenology of each test plant species to be able to conduct valid tests. We received a recommendation for release of *C. scrobicollis* in February 2017 from APHIS PPQ TAG, and now have begun the next step to gain approval by USFWS. Towards that end, single-choice larval development, oviposition and impact tests with *C. scrobicollis* are in progress or have been completed for *Lepidium barnebyanum* and *Nasturtium gambelii.* To improve host range prediction for garlic mustard, we are determining the chill units required for vernalization. Seeds have been obtained and plants grown in preparation for the continuation of host range experiments with *C. constrictus* in the spring of 2018. EDDMapS and ISM Track have been used to map five of the long-term monitoring sites as part of the effort to find alternatives to permanent transects to characterize garlic mustard populations on the landscape. Cooperators with CABI in Delémont Switzerland have shipped insects collected near Berlin Germany this fall for specificity testing and to rebuild colonies at our U of M containment facility.

Sub-project Status as of July 30, 2018
The project is on track to meet deadlines and achieve our goals. Budget expenditures are on target, with considerable expenditures through June 2018 still pending in the system. We are preparing a response to APHIS PPQ and USFWS in a preliminary round of questions and clarifications of non-target effects and potential impacts. APHIS will then prepare a Biological Assessment and send to USFWS to begin their review of the petition to release *Ceutorhynchus scrobicollis*. Trials to define impacts of *C. scrobicollis* on native *Nasturtium gambelii* and *Lepidium barnebyanum* were completed. Progress has been made to characterize the Henneke serpentine soil to determine the effect of heavy metals on *C. scrobicollis* herbivory. The vernalization study is being repeated due to viral contamination of the garlic mustard test plants. *C. constrictus* testing continues to complete the test plant list in preparation for submitting the 1st petition to APHIS PPQ TAG to release *C. constrictus* for biological control of garlic mustard. The oviposition temperature thresholds have been determined for *C. scrobicollis*. Tests to determine if weevils acclimate to lower temperatures to oviposit are underway. Progress has been made on collecting distribution data of *C. scrobicollis* and *C. constrictus* in Europe. A trial to determine the labor and sample design needed to characterize garlic mustard has been completed, populations of garlic mustard mapped at five long-term monitoring sites, and the June data collected on all 10 of the 12 original sites that remain to cap the multiple years of data collection. These sites will be left in place, but annual data collection on all will no longer occur.

Sub-project Status as of January 31, 2019
A key regulatory milestone was achieved in that we submitted a response to the USFWS pre-Biological Assessment questions to begin the official USFWS review of our petition. We presented information at The International Symposium on the Biological Control of Weeds. Engelberg, Switzerland, The Upper Midwest

Invasive Species Conference, Rochester MN, and at the North Central Weed Science Society meeting, Milwaukee, WI. We had voucher specimens accepted at the Canadian National Collection of Insects, Arachnids and Nematodes; the Beaty Centre for Species Discovery, Canadian Museum of Nature; the Systematic Entomology Laboratory, Smithsonian Institution, Washington DC; and at the Instituto de Biología UNAM, Departamento de Zoologia, Ciudad Universitaria, México. The effect of heavy metals on herbivory and insect behavior on *Streptanthus glandulosus* subsp. *niger* grown on a Henneke serpentine soil is in progress. The first successful round of vernalization trials to improve understanding of garlic mustard biology and potential distribution is almost complete. Host specificity of *C. constrictus* has been completed on an additional 5 species with no eggs found in developing seeds of any species. The first version of a model under development for predicting temporal population interactions between garlic mustard and biocontrol agent(s) prior release was published through the Python Package Index (PyPI): https://pypi.org/project/generations/. Preliminary indications from a non-permanent belt transect sampling array at four sites characterized the difficulty in accurately characterizing garlic mustard populations on the landscape.

Status as of July 31, 2019:
Our permit request to release *C. scrobicollis* in the U.S. is no. 4 on the docket for the USDA APHIS Biological Assessment. Meanwhile, work continues on *Streptanthus glandulosus* subsp. *niger* and potential bridge species, unresolved questions underlying this assessment. Single-choice development tests with *S. glandulosus* subsp. *niger* are near completion and we will begin an impact study on this species grown in serpentine soil. We will determine the potential for multi-generational development on *T. arvense* and *R. sinuata,* considered potential bridge species by some in APHIS ending our efforts on *C. scrobicollis* specificity testing. Four months since initiation, F1 *C. scrobicollis* weevils are emerging from 15°C plants and 5°C plants in development tests, dissertation research to determine biological limits of *C. scrobicollis*. More weevil emergence is expected throughout the summer. The repeat of the vernalization experiment continues to inform improved predicted host range of garlic mustard. We have propagated native Brassicaceae test plants and representative species from other families to continue *C. constrictus* host range testing. An interface for a climate matching algorithm was set up at url: https://alfalimajuliett.shinyapps.io/climatematchapp/ Currently this application runs on the Bioclim algorithm but will host proposed climate suitability models as they are being developed. Permits have been acquired for a second year belt-transect sampling to determine methodologies appropriate to characterize garlic mustard on the landscape. The first fail-safe system failure in Facility 113 devastated our *C. scrobicollis* colony, impacts of which are still being determined.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Final Report Summary:

Sub-Project 2: MITPPC #2: Mountain pine beetle, phase II: Protecting Minnesota
Project Manager: Brian Aukema
Description: This research will focus on characterizing immigration risk of the mountain pine beetle to Minnesota from proximate pine refugia and determine the susceptibility of living pines in Minnesota to adult beetles and their fungal associates.

Summary of budget information for sub-project 2 **ENRTF budget:** $456,000

Outcomes, Activity 1	Completion date
1. Four years of mountain pine beetle detection survey completed in Minnesota	October 31, 2020

2. New recommendations available for chemical lure(s) to attract mountain pine beetle	October 31, 2019
3. Determine levels and identity of insect predators and competitors in Minnesota (and nearby states) that may (not) interfere with mountain pine beetle invasion	November 30, 2020
4. Determine distance mountain pine beetles might be carried by wind	November 30, 2020
5. Determine proximity of mountain pine beetle to Minnesota and identify new possible pathways for introduction	November 30, 2020
Outcomes, Activity 2	
1. Determine chemical response(s) of trees to infection and assess whether the identity and concentration of compounds might deter mountain pine beetle	April 31, 2021
2. Determine ability of live trees to survive attack by the fungus carried by mountain pine beetle	March 31, 2021
Outcomes, Activity 3	
1. Determine densities of *Ips gradicollis* needed to outcompete mountain pine beetle	March 31, 2021
2. Recommendations provided to increase biotic resistance against mountain pine beetle	May 31, 2021

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
Mountain pine beetle is an aggressive bark beetle that remains the biggest threat to pines of Minnesota, as epidemic population levels can colonize and kill mature pines. In April of 2017, we installed bark beetle traps in six sites across Minnesota, South Dakota and Nebraska. Each site contained five traps. Traps were baited with a variety of bark beetle pheromones to survey the species present in each state. Characterizing the insect complex is important to understand how populations of mountain pine beetle rise and fall, as mountain pine beetles in western North America depend on trees colonized by other bark beetles to persist during non-epidemic periods. The trapping arrangements included twelve traps baited with pheromones of the mountain pine beetle. In addition, we installed three traps around International Falls in concert with cooperators at APHIS, and installed seven traps between Grand Rapids, MN and Bemidji, MN in concert with cooperators at the DNR, to detect mountain pine beetle. The summer of 2017 was spent collecting insects from these traps every two weeks. In the fall, we began sorting and identifying the collections. To date, we have not detected mountain pine beetle in Minnesota, although populations continued to look robust in the Black Hills of South Dakota, the western most native range for this insect.

Sub-project Status as of July 30, 2018
Mountain pine beetle is an aggressive bark beetle that remains the biggest threat to pines of Minnesota, as epidemic population levels can colonize and kill mature pines. In April of 2017, we installed bark beetle traps in six sites across Minnesota, South Dakota and Nebraska. Each site contained five traps. Traps were baited with a variety of bark beetle pheromones to survey the species present in each state. Characterizing the insect complex is important to understand how populations of mountain pine beetle rise and fall, as mountain pine beetles in western North America depend on trees colonized by other bark beetles to persist during non-epidemic periods. The trapping arrangements included twelve traps baited with pheromones of the mountain pine beetle. Through the winter, we sorted and identified insects from the biweekly collections. Although we

collected a robust suite of bark beetles as well as various competitors and natural enemies, we did not detect mountain pine beetle in Minnesota or Nebraska. Moreover, we did not capture mountain pine beetles in the sampling transects emanating from the Black Hills of South Dakota, even though we did detect localized pockets of outbreaking populations of mountain pine beetle in the Black Hills in the summer of 2017. We have begun repeating sampling for 2018.

Sub-project Status as of January 31, 2019
All activities of this project went well this past summer, despite a major obstacle. The postdoc recruited as the lead personnel was unexpectedly invited to apply for a national lead position with a well-known tree care company. Dr. Chase accepted the position and departed the University of Minnesota in August. We are always thrilled when project personnel are recognized for their expertise, but the departure created some challenges maintaining all experiments in three states in late summer. Nonetheless, we completed all tasks as planned. We are now sorting through trap captures from transects testing new lures and the likelihood of long-distance dispersal from the Black Hills of South Dakota. Although we are still identifying species, it appears that no mountain pine beetles were captured in Minnesota this summer. We recruited a graduate student to undertake experiments in Aim 3, examining the basis for competitive interactions between bark beetles native to Minnesota and mountain pine beetle. These experiments are now underway. Two posters/updates on this project were presented to resource managers at the Upper Midwest Invasive Species Conference in Rochester, MN in October.

Status as of July 31, 2019:
All activities of this project continue to go well although we continue to negotiate the unexpected transition of Dr. Kevin Chase to industry. We have finished sorting through the trap captures from summer 2018 experiments testing new lures for mountain pine beetle and examining long-distance dispersal from nearest sources of mountain pine beetle, the Black Hills of South Dakota, towards Minnesota. We did not capture mountain pine beetles in Minnesota in summer 2018, and numbers of mountain pine beetles in the Black Hills of South Dakota were down slightly from 2017 levels. The new graduate student recruited to lead Aim 3, examining the basis for competitive interactions between bark beetles native to Minnesota and mountain pine beetle, analyzed his first experiment examining how bark beetles native to Minnesota respond to pheromones of mountain pine beetle and presented the results at the spring Western Forest Insect Work Conference.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Status as of July 31, 2021:
Final Report Summary:

Sub-Project 3: MITPPC #3: Biological control of the soybean aphid by *Aphelinus certus*
Project Manager: George Heimpel
Description: The goal of this research is to understand the extent to which *A. certus* is suppressing soybean aphid populations throughout the state and the extent to which it reduces pesticide use.

Summary of budget information for sub-project 3 **ENRTF budget:** $600,000
Sub-Project 3

Outcomes, Activity 1	**Completion date**
1. Determination of in-field efficacy of *A. certus* in suppressing soybean aphids	December 31, 2019
2. Estimation of reduction in insecticide use attributable to *A. certus*	December 31, 2019
Outcomes, Activity 2	

1. Detailed characterization of life-history of *A. certus* complete with an emphasis on characters that affect efficacy	December 31, 2018
2. Estimates of the level of parasitism needed to suppress soybean aphid by *A. certus*	December 31, 2018
Outcomes, Activity 3	
1. Maps of soybean aphid density and *A. certus* prevalence throughout the state	December 31, 2020
2. Determine the relationship between aphid abundance and *A. certus* parasitism rate	December 31,2020
Outcomes, Activity 4	
1. Site-specific information on overwintering success is available	March 31, 2021
2. Determine where soybean aphid parasitoids are overwintering	December 31, 2020

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018**:**
Aphelinus certus is an Asian parasitoid wasp that was discovered attacking soybean aphids in Pennsylvania in 2005 and was first found in Minnesota in 2011. This species was not intentionally introduced and indeed, had been previously been deemed ecologically risky due to its ability to attack numerous aphid species, including species native to North America. Despite this risk to native aphids however, *A. certus* has the potential to deliver significant benefits by attacking the soybean aphid, which is also native to Asia. We have been monitoring this parasitoid since its arrival in Minnesota and have found that it is now widespread throughout the soybean-growing areas of the state, although it appears to be less prevalent in Southeastern Minnesota. It is now by far the dominant parasitoid of soybean aphid, having outpaced the native *Lysiphlebus testaceipes* and other introduced parasitoids that were sometimes found attacking soybean aphid.
Our main objective with the MITPPC award is to determine to what extent *Aphelinus certus* is suppressing soybean aphid populations and also whether farmers can utilize knowledge of the prevalence of this parasitoid in their fields to reduce foliar insecticide applications. We are addressing these questions with a combination of field experiments, laboratory studies and mathematical modeling. So far these studies show that *A. certus* is capable of suppressing soybean aphids but that this does not happen in every field. Indeed, soybean aphid outbreaks have occurred since the establishment of *A. certus*, including in North-western Minnesota in 2017. However, the levels of parasitism found in many parts of the state indicate that suppression is occurring and that a substantial acreage does not need to sprayed due to the arrival of this biological control agent.
As this project continues, we will be better able to identify under what conditions suppression is likely to occur and we hope to provide usable guidelines to farmers so that they can use information on this parasitoid to optimize their pest management practices. This should lead to increased profitability as well as increased environmental protection from reduced foliar insecticide applications. This latter benefit is particularly critical since prairie habitats adjacent to soybean fields support endangered species of butterflies that are at risk of being impacted by foliar insecticide applications. In an extension of this work we will also determine the actual risk that *A. certus* poses to native aphid species in prairies adjacent to soybean fields. Thus, our aim is to provide a relatively comprehensive picture of the beneficial and detrimental effects of the accidental invasion of this aphid parasitoid to agricultural and natural landscapes of Minnesota.

Sub-project Status as of July 30, 2018
We plan to establish cages at an additional 5 sites for the 2018 field season (Obj. 1) and we are also planning further statewide sampling of soybean aphid (Obj. 3). Further laboratory studies have been done that show that *A. certus* females can parasitize over 300 soybean aphid over their lifetime (Obj. 2). These studies also showed

that of *A. certus* encounters less than one aphid per day they are not able to live more than a few days. The outcome of the 2017-2018 overwintering studies are now being analyzed – they show that *A. certus* are able to overwinter within soybean fields as well as within woodlots (Obj. 4). We also completed laboratory cold-tolerance studies on *A. certus* over this time period, obtaining data on both super cooling points and on lower lethal temperatures.

Sub-project Status as of January 31, 2019
We completed three field experiments evaluating the ability of the parasitoid *Aphelinus certus* to control soybean aphids during the summer of 2018 in various parts of Minnesota. Parasitism rates in these studies were relatively low and so the experiments did not reveal strong effects of *A. certus*. To complement these studies we have finalized analyses of a mathematical model of soybean aphid – *A. certus* interactions that incorporates information from our own studies and the scientific literature. This model suggests that *A. certus* is currently suppressing soybean aphids to below the economic (spray) threshold in about 10% of Minnesota fields, which is consistent with our aggregated field results. The model also suggests that improvements in overwintering survival of and/or increased lifespan of *A. certus* could greatly improve aphid suppression. We believe that of these two factors, improvement of overwintering survival is achievable based on previous results showing that survival of the parasitoids in the leaf litter of no-till soybean fields can be high. Overwintering survival in tilled fields may be lower and this could reduce parasitoid impact statewide since most soybeans fields in Minnesota are tilled. Our current and future studies on overwintering of *A. certus* will focus on conditions that favor survival including differences in tillage practice. The results of our studies were shared in a number of forums during the second half of 2018 including the Upper Midwest Invasive Species Conference, a workshop of the International Organization of Biological Control and a meeting of the Entomological Society of America.

Status as of July 31, 2019:
Although no empirical progress was made on objective 1 (field cage studies) over the winter months, the population model prepared by James Miksanek (Ph. D student) relating *A. certus* to soybean aphid has been completed and parameterized with laboratory data on host-stage preference, post-parasitism reproduction and other aspects of parasitoid biology. The model suggests that *A. certus* makes insecticide applications unnecessary on 10% of soybean aphid fields, given the recommended spray threshold of 250 aphids per plant. A paper describing this model and its outcome has now been published in the journal *PLoS One*, and these activities complete objective 2 of the proposal. A second study completed by J. Miksanek shows that *A. certus* has increased lifespan when aphid densities are higher and also develops a parasitoid age-grading technique. Statewide surveys for soybean aphid and parasitoids (Obj. 3) did not take place over the winter, but laboratory studies on a hyperparasitoids species that had been found during previous surveys were completed by Jonathan Dregni (technician) over this period. These studies showed that the *A. certus* hyperparasitoid *Alloxysta brevis* is unisexual (i.e., only females are produced) and that this unisexuality is caused by an endosymbiotic bacterium. Progress on our understanding of *A. certus* overwintering (Obj. 4) included determination of an insulating effect of snow cover in likely overwintering sites (soybean fields and buckthorn patches) and studies comparing developmental times and milestones of diapausing and non-diapausing *A. certus*. These and related studies are being done by Dr. Carl Stenoien (Post-doc).

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Status as of July 31, 2021:
Final Report Summary:

Sub-Project 4: MITPPC #4: Decreasing environmental impacts of soybean aphid management
Project Manager: Robert Koch

Description: The goal of the research is to decrease insecticide use and ameliorate associated environmental impacts through development of aphid-resistant soybean varieties and avoid unnecessary insecticide use through remote sensing.

Summary of budget information for sub-project 4 **ENRTF budget:** $570,000

Sub-Project 4

Outcomes, Activity 1	**Completion date**
1. Seed for well-adapted aphid-resistant varieties carrying *Rag1* or *Rag2* is available to growers.	October 31, 2019
2. Ability to screen plants for *Rag3* and *Rag4* resistance using molecular markers.	January 31, 2019
3. Seed of breeding lines pyramided with *Rag1*, *Rag2*, *Rag3*, *Rag4* ready for yield testing.	August 31, 2021
4. Determination of variability of soybean aphid biotypes at different landscape levels in Minnesota.	July 31, 2021
Outcomes, Activity 2	
1. Identify spectral and/or thermal indices that are likely to be optimal for detection of soybean aphid	October 31, 2019
2. Develop remote scouting tools to estimate aphid densities from spectral and/or thermal indices and plant, field, and landscape factors	December 31, 2020
3. Validate remote scouting tools.	August 31, 2021
Outcomes, Activity 3	
1. Identify Real Time Kinematic GPS technologies that are suitable for ultra-high precision mapping with small UAS.	September 30, 2018
2. Develop hardware and software which gives small UAS the capability to perform aerial scouting for soybean aphids. Integrate hardware and software into prototype small UAS.	September 30, 2020
3. Hardware and software performance validated in field tests.	August 31, 2021

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
During this reporting period, we initiated efforts on all project activities by hiring qualified staff (i.e., post-docs and students) and beginning experiments. For development of aphid resistant soybean varieties, efforts are well underway to increase the availability to growers of well-adapted aphid resistant varieties, to develop pyramided soybean lines with multiple resistance (Rag) genes, and to refine methodology for assessing the diversity of virulent aphid biotypes in Minnesota. For biological assessment of remote sensing for soybean aphid scouting, an experiment at three locations was successfully carried by creating gradients of soybean aphid pressure in research plots and collecting visible, near-infrared, and thermal-infrared spectral data from those plots. For technological assessment of remote sensing for soybean aphid, a test of the current state of art of RTK/GPS technology (precise GPS positioning systems) was performed, results indicate that off-the-shelf technology does not meet the accuracy requirements of sub-centimeter accuracy necessary for direct geo-referencing. Communication among project partners has been effective and generally carried out via email and in-person meetings.

Sub-Project Status as of July 30, 2018
During this reporting period, progress has been made on all activities. For Activity 1, soybean lines confirmed to carry aphid resistance genes continue to advance through the soybean breeding pipeline. One aphid-resistant soybean variety M10-218053 has been licensed to Albert Lea Seeds as an early-maturity variety for organic production. In addition, seed from thirteen populations of soybean that were developed to carry different combination of Rag/rag genes (Rag1, Rag2, Rag3/rag3, rag4) are being planted for further evaluation in Saint Paul. Furthermore, a pilot study to test six different soybean aphid isolates against a panel of indicator lines revealed at least three biotypes (out of four previously known biotypes). For Activity 2, a greenhouse experiment was performed to evaluate the potential use of thermal infrared remote sensing for detection of soybean aphid injury. In addition, a second year of remote sensing field experiments have been set up in Rosemount and Crookston, Minnesota and in Kanawha, Iowa. These include a caged experiments and open field experiments that will have different levels of aphid infestation on soybean. For Activity 3, the assessment of the current state of art of precise GPS positioning systems has been published. In addition, work is underway to test algorithms and integrate two candidate precise geo-positioning systems with the U of MN autopilot (Goldy 3.0).

Sub-project Status as of January 31, 2019
During this reporting period, the project team continued to make good progress on all activities. For Activity 1, the first outcome has been met with a U of MN-developed aphid-resistant line now being commercially available; however, additional resistant lines continue to be advanced in the breeding pipeline. The ENRTF is listed as one of the funders of this research with the UMN Office of Technology Commercialization and will be compensated according to MS 116P.10 Royalties, Copyrights, Patents, and Sale of Products and Assets. Development of molecular tools to screen plants for resistance genes is nearly complete and work continues on combining multiple resistance genes in soybean lines and assess susceptibility of aphid populations. For Activity 2, experiments were performed at multiple locations. Analyses of spectral and thermal data are underway for optimization of aphid detection. Challenges were encountered in development of proposed experiments to assess field and landscape factors; therefore, an adjustment to research protocols is requested to focus efforts on assessing impacts of plant feeding by other insect pests on detection of soybean aphid. The adjustment does not affect the budget or timeline for this project. For Activity 3, available high-precision GPS technologies alone were found to be inadequate, but algorithms are being developed for fusion of high-precision GPS capable receivers with inertial measurement units to potentially meet requirements of use. Overall, the project is progressing well and results are being shared with stakeholders.

Status as of July 31, 2019:
During this reporting period, the project team continued to make good progress on all activities. To advance the adoption and availability of aphid-resistant soybean, new soybean lines carrying soybean aphid resistance genes were entered into the regional testing program to determine how the agronomics of these lines compares to other lines across a broad geography. In addition, based on previous work to combine multiple aphid-resistance genes into individual soybean lines, over 1,000 soybean lines were selected for evaluation in the next phase of the breeding pipeline in plant rows. Furthermore, analysis is nearly complete of 16 different populations of soybean aphid collected in 2018 and suggests considerable variability in response of aphid populations to different aphid-resistance genes in soybean. To advance the use of unmanned aerial systems to scout for soybean aphid, analyses have been completed of data collected from soybean fields in 2018 and suggest that soybean aphid infestations can be detected from aerial near-infrared sensors. However, preliminary analyses of data collected from a caged field experiment suggest that the potential for thermal-based remote sensing for soybean aphid may be limited. Finally, progress was made toward implementation of recently developed positioning algorithms. A tool chain is being developed to process images captured by unmanned aerial systems. Overall, the project is progressing well and results are being shared with stakeholders.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:

Status as of July 31, 2021:
Status as of January 31, 2022:
Final Report Summary:

Sub-Project 5: MITPPC #5: Optimizing tree injections against emerald ash borer
Project Manager: Brian Aukema
Description: This research will quantify the proportion of trees that must be treated to confer herd immunity to untreated trees for two different non-neonicitinoid compounds.

Summary of budget information for sub-project 5 **ENRTF budget:** $320,000
Sub-Project 5

Outcomes, Activity 1	**Completion date**
1. Determine proportion of trees that must be treated to achieve herd immunity against emerald ash borer	August 31, 2020
Outcomes, Activity 2	
1. Describe community of insects that utilize ash trees in Minnesota	August 31, 2019
2. Determine effects of emamectin benzoate and azadirachtin on non-target insects	March 31,2020
Outcomes, Activity 3	
1. Determine degree of exposure to emamectin benzoate and azadirachtin among non-target insects	April 31, 2020
2. Determine relationship between tissue concentrations and changes in non-target insect densities in treated ash trees.	April 31, 2020

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
Tree injections of insecticides against emerald ash borer remain one of the most effective strategies for canopy preservation of ash trees in urban environments. This project, which began in the summer of 2017, investigates whether injection of a proportion of trees – not necessarily on a rotational basis – will keep untreated trees alive indefinitely, due to a "sink" effect on emerald ash borers that are feeding on treated trees. Adult emerald ash borers typically live for up to six weeks, and females undergo maturation feeding in the canopy before commencing oviposition. We began working with eight communities in Minnesota and selected twelve sites of approximately 100 trees. Half of the trees at each site were injected with a non-neonicitoid insectide. Injections occurred on a gradient, such that in some areas 100% of the trees were injected, but in other areas none of them were, with a mix of treated and untreated trees in between. We await leaf flush in spring 2018 to begin to study whether untreated trees are conferred benefits by being located proximate to treated trees. This fall, we collected phenological data such as rates of colour change and leaf abscission. We found that there were no differences between treated trees and control trees. In other words, injections of insecticidal compounds to preserve ash canopies do not appear to cause any noticeable changes in autumnal ash tree phenologies.

Sub-project Status as of July 30, 2018
After troubleshooting our method for DNA extraction from soil and for amplification of the target gene from *F. viguliforme* for pathogen detection, we are having success with detection of this pathogen in soil. We are

continuing to validate and troubleshoot our DNA extraction and qPCR methods to set a reliable threshold for detection, and are exploring some alternative approaches for detection (e.g., digital PCR).

Preliminary host range studies were conducted over the past winter in greenhouses in St. Paul. We initiated a large, replicated field study focused on the host range of *F. virguliforme* in Rosemount, MN. This study with dry edible bean, alfalfa, clover, pea and 24 other plant species was planted on May 16, 2018. The study is in progress and will be completed in Fall 2018.

D. Malvick has discussed and presented preliminary information on potential risks of the root rot pathogen Fusarium virguliforme to soybean and other crops to multiple individuals in Agribusiness and Extension, and has made arrangements with many individuals working in agribusiness across Minnesota to collect samples for the survey work. Initial samples from this growing season started coming into the lab for analysis in early August 2018.

Sub-project Status as of January 31, 2019
We collected the second year of data as scheduled from twelve sites in eight communities that agreed to participate in the study. Approximately 100 ash trees were visited at each site; this is quite possibly the largest study of associational protection or herd immunity in North America. We took detailed notes on crown conditions, completed the scheduled treatments of select sites with non-neonicitinoid compounds, and harvested plant material for plant issue analysis. We sampled for non-target insects such as pollinators in both treated and control trees, and also in the seeds. This summer was an exceptional mast year, so there was an abundance of seeds and seed weevils. We began germination trials to determine whether treatments affect the viability of the germ tissue. The PhD student on the project mentored an undergraduate research project (registered credit at UMN) due to the latter's interest in the research that carried over from summer help. Presentations on this work were given at the Upper Midwest Invasive Species Conference and the Entomological Society of America. Due to an unexpected equipment breakdown, work on the final activity of plant tissue analysis has not yet commenced apart from initial methods development.

Status as of July 31, 2019:
Activities continue on schedule. Much of the past six months was spent identifying the bycatch on the sticky cards deployed for to study non-target effects of the different treatments. Harvested plant material was stored for plant issue analysis. We conducted another germination trial to determine whether treatments affect the viability of the germ tissue. We began arrangements for scheduled retreatments of select trees in the 1200 enrolled in the study, and corresponded with municipalities that sought to remove trees in instances of extreme decline. An outreach presentation was given as part of the spring outstate EAB meetings coordinated by the MDA.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Final Report Summary:

Sub-Project 6: MITPPC #6: Distribution and traits of the fungal pathogen *Fusarium virguliforme* that influence current and future risk to soybean and other legumes in Minnesota
Project Manager: Dean Malvick
Description: The research goals of this project is to fill in key gaps in knowledge of abiotic and biotic factors controlling *F. virguliforme*'s distribution and the diseases it causes, and to develop tools to accelerate breeding for resistant varieties.

Summary of budget information for sub-project 6 **ENRTF budget:** $412,000
Sub-Project 6

Outcomes, Activity 1	**Completion date**
1. Develop refined and validated molecular approaches to confirm *F. virguliforme*	June 30, 2018
2. Determine utility of aerial and satellite imagery for detection and monitoring of sudden death syndrome and develop protocols for most effective use	November 30, 2019
3. Survey and map the current geographic distribution of *F. virguliforme* in Minnesota in agricultural and non-agricultural fields and ecosystems for use by farmers, plant breeders, and agribusiness to prioritize and inform disease management strategies and crop breeding priorities	June 15, 2020
4. Determine potential crop damage from *F. virguliforme* to edible dry bean, alfalfa, and clover	June 15, 2020
Outcomes, Activity 2	
1. Describe whether there is a consistent correlation between sudden death syndrome disease incidence and severity and soybean cyst nematode infestation levels in soybean production fields	November 30, 2019
2. Determine if *F. virguliforme* is a frequent inhabitant of soybean cyst nematode cysts and define whether soybean cyst nematode cysts represent a significant risk for survival and spread of *F. virguliforme*	June 30, 2020
Outcomes, Activity 2	
1. Describe whether there is a consistent correlation between sudden death syndrome disease incidence and severity and soybean cyst nematode infestation levels in soybean production fields	November 30, 2019
2. Determine if *F. virguliforme* is a frequent inhabitant of soybean cyst nematode cysts and define whether soybean cyst nematode cysts represent a significant risk for survival and spread of *F. virguliforme*	June 30, 2020
Outcomes, Activity 3	
1. Describe competitiveness of *F. virguliforme* based on nutrient utilization, fungal competition assays, and survival of this pathogen in varied field soil types	July 15, 2019
2. Establish cold temperature limits for survival of *F. virguliforme* that may bound distribution and spread now and under climate change	June 30, 2019
3. Characterize virulence of different strains of *F. virguliforme* along a latitudinal gradient to determine if virulence and disease risk varies by regions	May 31, 2020
4. Identify genetic regions in *F. virguliforme* and evidence for adaptation that are involved in	June 30, 2020

temperature tolerance or traits that may control invasiveness and/or virulence.	
Outcomes, Activity 4	
1. Develop maps and risk models to describe geographic distribution and habitats/ environments favorable for *F. virguliforme* and the diseases it causes based on current and projected future climate patterns in Minnesota	June 30, 2020

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
Fusarium virguliforme is the causal agent of the soybean disease sudden death syndrome as well as root rot of dry edible beans, clover, alfalfa, and some native legumes. There is a lack of knowledge of the distribution and damage done by this pathogen in soybean and non-soybean systems, as well as the abiotic and biotic factors influencing its ability to spread, survive, and become a significant pathogen in new areas. To date field and laboratory studies have been conducted and key project personnel have been hired. We completed a field study focused on the host range of *F. virguliforme*. Field pea, processing pea, edible bean (navy, kidney, pinto, black, green bean), alfalfa, red clover, and white clover were evaluated in an inoculated field study. Preliminary results suggest that edible beans may be more susceptible to this pathogen than the other species under the field conditions in this study. With the help of multiple cooperators, 31 samples of plants and soil from different crop production fields were collected to survey for the distribution of *F. virguliforme* in MN. We have also optimized a petri-plate competition assay and a spore-germination assay and tested two strains of *F. virguliforme* against soybean root endophytic fungi. One isolate that outcompetes *F. virguliforme* and two isolates that show antagonism were identified. In summary, we have made solid progress and anticipate that much more progress will be made in the next project period after new project personnel begin working on the project in January 2018.

Sub-project Status as of July 30, 2018
Fusarium virguliforme (FV) is the causal agent of the soybean disease sudden death syndrome (SDS) and can cause root rot on edible bean and other legumes. However, its potential to damage plant species other than soybean in field environments is unknown. Because FV is a relatively new and spreading invasive species in MN, there is a need to understand its distribution and the abiotic and biotic factors influencing its ability to spread, survive, and become a significant pathogen on soybean and other plants in new areas. We initiated a multifaceted project to address these concerns in 2017. To date we completed one field study focused on the host range of FV. Field pea, processing pea, five classes of edible bean, alfalfa (two varieties), red clover, and white clover were included in this study. Initial results suggest that edible bean has greater potential to be a host to FV than the other species under the environmental conditions in this study. Additional host range studies are underway. To understand the distribution of FV in Minnesota, plants and soil were collected from 31 crop production fields with a focus on NW Minnesota, and additional samples are being collected from many counties and fields in 2018. They are being analyzed with a species-specific PCR assays. We have also developed and started competition assays to determine how FV competes with other soil pathogens. Our studies of FV are revealing new information on the host range, distribution, and invasive capacity of this spreading fungal plant pathogen.

Sub-project Status as of January 31, 2019
Work toward the major goals of this project has proceeded well over the past 6 months. Our effort on activity #1 has focused on surveys to determine where *Fusarium virguliforme* (FV) occurs, host range studies of this pathogen, and on improvement of methods to detect FV in soil and plant samples. Initial results indicate that FV is more widely distributed in Minnesota than previously known, edible bean has greater potential to be damaged by FV than many other legume crop species, and low levels of FV can be detected in soil and plant

roots with improved laboratory methods. These methods improve our abilities to survey for this pathogen. Our work on activity #2 has focused on obtaining soil samples with SCN from many counties in Western Minnesota. These samples will be analyzed for the presence of FV in soil and in SCN cysts in early 2019. The outcomes from Activity #3 suggest that isolates of FV isolates from different areas differ genetically, and they differ in their abilities to cause severe root rot and foliar disease and to utilize nutrients. This helps to explain how this pathogen is adapting to new environments and plant hosts. Our efforts during this period toward activity #4 have focused on obtaining background information needed to conduct the modeling. In summary, our studies on FV are revealing new information on its distribution and the factors influencing its ability to spread, survive, and become a significant pathogen on different plant species in new areas.

Status as of July 31, 2019:
Work on activity 1 has continued to focus on surveys to determine where *Fusarium virguliforme* (FV) occurs in MN, host range of this pathogen, and on improving methods to detect FV in soil and plant samples. The results indicate that FV is more widely distributed in Minnesota than previously known, a range of crop and native plant species can be infected by FV in field environments, FV can infect soybean cyst nematode (SCN) cysts in laboratory experiments, and low levels of FV can be detected in soil and plant roots with improved laboratory methods. Our accomplishments have included analysis of associations between SCN and FV from 50 soil samples from multiple counties in western and northwestern Minnesota. Our work shows that isolates of FV from different areas in MN and from different states differ genetically, differ in their abilities to utilize nutrients, and differ in their aggressiveness on soybean. Combined, these results further clarify how FV adapts to new environments and plant hosts. Much of our work is focused on obtaining information needed to conduct ecological modeling for this pathogen. In summary, our research on FV is continuing to reveal new information on its distribution in MN and multiple factors influencing its ability to spread, survive, and become a significant pathogen on different crops in new areas of the state. Results have been presented to agricultural professionals and crop producers at extension education programs across Minnesota.

Status as of January 31, 2020:
Status as of July 31, 2020:
Final Report Summary:

Sub-Project 7: MITPPC #7: Tools to distinguish native from exotic reed canary grass
Project Manager: Neil Anderson
Description: This project will identify the structural plant traits to distinguish native from exotic forms of reed canary grass and to develop a hand-held molecular testing tool to quickly identify the status of populations.

Summary of budget information for sub-project 7 **ENRTF budget**: $268,000
Sub-Project 7

Outcomes, Activity 1	**Completion date**
1. Determine the minimal genetic information (molecular markers) that is needed to distinguish native from exotic reed canarygrass	March 31, 2018
2. Develop a map of the distribution of native and exotic reed canarygrass in Minnesota	May 1, 2019
Outcomes, Activity 2	
1. ~~Develop hand-held field tool for DNA extraction and rapid detection of native vs. invasive/exotic reed canarygrass samples~~	~~August 31, 2019~~
~~2. Test efficiency of hand-held field tool for 100% ID accuracy with collected plant samples for native~~	~~December 31, 2019~~

~~vs. exotic status (confirmed with SSR analyses, Activity 1)~~	
~~3. Test efficiency of hand-held field tool for 100% ID accuracy of randomly collected samples in extant, wild populations of unknown origin~~	~~June 30, 2020~~
1. Collect additional reed canarygrass specimens from the transportation (highway) corridors and lakes across MN to identify the native vs. exotic status of populations".	June 30, 2020

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
The goal of this project is to determine native vs. exotic reed canary grass locations within MN (Activity 1) and to develop hand-held molecular testing tools for native/exotic types to enable land managers to quickly identify the status of populations (Activity 2). To date, we have obtained high quality and quantities of DNA suitable for genetic marker analysis. In addition to our existing collection of frozen leaf samples, herbarium tissue samples of reed canarygrass (<1940, presumed native) were collected at the UM Herbarium and seeds samples from UW Madison (Casler's research laboratory) were obtained and planted for DNA extraction. Remaining frozen and fresh tissue samples are being processed; to date DNA from ~1,400 genotypes (>50% of all samples) from leaves have been extracted. For genotyping of reed canarygrass we will use SBG (Sequencing by Genotyping) instead of SSRs (single sequence repeats). Technological improvements, robustness and cost effectiveness of SBG drove this decision. The SSR-based analysis would have consumed ~1 year of time setting up and running gels for each SSR primer, followed by lengthy scoring times. To ensure the SBG method effectively achieves our ultimate goal in Activity 2, a 2018 pilot project involving a sample set of diverse 25 individuals will be test the effectiveness of sequencing vs. SSR data. We anticipate that additional genomic markers (SNPs) could be found to distinguish between native and invasive reed canarygrass with higher precision then SSR markers. If this pilot project proves successful, the remaining samples will be submitted for GBS.

Sub-project Status as of July 30, 2018
Our goal is to determine native vs. exotic reed canary grass (RCG) locations within MN (genetic diversity and population structure) and to develop a hand-held molecular testing method for native vs. exotic genotypes. This will enable land managers to quickly identify the status of current RCG populations in MN. Our experiments are analyzing both living (extant) and preserved herbarium specimens (historic) which represent MN native and exotic RCG genotypes. To date, all (n=2,036) collected RCG tissue samples have been processed and high-quality DNA was purified. The next-generation sequencing (DArTseq) approach was used to generate multi-locus data to characterize RCG populations downstream along MN major rivers. Preliminary results from subsampling experiment (~188 individuals) produced 16,902 SNP markers. We analyzed a pilot set of samples (herbarium/native, MN rivers, forage cultivars, European rivers) with these DArTseq (SNPs) data for a preliminary assessment of the SNP data. Many herbarium specimens had low levels of SNPs due to high level of DNA degradation; a few were usable, however, resulting in separations between types of reed canarygrass. This, along with future analyses of all RCG samples will determine which SNPs will be the most useful for identifying native from exotic or hybrid types by land managers.

Sub-project Status as of January 31, 2019
Genetic variation among and within historic (herbaria) and extant (living) populations from Minnesota and the Czech Republic were assessed by Diversity Arrays Technology sequencing (DArTseqLD) analysis, a low-density DNA sequencing approach to detect clonality of individuals within each location and identify exotic vs. native SNP markers. Among all genotypes, 13,967 high quality SNP markers were found among all samples collected. Wild populations from Minnesota and the Czech Republic create relatively separate, genetically different populations. With the exception of Roseau River and its adjacent production fields, all wild Minnesota rivers are

a mixed (panmictic) population without particular genetic structure, in contrast with the Czech populations where each river is genetically distinct. Future research will focus on the distribution of genotypes along each river. The Roseau genotypes along with some herbaria and cultivar samples will be analyzed in the next six months to select potentially native markers (in relation to the other wild MN populations) for use in Activity 2. Five abstracts were published in the past six months relating to our Activity 1 findings. Two of these publications were for poster presentations while the remaining three were for talks given at national and regional meetings.

Status as of July 31, 2019:
Activity 1. Our most recent results showed that reed canary grass (RCG) herbarium samples (<1940; native) and their extant collections as well as RCG from a native unplowed field (Roseau, MN) all group together with the wild RCG collections from five MN rivers. Whereas, MN cultivars and those collected along the Roseau River formed a separate group. The Czech populations were distinct from all MN groups. Thus, the MN RCG river collections most likely native to MN (with the possible exception of Roseau river). The Analysis of Molecular Variance (AMOVA) analysis showed that the majority of variation of RCG collected along MN rivers is within populations (98.8%), not among populations (1.2%). The F_{st} values among RCG MN rivers (0.003-0.037) suggest very little divergence between those populations and a high level of shared genetic markers among RCG populations. Activity 2. Due to the fact that MN rivers RCG populations are without particular genetic structure (a panmictic or interbreeding population), identification of separate populations (MN rivers vs. commercial field) would only be possible with the use of a large number of single nucleotide polymorphism (SNP) markers. Overall, due to high genetic variation observed within RCG populations, differentiation of MN rivers RCG population vs. commercial field with use of single or few SNP markers (diagnostic marker) will be highly difficult. Thus, we propose modifying Activity 2 to collecting populations along highway corridors and lakes throughout MN to identify whether these are native as well.

Status as of January 31, 2020:
Status as of July 31, 2020:
Final Report Summary:

Sub-Project 8: MITPPC #8: Accurate Detection and Integrated Treatment of Oak Wilt (*Ceratocystis fagacearum)* in Minnesota
Project Manager: Jeannine Cavender-Bares
Description: This project will develop tools for detection and monitoring of oak wilt in Minnesota and to develop new tools and guidelines to prevent the spread of the disease.

Summary of budget information for sub-project 8 **ENRTF budget:** $357,420
Sub-Project 8

Outcomes, Activity 1	**Completion date**
1. Spectral indices associated with oak wilt, bur oak blight and drought at the leaf level and canopy level developed for use in the field	January 31, 2020
2. Sampling protocol and graphical user interface developed and tested	May 31, 2020
Outcomes, Activity 2	
1. Spectral indices associated with oak wilt, bur oak blight, borer and drought developed from hyperspectral imagery from NASA and NEON	January 31, 2020
Outcomes, Activity 3	
1. Up to twenty oak wilt centers treated	November 30, 2017

2. Determine efficacy of double vibratory plow control method and its economic costs compared with a single plow line	June 30, 2020

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
Oak wilt, caused by the invasive fungal pathogen, *Ceratocystis fagacearum*, threatens the health of oak forests in Minnesota and across North America. We are developing novel remote sensing methods for rapid and accurate diagnosis of oak wilt and testing the efficacy of management approaches through rigorous field experiments. Our team is using hyperspectral sensors to detect leaf and canopy reflectance in sapling experiments and in infected forest stands across a range of spatial scales. In 2017, we established a greenhouse experiment with bur oak and pin oak saplings in which we infected plants with oak wilt, bur oak blight or imposed drought, and compared them to well-watered control plants. From hyperspectral reflectance measurements of leaves over a two-month period, we successfully classified symptoms of disease progression throughout the experiment on all infected plants. We have processed hyperspectral imagery of Cedar Creek Ecosystem Science Reserve (CCESR) obtained from flights by NASA pilots and have found that known oak wilt disease centers can be detected with high accuracy, an ongoing focal area of our work. Ten oak wilt-infected study sites in Chisago, Anoka, Isanti, and Sherburne Counties were identified and treated using the single and double vibratory plow line methods in October 2017. These sites will be monitored and used for remote sensing model development and analysis. Training was provided to a University of Minnesota graduate student, two undergraduate students and a technician preparing for a long-term science career.

Sub-project Status as of July 30, 2018
Using the 2017 geolocated healthy and oak wilt infected trees at Cedar Creek Ecosystem Science Reserve (CCESR) and 2016 airborne hyperspectral imagery, we have trained models to 1) differentiate tree species and 2) to differentiate healthy and oak wilt infected oaks (Activity 2). Current models allow us to classify oak species compared to non-oak species with a 94% accuracy, to classify *Q. ellipsoidalis* compared to *Q. macrocarpa* with a 91% accuracy, and to classify healthy compared to oak wilt infected *Q. ellipsoidalis* trees with a 87% accuracy. We also collaborated with NASA scientists and were able to fly CCESR and the 10 oak wilt field sites established in 2017 to obtain new AVIRIS imagery. The imagery has not yet been processed but will be used for ongoing model development for accurate detection of infected trees.

We began (inoculations on July 2, 2018) a follow-up greenhouse experiment investigating hyperspectral detection of oak wilt and differentiating oak wilt from bur oak blight and drought in seedlings of *Quercus macrocarpa* and *Q. ellipsoidalis* (partially funded by a UMN Provost's Office Grand Challenges Grant). In our previous experiment, oak wilt cases were diagnosed correctly in 42% of cases in *Q. ellipsoidalis*, before most leaves were exhibiting symptoms. In the current experiment, we are including both leaf-level and whole-canopy hyperspectral reflectance measurements of seedlings to connect leaf-level and whole plant models for more accurate oak wilt detection (Activity 1). We are also measuring field-collected branches from mature oak wilt-infected and healthy *Q. ellipsoidalis* trees.

We are continuing to monitor the effectiveness of the double vibratory plow line (VPL) method in halting the spread of oak wilt in infected stands (Activity 3). In July and August, we will reassess the ten site that we treated with the VPL method in 2017 for any disease spread. We are selecting an additional ten sites for VPL treatment in September 2018.

Sub-project Status as of January 31, 2019
Using airborne hyperspectral imagery, we were able to differentiate oak species from other common mixed hardwood forest species with 84% accuracy, differentiate northern pin oak from bur oak with 91% accuracy, and differentiate healthy red oaks and oak wilt infected northern pin oak with 96% accuracy. Importantly, we were

able to detect oak wilt-infected trees from imagery collected the year prior to their death, demonstrating the potential to detect oak wilt disease in advance of visual symptoms. Using published health indices, we found significant differences between healthy and oak wilt infected trees at chlorophyll sensitive wavelengths (R683 nm and R694 nm/R760 nm), indicating a small number of wavelengths can be useful. We completed a second seedling experiment in which we infected oaks with oak wilt, bur oak blight, or subjected them to chronic drought and measured hyperspectral reflectance at the whole plant- and leaf-level. Oak wilt can be differentiated from other treatments with 50% accuracy at both the leaf and whole-plant level. Using only symptomatic leaves of any unhealthy plant, we can detect oak wilt with nearly 70% accuracy, showing efficient detection with simple leaf measurements once trees are found to be unhealthy. We identified field sites containing northern pin oak saplings to use for a field inoculation and detection experiment in 2019. We established and treated 10 additional oak wilt centers with vibratory plow lines and completed surveys of previously treated sites. We presented our research findings at multiple local, regional and national or international venues.

Status as of July 31, 2019:
We have continued to make progress on our efforts to accurately detect oak wilt at multiple scales and to document best practices in management efforts to prevent spread of the disease. We began analysis of the AVIRIS NG airborne imagery following analysis protocols developed for the AISA imagery. We find that both data types can detect and differentiate oak species from other common mixed hardwood forest species and accurately classify oak wilt-diseased oak species from healthy species (Activities 1 & 2). In the last six months, we initiated an outdoor potted sapling experiment and a field experiment using naturally growing oak saplings at the Cedar Creek Ecosystem Science Reserve. In the potted experiment, large northern pin oak saplings were infected with oak wilt or drought-treated, or both. Hyperspectral reflectance at the whole plant- and leaf-level (Activity 1) and a suite of physiological changes are being measured. In the field experiment, naturally growing northern pin oak or red oak saplings were inoculated with oak wilt and will be compared to healthy saplings using spectroscopy at the leaf and whole plant level. Our team submitted a manuscript for publication based on the greenhouse seedling experiment, and an undergraduate submitted an honors thesis. We have collectively given five oral or poster presentations at state, federal or university venues summarizing the work from the MITPPC project. We have also educated undergraduates through a field trip and contributed to the career advancement of a former post doc, a former junior researcher, and an undergraduate researcher.

Status as of January 31, 2020:
Status as of July 31, 2020:
Final Report Summary:

Sub-Project 9: MITPPC #9: Characterizing dispersal of larval gypsy moth to improve quarantine regulations
Project Manager: Brian Aukema
Description: This research will conduct laboratory and field-based behavioral and mark-resight studies to determine how feeding status and age affect dispersal and the costs and effectiveness of different barriers around woodpiles.

Summary of budget information for sub-project 9 **ENRTF budget:** $35,000
Sub-Project 9

Outcomes, Activity 1	**Completion date**
1. Determine effects of developmental stage, feeding status, and environmental stimuli on larval movement to determine “worst case” conditions	December 31, 2017
2. Determine the maximum and expected distances that gypsy moth larvae can move as a foundation for a new recommendation for isolation zones around commercial log decks	April 31, 2018

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
Due to health issues at Syntech, manufacturing and shipping took longer than anticipated. We have spent the month of December setting up the base unit, configuring the software, and testing it with non-quarantine insects like Madagascar hissing cockroaches. We have built a custom enclosure that allows us to conduct more nuanced experiments. The first larvae of gypsy moth are scheduled to hatch in the last week of December in the quarantine facility, and we look forward to conducting our first experiments.

Sub-Project Status as of July 30, 2018
The European gypsy moth, *Lymantria dispar* L. (Lepidoptera: Erebidae) is an invasive insect in North America. Gypsy moth larvae are highly polyphagous and capable of extensive defoliation during population outbreaks. The United States maintains a quarantine across the established range of the gypsy moth to slow the spread of the moth. One component of the quarantine requires that entities that move wood products across quarantine boundaries stage those wood products within a buffer zone area devoid of any host vegetation. The purpose of the buffer zone is to reduce the likelihood that late instar gypsy moth larvae will pupate nearby, emerge as adults, mate, and lay eggs on the wood. In practice, this buffer zone is 100 feet in radius. It is difficult to evaluate the efficacy of the buffer zone practice, however, due to our limited understanding of the movement ecology of these larvae. In this project, we investigate how host type and food deprivation affects the movement capacity and behavior of larvae in the laboratory using a servosphere. Testing is complete and results are now being analyzed for the final report.

Final Report January 31, 2019
The European gypsy moth is an invasive insect that feeds on over 300 species of trees and shrubs. Management guidelines within a national quarantine recommend that wood products, such as timber being harvested and moved from the forest, are staged within a buffer zone area devoid of any host vegetation during harvesting operations. This buffer zone reduces the likelihood that late instar gypsy moth larvae will pupate nearby, emerge as adults, mate, and lay eggs on the wood. In practice, this buffer zone is 100 feet in radius, but this distance was established with limited understanding of the movement ecology of gypsy moth larvae. We conducted laboratory experiments at the University of Minnesota to determine how host type and food deprivation affected movement of gypsy moth caterpillars. During outbreaks, food can become scarce as larvae strip trees of foliage. Larvae were raised on one of five foods: oak, tamarack, Norway maple, sugar maple, or artificial diet. Subsets of larvae were also deprived of food for zero, 24, or 48 hours. After the food deprivation period, late instar larvae were placed on the servosphere. Larvae raised on oak, a preferred host, were unlikely to move unless starved. They moved farther and faster the longer they were starved. In contrast, when larvae were raised on less preferred hosts, they were more likely to move without prior starvation. These results suggest that feeding on optimal hosts provides gypsy moth larvae with the energy and nutritional requirements to move more quickly to more food when there is none immediately available. Thus, risks of larvae crossing a regulatory buffer zone may increase where an outbreak results in complete defoliation of preferred hosts. Results from this laboratory study were integrated with a federally-funded field study to inform best management practices of this invasive species in Minnesota.

Sub-Project 10: MITPPC #10: Management strategies for the invasive spotted wing drosophila
Project Manager: Mary Rogers
Description: This research will seek to understand the relative impacts of local movement, long-distance migration, and potential overwintering sources. Additionally, the research will investigate the efficacy of innovative and alternative management techniques, evaluate the cost effectiveness and economic impact of SWD management alternatives, and develop decision-making tools for growers.

Summary of budget information for sub-project 10 **ENRTF budget:** $505,000

Sub-Project 10

Outcomes, Activity 1	**Completion date**
1. Determine the possible extent of local overwintering by spotted wing drosophila in Minnesota	May 31, 2021
2. Determine the role of local movement in colonization of raspberry fields through laboratory-flight-chamber and in-field vertical trapping studies	May 31, 2021
3. Determine the possible role of long-distance movement in colonization of raspberry fields through aerial observation	May 31, 2021
4. Develop new forecasting models for integrated pest management based on an improved understanding of the ecology of spotted wing drosophila, and source of populations	May 31, 2021
Outcomes, Activity 2	
1. Determine efficacy of novel biopesticide products (Erythritol, lufenuron, Spear-T, P, and C) against spotted wing drosophila in laboratory bioassays and on raspberries in the field	December 31, 2019
2. Determine efficacy of physical exclusion using poly-covered high-tunnels and fine mesh netting on reducing spotted wing drosophila damage in raspberries	December 31, 2019
3. Determine interaction of novel biopesticide products and poly-covered high-tunnels for increased efficacy against spotted wing drosophila in raspberries	December 31, 2019
Outcomes, Activity 3	
1. Estimate the current economic impact of spotted wing drosophila infestation rates in the Minnesota raspberry industry.	December 31, 2019
2. Calculate the potential costs and benefits associated with alternative spotted wing drosophila management practices for conventional and organic raspberry growers.	December 31, 2020
3. Estimate the aggregate economic benefits, if any, of conventional and alternative spotted wing drosophila management practices.	December 31, 2020
4. Develop an estimation tool that can be used by growers to make informed financial decisions about spotted wing drosophila control for soft fruit production.	December 31, 2020

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:

Spotted wing drosophila (*Drosophila suzukii*, SWD) is an invasive, cosmopolitan fruit fly that has been present in MN since 2012. Female flies lay eggs in ripe, soft skinned fruit including raspberries, blueberries, and strawberries. Eggs hatch into larvae that feed inside the fruit, rendering fruit unmarketable. SWD is causing significant economic damage to the berry industry as a whole, but the economic impact in our state is not well documented. Worldwide, growers are increasing pesticide spray applications in attempts to manage this new pest. Repeat applications of broad-spectrum pesticide sprays can increase the risk to non-target insects and have negative environmental consequences. Additionally, insecticide sprays may fail to adequately protect fruit from damage due to high pest populations and low thresholds. Because SWD is a new pest in MN, it is not known whether or not adults survive through winter or migrate into the state from warmer regions, making it difficult to predict when SWD will first appear. In this project, we aim to minimize the threat of SWD to natural resources and the economy of our state in three ways: 1) improve our understanding of the relative impacts of local movement, long-distance migration, and potential overwintering sources of SWD; 2) investigate the efficacy of alternative management techniques including biological pest pesticides and exclusion; and 3) evaluate the cost effectiveness of SWD management alternatives and develop decision-making tools for Minnesota berry growers.

Sub-Project Status as of July 30, 2018
Spotted wing drosophila (*Drosophila suzukii*, SWD) is an invasive, cosmopolitan fruit fly that has been present in MN since 2012. Female flies lay eggs in ripe, soft skinned fruit including raspberries, blueberries, and strawberries. Eggs hatch into larvae that feed inside the fruit, rendering fruit unmarketable. SWD is causing significant economic damage to the berry industry as a whole, but the economic impact in our state is not well documented. A team of researchers at the University of Minnesota are working together to better understand the biology of this pest in our cold climate, determine effective management practices for this pest, and assess the economic impact of SWD in our state. Based on this last objective, our team has found that most raspberry growers in our state are small-scale producers, experiencing infestation rates of 2-100%. Most raspberry growers in MN use U-Pick operations, which makes chemical management difficult due to pesticide reentry intervals. Consequently, many growers are plowing under berries and/or refraining from harvesting fruit due to SWD infestation. Growers report that summer-bearing, floricane cultivars experience less infestation, whereas fall-bearing, primocane cultivars are more seriously impacted, due to increased pest population density. Our results indicate that growers in the south and south-central regions of the state report higher levels of infestation. Organic growers primarily practice sanitation for SWD control, whereas non-organic utilize pesticides, mass trapping, pruning, scouting and sanitation. This information helps inform and guide our management recommendations and improve outreach for fruit growers in Minnesota.

Sub-project Status as of January 31, 2019
The overall major accomplishments in the past 6 months include key developments on our SWD research in Minnesota. Specifically, we are building evidence to determine how this invasive pest moves to and within the state, which will help guide future pest management recommendations (i.e. field sanitation, monitoring). In addition, our research is uncovering which pest management products are practical for chemical control of this pest, and best management practices for using exclusion and controlled environment techniques to reduce infestation, increase marketability and profitability of fresh berries. In addition, our work has shown that the economic impact of SWD on raspberry production in MN is $2.2 million annually. Major accomplishments over the last 6 months include the submission of a manuscript on the economic impacts of SWD on Minnesota to the Journal of Integrated Pest Management; and graduate research assistant Anh Tran in the Hutchison lab won 2nd place for her oral presentation on determining SWD morphs based on body size at the annual Entomological Society of America conference. These efforts elevate our work to a national audience and may be used to leverage additional funding sources to continue research on this pest, to the benefit of small fruit growers in Minnesota. So far, our project has not experienced any major obstacles that influence our ability to meet our proposed deadlines. So far, we are on track to complete all outcomes by the end of our funding period in June, 2021.

Specifically, for Activity 1, additional Degree-day (DD) modeling analyses (base threshold of 10^{o} C) were completed and found to be in agreement with May and mid-June SWD adult catch dates, reflecting potential winter and summer morph activity. Given these results, and agreement with the DD model, we have secured two additional locations, with collaborating berry farmers known to have high SWD populations (Hastings, Forest Lake) to repeat the early spring/summer monitoring in 2019. This research is getting us closer to understanding how SWD moves to and within MN, which will help us refine pest management recommendations. This work will continue in 2019 and is currently on track to meet deadlines (ending in May, 2021). For activity 2, the team completed 20 unique laboratory bioassays, including measuring adult mortality, oviposition, larval development, pupal development, and emergence of 2nd generation of adults on fresh raspberry fruit. Data was analyzed and is being prepared for publication. In addition, we completed the first year of the semi-field assays at the Rosemount Research and Outreach Center using the eight most promising treatments from the lab assays. However, of the eight treatments, only Mustang Maxx (conventional restricted use pesticide) resulted in significantly higher mortality than the untreated control. We also completed the first year of research on exclusion netting plus insecticide treatments at the West Central Research and Outreach Center in Morris, MN. We found that total yield and marketable yields of raspberries were significantly higher in the full season mesh exclusion treatment. From a stakeholder perspective, this research will guide insecticide recommendations for management of SWD, and also determine best management practices for exclusion of SWD, while highlighting the benefits of controlled environment techniques. The work is on track for completion and a second year of field research will be completed in 2019. Finally, team member, Gigi DiGiacomo submitted a manuscript titled *Economic Impact of Spotted Wing Drosophila (Diptera: Drosophilidae) Yield Loss on Minnesota Raspberry Farms: A 2017 Grower Survey*, to the Journal of Integrated Pest Management for consideration. Additionally, a second round of telephone surveys was completed in November 2018 to obtain additional data in an effort to verify SWD infestation rates, SWD-related yield and labor expenditures for SWD control. This study will determine the cost of labor-related SWD management practices: scouting, pesticide/bio-pesticide applications, pruning, mass trapping, increased harvest frequency, field sanitation and installation of exclusion measures. The on-farm labor data eventually will be paired with material input costs for conventional and alternative SWD control measures studied by field researchers for this project. The labor and material input costs will be used to calculate on-farm costs and returns associated with conventional and organic SWD control strategies. The work is on-track to meet deadlines and work will be completed in Dec. 2020.

Status as of July 31, 2019:
Key accomplishments within the past 6 months (from Dec. 2018-May 2019) include publication of a manuscript, titled *Economic Impact of Spotted Wing Drosophila (Diptera: Drosophilidae) Yield Loss on Minnesota Raspberry Farms: A Grower Survey*, was accepted and published in April 2019 in the Journal of Integrated Pest Management 10(1): 11; 1-6. A press release was prepared by Dana D'Amico for the manuscript in April 2019. DiGiacomo and Rogers worked with D'Amico to provide quotes and data for the press release. A second manuscript, titled *Efficacy of Organic and Conventional Insecticides for* Drosophila suzukii *when Combined with Erythritol, a Non-nutritive Feeding Stimulant*, was accepted for publication with minor revision, to the journal Crop Protection in May 2019. A third manuscript is in preparation for the development of a quantitative scale to identify and distinguish winter and summer morphs of SWD. Additionally, multiple SWD traps (n = 90) across three sites have been deployed to increase the likelihood detecting an overwintering SWD earlier in the season. Additional lab assays on botanical products are showing promise for repelling SWD and preventing oviposition. A NC-SARE graduate student grant has been submitted to fund additional work in this area. Three talks on our project were given at the MN Fruit & Vegetable Growers Association meeting in St. Cloud, MN in January 2019. Additionally, three team members attended the MITPPC board meeting in February 2019 to share research findings. Our second season of field work is underway.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Final Report Summary:

Sub-Project 11: MITPPC #11: Will future weather favor Minnesota's woody invaders?
Project Manager: Peter Reich
Description: This research will quantify and map how four woody invaders will compete with key native tree species in forest settings under current and future climate conditions.

Summary of budget information for sub-project 11 **ENRTF budget:** $526,000
Sub-Project 11

Outcomes, Activity 1	**Completion date**
1. Quantify sensitivity of woody invasives to recent climate and its statewide variation and determine competitive ability of these invasives versus native trees	April 30, 2021
2. Complete assessment of the potential for threat of woody invasive spread statewide	April 30, 2021
Outcomes, Activity 2	
1. Characterize capacity of woody invasives to colonize forest sites under potential future weather and climate in northern Minnesota	May 31, 2021
2. Complete assessment of the potential threat of spread of woody invasives in northern forests where these invasives are currently scarce	May 31, 2021
Outcomes, Activity 3	
1. Develop maps that show the current distribution of woody invaders, as well as uncertainty regarding their presence, to highlight the areas that will benefit most from more information.	June 30, 2021
2. Complete maps of shifts in encroachment vulnerability under a changing climate and therefore aid in prioritizing which areas require the most urgent management attention.	June 30, 2021
Outcomes, Activity 4	
1. Development of methods of creating effective local barriers to woody invasive spread.	June 30, 2021

Sub-Project Status as of June 30, 2017:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of January 30, 2018:
Minnesota's forests face unprecedented challenges, including from invasive species, climate change, and their joint impacts. Four non-native woody invasive species including two honeysuckle (*Lonicera morrowii, Lonicera tatarica*) and two buckthorn species (*Frangula alnus, Rhamnus cathartica*) are already abundant in many regions of the state, and could become major problems in the future in forest-dominated northern Minnesota; further, climate change could increase that possibility. These four species were the four highest priority woody invasives, according to "Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research". Among the reasons for such high concern are reductions in tree regeneration that can occur when the invasives colonize in high density. This is of particular concern in northern Minnesota, which supports the bulk of the state's forest industry and recreation, but is also of concern in other forested regions of the state, in many of which woody invasives are already present. In this project we will we address key knowledge gaps with the following activities. We will provide climate sensitivity assessments for the four key woody invasives based both on retrospective analyses of growth performance of existing shrubs at sites that span the state's climate gradient and on a realistic field experiment in which the exotics and native trees will be grown at contrasting climate

conditions. We will also produce maps of current distribution as well as projected future hotspots for invasion under climate change, and test new approaches to slow the spread of woody invaders at nascent invasion locations.

Sub-Project Status as of July 30, 2018
Two non-native honeysuckle (*Lonicera morrowii, Lonicera tatarica*) and buckthorn (*Frangula alnus, Rhamnus cathartica*) species are already abundant in many Minnesota forests, and have the potential to become major problems elsewhere; future climate could make them more competitive and more challenging to manage state-wide. We address knowledge gaps about their potential to become increasingly widely distributed, aggressive, and abundant, with four activities:

(i) Characterize growth sensitivity to past climate of these invaders, based on height and diameter growth analyses statewide. This work has not yet begun.

(ii) Assess whether the invasive species will out-compete native tree species with changing weather. Individuals of 11 native and the 4 invasive species were planted by spring 2018 in all 36 plots in an open-air experiment. Warming treatments began in April and rainfall manipulations in June. Shoot and leaf phenology were measured in all plots throughout spring and early summer. Measurements of net photosynthetic capacity began in June 2018.

(iii) Map the current distribution of these invaders and their likely distribution given both time to spread and a changing climate in which that spread will occur. This work has not yet begun.

(iv) Begin field tests of "buffer/barrier zone" techniques for slowing spread of woody invasives. No active research has begun, but preliminary scouting of field sites indicated our original design would likely be inefficient and cost-ineffective. We developed an alternative approach that should provide more meaningful information for less work and lower cost and are designing a specific field plan using that approach.

Sub-project Status as of January 31, 2019
Overall we made significant progress on activities two and four placing both on track to achieve planned goals. The main accomplishment(s) for activity two was successful establishment of the model plants cohort into research plots and application of the experimental treatment throughout the season. In addition, a number of physiological and growth performance measurements were taken on the model plants and collected data are currently being prepared for analysis. For activity four we successfully scouted potential locations for the experimental testing of the barrier strips and dendrochronological surveys. Currently, we are developing final protocols and overall plans for the upcoming season including preparation to scout for two remaining research sites for activity four.
In addition, during last season we hosted a number of visitors at the site of activity two that included;

- Five field classes for students from local Colleges and Universities (FDLTCC, UMD and UMN) with total attendance of approximately 80 students,
- A group of 12 international students including three faculty members from Nord University in Norway.
- A group of DNR area supervisors (around 60 individuals attended)
- A group of researchers from Finland including faculty members from Forest Resources department at the UMN

Currently, we are in the processes of post season organization and described lab work that includes processing of samples and data from 2018 and preparation for the next field season.

Status as of July 31, 2019:
Since conclusion of the field work late in 2018 we focused on winterizing the project and we shifted to the lab component of the work. This included post collection processing of samples and data (*e.g.* biomass weighing, data entry, cleaning and organization *etc.*). and necessary repairs, general cleanup and preparation for the next season. We also did preliminary data exploration in preparation for upcoming publications. Preliminary data

exploration shows that woody invaders benefited from warmer growing conditions as their rate of carbon assimilation and overall biomass accumulation was enhanced while not all native species showed such favorable response to warming. The least favorable growth with warming were shown by native conifers and boreal species. In late winter and early spring we shifted to preparation of the research site for the growing season by reassembling warming and rainfall reduction treatments, planning treatments and measurements, fixing fences, wiring and other problems, hiring summer interns, and updating protocols for the upcoming season. In the first week of April we turned on warming treatment and begun 2019 field data collections. The project is on track to achieve its goals.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Status as of July 31, 2021:
Final Report Summary:

Sub-Project 12: MITPPC #12: Developing robust identification assays for *Amaranthus palmeri* in seed mixtures
Project Manager: Don Wyse
Description: A proactive certification process is needed to protect Minnesota's environment and agricultural industries from further Palmer amaranth introductions. To enable proactive certification and additional testing of seed lots as needed, a robust and fully validated molecular method is needed to differentiate among Palmer amaranth and visually-similar seed from other species.

Summary of budget information for sub-project 12 **ENRTF budget:** $208,230
Sub-project 12

Outcomes, activity 1	**Completion Date**
1. Develop high-throughput method for mechanical separation of *Amaranthus*-sized seed from mixed sampled	March 30, 2018
2. Optimize techniques for high throughput tissue disruption and DNA isolation procedure from filtered seed lots	September 30, 2018
Outcomes, activity 2	
1. Complete assessment of the specificity of molecular testing for distinguishing *A. palmeri* in *Amaranthus*-only seed mixes	January 30, 2019
2. Determine robustness of molecular tests to identify Palmer amaranth across a diverse panel of accessions	January 30, 2019
3. Optimize molecular tests to identify *A. palmeri* contamination in filtered subsamples from seed mixes	June 30, 2019
Outcomes, activity 3	
1. Complete genome sequencing to provide reliable and robust methods to identify Palmer amaranth from related species	June 30, 2019
2. Finish testing to with diverse Palmer amaranth lines to ensure the robustness of detection technologies	June 30, 2019

Sub-Project Status as of January 30, 2018:
Labs are being set up and the necessary personnel hired.

Sub-Project Status as of July 30, 2018
Palmer Amaranth (*Amaranthus palmeri*) is one of the largest emerging threats to agricultural systems in the upper Midwest. Traditional screening methods are unable to differentiate Palmer Amaranth from related non-invasive species of Amaranth, leading to introduction through contaminated seed mixes. In response we are developing a species species-specific screening method to be implemented by the Minnesota Department of Agriculture. The end goal is to develop an assay with clear categorization for the presence/absence of Palmer Amaranth in a sample.

The development of mechanical separation protocol (Activity 1) is anticipated to begin in late October. This delay is to allow for more rapid progress on Activity 2, which will be presented in an oral session at the Upper Midwest Invasive Species Conference meeting this October.

Activity 2 is progressing well. *Amaranthus* seed has been acquired from multiple sources and is being grown in a greenhouse to provide DNA for this project. This step is expected to end in September. At that point high through-put DNA extraction will be performed through the use of Qiagen Biosprint kits. The resulting DNA will be used to validate the existing KASP marker developed by our Colorado team.
Development of new KASP markers (Activity 3) will be performed by submitting our DNA to UMGC for Genotype-by-Sequencing (GBS). GBS will allow us to identify species-specific single nucleotide polymorphisms (SNPs), which can then be used to design additional KASP markers. Submission to UMGC is anticipated to start in October/November.

Sub-project Status as of January 30, 2019
Our team has grown and extracted DNA from a large panel of Palmer Amaranth selected to cover the largest possible genetic diversity. We have coverage across a wide geographic range; from California to Georgia, and from Mexico to Minnesota. Additional samples from Senegal and Mali have been included to maximize genetic diversity of the panel. The extracted DNA is on hand, and ready to be deployed for later stages of the project. The initial Palmer marker, developed by our team members at Colorado State University, has been validated against this panel. The maker performed extremely well, with a 99.7% accuracy across 1,100 samples and a 0% failure to identify Palmer individuals. The marker performed well enough to overturn two species identifications from our seed suppliers. As a result of our testing we were able to halt distribution of Palmer seed through a national germplasm repository. These findings were disseminated at an oral session of the Upper Midwest Invasive Species Conference meeting on October 15th, 2018.The project is on track and has met its deadlines, with the exception of mechanical seed separation. This objective was deferred due to the higher priority and development time needed for the genetic part of the project. We will begin seed separation in January/February of 2019 and anticipate its completion by June 30th, 2019.

Status as of July 31, 2019:
In the last six months we have made substantial progress in validating the first KASP marker for identifying Palmer Amaranth. The marker was validated against a panel of 1,100 individuals and demonstrated an overall accuracy of 99.73%. The assay showed a false negative rate of 0%, meaning that the assay was able to correctly detect all Palmer samples. The false positive rate for our assay was 0.44%, representing only 3 non-palmer individuals who were erroneously flagged as being Palmer. The low false positive rate is important because erroneous calls represent a waste of time and resources in unnecessary control efforts. The combination of low error rates indicate that our assay will be a reliable tool for identification of Palmer Amaranth.

Bulk seed testing of this marker has shown the ability to reliably flag contamination of Palmer Amaranth in a mixture of Waterhemp seeds at a rate of 1:20. Additional work is being conducted to increase the sensitivity of our bulk seed testing protocol.

DNA samples for additional marker development have been submitted to the University of Minnesota Genomics Center for sequencing. Development of these markers is on schedule and validation is expected to be performed this summer.

Preliminary results have been presented at the UMN Palmer Amaranth Summit on January 22nd, 2019 and as an invited speaker at Colorado State University on April 17th, 2019.

Final Report Summary:

Sub-Project 13: MITPPC #13: Terrestrial invasive species prioritization
Project Manager: Amy Morey
Description: The Minnesota Invasive Terrestrial Plants and Pests Center undertook an expansive research prioritization to systematically evaluate threats posed by a wide array of terrestrial invasive insects, plants, and plant pathogens in 2017 and created the document, "*Minnesota's Top 124 Terrestrial Invasive Plants and Pests: Priorities for Research*," which has provided guidance on funding MITPPC research projects in subsequent years.

Since its publication, a number of plants and pests have been suggested for further review by stakeholders, including Palmer amaranth and jumping worms. The movement of TIS into Minnesota calls for a thorough review of suggested species. We will utilize the same methodology applied in the 2017 paper. An Analytical Hierarchy Process (AHP) was used to rank these threats. AHP is a form of multi-criteria decision analysis that makes the process of selecting the highest priority threats consistent and transparent. AHP has been used by many agencies and organizations to facilitate complex decision making. This six month project will assess up to fifty species of plants, pests, and pathogens to update the prioritized lists used by MITPPC

Summary of budget information for sub-project 13 **ENRTF budget:** $36,126

Outcomes, Activity 1	**Completion Date**
1.10 TIS assessment completed	July 14, 2019
2. 11 additional TIS assessments (21 total)	August 12, 2019
3. 25 additional TIS assessments (46 total)	November 25, 2019
4. Updated prioritization of 170 species completed	December 1, 2019

Status as of July 31, 2019:
The first outcome deadline of 10 completed TIS assessments has been met. The following species have been completed:
*Acer ginnala (*Amur maple)
Ailanthus altissima (tree of heaven)
Alium tuberosum (garlic chives*)*
Contarinia nasturtii (Swede midge)
Elaeagnus angustifolia (Russian olive tree)
Impatiens balfourii (Balfour's touch-me-not)
Lamium galeobdolon (yellow archangel)
Microstegium vimineum (Japanese stiltgrass)
Pyrenopeziza brassicae (no common name)
Resseliella maxima (soybean gall midge)

Status as of January 31, 20*20:*
Final Report Summary:

Sub-project 14: MITPPC #14: Improved Detection and Future Management of Leafy Spurge and Common Tansy using Remote Sensing, Mechanistic Species Distribution Models, and Landscape Genomics

Sub-project managers: David Moller and Ryan Briscoe Runquist
Description: Species Distribution Models (SDMs) are developed to predict which geographic areas are under current risk of invasion and how distributions will expand or contract under climate change. Traditional SDMs

are constructed only from environmental data and often underperform because they fail to account for how population demography and functional traits vary with environmental variables across geographic ranges. Here, we propose to develop mechanistic and process-based SDMs in order to provide fine-scale predictions of current and future distributions of two invasive species (leafy spurge and common tansy) that are widespread across much of the northern tier of the United States but considerably less common to the south. We will take a novel approach where we use remote sensing to gather demographic information on each species across MN. Publicly-available multi- and hyper-spectral satellite images will be analyzed to quantify abundance and population growth over the las 18 years. Those data will be used to develop process-based SDMs. We will also use manipulative controlled environmental experiments to assess population differentiation in ecologically-important traits across the region and determine critical thresholds that limit performance. Those data will be used to construct mechanistic SDMs. Finally, we will use landscape genomics to assess fine-scale population structure and patterns of dispersal across the region using low-cost, high resolution sequence data. Together, these integrative datasets will provide detailed predictions of habitat under current and future climates and inform near- and long-term management strategies.

This project is jointly funded by the M.L. 2016, Chp. 186, Sec. 2, Subd. 06a appropriation to MITPPC and will be split as follows:
ML 2015: $70,812
ML 2016: $352,000

Summary of budget information for sub-project 14 **ENRTF budget:** $70,812

Outcomes, Activity 1 Remote sensing and machine learning to gather environmental, population, and demographic data	**Completion date**
1. Gather remotely sensed environmental data from publicly-available sources	December 13, 2019
2. Develop classifier using DL and remotely-sensed data to detect leafy spurge	December 31,2020
3. Gather demographic data on leafy spurge populations identified by classifier	June 30, 2021
4. Develop classifier using DL and remotely-sensed data to detect common tansy	June 30, 2021
5. Gather demographic data on common tansy populations identified by classifier	December 31, 2021
6. Validate classification model and demographic data through field surveys	June 30, 2022
Outcomes, Activity 2: Common garden experiments to assess niche thresholds and trait differentiation among populations	
1. Collect seeds for leafy spurge and common tansy from across range	December 31, 2019
2. Conduct growth chamber experiments on leafy spurge seeds at varying temperatures to assess germination niche	June 30, 2020
3. Conduct growth chamber experiments on leafy spurge juveniles at varying temperatures to assess first year emergence	June 30, 2021
4. Conduct growth chamber experiments on leafy spurge juveniles and adults at varying temperatures to assess relative growth rate, reproductive allocation, and biomass allocation (above- and below-ground)	December 31, 2021
5. Conduct growth chamber experiments on common tansy seeds at varying temperatures to assess germination niche	June 30, 2021
6. Conduct growth chamber experiments on common tansy juveniles at varying temperatures to assess first year emergence	June 30, 2021
7. Conduct growth chamber experiments on common tansy juveniles and adults at varying temperatures to assess relative growth rate, reproductive allocation, and biomass allocation (above- and below-ground)	December 31, 2021
Outcomes, Activity 3 Build traditional mechanistic and process based distribution models	
1. Build traditional SDMs (Maxent and Boosted Regression Trees) of leafy spurge	December 31, 2020
2. Build traditional SDMs (Maxent and Boosted Regression Trees) of common tansy	December 31, 2020

3. Build process-based SDMs of leafy spurge	December 31, 2021
4. Build process-based SDMs of common tansy	June 30, 2022
5. Build mechanistic SDMs of leafy spurge	June 30, 2022
6. Build mechanistic SDMs of common tansy	June 30, 2022
Outcomes, Activity 4 Using landscape genomics to infer major dispersal pathways and sources of new infestations	
1. Tissue collection and extraction	December 31, 2020
2. Enzyme optimization for sequencing	June 30, 2021
3. Sequencing and analysis of data within a spatial framework for leafy spurge	December 31, 2021
4. Sequencing and analysis of data within a spatial framework for common tansy	June 30, 2022

Status as of July 31, 2019:
Sub-project is in early phases of organization. No update is required per LCCMR instruction.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Status as of July 31, 2021:
Status as of January 31, 2022:
Status as of July 31, 2022:
Status as of January 31, 2023:
Final Report Summary:

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.

Status as of January 31, 2016:
There has been no activity yet under this appropriation. Details on the MITPPC's work may be found in the ML 2014 ENRTF workplan and sub-workplans.

Status as of July 31, 2016:
There has been no activity yet under this appropriation. Details on MITPPC's work to-date, including details of the prioritization process, may be found in the ML 2014 ENRTF workplan and sub-workplans.

Status as of January 31, 2017:
There has been no activity yet under this appropriation. Details on MITPPC's work to-date, including details of the prioritization process, may be found in the ML 2014 ENRTF workplan and sub-workplans.

Status as of July 31, 2017:
For a description of dissemination by the MITPPC on the ML 2014, 2015, and 2016 appropriations may be accessed in the ML 2014 workplan.

Status as of January 31, 2018:
Please note for all future updates under this section: For a description of dissemination by the MITPPC on the ML 2014, 2015, and 2016 appropriations may be accessed in the ML 2014 workplan.

Status as of July 30, 2018:
Please note for all future updates under this section: For a description of dissemination by the MITPPC on the ML 2014, 2015, and 2016 appropriations may be accessed in the ML 2014 workplan.

Status as of January 31, 2019:
Please note for all future updates under this section: For a description of dissemination by the MITPPC on the ML 2014, 2015, and 2016 appropriations may be accessed in the ML 2014 workplan.

Sub-project 1:

- Presentations:
  Katovich, E., R. Becker, M. Marek-Spartz, G. Cortat, H. Hinz, and L. Van Riper. 2018. Biological Control of Garlic Mustard with *Ceutorhynchus scrobicollis*, an Update. Poster at the XV International Symposium on Biological Control of Weeds. Engelberg, Switzerland. Session 1-P22-Target and agent selection. Aug. 26-31, 2018.

  Marek-Spartz, M., and K. Marek-Spartz, G. Heimpel, and R. Becker. 2018. Generations: understanding weed-herbivore interactions using Python. Poster at the XV International Symposium on Biological Control of Weeds. Engelberg, Switzerland. Session 4-P13-Novel methods to determine efficacy and environmental safety of agents. Aug. 26-31, 2018.

  Becker, R., L. Van Riper, R. Montgomery, L. Knosalla, M. Marek- Spartz, J. Katovich, and B. Kinkaid. 2018. Monitoring Garlic Mustard in Minnesota - Now You See Them, Now You Don't. Presentation at the Upper Midwest Invasive Species Conference. Rochester Convention Center, Rochester MN. Oct. 15-18, 2018

  E. Katovich, R. Becker, M. Marek-Spartz, G. Cortat, H. Hinz, and L.Van Riper. 2018. Biological Control of Garlic Mustard with *Ceutorhynchus scrobicollis*, an Update. Poster at the Upper Midwest Invasive Species Conference. Rochester Convention Center, Rochester MN. Oct. 15-18, 2018.

  Marek-Spartz, M., G. Heimpel, R. Becker, and K. Marek-Spartz. 2018. Generations: Understanding Weed-Herbivore Interactions Using Python. Poster at the Upper Midwest Invasive Species Conference. Rochester Convention Center, Rochester MN. Oct. 15-18, 2018.

  Becker, R., L. Van Riper, R. Montgomery, L. Knosalla, M. Marek- Spartz, J. Katovich, and B. Kinkaid. 2018. Monitoring Garlic Mustard in Minnesota - Now You See Them, Now You Don't. Presentation: North Central Weed Science Soc. Hyatt Regency, Milwaukee, WI. Dec. 3–6, 2018. (206)

  Poster: Katovich, E., R. Becker, M. Marek-Spartz, L. Van Riper, G. Cortat, and H. Hinz. Biological Control of Garlic Mustard: No Impact of *Ceutorhynchus scrobicollis* on Two Endangered Brassicaceae. Proc. North Central Weed Science Soc. Hyatt Regency, Milwaukee, WI. Dec. 3–6, 2018. (36)

  Poster: M. Marek-Spartz, K. Marek-Spartz, G. Heimpel, and R. Becker. *Generations*: Understanding Weed- Herbivore Interactions using Python. Proc. North Central Weed Science Soc. Hyatt Regency, Milwaukee, WI. Dec. 3–6, 2018. (34)

- Other dissemination:
  In preparation for regulatory approval to release in North America, voucher specimens for *C. constrictus* and *C. scrobicollis* were accepted to the Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, Ottawa, CANADA; the Beaty Centre for Species Discovery, Research and Collections Division, Canadian Museum of Nature, Ottawa, CANADA; the Systematic Entomology Laboratory- ARS, USDA, Smithsonian Institution – National Museum of Natural

History, Washington DC, and the Instituto de Biología UNAM, Departamento de Zoologia, Ciudad Universitaria, México.

Submitted a response to the USFWS on pre-Biological Assessment questions the agency had on our petition for release of C. scrobicollis in North America**:** Becker, R., E. Katovich, M. Marek-Spartz, G. Cortat, H. Hinz, and L. Van Riper. Response to USFSW re: An APHIS authored document derived from "A Petition for the Introduction, Experimental Release and Open-Field Release of the Root-Mining Weevil *Ceutorhynchus scrobicollis* (Coleoptera: Curculionidae) for the Biological Control of *Alliaria petiolata* (Garlic Mustard) in North America." August 10, 2018. 16 pp.

Sub-project 2:

- Presentations:
  Smith, Z.M., Chase, K.D., and B.H. Aukema. Competition between mountain pine beetle *Dendroctonus ponderosae* and native Minnesota bark beetles *Ips grandicollis.* The Upper Midwest Invasive Species Conference, Rochester, MN

  Chase, K.D., Abrahamson, M.D., Ambourn, A.K., Vennette, R.C., and B.H. Aukema. Evaluating components of biotic resistance in Minnesota against mountain pine beetle. The Upper Midwest Invasive Species Conference, Rochester, MN

Sub-project 3:

- Publications:
  Kaser, J.M & G.E. Heimpel. 2018 Impact of the parasitoid *Aphelinus certus* on soybean aphid populations. Biological Control 127: 17-24.

  Christianson, L.D.E., C.M. Stenoien, G.E. Heimpel & K.R. Hopper. Laboratory measures as an initial assessment of *Aphelinus* spp. overwintering ability. Poster presentation. The Upper Midwest Invasive Species Conference, Rochester, MN

  Miksanek J.R. & G.E. Heimpel. Understanding the theoretical and ecological influence of the parasitoid *Aphelinus certus* on soybean aphid. The Upper Midwest Invasive Species Conference, Rochester, MN

  Miksanek J.R., G.E. Heimpel & J. Kaser. Infiltration of native prairie habitat by the Asian parasitoid *Aphelinus certus* (Hymenoptera: Aphelinidae). MN. Poster presentation. The Upper Midwest Invasive Species Conference, Rochester, MN

  Stenoien C, Christianson, L., Welch K, Hopper, K.R., & Heimpel G.E. The overwintering biology of *Aphelinus certus*, an adventive parasitoid of soybean aphid. The Upper Midwest Invasive Species Conference, Rochester, MN

  J. Kaser, J. Miksanek & G.E. Heimpel. Cessation of enemy release or continuation of invasion meltdown? The case of soybean aphid and its natural enemies. Invited symposium presentation at the Annual meeting of the Entomological Society of America, Vancouver, Canada.

  C. Stenoien, L. Christianson, K. Welch, K. Hopper & G.E. Heimpel. The overwintering biology of *Aphelinus certus*, an adventive parasitoid of soybean aphid. Oral presentation at the Annual meeting of the Entomological Society of America, Vancouver, Canada.

  Miksanek J.R. & G.E. Heimpel. Evaluating the risks and benefits of *Aphelinus certus*, an introduced enemy of soybean aphid, in North America: Integrating ecosystem-level effects into the decision-making

process. IOBC-WPRS Working Group Meeting [Benefits and risks of exotic biological control agents]. Ponta Delgada, Açores, Portugal. September 2018

Sub-project 4:

- Presentations:
  Cira TM, Z Marston, I McRae, RL Koch. Oct 2018. Using drones to detect pests: A soybean aphid case study. Upper Midwest Invasive Species Conference, Rochester, MN

  Bhusal, S, R Koch, A Lorenz. Oct 2018. Advancing host-plant resistance for more sustainable management of soybean aphid. Upper Midwest Invasive Species Conference, Rochester, MN

  Cira TM, Z Marston, I McRae, E Hodgson, RL Koch. Nov 2018. Remote sensing for soybean aphid. Entomological Society of America Annual Meeting.

  Koch, R.L. 2018, December. Soybean aphid management: New challenges posed by insecticide resistance. Manitoba Agronomists Conference, Winnipeg, Manitoba, Canada (35-minute presentation with 380 attendees).

  Koch, R.L. 2018, September. Soybean aphid research and management. Advanced Ag Professional Insect and Disease Workshop. University of Minnesota, Extension. Rosemount, MN (60-minute presentation with 15 attendees).

  Naeve, S. and R.L. Koch. 2018, July. Managing the soybean environment and insect pests to maximize yield. Field School for Agricultural Professionals. Institute for Agricultural Professionals, University of Minnesota Extension. St. Paul, MN (two 120-minute presentations with 25 and 27 attendees).

  Koch, R.L. 2018, July. Soybean insects updates: Insecticide-resistant soybean aphid and Japanese beetles. Agronomy in Action Event, Golden Harvest/Syngenta. Stanton, MN. (45-minute talk with 20 attendees)

  Koch, R.L. 2018, June. Management of insecticide-resistant soybean aphids. Crops Field Day. Southern Research and Outreach Center. Waseca, MN. (30-minute talk with 85 attendees)

Sub-project 5:

- Presentations:
  Mwangola, D.M., Burrington, J.A., Ambourn, A.K., Abrahamson, M.D., and B.H. Aukema. Systemic insecticide treatment against Emerald ash borer: associative protection. Upper Midwest Invasive Species Conference, Rochester, MN
  Mwangola, D.M., and B.H. Aukema. Systemic insecticide treatments against emerald ash borer: Associational protection and potential non-target effects. ESA/ESC/ESBC Joint Annual Meeting Nov 11-14, 2018, Vancouver, BC

  The team met with a property management company and the executive board of a homeowner association at a local community involved with the project, to explain project design and answer questions about how they might expand involvement.

Sub-project 6:

- Presentations:
  Malvick, D. Distribution and Invasive Traits of the Fungal Plant Pathogen Fusarium virguliforme Upper Midwest Invasive Species Conference, Rochester, MN

Sub-project 7:

- Presentations:
  Noyszewski, A.K., N.O. Anderson, A.G. Smith, D. Dalbotten, E. Ito, M. Dockry, A. Timm, and H. Pellerin. 2018. Comparative DNA extraction of historic vs. extant reed canarygrass to determine native/exotic status. Upper Midwest Invasive Species Conference

  Anderson, N.O. 2018. Throwing out the bathwater but keeping the baby. Invasive Plants Research (INPR) Workshop "It's native. Wait! It's exotic…Oh no, It's a nuisance!", Proceedings of the Annual Conference of the American Society for Horticultural Science. Abstract, n.p. [presentation]

  Noyszewski, A.K., N.O. Anderson, A.G. Smith, D. Dalbotten, E. Ito, M. Dockry, A. Timm, and H. Pellerin. 2018. Challenges of establishing native vs. exotic status of reedcanary grass herbarium specimens. Invasive Plants Research (INPR) Workshop "It's native. Wait! It's exotic…Oh no, It's a nuisance!", Proceedings of the Annual Conference of the American Society for Horticultural Science. Abstract, n.p. [presentation]

  Noyszewski, A.K., N.O. Anderson, A.G. Smith, D. Dalbotten, E. Ito, A. Timm, and H. Pellerin. 2018. Challenges of establishing native vs. exotic status of reedcanary grass herbarium specimens. Floriculture Research Alliance, Annual Meeting, Minneapolis, MN, Oct. 16-17, 2018. Abstract, n.p. [poster]

  Smith, A.G., A.K. Noyszewski, A. Kilian, D. Dalbotten, E. Ito, M. Dockry, A. Timm, H. Pellerin and N.O. Anderson. 2018. Native and exotic reed canarygrass genetic structure and management. Plant Biology 2018, Annual Meeting of the American Society of Plant Biology, 14-18 August 2018, Montreal, Quebec. Abstract, Zone 300, n.p. [poster]

Sub-project 8:

- Presentations:
  "Tylose formation defies expectation: xylem anatomy and response to vascular wilts among temperate oaks". Isabella Armour (presenter), Beth Fallon, Jenny Juzwik, Rebecca Montgomery, Jeannine Cavender-Bares Botany Meeting, Rochester, MN. July 23, 2018.

  "Preserving forest biodiversity: Protection of biodiversity and ecosystem services through early detection of tree disease using hyperspectral remote sensing". Beth Fallon, Cathleen Nguyen, Anna Yang, Isabella Armour, Anna K. Schweiger, John A.Gamon, Hamed Gholizadeh, Jenny Juzwik, Rebecca Montgomery, Jeannine Cavender-Bares (presenter) International Oak Society Meeting, Davis, CA. October 22, 2018

  "Accurate detection of oak wilt (*Bretziella fagacearum*) using airborne imaging spectroscopy". Anna Schweiger (presenter), Cathleen Nguyen, Rebecca Montgomery, Jenny Juzwik, Phil Townsend, John Gamon, Hamed Gholizadeh, Jeannine Cavender-Bares**.** American Geophysical Union, Washington, D.C., December 13, 2018.

  Invited symposium talk, Ecological Society of America, New Orleans, LA. August 8, 2018
  "Detecting and differentiating fungal infection and drought stress in temperate oaks using leaf hyperspectral reflectance." Beth Fallon, Anna Yang, Cathleen Nguyen, Isabella Armour, Anna Schweiger, Jenny Juzwik, Rebecca Montgomery, John Gamon, Phil Townsend**, J**eannine Cavender-Bares (speaker)

  Public science outreach with Market Science (UMn CBS) at Midtown Farmer's Market, August 18. 2018.
  "Oak wilt and other tree killers: what are they and how can we find them?" Beth Fallon

Minnesota Master Naturalists - West Metro Chapter meeting. September 2018.
Jeannine Cavender-Bares

University of Minnesota Plant Pathology Department, December 3, 2018."Advances in the detection of oak wilt (Bretziella fagacearum) using leaf-level, whole plant and remotely sensed spectroscopy". Beth Fallon, Anna Schweiger, Cathleen Nguyen, Anna Yang, Jenny Juzwik, Rebecca Montgomery, John Gamon, Hamed Gholizedeh, Jeannine Cavender-Bares (speaker)

"Detecting and differentiating fungal infection and drought stress in temperate oaks using leaf hyperspectral reflectance". Beth Fallon (speaker), Anna Yang, Cathleen Nguyen, Isabella Armour, Anna Schweiger, Jenny Juzwik, Rebecca Montgomery, John Gamon, Phil Townsend**,** Jeannine Cavender-Bares**.** Joint Conference of the Upper Midwest Invasive Species Conference and the North American Invasive Species Management Association, Rochester MN, October 16, 2018.

Sub-project 9:

- Presentations:
  Upper Midwest Invasive Species Conference Oct 15-18, 2018. Rochester, MN. Wittman, J.T., Kees, A.M., and B.H. Aukema. Characterizing the movement behavior of gypsy moth (*Lymantria dispar*) caterpillars using a servosphere.

  ESA/ESC/ESBC Joint Annual Meeting Nov 11-14, 2018. Vancouver, BC. Wittman, J.T. and B.H. Aukema. Effects of host foliage on the movement behavior of larvae of gypsy moth *Lymantria dispar.*

- Publications:
  Wittman, J.T. 2018. Effects of host type and food deprivation on the movement behavior of late-instar larvae of gypsy moth *Lymantria dispar* (Lepidoptera: Erebidae). Master's of Science thesis. Department of Entomology, University of Minnesota. Available on-line at: https://conservancy.umn.edu/bitstream/handle/11299/200988/Wittman_umn_0130M_19734.pdf?sequence=1&isAllowed=y (Accessed December 31, 2018).

  Wittman, J.T. and B.H. Aukema. (201x) Foliage type and availability alters the movement behavior of late instar European gypsy moth *Lymantria dispar* (Lepidopera: Erebidae).*Journal of Insect Behavior* Submitted Nov 22, 2018.

Sub-project 10:

- Presentations
  Matthew Gullickson October 2018: Upper Midwest Invasive Species conference, Rochester, MN. Morphological and behavioral differences in spotted wing drosophila winter and summer morphs.

  University of Minnesota Organic Open House, St. Paul, MN. Integrated pest management for spotted wing drosophila. Presenter: Matthew Gullickson, September 2018: Defending berries against spotted-wing drosophila. (blog post) URL: http://fruit.umn.edu/content/defending-berries-swd

  Anh Tran, Mark Asplen, and Bill Hutchison, October 2018: Upper Midwest Invasive Species conference, Rochester, MN. Lethal and sub-lethal effects of novel insecticides on invasive spotted wing drosophila (*Drosophila suzukii*).

  Matthew Gullickson, Mary Rogers, Eric Burkness, Bill Hutchison, October 2018: Upper Midwest Invasive Species conference, Rochester, MN. Economic impacts of spotted wing drosophila SWD in MN.

  Gigi Digiacomo, November 2018: Entomological Society of America Annual Meeting, Vancouver, Canada. Does size matter? Using body measurements to differentiate *Drosophila suzukii* seasonal morphs. (Oral

presentation)

Anh Tran, Mark Asplen, and Bill Hutchison, November 2018: Entomological Society of America Annual Meeting, Vancouver, Canada. Lethal and sub-lethal effects of novel insecticides on spotted-wing drosophila (*Drosophila suzukii*). (Poster presentation)

Matthew Gullickson, Mary Rogers, Eric Burkness, Bill Hutchison, November 2018: Economic Impact of Spotted Wing Drosophila (Diptera: Drosophilidae)

- Publications:
  Yield Loss on Minnesota Raspberry Farms: A 2017 Grower Survey. *Submitted to*: Journal of Integrated Pest Management. Authors: Gigi Digiacomo, Joleen Hadrich, William Hutchison, Hikaru Peterson, Mary Rogers.

Sub-project 11:

- Presentations:
  Plant ecophysiology field class – Department of Biology – UMD
  Summer field session – Department of Forest Resources – UMN
  Ecology – FDL TCC
  NASP – National Advanced Silviculture Program
  DNR area supervisors meeting
  International students from Nord University – Norway
  University Zurich (September 2018). Oral presentation by Reich (approx. 100 attendees).
  University ETH Zurich (September 2018). Oral presentation by Reich (approx. 60 attendees).
  University of Utah (October 2018). Oral presentation by Reich (approx. 50 attendees).
  Marine Community Library (November 2018). Oral presentation by Reich (approx. 160 attendees).

- Other media
  Media mentions in the fall of 2018 include CFANS, Duluth News Tribune, Phys.org, Inforum.com, MN Daily

Sub-project 12:

- Presentations:
  "Developing robust identification assays for *Amaranthus palmeri* in seed mixtures " presented at an oral session of the Upper Midwest Invasive Species conference on October 15th, 2018

Status as of July 31, 2019:
Sub-project 1:
Findings of this research were presented in Biology, Ecology, and Management of Invasive Plants, AGRO 4505.

Sub-project 2:
Presentations:
Smith, Z.M. and B.H. Aukema. Field responses of mountain pine beetle and *Ips grandicollis* to pheromone baits in a novel sympatric range. Western Forest Insect Work Conference, April 17-20, Anchorage, AK

Sub-project 3:
Publication:
Miksanek, J.R. & G.E. Heimpel. 2019. A matrix model describing host-parasitoid population dynamics: the case of *Aphelinus certus* and soybean aphid. PLoS ONE 14(6): e0218217

Presentations:

6/2019. G.E. Heimpel**.** Biological Control as a Conservation Science. Plenary Address at the Foro BioProtección Vegetal, Valencia, Spain.

6/2019. G.E. Heimpel**.** Biological Control as a Conservation Science. Keynote Address at the International Symposium on Biocontrol and Integrated Pest Management for Crop Protection and Trade Facilitation, Taichung, Taiwan.

Sub-project 4:

Presentations:

- Siddhi J Bhusal presented a poster entitled "Variability of soybean aphid biotypes in Minnesota" at the Soybean Breeders' Workshop 2019 held in Saint Louis, MO on Feb 11-13th, 2019.

Publications:

- Bhusal, S., A. Hanson, A. Lorenz and R.L. Koch. 2019. Updated list of aphid-resistant soybean varieties available for Minnesota. Minnesota Crop News, University of Minnesota Extension. January 15, 2019. https://blog-crop-news.extension.umn.edu/2019/01/updated-list-of-aphid-resistant-soybean.html
- Hanson, A.A., S.J. Bhusal, A. Lorenz and R.L. Koch. 2019. Aphid-resistant soybean varieties for Minnesota. University of Minnesota Extension. https://extension.umn.edu/soybean-variety-selection/aphid-resistant-soybean-varieties-minnesota
- Marston ZPD, TM Cira, EW Hodgson, IV MacRae, RL Koch. [submitted] Detection of stress induced by soybean aphid (Hemiptera: Aphididae) using multispectral imagery from unmanned aerial vehicles. Environ Entomology.

Sub-project 5:

Presentations:

- Brian Aukema - Research update on EAB: The search for associational protection. MDA Regional Outreach Meeting in Detroit Lakes , MN 2/27/2019

Sub-project 6:

Presentations:

- Dean Malvick presented results from this work to agricultural professionals and crop producers at multiple extension education events across Minnesota to about 300 attendees.

Publications:

- An abstract on the distribution of FV was written and submitted to the American Phytopathological Society. It will be published on-line soon and the work will be presented at a conference in Ohio in August.

Sub-project 7*:*

Presentations:

- Noyszewski AK, Anderson NO, Smith AG, Kilian A, Dalboten D, Ito E, A. Timm, Pellerin H. 2019. Distinguishing Among Native vs. Exotic Reed Canarygrass (Phalaris arundinacea) using GBS (DArTseqLD). Plant Animal Genome Conference, 2019, San Diego, CA.

Publications:

- Noyszewski AK, Anderson NO, Smith AG, Kilian A, Dalboten D, Ito E, A. Timm, Pellerin H. 2019. Challenges of Establishing Native Vs. Exotic Status of Herbarium Specimens. *HortTechnology* (accepted).

Sub-project 9:
Project completed

Sub-project 10:
Presentations:

- April 2019. Matt Gullickson (Rogers lab) gave a spark-talk on his research on SWD at the Department of Horticultural Science day-long public outreach event, *Hort Sci Grows* (approx. 50 people in attendance)
- April 2019: Hutchison gave two outreach presentations, "IPM and Research Update for Spotted Wing Drosophila, and other Fruit Insects," to Fruit & Vegetable growers; Little Falls, and Alexandria MN, in collaboration with UMN Extension and Extension Educators at each location (~50 growers attending).
- January 2019: MN Fruit & Vegetable Association annual conference, St. Cloud, MN. Rogers & Gullickson delivered 3 talks in total covering exclusion strategies, holistic management strategies, and economic impacts of SWD on fruit crops (approx. 50 people in attendance)
- January 2019: MN Fruit & Vegetable Growers Assoc. annual conference, St. Cloud, MN. Hutchison's IPM Team participated with a Trade Show booth, for hands-on identification of SWD flies, use of traps for SWD, and free 10X hand lens' to assist growers with identification; specimens and live insects and brochures representing other invasive insect species were also available.

Publications:

- June 2019: Dana D'Amico and Gigi DiGiacomo collaborated to develop an info-graphic targeted at MN fruit growers thanking them for their participation in the electronic and telephone surveys (conducted in 2017 and 2018). Links to recent publications and key "take away" ideas from the surveys were included in the info-graphic. The info-graphic was emailed to the original survey population of 149 MN fruit growers. The open rate for growers was 42% (industry average for "Agriculture and Food Services" is 22%). < https://z.umn.edu/swd-survey>
- May 2019: peer-reviewed publication. DiGiacomo, G., Hadrich, J., Hutchison, W.D., Peterson, H., and Rogers, M. 2019. Economic impact of spotted-wing drosophila-related yield loss on MN raspberry farms: 2017 survey results and estimates. *Journal of Integrated Pest Management.* https://doi.org/10.1093/jipm/pmz006
- May 2019: Hutchison and IPM web coordinator, Suzanne Wold, updated the FruitEdge page, to include weekly SWD trap-catch data for the 2019 season, where growers can track the dates of 1st catch, and the annual build-up in infestations by berry crop group (https://www.fruitedge.umn.edu/swdtrap)
- May 2019: Dana D'Amico assisted the team with a press release related to the release of the DiGiacomo paper referenced above. Title: *New economic research reveals high cost of invasive species for Minnesota-grown raspberries* < https://mitppc.umn.edu/news/high-cost-invasive-species-mn-grown-raspberries>
- April 2019. Matt Gullickson wrote a blog post for the UMN Fruit & Vegetable newsletter. Title:Using high tunnels to protect raspberries from spotted-wing drosophila. < https://blog-fruit-vegetable-ipm.extension.umn.edu/2019/04/author-matthew-gullickson.html>

Sub-project 11:

Presentations:

- Two field classes for students from local Colleges and Universities (FDLTCC – Fond Du Lac Tribal Community College, UMD – University of Minnesota – Duluth) were hosted with total attendance of 21 students plus their instructors,
- A group of 9 international students including three faculty members from Nord University in Norway.
- We engaged in undergraduate research project that will look at the effect of warming and summer rainfall reduction on invasive species mycorrhizal associations.

Sub-project 12:

- Presentations:
  Developing robust identification assays for *Amaranthus palmeri* in seed mixtures. Poster presented at the UMN Palmer Summit, January 22nd 2019.

- Developing robust identification assays for the high impact invasive *Amaranthus palmeri*, seminar given as invited speaker at Colorado State University, April 17th 2019

Publications:

- Work mentioned in Star Tribune article "Invasive weed that threatens corn, soybean crops is spreading in Minnesota" on April 24th 2019

http://www.startribune.com/devastating-invasive-weed-is-spreading-in-minnesota/509009672/

- Created short video New Genetic Test for Palmer Amaranth for use by MITPPC communications. Video is available at: https://youtu.be/k3CinaswUCc

Sub-project 13:
No activity during this period.

Sub-project 14:
No activity during this period.

Status as of January 31, 2020:
Status as of July 31, 2020:
Status as of January 31, 2021:
Status as of July 31, 2021:
Status as of January 31, 2022:
Status as of July 31, 2022:
Status as of January 31, 2023
Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: More detail to be provided as specific research projects are proposed (if applicable)

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 42

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: None

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:			
Minnesota Soybean Research and Promotion Council	$30,000	$30,000	Funds used to co-support MITPPC Sub-Project 4: Decreasing environmental impacts of soybean aphid management
Other State $ To Be Applied To Project During Project Period:			
General Fund Appropriation ML 2014, Chapter 312, Article 12, Section 8	$3,400,000	$572,876	Funds will be used to support the core operations and leadership of the Minnesota Invasive Terrestrial Plants and Pests Center by a Center Director and administrative support for the 8-year project period. This includes funding for est. 2 additional research projects, personnel costs (faculty, graduate students, postdoctoral associates), equipment, materials and supplies necessary for research. Each project is estimated at $180-210K/year for 3-4 years. 6/30/22
Past and Current ENRTF Appropriation:			
ML 2014, Chapter 312, Article 12, Section 8	$1,460,000	$678,743	Funds will be used to convene expert panel to create a framework and conduct initial assessment to establish highest priority species; convene expert panel annually in years 2 and 3 to assess net impacts of invasive species and control responses; and support 2-3 research projects (at $180-$210K/year for 3-5 years). 6/30/22
ML 2016, Chapter 186, Article Section 2, Subd. 6a	$3,750,000	$0	Funds will be used to conduct research to prevent, minimize, and mitigate the threats and impacts posed by terrestrial invasive plants, pathogens, and pests to the state's prairies, forests, wetlands, and agricultural resources. 6/30/23
Institute on the Environment, UMN	$2,840	$2,840	Funds will be used to convene a panel to discuss to discuss the relationships between soybean aphids, an invasive species, soybean production, and the effects of pesticides on the Dakota skipper and other insect populations. 6/30/18
Other Funding History:			
	$	$	

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
N/A			

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role

B. Project Partners (not receiving funds):

- USDA Forest Service Northern Research Station
- Minnesota Department of Agriculture
- Minnesota Department of Natural Resources
- Minnesota Forest Resource Council

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. While M.L. 2014 ENRTF and General Fund dollars will be used to conduct a risk assessment and launch initial research or prioritized species, funding is being sought through the M.L 2015 ENRTF request 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 15-20 species upon which we will focus.

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than ~~January 31 and July 31~~ February 28 and August 30 of each year (every 6 months). A final report and associated products will be submitted between June 30 and August 15, 2023.

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map
C. Parcel List Spreadsheet
D. Acquisition, Easements, and Restoration Requirements
E. Research Addendum

X. RESEARCH ADDENDUM: A research addendum was developed after a panel of researchers from the University of Minnesota provided competitive reviews of the pre-proposals under this appropriation. The addendum was distributed to relevant experts outside the University of Minnesota and reviewed for scientific novelty, appropriateness of methods, qualifications of the research team, and potential impact on invasive species management. The research addendums were modified as necessary in response to comments received during the peer-review process. The final documents provide a technically detailed description of the research to be completed under this sub-project work plan. The research addendums are on file with the Minnesota Invasive Terrestrial Plant and Pest Center**.**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Pests and Plants Center-- Sub Project List
Legal Citation: ML 2015, Ch. 76. Art. 2, Sec. 6a
Project Manager: Robert Venette
Project Title: Minnesota Invasive Terrestrial Plants and Pests Center, Ph. 2
Organization: University of Minnesota
College/Department/Division: College of Food, Agriculture, and Natural Resource Sciences
Project Budget: $5,000,000
Project Length and Completion Date: 8 years, June 30, 2022
Current Date: July 30, 2019

Sub Project #	Sub Project Title	Species	Project Manager	LCCMR Approval Date
reserve				
1	Garlic Mustard Biocontrol	Garlic mustard	Roger Becker	3/7/2017
2	Mountain Pine Beetle, Ph. 2	Mountain pine beetle	Brian Aukema	3/31/2017
3	Biological Control of Soybean Aphid	Soybean aphid	George Heimpel	4/12/2017
4	Decreasing Environmental Impacts of Soybean Aphid	Soybean aphid	Robert Koch	4/27/2017
5	Optimizing tree injections against emerald ash borer	Emerald ash borer	Brian Aukema	4/12/2017
6	Distribution and Traits of the Fungal Pathogen Fusarium virguliforme that Influence Current and Fugture Risk to Soybean and other Legumes in Minnesota	Sudden soybean death	Dean Malvick	4/12/2017
7	Tools to Distinguish Native from Exotic Reed Canary Grass	Reed canary grass	Neil O Anderson	4/12/2017
8	Accurate Detection and Integrated Treatment of Oak Wilt in Minnesota	Oak wilt	Jeannine Cavender-Bares	4/12/2017
9	Characterizing dispersal of larval gypsy moth to improve quarantine regulations	Gypsy moth	Brian Aukema	6/13/2017
10	Management Strategies for the Invasive Spotted Wing Drosophila	Spotted wing drosophila	Mary Rogers	5/17/2017
11	Will Future Weather Favor Minnesota's Woody Invaders?	Common& glossy buckthorn, Morrow's &tatarian honeysuckle	Peter Reich	6/13/2017

12	Developing Robust Identification Assays for Amaranthus palmeri in seed mixtures	Palmer amaranth	Donald Wyse	11/10/2017
13	Terrestrial Invasive Species Prioritization	46 TIS TBD	Amy Morey	
14	Improved Detection and Future Management of Leafy Spurge and Common Tansy using Remote Sensing, Mechanistic Species Distribution Models, and Landscape Genomics	Leafy spurge and common tansy	David Moeller & Ryan B. Runquist	
Notes:				

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Budget	Amount Spent	Balance	Status (select from dropdown menu)
$35,412		$35,412	
$600,000	$273,948	$326,052	In Progress
$456,000	$187,920	$268,080	In Progress
$600,000	$146,102	$453,898	In Progress
$570,000	$230,441	$339,559	In Progress
$320,000	$124,463	$195,537	In Progress
$412,000	$175,424	$236,576	In Progress
$268,000	$157,864	$110,136	In Progress
$357,420	$193,389	$164,031	In Progress
$35,000	$35,000	$0	Complete
$505,002	$212,365	$292,637	In Progress
$526,000	$222,677	$303,323	In Progress

$208,230	$134,698	$73,532	In Progress
$36,126	$4,749	$31,377	In Progress
$70,812	$0	$70,812	In Progress
$5,000,002	**$2,099,040**	**$2,900,962**	

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #1: Garlic Mustard Biocontrol: Ecological Host Range of Biocontrol
Legal Citation: ML 2015, Ch. 76. Art. 2, Sec. 6a
Sub-Project Manager: Roger Becker
Organization: University of Minnesota
Sub-Project Budget: $ 600,000
Sub-Project Length and Completion Date: 4 Years, December 31, 2020
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits) Overall
Salary - 1- PhD FTE/yr. for 3.5 yrs. (1 student stipend + $18,419/yr. Tuition/Benefits fringe + 3% inflation/yr.) = **$149,760 total.**
Salary - Civil Service. 1.1 FTE/yr. for 4 yrs. (salary + fringe + 3% inflation for a composite of 3 personnel/yr.) = **$319,797 total.**
Salary - Student Labor $11.50/hr. for 840 hr./yr. for 4 yrs. (full time summer, 1/4 time school year + 3% inflation adj./yr.) = **$40,414 total.**
Professional/Technical/Service Contracts
(General Operating Services and Short Term Rents). University of Minnesota watering charges and other service charges for greenhouse and field space (est. $600/yr.). Charges from a qualified carrier for insect APHIS permitted shipment, most recently OPTIMIZE Courier. Est. 5 shipments at $1500/per shipment - (ACTUAL COSTS TO COMPLY WITH REGULATORY REQUIREMENTS) from CABI Delémont Switzerland. Est. 2 scrobicollis and 3 constrictus over course of the grant. $300 ArcGIS annual license via U of MN. Together, plus anticipated $300 incidentals is $3700/yr. Totals $13,936. University of Minnesota greenhouse, containment facility and field space rental fees initially an est. $1200 per month. Yr. 3,4 decrease as C. scrobicollis need for quarantine space decreases. As
Subcontract $8,000 per year plus 3% inflation for CABI, Delémont, Switzerland to conduct specificity testing we can not do in a quarantine facility such as choice tests outdoors, travel and labor to collect insects for shipment to quarantine in Minnesota. CABI conducts work that can not be conducted in Minnesota as we must be in a quarantine facility. CABI at Delémont has been involved from the beginning of this project and are capable, knowledgeable, experienced in biological control of garlic mustard.
Equipment/Tools/Supplies
Temperature probes, Garmin Monterra GPS navigator (est. $600), field supplies: flags, netting, stakes, pots, potting medium, etc.
Travel expenses in Minnesota
Covers 80% of est. travel to monitoring site research plots @ $0.54/ mile, 10 sites twice a year for first two years with increase to possible 15 sites in year 3 if releasing C. scrobicollis at an avg. 100 miles per site trip to monitor possible release sites pre-release and facilitate release of insects in year 3 if approved. $750 or to present or report findings at professional meetings, and may need to attend, present, discuss findings at with APHIS Technical Advisory Group at their annual mtg., typically in suburban Washington, D.C. est. $1500 travel
COLUMN TOTAL

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TOTAL BUDGET	BUDGET REVISION	AMOUNT SPENT	TOTAL BALANCE
~~$508,771~~	**$476,771**	**$192,095**	**$284,676**
~~$80,565~~	**$110,565**	**$75,778**	**$34,787**
~~$13,707~~	$77,096	$51,051	$26,045
$66,858	$33,469	$24,727	$8,742
~~$2,900~~	**$4,900**	**$3,575**	**$1,325**
~~$2,900~~	$4,900	$2,171	$1,325
$7,764	**$7,764**	**$2,500**	**$5,264**
$7,764	$7,764	$2,500	$5,264
$600,000	**$600,000**	**$273,948**	**$326,052**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #2: Mountain Pine Beetle Phase II: Protecting Minnesota
Legal Citation: M.L. 2015, Chp.76, Sec.2, Subd. 6a
Sub-Project Manager: Brian Aukema
Organization: University of Minnesota
Sub-Project Budget: $456,000
Sub-Project Length and Completion Date: 4 Years, June 30, 2021
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET

BUDGET ITEM
Personnel (Wages and Benefits) - Total
One postdoc, 4 years, $48,080 (22.4% fringe) indexed at 2.5% increase annually One 10% graduate summer student, Blanchette lab, to help with Activity 3 for 2 yrs ($1,342) Undergrad summer help, base $8,960 with 2.5% increases, 2 per year except year 4 (1) Faculty time, maximum of 3 pay periods each summer four years, total $58,480 + 33.4% benefits.
Faculty time, maximum of 3 pay periods each summer four years, total $58,480 + 33.4% benefits.
One postdoc, 4 years, $48,080 (22.4% benefits) indexed at 2.5% increase annually
One 10% graduate summer student (17.6% benefits), Blanchette lab, to help with Activity 3 for 2 yrs ($1,342)
Undergrad summer help (0% benefits) , base $8,960 with 2.5% increases, 2 per year except year 4 (1)
Professional/Technical Services and Contracts - Total
Wheaton College Science Station rental (similar to Phase I funded by LCCMR) - 4 yrs x $1500, Quarentine Lab Facility rental - 3yrs x $2850
Wheaton College Science Station
Quarentine Lab Facility at UMN
Equipment/Tools/Supplies - Total
Lures, traps, chemical standards, t-posts, insect rearing supplies, industrial cardboard tubes, safety equipment, scaffolding. Estimated between $5,340-$10,650 per year, with most expenses in Year 1 for Activities 1 and 2.
Supplies- Lab and/or Field: [List out description/details]
Printing - Total
Printing of project reports and testing plans
Travel - Total
Rental of truck at Fleet rates each year, although lab truck will be assigned to project as possible to reduce expenses. Includes per diems and lodging along survey routes (Activities 1 & 2). Similar to phase I, much work on the insect will occur outside of the state to avoid introductions to MN.
Travel in state
Travel out of state
Shipping - Total
Shipping insects and lures between field sites
COLUMN TOTAL

TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$387,936	**$165,619**	**$222,317**
$14,550	**$0**	**$14,550**
$6,000	$0	$6,000
$8,550	$0	$8,550
$20,549	**$12,586**	**$7,963**
$20,549	$12,586	$7,963
$800	**$83**	**$717**
$800	$83	$717
$31,765	**$9,569**	**$22,331**
$19,045	$7,655	$11,510
$4,360	$957	$3,418
$8,360	$957	$7,403
$400	**$63**	**$337**
$400	$63	$337
$456,000	**$187,920**	**$268,080**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC)
M.L. 2015 Sub-Project Budget

Sub-Project Title: MITPPC #3: Biological control of the soybean aphid by *Aphelinus certus*
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: George Heimpel
Organization: University of Minnesota
Sub-Project Budget: $600,000
Sub-Project Length and Completion Date: 4 Years, June 30, 2021
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
James Miksanek, PhD student: $145,300 (52% salary, 48% fringe); 50% FTE each year for 4 years.
Kelton Welch & Carl Stenoien; Post-doctoral Associates: $253,109 (83% salary, 17% benefits); 100% FTE each year for 4 years.
Undergraduate Research Assistants: $80,687 (96% salary, 4% benefits); 35% FTE each year for 4 years
Civil Service salary, fringe: $11,891
Professional/Technical/Service Contracts
Contract with Minnesota Dept. of Ag. $12,000 in year 1 with 3% increases. Activity 3
Greenhouse, growth chamber, plot fee charges; total $16,735; split evenly over activities 1, 2 and 4
Equipment/Tools/Supplies
Materials to construct field cages, vials and other storage supplies for laboratory work, insect traps. Total: $24,215 split evenly over activities 1, 2 and 4.
Printing
Printing extension materials; total $1,000 split evenly over all activities
Publishing fees for open access; total $4,000 split evenly over all activities
Travel
Travel to and from field sites: vehicle rental and/or mileage, lodging: $6K per year for Activity 1.
Travel to and from meetings and field days in Minnesota; $1K split evenly for all 4 activities.
COLUMN TOTAL

TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$478,847	**$100,475**	**$378,372**
$66,938	**$32,860**	**$34,078**
$50,204	$23,110	$27,094
$16,734	$9,750	$6,984
$24,215	**$11,369**	**$12,846**
$24,215	$11,369	$12,846
$5,000	**$0**	**$5,000**
$1,000	$0	$1,000
$4,000	$0	$4,000
$25,000	**$1,398**	**$23,602**
$24,000	$1,398	$22,602
$1,000	$0	$1,000
$600,000	**$146,102**	**$453,898**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC)
M.L. 2015 Sub-Project Budget

Sub-Project Title: MITPPC #4: Decreasing environmental impacts of soybean aphid managem
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Dr. Robert Koch
Organization: University of Minnesota
Sub-Project Budget: $570,000
Sub-Project Length and Completion Date: 4 Years, December 31, 2021
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits) Total
Robert Koch, Project Manager [summer salary]: $25,318 (75% salary, 25% fringe; calculation assumes 3% annual salary increase); 5% FTE each year for 4 years
2 Graduate Research Assistants: $364,256 (57% salary, 43% tuition and fringe; calculation assumes 3% annual salary increase); 50% FTE each year for 4 years
Post-Doctoral Research Associate: $149,932 (82% salary, 18% fringe; calculation assumes 3% annual salary increase); 62% FTE each year for 4 years
Equipment/Tools/Supplies Total
RTK capalbe OEM GPS receivers and associated peripherals to support installation
reagents and supplies for molecular marker assays
Travel expenses in Minnesota Total
Travel to field research sites (vehicle rental/lease)
Other Total
rental of field plot, greenhouse, growth chamber space
COLUMN TOTAL

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TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$539,506	**$225,483**	**$314,023**
$11,494	**$0**	**$11,494**
$3,494	$0	$3,494
$8,000	$0	$8,000
$14,000	**$79**	**$13,921**
$14,000	$79	$13,921
$5,000	**$4,879**	**$121**
$5,000	$4,879	$121
$570,000	**$230,441**	**$339,559**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget

Sub-Project Title: MITPPC #5: Optimizing tree injections against emerald ash borer
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Brian Aukema
Organization: University of Minnesota
Sub-Project Budget: $320,000
Sub-Project Length and Completion Date: 4 years, Aug 31, 2021
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Graduate Research Assistant: $161,556 (57% salary, 43% benefits and tuition); 50% FTE each year for 4 years
Undergraduate research assistant: $37,207 (100% salary, 0% benefits); 35% FTE each year for 4 years
Brian Aukema, Project Manager [summer salary]: $47,773 (75% salary, 25% benefits); 7.7% FTE each year for 4 years
Professional/Technical/Service Contracts
Administration of emamectin benzoate
Administration of azadirachtin (moved to supplies)
Contract for use of chemical analysis equipment
Equipment/Tools/Supplies
Supplies for crown ratings, insect collection and husbandry, and chemicals for tissue analysis, and ArborJet azadirachtin treatment.
Computer for data management and analysis
Printing
Poster printing and/or page charges for dissemination of results
Travel expenses in Minnesota
Rental of university vehicle at fleet rates each summer, predominantly for Activities 1 and 2. As possible, laboratory truck will be assigned to project to reduce travel costs. Travel includes minimum of one meeting/workshop per year to present results to relevant audiences.
COLUMN TOTAL

TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$246,536	**$93,820**	**$152,716**
$37,000	**$15,640**	**$21,360**
$31,000	$15,640	$15,360
$0	$0	$0
$6,000	$0	$6,000
$16,314	**$9,192**	**$7,122**
$15,000	$9,192	$5,808
$1,314	$0	$1,314
$150	**$0**	**$150**
$150	$0	$150
$20,000	**$5,811**	**$14,189**
$20,000	$5,811	$14,189
$320,000	**$124,463**	**$195,537**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #6: Distribution and Traits of the Fungal Pathogen *Fusarium virgul* Future Risk to Soybean and other Legumes in Minnesota
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Dean Malvick
Organization: University of Minnesota
Sub-Project Budget: $412,000
Sub-Project Length and Completion Date: 3 Years, June 30, 2020
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Post-doctoral Research Associate: $184,500 (80% salary; 20% benefits); 100% FTE each year for 3 years
Post-doctoral Research Associate: $11,000 (80% salary, 20% benefits); 5% FTE each year for 3 years
Graduate Research Asssistant: $135,223 (50% salary, 50% benefits and tuition); 50% FTE each year for 3 years
Undergraduate research assistant: $15,700 (100% salary, 0% benefits); 35% FTE each year in years 1-2; 5% FTE each year in year 3
Professional/Technical/Service Contracts
Services for soil analysis and DNA sequencing at the University of Minnesota will comprise the bulk of this portion of the budget. In additon we will seek out qualified sources of aerial imagery that will comprise a minor part of this budget, and there will be shipping/mailing costs.
Equipment/Tools/Supplies
Laboratory supplies for fungal isolation and grown, equipment and supplies for phenotypic assays of fungi, qPCR analysis, greenhouse supplies, and soil temperature monitors.
Travel expenses in Minnesota
Funding for travel is requested because of extensive field survey and sampling work to cover mileage to collect samples, and registration and travel to three scientific meetin. (Approximatedly 65% is estimated for mileage, 15% for lodging, 5% for meals, and 15% for transportation costs to scientiric meetings).
COLUMN TOTAL

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TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$346,423	**$153,525**	**$192,898**
$25,000	**$5,967**	**$19,033**
$25,000	$5,967	$19,033
$30,877	**$14,736**	**$16,141**
$30,877	$14,736	$16,141
$9,700	**$1,196**	**$8,504**
$9,700	$1,196	$8,504
$412,000	**$175,424**	**$236,576**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #7: Tools to Distinguish Native from Exotic Reed Canary Grass
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Neil O. Anderson
Organization: University of Minnesota
Sub-Project Budgt: $268,000
Sub-Project Length and Completion Date: 3 Years, June 30, 2020
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Andrzej Noyszewski, Postdoctoral Research Associate: $181,597 (82% salary, 18% benefits); 100% FTE each year for 3 years
2 Undergraduate Research Asssistants: $25,333 (93% salary, 7% benefits); both positions 27% FTE each year for 2 years
Equipment/Tools/Supplies
Laboratory supplies for molecular genotyping of collected plant samples, molecular analyses of reed canarygrass plant DNA samples (chemicals, markers, DNA extraction kits, SSR primer development, pilot SNP chip development, SNP development; draft DNA seqencing of selected genotypes: native, invasive, hybrid)
Laboratory supplies for development of hand-held tool for land managers and ABI fragment analysis to confirm effectiveness of hand-held device (chemicals, tools, markers)
Professional Services
Service fees for DArT genotyping
COLUMN TOTAL

TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$206,930	**$115,230**	**$91,700**
$31,070	**$12,219**	**$18,851**
$12,357	$244	$12,113
$18,713	$11,975	$6,738
$30,000	**$30,415**	**-$415**
$30,000	$30,415	-$415
$268,000	**$157,864**	**$110,136**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #8: Accurate Detection and Integrated Treatment of Oak Wilt (*Cer*
Legal Citation: ML 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Jeannine Cavender-Bares
Organization: University of Minnesota
Sub-Project Budget: $ 357,420
Sub-Project Length and Completion Date: 4 Years, June 30, 2020
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Post doctoral Research Associate: $183,891 (66% salary, 34% benefits); 100% FTE each year for 3
Civil Service
Graduate Research Assistant: $62,822 (57% salary, 43% benefits and tuition); 50% FTE each year for 3
Undergraduate research assistant: $18,720 (100% salary, 0% benefits); 35% FTE each year for 3 years
Dr. Jeannine Cavender-Bares, Project Manager: $22,562 (66% salary, 34% benefits); 4% FTE each year
Dr. Rebecca Montgomery, Project Manager: $18,539 (66% salary, 34% benefits); 4% FTE each year for
Professional/Technical/Service Contracts
Metro Tall Timbers/Paul Kujawa and separate contract for tree removal via an RFP bid process.
Rental of high precision GPS equipment $500
Aerial lift rental $12,000
Equipment/Tools/Supplies
Field equipment: including but not limited to tree marking paint, nails, tags, flagging, binoculars,
Laboratory supplies for PCR detection of oak wilt and bur oak blight, including agar, media, Petri
Equipment maintenance (spectroscopy equipment, Scholander pressure chamber) $3,000
Travel expenses in Minnesota
Travel for field work to multiple field sites over four years, three workshops and one field
COLUMN TOTAL

atocystis fagacearum) in Minnesota

TOTAL BUDGET	Revised Budget	AMOUNT SPENT	TOTAL BALANCE
$306,533	**$306,533**	**$165,719**	**$140,814**
~~$38,500~~	**$33,029**	**$10,700**	**$22,329**
~~$26,000~~	$20,529	$10,700	$9,829
$500	$500	$0	$500
$12,000	$12,000	$0	$12,000
~~$9,387~~	**$14,858**	**$14,858**	**$0**
~~$3,444~~	$3,499	$3,499	$0
~~$2,943~~	$4,945	$4,945	$0
~~$3,000~~	$6,414	$6,414	$0
$3,000	**$3,000**	**$2,112**	**$888**
$3,000	$3,000	$2,112	$888
$357,420	**$357,420**	**$193,389**	**$164,031**

PROJECT COMPLETED

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget

Sub-Project Title: MITPPC #10: Management Strategies for the Invasive Spotted Wing Droso
Legal Citation: ML 2015, Ch. 76, Art. 2, Sec. 6a
Project Manager: Mary Rogers
Organization: UMN-Horticulture
M.L. 2014 ENRTF Appropriation: $504,390
Sub-Project Length and Completion Date: 4 Years, June 30, 2021
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Mary Rogers, Project Manager: $38,603 (66% salary, 33% benefits); 3.25 FTE for 4 years
Graduate Research Assistant in Entomology: (50% salary, 17.6% benefits) plus tuition; 24 FTE for 4 years
Graduate Research Assistant in Horticulture: (50% salary, 17.6% benefits) plus tuition; 18 FTE for 4 years
Gigi DiGiacomo, Applied Economics Research Fellow: $90,931 (68% salary, 32% benefits); 15.6 FTE for 4 years
Undergraduate research support: $10,560 (100% salary, 0% benefits); 5.54 FTE for 4 years
Labor and project support for experimental plots of raspberries at the West Central Research & Outreach Center in Morris, MN, $6,000 per year for YR 1-2 & $3,000 for YR 3
Professional/Technical/Service Contracts
Contract for service fee by Dr. Demoz Gebre-Egziabher (Aerospace Engineering, UMN), for use of his UAV Technician/crew to conduct SWD dispersal sampling studies using Fixed-wing UAVs each year (Activity 1), with extra set up/validation costs in Year 1. Total: YR1 $10,000, YRS 2-4 @ $5,000 ea.
Contract for service fee by Dr. Mark Asplen (Assist. Professor, Metro State University), for use of his flight chamber to conduct SWD dispersal studies, comparing the propensity and duration of flights between Winter and Summer morphs of SWD; study will use a flight chamber developed by Dr. Asplen, and multiple years of expertise; @ $5,000/year for Yrs 1-3; total, $15,000
Growth chamber fees
Equipment/Tools/Supplies
Helium balloons and monitoring supplies, traps and lures (YRs 1-4, $1,200/yr)
Field equipment including tunnel construction (netting, PVC, wiggle wire, poly for exclusion) and irrigation, biopesticide products
Microclimate sensor for ambient air temperature, RH (YR 1 only), sensor with remote monitoring sensing capabilities, weatherproof housing, solar panel and extension cablesMicroclimate sensor for ambient air temperature, RH (YR 1 only), sensor with remote monitoring sensing capabilities, weatherproof housing, solar panel and extension cables
Travel
Rental vehicle for travel to research sites in Minnesota. Estimated at $5,400 per year (YR 1-4)
Mileage, lodging and meals requested to present at grower conferences in MN in YR 2-4, estimated at $250/event x 4 events.

Travel requested for two Graduate Research Assistants and PIs to present research and learn about related SWD research at the annual Entomological Society of America conference. Estimated at $1,700 per attendee (x4) to cover registration, airfare, lodging and meals (YR 3 & 4)
COLUMN TOTAL

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TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$417,133	**$182,985**	**$234,148**
$43,500	**$2,886**	**$40,614**
$25,000	$2,250	$22,750
$15,000	$0	$15,000
$3,500	$636	$2,864
$14,969	**$14,969**	**$0**
$4,800	$2,673	$2,127
$9,169	$12,174	-$3,005
$1,000	$122	$878
$29,400	**$11,525**	**$18,044**
$21,600	$7,797	$13,577
$1,000	$870	$967

$6,800	$2,858	$3,500
$505,002	**$212,365**	**$292,806**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #11: Will Future Weather Favor Minnesota's Woody Invaders?
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Peter Reich
Organization: University of Minnesota
Sub-Project Budget: $526,000
Sub-Project Length and Completion Date: 4 Years, June 30, 2021
Date of Report: July 30, 2019

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BUDGET ITEM
Personnel (Wages and Benefits)
Four research professionals (post docs): $370,092 (81% salary, 19% benefits); 1 at 12 month/yr @ 0.70 FTE, 1 at 12 month/yr @ 0.3 FTE, and 2 at 12 month/yr @ 0.2 FTE
One - four undergraduate students @ $11/hour: $17,667 (93% salary, 7% benefits)
Professional/Technical/Service Contracts
Electrical costs for B4WARMED experiment
Data services; shipping
Equipment/Tools/Supplies
Lab supplies: Supplies, materials, maintenance, repair
Foliar chemistry analysis
Plot Rental
Travel expenses in Minnesota
Field site mileage & lodging
COLUMN TOTAL

TOTAL BUDGET	Total	AMOUNT SPENT	TOTAL BALANCE
$387,759	**$387,759**	**$118,035**	**$269,724**
$102,500	**$104,825**	**$91,661**	**$10,839**
$102,500	$102,500	$91,661	$10,839
	$2,325	$91,661	
$19,441	**$16,841**	**$3,968**	**$15,473**
~~$15,441~~	$12,841	$3,968	$13,687
$4,000	$4,000	$0	$4,000
	$275	$0	$275
$16,300	**$16,300**	**$9,013**	**$7,287**
$16,300	$16,300	$9,013	$7,287
$526,000	**$526,000**	**$222,677**	**$303,598**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #12: Developing robust identification assays for *Amaranthus palme*
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Don Wyse
Organization: University of Minnesota
Sub-Project Budget: $208,150
Sub-Project Length and Completion Date: 2 Years, January 31, 2020
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Postdoctoral Research Associate: $64,910 (82% salary, 18% benefits); 100% FTE each year for 2 years with a 2.5% increase in year 2
Equipment/Tools/Supplies
Lab supplies and reagents for Activity 2 (for example, DNA extraction kits, chemical reagents for PCR, eletrophoresis materials)
Professional/Technical/Service Contracts
DNA sequencing costs for Activity 3 to be completed at University of Minnesota Genomics Center.
Travel
$2,150 for out of state travel to Colorado State University. Trip 1: $1,190 for 5 days of travel for training in advanced DNA sequencing techniques. Trip 2: $960 for 4 days of travel for advanced training in informatics analysis of DNA sequences and protocols for information exchange (terrabytes of data)
COLUMN TOTAL

eri in seed mixtures

TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$131,442	**$87,127**	**$44,315**
$15,338	**$15,554**	**-$216**
$15,338	$15,554	-$216
$58,957	**$29,524**	**$29,433**
$58,957	$29,524	$29,433
$2,493	**$2,493**	**$0**
$2,493	$2,493	$0
$208,230	**$134,698**	**$73,532**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #13: Terrestrial Invasive Species Prioritization
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: Amy Morey
Organization: University of Minnesota
Sub-Project Budget: $36,126
Sub-Project Length and Completion Date: 7 months, December 31, 2019
Date of Report: July 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Postdoctoral Research Associate: $36,126 (75.7% salary, 24.3% benefits); 100% for 7 months
COLUMN TOTAL

TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$36,126	$4,749	$31,377
$36,126	**$4,749**	**$31,377**

Environment and Natural Resources Trust Fund
Minnesota Invasive Terrestrial Plants and Pests Center
M.L. 2015 Sub-Project Budget
Sub-Project Title: MITPPC #14: Building mechanistic and process based species distibution m
spurge: from landscapes to genomes
Legal Citation: M.L. 2015, Ch. 76, Art. 2, Sec. 6a
Sub-Project Manager: David Moeller
Organization: University of Minnesota
Sub-Project Budget: $70,812
Sub-Project Length and Completion Date: 3 years, June 30, 2022
Date of Report: June 30, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET
BUDGET ITEM
Personnel (Wages and Benefits)
Researcher: $70,812 (55.8% salary, 34.2% fringe) 1 FTE
COLUMN TOTAL

nodels for common tansy and leafy

TOTAL BUDGET	AMOUNT SPENT	TOTAL BALANCE
$70,812	$0	$70,812
$70,812	**$0**	**$70,812**

Activity 1								Activity 2								Activity 3							
Salaries	**Current Base Salary**	**Yr 1 Base Salary**	**% effort**	Year 1	Year 2	Year 3	Total	**Salaries**	**Current Base Salary**	**Yr 1 Base Salary**	**% effort**	Year 1	Year 2	Year 3	Total	**Salaries**	**Current Base Salary**	**Yr 1 Base Salary**	**% effort**	Year 1	Year 2	Year 3	Total
Name- Professor: $Salary; XX% FTE		$0		$0	$0	$0	$0	Name- Professor: $Salary; XX% FTE		$0		$0	$0	$0	$0	Name- Professor: $Salary; XX% FTE		$0		$0	$0	$0	$0
Name- Research Assistant Professor: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Research Assistant Professor: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Research Assistant Professor: $Salary; XX FTE		$0		$0	$0	$0	$0
Name- Professional & Admin: $Salary, XX FTE		$0		$0	$0	$0	$0	Name- Professional & Admin: $Salary, XX FTE		$0		$0	$0	$0	$0	Name- Professional & Admin: $Salary, XX FTE		$0		$0	$0	$0	$0
Name- Post Doctoral Fellow: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Post Doctoral Fellow: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Post Doctoral Fellow: $Salary; XX FTE		$0		$0	$0	$0	$0
Name- Graduate Student-Academic Yr: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Graduate Student-Academic Yr: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Graduate Student-Academic Yr: $Salary; XX FTE		$0		$0	$0	$0	$0
Name- Graduate Student-Summer: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Graduate Student-Summer: $Salary; XX FTE								Name- Graduate Student-Summer: $Salary; XX FTE							
Name- Undergraduate Student: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Undergraduate Student: $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Undergraduate Student: $Salary; XX FTE		$0		$0	$0	$0	$0
Name- Title (Civil Service): $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Title (Civil Service): $Salary; XX FTE		$0		$0	$0	$0	$0	Name- Title (Civil Service): $Salary; XX FTE		$0		$0	$0	$0	$0
Fringe								**Fringe**								**Fringe**							
Professor- fringe 19.83% (summer salary)				$0	$0	$0	$0	Professor- fringe 19.83% (summer salary)				$0	$0	$0	$0	Professor- fringe 19.83% (summer salary)				$0	$0	$0	$0
RAP- fringe 33.6%				$0	$0	$0	$0	RAP- fringe 33.6%				$0	$0	$0	$0	RAP- fringe 33.6%				$0	$0	$0	$0
P&A- fringe 33.6%				$0	$0	$0	$0	P&A- fringe 33.6%				$0	$0	$0	$0	P&A- fringe 33.6%				$0	$0	$0	$0
Post Doc- fringe 20.75%				$0	$0	$0	$0	Post Doc- fringe 20.75%				$0	$0	$0	$0	Post Doc- fringe 20.75%				$0	$0	$0	$0
Graduate Student- fringe 108.5%				$0	$0	$0	$0	Graduate Student- fringe 108.5%				$0	$0	$0	$0	Graduate Student- fringe108.5%				$0	$0	$0	$0
Graduate Student Summer- fringe 23.1%				$0	$0	$0	$0	Graduate Student Summer- fringe 23.1%				$0	$0	$0	$0	Graduate Student Summer- fringe 23.1%				$0	$0	$0	$0
Undergrad Assistant- fringe 7.4%				$0	$0	$0	$0	Undergrad Assistant- fringe 7.4%				$0	$0	$0	$0	Undergrad Assistant- fringe 7.4%				$0	$0	$0	$0
Civil Service- fringe 36.8%				$0	$0	$0	$0	Civil Service- fringe 36.8%				$0	$0	$0	$0	Civil Service- fringe 36.8%				$0	$0	$0	$0
Total combined salary and fringe (enter this number in Row 14 on subproject budget tab)							**$0**								**$0**								**$0**