2018 Project Abstract
For the Period Ending June 30, 2022

PROJECT TITLE: Palmer amaranth detection and eradication continuation
PROJECT MANAGER: Monika Chandler
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WEBSITE: https://www.mda.state.mn.us/plants-insects/noxious-invasive-weed-program
FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 06b as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2 as extended by First Special Session, Chp. 6, Art. 5, Sec. 3, Sub 19a.2 [to June 30, 2022] and as amended by M.L. 2021 First Special Session, Chp. 6, Art. 5, Sec. 4 (See below)

Appropriation Language (as amended by M.L. 2021 First Special Session, Chp. 6, Art. 5, Sec. 4) **:** $431,000 the second year is from the trust fund to the commissioner of agriculture to continue to monitor, ground survey, and control Palmer amaranth primarily in ~~conservation plantings~~ natural areas and to develop and implement aerial-survey methods to prevent infestation and protect prairies, other natural areas, and agricultural crops.

M.L. 2020 - Sec. 2. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2021]

APPROPRIATION AMOUNT: $ 431,200
AMOUNT SPENT: $ 430,074
AMOUNT REMAINING: $ 926

Sound bite of Project Outcomes and Results
Palmer amaranth is an aggressive weed that is expensive and damaging to control. It was found as a contaminant in a small number of conservation planting seed mixes sold in Minnesota. Rapid response to the situation resulted in Palmer amaranth eradication from impacted conservation plantings.

Overall Project Outcome and Results
Palmer amaranth is an invasive plant that threatens row crop production and prairies. In 2016, it was found in a small number of conservation planting seed mixes. There were concerns that Palmer amaranth would spread to nearby crop fields and cause high yield losses, up to 91% in corn and 78% in soybeans. Palmer amaranth can be resistant to multiple herbicides making it difficult to control. There was a lot of concern about the conservation planting pathway for Palmer amaranth and it was declared an agricultural emergency by the commissioner of agriculture.

This project enabled rapid response to the situation as it unfolded.

- Palmer amaranth was controlled in the field by Conservation Corps Minnesota using propane torches, prescribed fire and hand pulling. As a result, Palmer amaranth was eradicated from all impacted conservation plantings. There were 92 infestations (some in crop fields) of which 67 were eradicated, 13 were negative (no Palmer found in field planted with contaminated seed mix) and 12 are active infestations in crop fields that MDA will continue to monitor.
    - Intensive infestation monitoring was required to achieve this successful outcome.
- Drones were utilized to help look for Palmer amaranth in large fields. This work with drones was experimental and led by the University of Minnesota's UAV Lab. We learned much that can be applied for future aerial survey efforts.
    - MDA now uses a drone for aerial survey.

Palmer amaranth control efforts were so effective that some Conservation Corps Minnesota funding could be diverted to control other priority target species infestations including black swallow-wort, common teasel, cutleaf teasel, Japanese hops, oriental bittersweet, poison hemlock and knotweeds.

Project Results Use and Dissemination

Presentations, articles, and a paper were the primary dissemination means. There were 40 presentations, trainings or updates about Palmer amaranth and this project. In trainings, we used resources developed for the ENRTF project Elimination of Target Invasive Plant Species including 3D printed models of Palmer amaranth seedlings, pressed plant samples, and large format printed displays. Two popular press articles were written and sent to outstate media. Our paper Timeline of Palmer amaranth invasion and eradication in Minnesota was open access published in Weed Technology. To date, it was accessed via HTML by 741 and via PDF by 4,580.

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

Today's Date: 08/15/2022

Date of Final Report: 08/15/2022

Date of Work Plan Approval: 06/05/2018

Project Completion Date: 06/30/2022

PROJECT TITLE: Palmer amaranth detection and eradication continuation

Project Manager: Monika Chandler

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http://www.mda.state.mn.us/plants/pestmanagement/weedcontrol/noxiouslist/palmeramaranth.aspx

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Location: Statewide

Total Project Budget: $ 431,200

Amount Spent: $ 430,074

Balance: $ 926

Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 06b as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2 as extended by First Special Session, Chp. 6, Art. 5, Sec. 3, Sub 19a.2 [to June 30, 2022] and as amended by M.L. 2021 First Special Session, Chp. 6, Art. 5, Sec. 4 (See below)

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M.L. 2020 - Sec. 2. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2021]

I. PROJECT STATEMENT:

Palmer amaranth is an invasive plant that threatens row crop production and prairies. Growing quickly at 2-3 inches per day and reaching heights of 10 feet tall, it outcompetes other plants. Palmer amaranth is an annual that produces prolific seed – up to a million per plant. It developed resistance to multiple classes of herbicides making it challenging to control. Palmer amaranth can cause yield losses up to 91% in corn (Weed Sci. 49:202-208) and 78% in soybeans (Weed Sci. 51:37-43). It has invaded established prairies in Illinois.

Palmer amaranth was first found in Minnesota in fall 2016 and declared an agricultural emergency. Palmer amaranth seed was a contaminant of a conservation seed mix that was planted at 30 locations. Infrastructure developed with our *Elimination of Target Invasive Plant Species* LCCMR project and Minnesota Department of Agriculture (MDA) emergency funds enabled us to respond quickly. In 2016, Palmer amaranth was documented in Lyon and Yellow Medicine Counties. Fourteen landowners were involved and there were 33 plantings where contaminated seed mix was sown. Palmer plants, including seedheads, were incinerated to reduce establishment and spread. This proved to be very effective. In 2017, only a handful of Palmer amaranth plants were found at three plantings identified in 2016. There were additional Palmer amaranth finds in 2017. An additional two landowners are now involved and together they have 10 plantings. Continued rapid and effective management could prevent statewide establishment and spread. We will:

- **Intensively monitor sites with Palmer amaranth.** Vegetation at Palmer sites will be monitored closely to identify Palmer plants before seed is produced. Palmer germinates throughout the growing season so monitoring the entire season is needed. Palmer amaranth seedbanks are not long-lived so aggressive management now could eradicate Palmer from these sites.
- **Continue control efforts at sites with Palmer amaranth.** Control methods may include flame weeding with torches, prescribed fire, spot treatment, increased plant competition by seeding more native grasses and, if necessary, broadcast herbicide application (ENRTF dollars will not be used for broadcast application).
- **Conduct ground and aerial surveys.** Additional conservation planting will be surveyed for Palmer amaranth presence or absence. Aerial survey will increase efficiency of ground survey by advance scouting for Palmer or similar looking plants. It will also reduce the amount of field entries and exits thereby reducing the risk of inadvertent spread of Palmer.

We received funding from the emerging issues account to begin this work in 2017. This project continues this work.

II. OVERALL PROJECT STATUS UPDATES:

Amendment Request January 31, 2019
MDA requests changing the project status update report dates from May and November to January and July. Monika Chandler is the project manager for three LCCMR projects with status reports due in May and November. Changing the dates of this report to January and July will help the project manager focus on this Palmer project report.
Amendment Approved by LCCMR February 19, 2019

The project partners also request to work on other early detection target species with Palmer amaranth as the primary focus. Palmer amaranth would remain the focus of this project. For aerial survey, we learned that flying for Palmer helps us with flying with oriental bittersweet in the Elimination of Target Invasive Plant Species project and vice versa. We would like to also survey for oriental bittersweet in the fall and winter with this funding. Additionally, we would like to work on detection and control of other target species as time permits. Primarily during the winter and spring, there would be opportunity for the Plant Health Specialist and CCM to

work on other target species on the noxious weed eradicate list. With this flexibility about target species, we could accomplish more with the same funds.
Withdrawn due to potential inconsistency with appropriation intent. To be revisited if needed in late summer 2019 depending on status of further Palmer amaranth findings.

First Update January 31, 2019
We are pleased that no Palmer amaranth plants were found at any conservation plantings in Minnesota in 2018. This was an achievement and showed that our control methods were effective. A small number of Palmer plants were found by famers in row crops in Jackson County (1 Palmer plant) and Redwood County (4 Palmer plants). This indicates that Palmer continues to enter the state, likely via a different pathway. We need to remain vigilant and respond quickly to new infestations. Our continued development of aerial survey will aid early detection.

Amendment Request July 31, 2019 with update on September 9, 2019 and Amendment Approved by LCCMR October 10, 2019
Many of the new potential Palmer amaranth finds have been the row crop or feedlot setting. Our project had been focused on conservation plantings. It is essential that Shane Blair follow up on these reports. However, this leaves him without time to work on aerial survey, monitor conservation plantings where Palmer was a contaminant in the seed mix sown and ground survey of additional conservation planting (no Palmer suspected). Because row crop fields and feedlots are outside the scope of this project, Shane will charge his time and expenses for work in row crop and feedlot settings to another account. We will add Eric Yu to the project to facilitate aerial survey and monitor conservation plantings where Palmer had been in the seed mix and help with dissemination. When we wrote our proposal, we expected to monitor less than 200 acres of conservation plantings. Because Palmer was a contaminant in many more conservation plantings, we are monitoring 2,293 acres. We request to change our work plan so that we will not do Activity 2, Outcome 2 "at least 25 additional conservation plantings statewide are surveyed each year for the presence/absence of Palmer amaranth". This will allow us to focus on (outcomes 1, 3, and 4) plantings where Palmer either was present or a contaminant of the seed mix or is suspected for another reason. Our efforts will be concentrated on the plantings most likely to contain Palmer amaranth.

Our previous request to work on other early detection target species in the fall, winter and early spring is still of interest.

Second Update July 31, 2019
Our focus over the winter and spring was on testing our aerial survey systems, Palmer amaranth outreach and report follow up. We look forward to flying areas with known Palmer amaranth in other states to collect image sets. We will continue report follow up and monitoring sites where Palmer had been in the seed mix.

Amendment Request 1 January 23, 2020
We request to extend the project end date from June 30, 2020 to June 30, 2021. Palmer amaranth management has been very successful. No Palmer amaranth was found in 2019 at any previous infestation sites. We have not needed as much funding for Palmer management by CCM as we originally anticipated. That is very positive. Extending the funds for an additional year means they would be available for Palmer management until June 30, 2021. We would be able to address new infestations in conservation plantings and similar settings.

Project extended to June 30, 2021 by LCCMR 6/18/20 as a result of M.L. 2020, First Special Session, Chp. 4, Sec. 2, legislative extension criteria being met.

Amendment Request 2 January 23, 2020
We also request to use these funds for work on other invasive plants that are regulated Prohibited Eradicate species. This includes oriental bittersweet, diffuse, brown and meadow knapweeds, poison hemlock, black

swallow-wort, Grecian foxglove, common and cutleaf teasels, Japanese hops and Dalmatian toadflax. Palmer amaranth would remain the priority, but we would accomplish more by also controlling these species that are highly damaging and have limited distribution. This would continue work begun with the LCCMR projects Elimination of Target Invasive Plant Species Phases 1 and 2.

We would gain an efficiency with aerial survey by working on both oriental bittersweet and Palmer amaranth. Image process continues to improve. Working with images from oriental bittersweet survey facilitates work with Palmer amaranth images and vice versa. The same processing steps (stitching images together, analyzing images, etc.) are used for both species and improve with each new image set handled.

Amendment pending further LCCMR and legislative action as of 02/18/20

Amendment approved by the legislature and governor 6/29/21

Budget Amendment Request March 11, 2020

We request to move $7,000 from Personnel to Travel. Travel costs are high because we need to rent a truck to drive field roads on farms. Also, all new Palmer finds result in extensive travel to diligently document infestations, meet with landowners, and enact control measures.

Amendment approved by LCCMR 4/8/2020

Amendment Request April 1, 2020

In response to COVID 19 social distancing guidelines and Governor Walz' Stay at Home order, we request to reassign 6 CCM field specialists from invasive plant control to aerial image analysis. This work can be done safely from home and will further project progress. This would increase the scope of work that CCM does.

Tens of thousands of aerial images of Palmer amaranth infestations were collected with drone flights. An automated process for image analysis to find Palmer has not been invented yet. By having the field specialists review and mark Palmer on images, we gain their analysis. We also gain data about analysis patterns that may inform machine learning/artificial intelligence development for future image analysis.

Amendment approved by LCCMR 4/8/2020

Third Update January 31, 2020

No Palmer amaranth was found in any plantings where it had been found in 2016 and/or 2017. This means that control measures (torch, prescribed fire and hand-pulling) were very effective. There were two new finds in Houston County in the late summer of 2019. One infestation was approximately 0.5 acres in size and the other infestation was a few plants that were hand-pulled. The 0.5 acre infestation was torched. Aerial survey image sets were collected at the 0.5 acre infestation both pre and post torching. Image sets were also collected in Iowa where there was untreated Palmer amaranth. Image post-processing is continuing over the winter.

Fourth Update July 31, 2020

We were able to utilize CCM field specialists to review aerial images of Palmer amaranth while field operations were suspended. We learned that we need higher quality aerial images for consistent Palmer amaranth identification and are working toward that.

There was a new Palmer find in Winona County. Fortunately, there were only 10 plants found and they were hand pulled. The site will be monitored.

Amendment 1 Request January 29, 2021

We request to extend our project one year until 06/30/22. Our request to spend funds on additional species is in the ENRTF bill. This bill was delayed from the standard cycle timing so additional time is requested to utilize CCM funds for invasive plant management. This additional time will also extend the time to completion for Activity 2, Outcomes 4 and 5.

Amendment pending further LCCMR and legislative action as of 02/12/21

Amendment approved by the legislature and governor 6/29/21

Amendment 2 Budget Request January 29, 2021
We request to move $465 from Supplies into Travel. We also request to move $235 from Supplies into Personnel. We slightly overspent Personnel and Travel and will not utilize the full supply budget. This would increase the Personnel budget from $149,300 to $149,535 and the Travel budget from $23,000 to $23,465. The Supplies budget would decrease from $1,000 to $300.
Amendment approved by LCCMR 02/12/2021

Fifth Update January 31, 2021
We co-wrote a manuscript with U of M Extension weed scientists. The manuscript was submitted for publication on 01/19/21. The purpose of the manuscript is to document and share the activities, collaboration and funding that led to successful Palmer amaranth management to date. We continue to improve aerial survey. Low altitude flights yielded excellent images. Palmer amaranth was effectively managed during the 2020 field season.

Sixth Update July 31, 2021
Our article Timeline of Palmer amaranth invasion and eradication in Minnesota documents what happened with Palmer in Minnesota. The article was published in Weed Technology and is available to all with open access. An abstract was published in April and the full article was published in July. To date, the article has been accessed via HTML by 102 and via PDF by 4,278. Palmer amaranth continues to come in on different pathways. Screenings and feed are increasingly important pathways. MDA will continue to try to stop Palmer movement into Minnesota. There have been no new infestations in conservation plantings. New Palmer infestations were drone surveyed and closely related pigweeds were detected. To continue to improve aerial survey, a drone that can carry a heavier camera was purchased and will be deployed.

Amendment Budget Request January 30, 2022
We request to move $2 from Supplies plus $42 from Travel to Personnel. We overspent a little on Personnel and will not spend any more funds in the Supplies and Travel categories.

Amendment approved by LCCMR 2/10/22

Seventh Update January 31, 2022
MDA continues to stop Palmer seed movement in Minnesota. A contaminated seedlot of pearl millet was detected during routine seed inspection. Some seed had already been planted in multiple fields. Fortunately, no Palmer was found growing in these fields. Drone survey was used to look for Palmer at two of these near Windom. Control work was done on black swallow-wort, common and cutleaf teasels, Japanese hops, oriental bittersweet, poison hemlock and knotweeds.

Final Update August 15, 2022
MDA continued to monitor active Palmer amaranth infestations using general funds. Most project funds were spent prior to this final period but we did control a cutleaf teasel infestations that was found in fall 2021 along the Munger Trail in Duluth. We also held a workshop to train 92 CCM members to identify and report priority species.

Overall Project Outcome and Results
Palmer amaranth is an invasive plant that threatens row crop production and prairies. In 2016, it was found in a small number of conservation planting seed mixes. There were concerns that Palmer amaranth would spread to nearby crop fields and cause high yield losses, up to 91% in corn and 78% in soybeans. Palmer amaranth can be resistant to multiple herbicides making it difficult to control. There was a lot of concern about the conservation

planting pathway for Palmer amaranth and it was declared an agricultural emergency by the commissioner of agriculture.

This project enabled rapid response to the situation as it unfolded.

- Palmer amaranth was controlled in the field by Conservation Corps Minnesota using propane torches, prescribed fire and hand pulling. As a result, Palmer amaranth was eradicated from all impacted conservation plantings. There were 92 infestations (some in crop fields) of which 67 were eradicated, 13 were negative (no Palmer found in field planted with contaminated seed mix) and 12 are active infestations in crop fields that MDA will continue to monitor.
    - Intensive infestation monitoring was required to achieve this successful outcome.
- Drones were utilized to help look for Palmer amaranth in large fields. This work with drones was experimental and led by the University of Minnesota's UAV Lab. We learned much that can be applied for future aerial survey efforts.
    - MDA now uses a drone for aerial survey.

Palmer amaranth control efforts were so effective that some Conservation Corps Minnesota funding could be diverted to control other priority target species infestations including black swallow-wort, common teasel, cutleaf teasel, Japanese hops, oriental bittersweet, poison hemlock and knotweeds.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Develop and utilize aerial survey methods (U of M)
Description: Remote sensing will be utilized with the goal of developing methods to identify probable Palmer amaranth by aerial survey. This will increase the efficiency of ground survey by identifying areas with possible Palmer amaranth plants. We request to use project funds for out of state travel to areas where Palmer is more common such as Iowa for method testing.

Aerial survey will be done by imaging fields with a camera/sensor attached to a UAV. Initial survey will be done at plantings selected for ground survey so they are ground truthed. We will also image plantings in another state such as Iowa where Palmer amaranth is present so that we can test our methods and develop a library of aerial images of Palmer amaranth. Imaging fields during the growing season will enable us to work with these images over the winter.

ENRTF BUDGET: $ 159,700

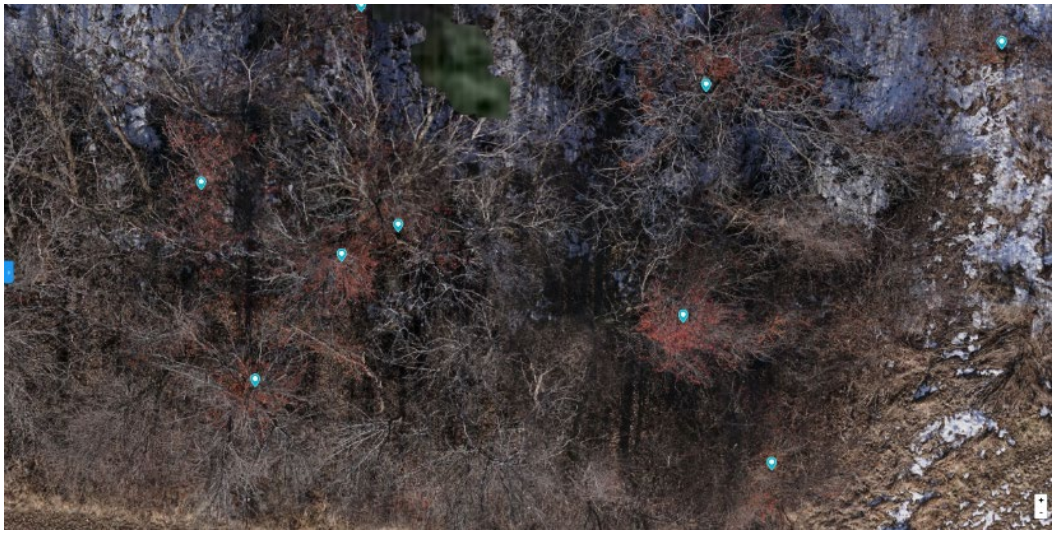
Outcome	Completion Date
1. Test remote sensing methods	03/31/21
2. Identify areas with Palmer or similar looking plants for targeted ground survey	06/30/21

First Update January 31, 2019
In July 2018 the UAV purchased software called Drone Deploy which also performs basic map stitching tasks. While Pix4D is the de facto industry standard software for map stitching, we found with our data sets (which are typically comprised of natural environments such as grassy fields for Palmer amaranth and heavily wooded areas for bittersweet surveys) that Drone Deploy was able to fit more of the images together with fewer artifacts and produced a better final map with more of the original details and resolution.

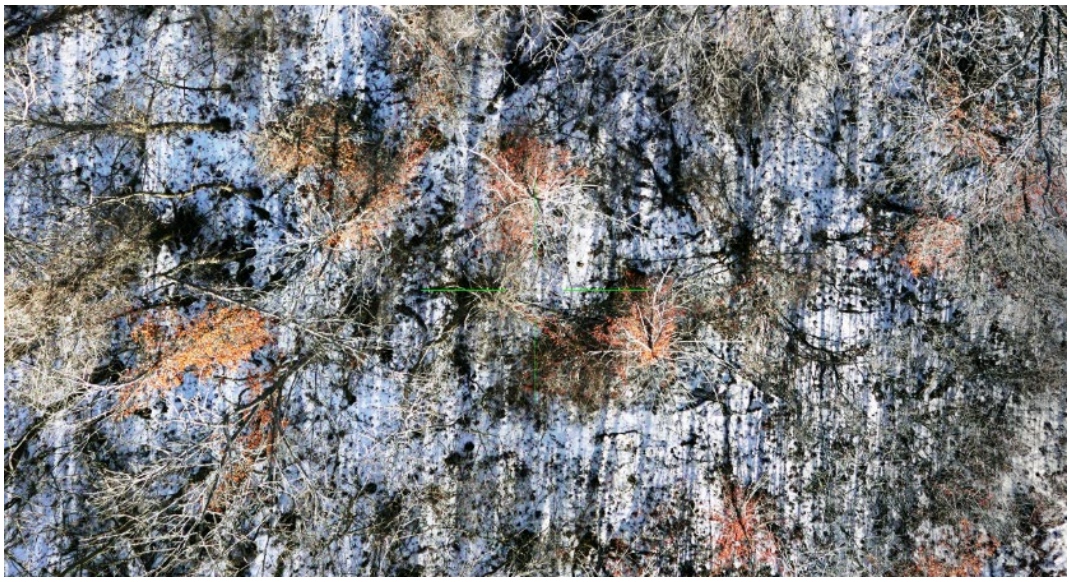
In fall 2018, we constructed a new fixed wing aircraft that is optimized for collecting very high resolution imagery. Three students worked on customizing the design of an off-the-shelf aircraft. This work included designing a custom 3D printed camera mount and integrating the UMN Goldy3 autopilot and flight sensors. The

new aircraft has an onboard route planning algorithm that optimizes the survey route for current wind conditions, altitude, and camera field of view. It also has a custom camera triggering system that enables capturing images at high rates with precise amounts of overlap. A typical drone can fly for around 20-25 minutes. Our new aircraft can perform 75 minute flights and capture more than 3000 (24 megapixel) images in a single flight. This new system has been flight tested and refined through December and January oriental bittersweet surveys for the Elimination of Target Invasive Plant Species project and is working very well. Late fall and winter are perfect seasons for oriental bittersweet surveys, and combined with the unseasonably warm weather we had in December and early January allowed us to do extra flight testing in order to make sure the system is ready for the spring and summer Palmer amaranth work. We have some tentative dates scheduled at the end of February to test this aircraft for Palmer detection. We are lining up sites in Iowa to survey since there is no known Palmer in the field in Minnesota. We hope for snow on the ground for good color contrast with plant material as we found with oriental bittersweet survey.

Along with our purchase of commercial image stitching tools, the UAV lab continues to improve a set of in-house image processing software tools that enable analyzing and searching our image sets in ways the commercial tools don't support. Our in-house tools preserve the original images in their full detail. We can apply light equalization and color enhancement filters, and in areas where multiple images overlap, the user can select between all available perspectives.



The red fruit of oriental bittersweet vines stands out in geotagged images the latitude and longitude are marked with blue balloons. Techniques used will be transferred to Palmer survey.



This image was enhanced with light and color to make the red fruit of oriental bittersweet vines stand out. We plan to apply these techniques to Palmer survey.

In December 2018 we purchased a DJI drone with an aftermarket (Sentera) 5-channel multispectral camera. This system will allow us to capture the varying light reflectance of different plant species at different light bands and explore if a specific signature can be found for Palmer amaranth. In addition the DJI drone will allow surveys of smaller areas that don't have sufficient open space to safely operate an aircraft. It can also operate safely at lower altitudes which allows us to target smaller regions with much higher detail.

We plan to continue to fly surveys, improve our processes, and collect image sets as weather permits through the remainder of the winter. We hope to begin performing specific Palmer amaranth test surveys in February and continue on through the growing season. As opportunities arise for flying in other states with known Palmer infestations, we will begin using our new multispectral camera to collect image data to search for a specific palmer signature. When the weather does not permit safe flying, we continue to develop our in-house survey systems and analysis tools.

Second Update July 31, 2019

During the months of March, April, and May we performed 20 test survey flights with the DJI Phantom 4 drone and 5-channel multispectral camera. The data collected during these flights was used to learn about the platform, refine our survey strategies, and further develop our in-house mapping and detection tools. The DJI Phantom system includes a 5-channel multispectral camera. As part of these early test flights, we have been collecting 5-channel multispectral imagery and exploring strategies for processing this data. The goal remains that we can differentiate species with this data and use that capability to identify Palmer amaranth.

In late April 2019 we flew our DJI Phantom 4 + Sentera multi-spectral camera at the the UMN Landscape Arboretum in Chanhassen. They were interested in the feasibility of detecting evidence of emerald ash bore (EAB) from a drone survey, and our lab was looking for new areas to test our system. We weren't able to achieve a positive result with this camera system, but we would like to return at some point with our higher resolution fixed wing survey system to see if we can achieve any better results. Although the target was EAB rather than Palmer, it was an opportunity to test our system during the non-growing season.

In June 2019 we were contacted by a drone operator from the Nature Conservancy in Duluth. We processed several of their data sets through our in-house mapping tools to evaluate their effectiveness in forest management. This particular project hoped to be able to monitor seedling plantings and growth. The ability of our in-house tools to show the full detail of each image along with every view of a feature was attractive to

them. For Palmer amaranth detection, we are very interested in the ability to monitor plant growth and development.

Although not directly related to Palmer detection, our aerial survey development is receiving attention.

- In July 2019 we were contacted by California State University (Long Beach) regarding a project to survey and study white sharks near beaches. We are still discussing if there is a way forward where our in-house mapping and identification tools can be applied to their imagery versus modifications to their data collection process to improve their potential results.
- In July we were contacted by a group in Australia interested in evaluating our mapping tools for use in rapidly geo-locating features of interest in an agricultural setting. Exploring these additional use cases improves the robustness and functionality of our in-house software. New data sets from new locations stretch and challenge the current capabilities of our software and help us improve it.

In early June we had a mishap with our fixed wing survey aircraft, an X-UAV Talon named "Idun". There was enough damage to the airframe that we decided it should be replaced. We have purchased two replacement airframes and are in the process of assembling the first and moving our avionics and camera survey system over to the new aircraft. We also purchased an updated ground station.

We are planning flights in areas with abundant Palmer amaranth to collect high quality image sets of known Palmer. We will test whether our multi-spectral camera can detect a signature wavelength for Palmer.

Third Update January 31, 2020

On August 21, 2019, a Houston County environmental specialist alerted the MDA about a potential Palmer amaranth infestation located in their county. On August 27, 2019, the MDA investigated the site and confirmed the presence of Palmer. After confirmation, UMN travelled to the site and performed several aerial surveys with their Phantom drone. The phantom includes a high resolution built-in DJI camera and a Sentera multispectral camera. We flew surveys from several altitudes to test the performance of both cameras and to determine which pixel resolution is most feasible for identifying Palmer. The infestation was treated with a prescribed burn on September 18, 2019. Following the prescribed burn, we returned to the site on September 26, 2019 to perform follow-up aerial survey work. We determined that with our available aerial imaging tools, we needed to fly at altitudes below 20 meters in order to identify Palmer. Lower altitudes are required to provide enough image detail to visually distinguish the individual palmer seed heads and leaves. This improves the accuracy of identifying Palmer, but also significantly lowers the amount of area we can cover. We carefully evaluated the imagery from the Sentera multispectral camera but could not identify any unique characteristics in the available spectral regions to differentiate Palmer from the surrounding plants. We were able to see and identify the Palmer plants visually with the most detailed (low altitude) imagery from the built-in DJI camera.

In the early Fall, we spoke with a weed specialist from Iowa State University, and he directed us to three confirmed Palmer infestations located in the Council Bluffs, IA area. We visited the sites on October 7, 2019. The first site was a roadside infestation, but we were not able to fly there due to overhead power lines. However, we were able to fly successfully at the other two sites. The second site was located on an abandoned lot in a commercial area. This provided a great example of what a Palmer infestation looks like when it goes untreated for several consecutive years. The third site was located on farmland and there have been attempts to treat it in the past few years. We flew surveys at several different altitudes, collecting high resolution RGB data and 5-channel multispectral images from the Sentera camera. From air and ground surveys, we were able to determine additional locations in the vicinity of the original known infestation where Palmer could be identified. After this trip, we visited Sentera, a Minnesota based agricultural imaging company, and discussed our images and results with their machine vision experts. Sentera is a leader in developing artificial intelligent algorithms to automatically identify weeds from drone imagery. Our discussion confirmed that for the purposes of automatic weed identification, very high visual detail is very important, and in most cases multispectral data does not offer

useful distinguishing characteristics. Sentera recommended that we could get improved results by flying surveys at lower altitudes or using higher resolution cameras.

In January of 2020 we purchased a DJI Mavic 2 pro drone. The Mavic is smaller and quieter than the phantom, has similar endurance, and has a slightly improved camera sensor. The Mavic serves a dual purpose of expanding the amount of area we can survey in a day. Or if there are technical issues, having a second drone as a backup to the first can salvage a day.

In between survey trips, the UMN has been working to improve our image analysis software tools. We have developed and refined a robust software package that can stitch all the aerial images together into a seamless mosaic while preserving all the original details of each image that contributes to the mosaic. For the purposes of weed identification it is critical to maintain all the original image detail and be able to look through all the images and vantage points that cover a single point of interest. Areas where weeds show up tend to be in mature agricultural fields or dense forested regions. These areas present unique challenges to successful stitching with commercial software tools. Through the Fall/Winter of 2019-2020 the U of MN UAV Lab has spent time developing algorithms and strategies that significantly outperform similar commercial proprietary tools with respect to stitching images together in challenging regions while preserving the maximum detail from all the original images. This benefits our specific use-case of weed identification which isn't well represented by commercial software tools. These tools then facilitate quickly reviewing the surveyed area and locating any areas of potential concern, or possibly declaring the area free of specific invasive weeds. The UAV lab makes all its software tools available for free under an open-source (MIT) license so that other groups can access and benefit from this same technology.

In addition to the mapping tools the UMN has also been investigating artificial intelligent machine vision techniques to improve weed identification reliability. Our early results indicate that Palmer amaranth will be difficult to reliably identify because it can bear so many similarities to surrounding plants. This upcoming Spring and Summer we plan to fly surveys that yield much more detailed imagery and hope that this will enable computer algorithms to more reliably identify Palmer versus other plants in an area of interest. The machine vision work is ongoing and will hopefully also benefit survey projects which target other invasive plants throughout the year.

Fourth Update July 31, 2020
Please see the update about aerial imagery analysis by CCM field specialists in Activity 2.

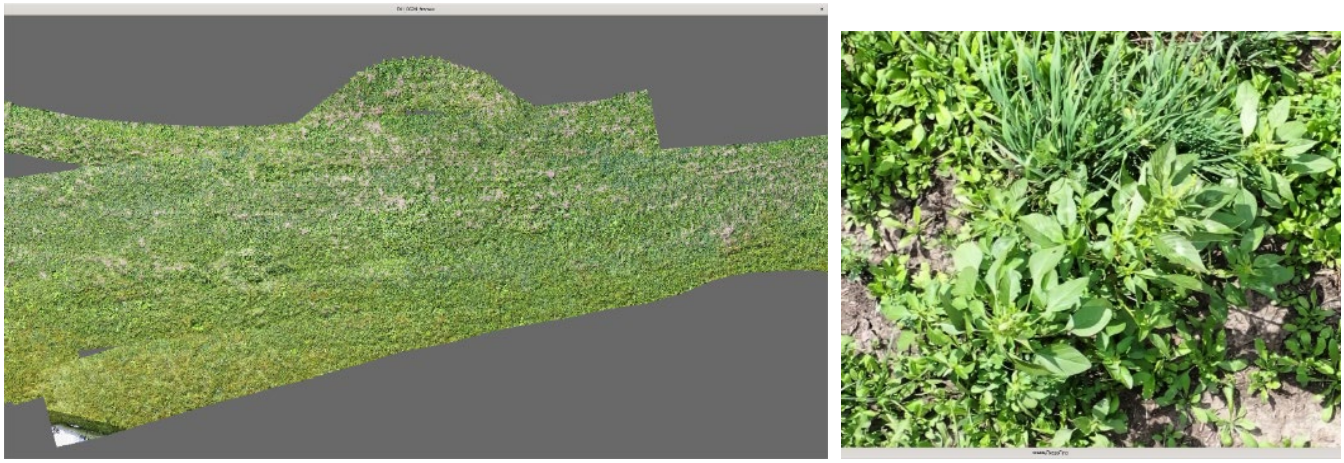
Over the winter months we continued to fly aerial surveys. This helped us refine our strategies for operating in challenging conditions such as extreme cold and hiking into remote areas with our survey gear. We continued to develop strategies to survey very large areas, areas with widely varying terrain, managing large volumes of data, and communicating summaries of our results to our ground teams via google maps.

This month we purchased a larger hexacopter drone. This drone will enable us to fly our high resolution digital mirrorless camera over areas which are too constrained for fixed wing UAV's. It will enable us to capture much more detailed and high quality images in areas where we are limited right now.

Throughout this period we have continued to develop and refine our in-house software tools. We were able to write several custom programs to support importing and exporting out data to/from the zooniverse site. We continue to improve our ability to support surveys of challenging subject material such as crops and heavily forested areas as well as hard to access areas such as marshy areas or areas with difficult terrain.

Fifth Update January 31, 2021
In August we began developing methods for low altitude surveys to produce very high detailed images and maps. At altitudes of approximately 10 feet above the ground, individual leaves and plant structures can be

clearly distinguished. Surveys at these extremely low altitudes require manual piloting, sometimes flying underneath overhanging tree branches and following the contours of terrain elevation up and down. The payoff is an orthomosaic map and individual photos with stunning details.



An orthomosaic image on the left resulted from a manual, low altitude flight. On the right are Palmer amaranth and other plants that are clearly visible.

Through the fall we have continued to enhance our in-house mapping tools to support the specialized challenges of flying and collecting image data at very low altitudes.

This winter we have also continued efforts to leverage computer vision and machine learning to help with the process of identifying Palmer plants. Computer vision algorithms can be used to find individual leaf outlines in the very high detailed original images. Once individual leaves or groups of leaves are separately identified, they can be characterized in a number of ways relating to their shape and complexity. The goal is to use these physical characteristics to train a machine learning system to quickly scan large data sets and identify candidate Palmer plants.

Original image with annotation to indicate Palmer amaranth plants

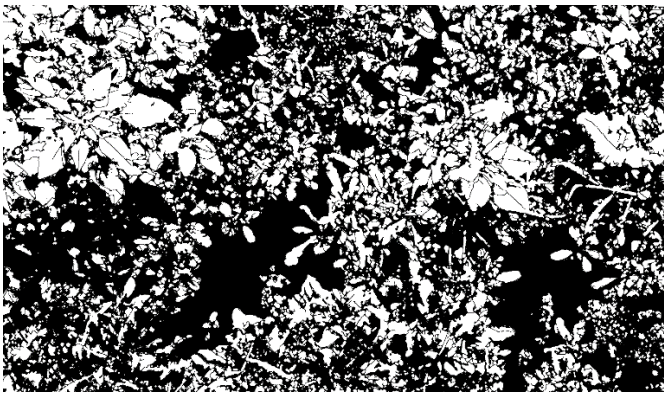


Image of a “mask” generated using computer vision algorithms to find individual leaves and their outlines

This image has the original image combined with the “mask” to highlight only the dominant leaves.

Sixth Update July 31, 2021

On June 16, the U of MN conducted an aerial survey at a site in Winona County where Palmer amaranth had been found. Two fields were imaged from an altitude of 100’ above ground and a total of 2400 images were collected. These images were stitched into highly detailed maps of the two fields. Unfortunately, the fields had been treated with herbicide a few days prior to our survey so no visible weeds remained. The need to aggressively manage Palmer amaranth infestations in a timely manner versus developing and testing aerial survey methods has proved to be an unexpected challenge with this project. Still we were able to record the regions of the field with gaps and open areas. These areas with less crop coverage are often the locations of highest weed pressure later in the growing season. Even though specific weeds were not visible, the overall map still provides enhanced situational awareness for managing and tracking the site treatment plan.

Images from the Winona county site. The detailed image shows bare ground and gaps in planting. The second image shows a stitched overview of the entire field.

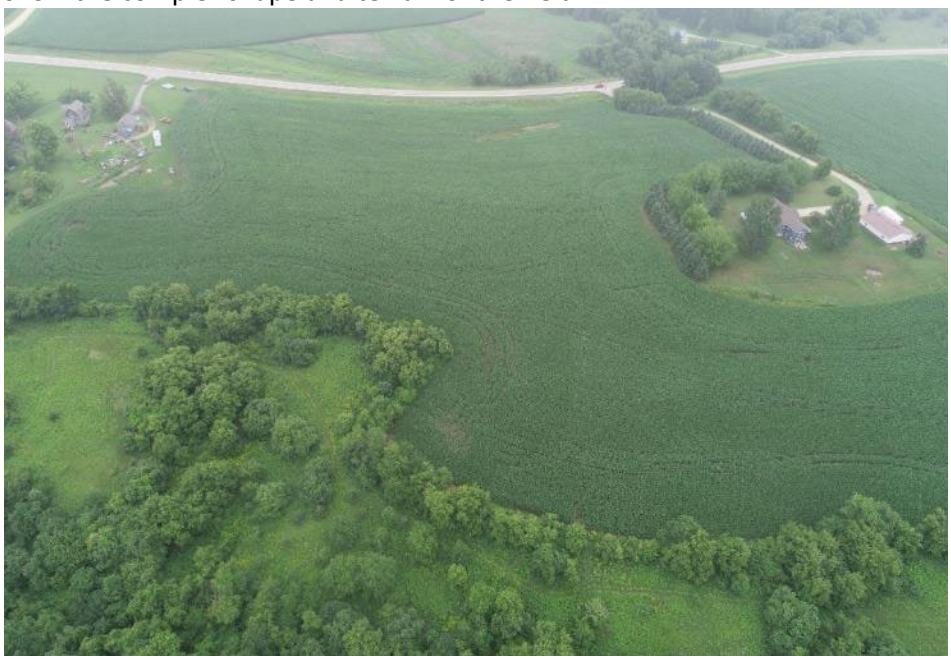
On July 7, the U of MN conducted an aerial survey at a site in Goodhue County where Palmer amaranth had been confirmed. The first field was surveyed at an altitude of 60’ above ground. This was the minimum safe altitude considering terrain variations and surrounding obstacles. The layout of the second field allowed flying a survey altitude of 45’ above the ground. A total of 3263 images were captured at the Goodhue County site.

Altitude is important because the lower the drone is able to fly, the more detail it can capture in the photographs (at the expense of covering a smaller area for the same flight time.) At 60' altitude, weeds were clearly visible between the rows of corn, however not enough detail was available to clearly identify individual weed types. Marker flags placed during an earlier ground survey were clearly visible in the imagery. A 2nd field was surveyed at an elevation of 45' above ground and this provided much clearer images of individual weed and leaf shapes.

On Jul 27, 2021Shane Blair (MDA) and Curt Olson (UMN) walked one of the fields at the Goodhue County site to ground-truth a set of suspicious pigweed plants identified in the previous aerial survey. The results of this test showed that generic pigweeds could be reliably identified in the aerial survey images. However, most of the suspicious plants were found to be Powell's amaranth which is very similar in appearance, especially when the plant hasn't developed a mature seedhead. One likely palmer plant was found and removed through this process.

First image: a portion of the Goodhue County site where suspicious plants have been marked and ground-truthed. 2nd image: an example of the detail visible at 45' altitude with a cluster of suspect palmer plants marked.

In addition to detailed low altitude mapping, the aerial survey drone can be used to take overview pictures of sites. These pictures can be useful for situational awareness and communication between team members who may not have visited the site. For example, this overview picture was taken at the Goodhue county site to help show the complex shape and terrain of the field.



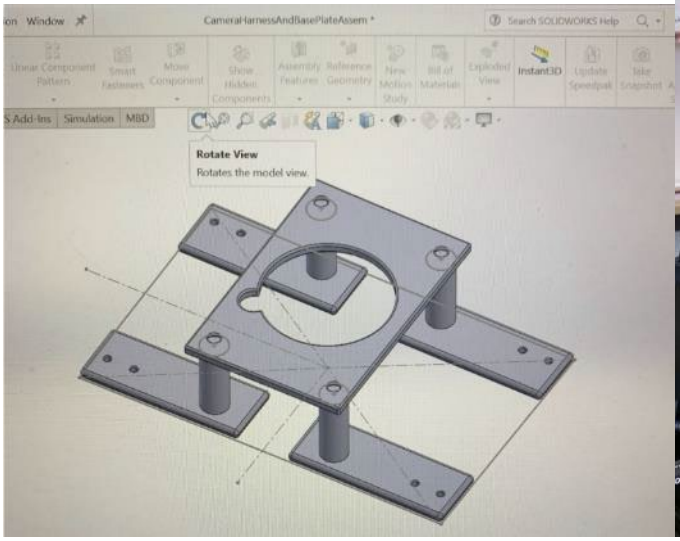
On July 27, a portion of a corn field near Wanamingo, MN was surveyed at an altitude of 40’ above ground. A total of 2053 images were collected across 6 flights. At the same time the aerial survey was being conducted, Shane Blair of MDA and a crop consultant walked the field on foot. At this site the corn was so consistently well developed that no weeds were visible from the air, and very few spots afforded any small openings to see down through the interwoven corn leaves to the ground.

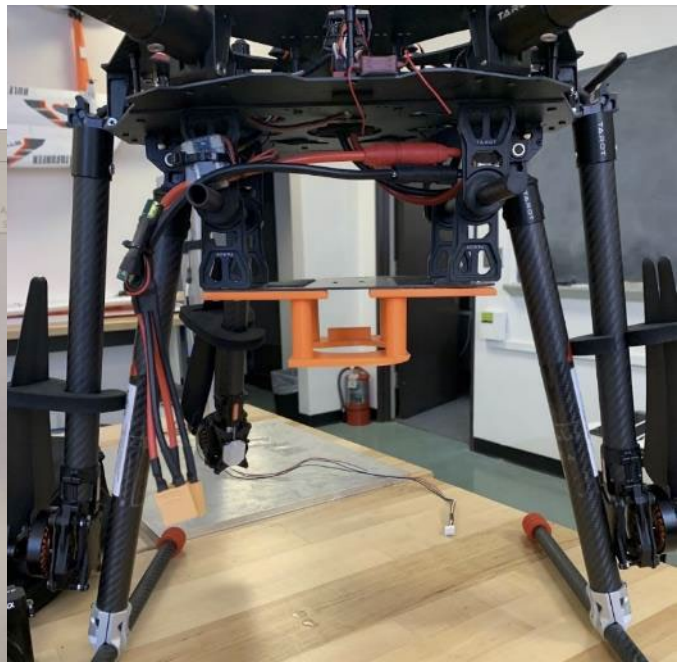
A heavy lift drone was purchased for the project with the intention of integrating a high quality digital mirrorless camera. The process of bringing this new drone online has been slowed due to supply chain issues and working from home during covid. The new heavy lift drone (pictured below) was successfully test flown in May.

Seventh Update January 31, 2022

On September 15, two fields near Windom, MN were surveyed looking for potential Palmer plants. There were reports that the seed mix used in these field may have been contaminated with Palmer amaranth seeds. The fields were flown at an altitude of approximately 35’ to achieve extremely high image resolution. 2,500 images were collected. Thankfully, no Palmer Amaranth was found in the imagery or when walking the fields.

During the Fall semester, the UMN AEM UAV Lab had a volunteer student worker design and 3D print a fixed camera mount system for the Tarot X6 hexicopter pictured above. The goal is to carry our higher quality digital mirrorless camera in order to improve our survey quality and range.





The new camera mount consists of two main parts, there is the base section and the harness. The base section sits flush against the underside of the carbon fiber plate and is mounted coincident to dampening brackets that hold the plate. The base section has four protruding studs for the harness. The harness section of the mount was designed so that it cradles the camera but also allows for easy access to the camera and quick removal. The benefit of the harness being separate from the base section is that it can be quickly redesigned to fit a different style camera and the whole mount does not need to be redesigned/reprinted, simply the harness has to be reprinted. To get the camera in the harness, simply remove the lens, seat the camera into the harness so that the lens release button sits flush within the frame and screw the lens back into the back through the outside of the harness. The lens will be pointing directly at the ground and will not be able to move in any direction.

Final Update August 15 2022

Goal: Adapt and extend survey/mapping strategies shown to be successful for identification and management of Oriental Bittersweet into the domain of Palmer Amaranth.

Survey Tools

Strategy: employ a two-pronged approach of evaluating available commercial tools and simultaneously developing in-house tools. Commercial tools are readily available and scale well. However, they have critical limitations that are difficult to overcome. These limitations can be addressed by developing targeted tools to address the unique needs and challenges of identifying palmer amaranth and other weeds.

Commercial drones

- DJI Phantom 4 with 20 Megapixel DJI camera and an aftermarket Sentera multispectral (5 channel) “Dual 4k” camera.

- Mavic 2 Pro with 20 Megapixel Hasselblad camera.

In-house developed drones

- Skywalker with 24 Megapixel Sony A6000 camera.

- XUAV Talon with 24 Megapixel Sony A6000 camera (with 30mm prime lens.) Fixed wing aircraft better suited than the skywalker for carrying a mirrorless camera payload.

- Tarot X6 with Sony A6000 camera. Multirotor aircraft.

Commercial mapping software

- Pix4d image stitching/mapping tools.
- Drone-Deploy image stitching/mapping tools.

Both pix4d and drone-deploy are tremendous tools, however for the purpose of weed identification we encountered some limitations.

- Both tools often struggled to correctly stitch the types of areas we were focusing on. In the case of oriental bittersweet we were imaging heavily forested areas. In the case of palmer amaranth we were imaging crop fields at very low altitudes (like mid to late season corn.) Our in-house mapping tool project included some advanced strategies for more successfully stitching these difficult regions.
- Drone deploy made it difficult to share results and collaborate with team members without purchasing a separate license for each collaborator (even when only one person was building the maps.)
- Both tools produced ortho-photos, however, these were a combination of all the perspectives and much of the individual details of each image were lost. These details were often critical for identifying weeds.

In-house developed mapping software

The UAV lab developed a set of open source “ImageAnalysis” mapping, stitching, and visualization tools optimized for “finding a needle in a haystack” use cases. These in-house tools addressed the limitations of the commercial tools in several ways.

- The in-house stitching tools were far more successful at stitching the challenging data sets we collected for our weed surveys, missing fewer of the images and avoiding the common bizarre artifacts of misaligned featured and images.

- The map visualizer draws out the original images stacked together in their correct location. Any view can be selected and the original image is shown in full original detail.
- Tools are open-source so cost and sharing and license restrictions are no longer a prohibitive issue.
- In addition to being free, open-source tools present the opportunity to extend and modify the code for specific project needs in the future.
- Map data sets are large so there are some logistical challenges to sharing them, but there are no license restrictions on sharing or copying the maps between any number of team members or other project participants.

Sites Visited

- Iowa, Council Bluffs area: Traveled to several sites in Iowa that had known Palmer infestations. This provided a ground truth and helped us to explore different altitudes and techniques for identifying Palmer.

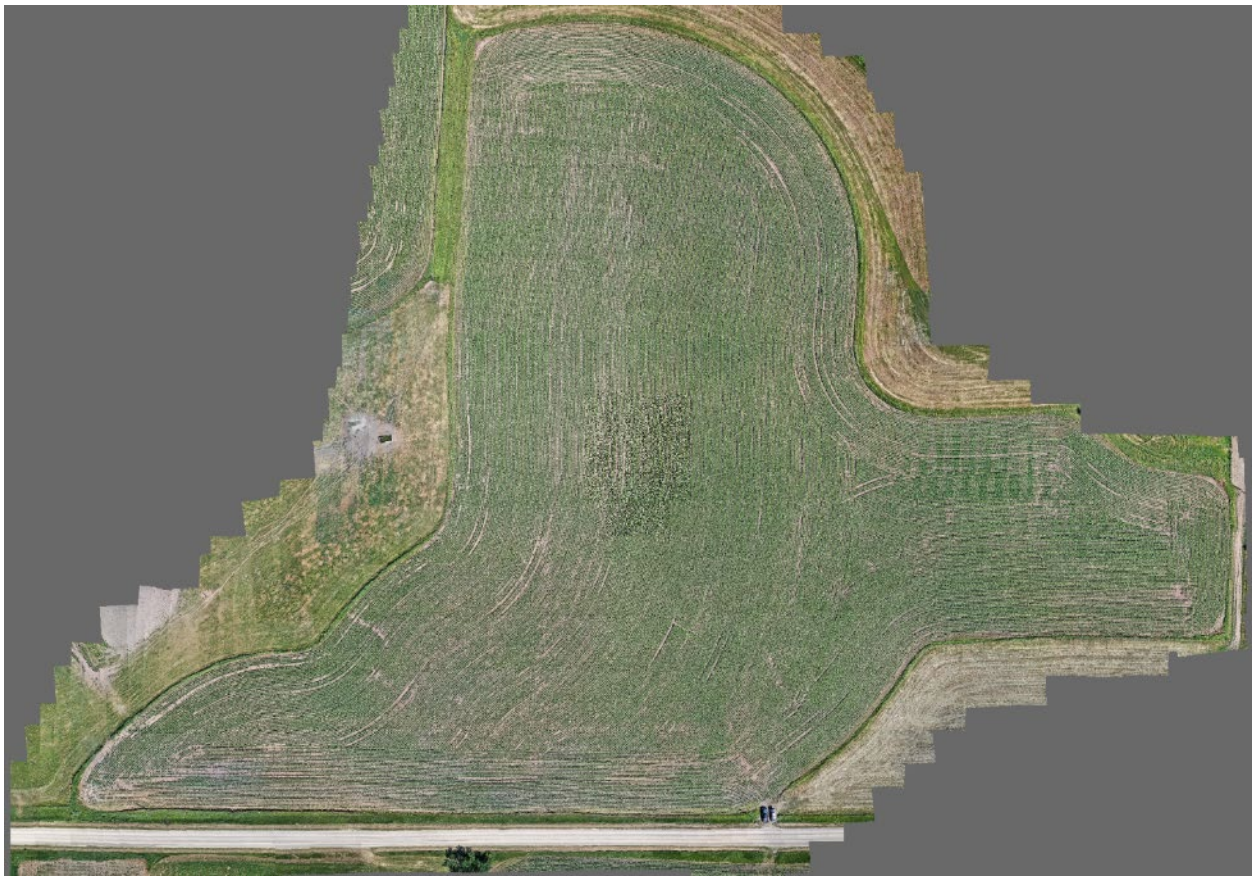
- Traveled to a site in Nebraska that had extreme/untreated infestation.

- Several visits to a site in Houston County, partnering with CCM.

- Imaged a mature corn field in Chandler, MN where a suspicious plant had been found (but not verified.) No further Palmer was found. This was a site where the commercial map stitching tools completely failed, and the in-house mapping tools were largely successful.
- Lyon County and Yellow Medicine County (CRP sites.) Early surveys with our first survey aircraft (a Skywalker.)
- Goodhue County: Surveyed several fields with verified Palmer finds looking to validate and find further plants, however the fields had been sprayed recently so all the weeds were heavily damaged and

difficult to identify.

- Winona County: Surveyed a site with verified palmer, but the fields had been sprayed several days prior and all the weeds were completely dead and there was no chance of identifying palmer.



- Wanamingo, MN
- Windom, MN

Identification

- Aerial images can be examined individually, but this is very time consuming with quite a bit of repeated effort due to the overlap in image coverage. In addition, a standalone image doesn't show context or orientation. It is helpful and much more efficient to stitch (or arrange) the images in their proper physical location. This is analogous to examining a single data point versus seeing all the data together in a graph or plot.
- Manual examination of stitched maps (or original imagery.)
    - Placing images in their correct places on the map reduces the workload due to not needing to reexamine redundant (overlapping) portions of the images in uninteresting areas.
    - With in-house map explorer tool, all the original imagery is visible in context (stretched, fit, oriented correctly on the map, accounting for 3d terrain height changes as well.)
    - Added image/color enhancement option to help highlight possible regions of interest.
- Explored several avenues for identification
    - Machine vision (support vector classification). Used gray level co-occurrence matrix (GLCM) to characterize and classify textures, mixed with color as well. However, the differences in texture and color for palmer amaranth were much too subtle for this approach to be successful.
    - Leaf shape extraction. I explored using machine vision techniques to extract leaf shape outlines, however this requires extremely high resolution imagery and is highly imprecise due to the amount of overlap and shadowing of plants and leaves in the imagery.
    - Multispectral bands. We explored the multispectral bands of the Sentera dual-4k camera to evaluate if palmer amaranth exhibits any unique traits in the near IR or red edge spectrums, but were unable to identify any unique features relative to surrounding plants. A full hyperspectral analysis might prove useful, but for real world applications, the hyperspectral signature needs to be observable from altitudes of 50-400' (compared to hypothetical lab testing where sensors may be clipped directly to the plant leaves.)
    - Extremely high detailed (low altitude) imaging. We explored several approaches to collecting very low altitude imagery. This presents stitching challenges due to significant perspective (parallax) changes between adjacent images. Low altitude surveys are slow, tedious, and collect an immense amount of data. Thus they present challenges scaling up to larger areas.
    - When presented with terrain or obstacles, we explored the idea of flying surveys manually while collecting video data. Video frames are less detailed than still frames, but it would be impossible to manually trigger the camera and manually fly survey routes simultaneously.
- Zooniverse (crowd source) identification. Near the start of the covid pandemic we setup a crowd sourcing project on zooniverse to evaluate the idea of using people power to quickly scan a large image data set. The results were somewhat disappointing. This is exceedingly boring work for many people to perform hours on end. Accuracy of identification was poor. The expected efficiency gains did not seem to materialize when using the zooniverse system.
- We flew surveys at various altitudes to evaluate the tradeoff between resolution and coverage. Higher altitudes allow for much greater area coverage, but at significantly reduced detail. The results always pointed towards lower altitudes and more detailed yielded better identification accuracy. The alternative to flying lower altitudes is to build (or source) a drone with a much higher resolution camera, better optics, better sensor. This is the avenue we were pursuing with the Tarot X6 multirotor, but covid delays significantly impacted our progress in getting that system ready to use operationally.

- Explored identification of other invasives:
    - Spotted knapweed. We traveled to Cass County, and met with a group from the Leech Lake Tribal College and went to two sites to demonstrate our aerial survey strategies and evaluate their effectiveness with spotted knapweed. This was interesting from the perspective of considering differences of culture and cultural expectations with respect to invasive plants, how they should be treated, and even what is an invasive plant?
    - Emerald ash bore. We flew a survey at the Minnesota Landscape Arboretum to evaluate our tools with respect to identifying emerald ash bore. The specific features we needed to see were too small to show up in camera imagery, especially top-down imagery. During the test we were able to demonstrate our system to a group of a dozen ARB volunteers and do a small bit of outreach.

Management

- Annotating survey maps: Our in-house mapping tools have a feature to mark (annotate) possible palmer plants (or any point of interest.) Then these locations can be exported (via CSV) to other tools like google maps for sharing and for use on a cell phone in the field.
- Situational awareness: We discovered that even when we struggled to identify specific palmer plants, the aerial surveys collected by our systems could be immensely useful for situational awareness. The overview (the whole stitched map), and oblique photos of the field were found to be very useful for team meetings and higher level management / strategizing because these gave much better situational awareness compared to looking at a field in google maps.
- Importing ground truth into survey maps: we also experimented with importing ground survey points into our aerial survey maps so we could look at what known infestation points looked like from the air.

Lessons Learned

- Coordination with the land owner is critical (they may take their own remedies that conflict with or limit MDA survey and management strategies.)
- Unable to find a specific spectral band/signature that characterizes Palmer Amaranth differently than surrounding weeds. This means visual identification by shape/color is the most plausible strategy.
- Identifying visually by shape/color requires very high resolution (typically flying low and slow and with a very high resolution camera.)
- Low flight surveys present challenges with collisions with trees/powerlines, navigating terrain.
- Manual surveys were tested where the camera was placed in video mode and the drone was flown manually near trees and over tricky terrain. This yielded very high resolution maps and good detail for visual identification, but was difficult, not automated, and didn't scale well.
- Deep learning AI identification techniques seem interesting, but we didn’t have enough time to investigate these tools.
- Lightly trained humans are not reliable for plane identification in aerial images.
- Sometimes the overview imagery (not the details) is most helpful when managing a site, coordinating the efforts of the team, and trying to understand the evolution of the infestation.
- Identification of plants (manual and ai) is context sensitive. Aerial imagery provides clues and identification is made with varying degrees of certainty.
- It can be very difficult to distinguish between like species in aerial images. For example, Oriental Bittersweet vs. American Bittersweet, or Palmer Amaranth vs. Powell Ameranth.

Conclusion

Aerial survey isn’t a complete standalone solution to weed management, but as a tool contributing to a larger strategy, it can be helpful in the MDA arsenal for detecting and managing weed infestations.

ACTIVITY 2: Monitor, ground survey, aerial image analysis and control (MDA and CCM)
Description: We will regularly monitor existing infestations to look for Palmer and determine control steps needed. We will survey additional conservation plantings on the ground. Prescribed fire and flame weeding are methods that will control Palmer amaranth while benefitting native species in conservation plantings. Additionally, these methods will not lead to herbicide resistance development.

Monitor
Monitoring existing infestations will involve visiting each site a minimum of three times per growing season to walk the fields and look for Palmer amaranth. If it is difficult to tell whether a pigweed is Palmer amaranth, samples from the suspect plant will be sent to the University of Illinois Plant Clinic for a species determination with a genetic test. MDA general or emergency funds will be used for this testing. If Palmer amaranth is found, control measures will be implemented. Monitoring data will be entered into ISMTrack, an EDDMapS product.

Ground Survey
To ground survey additional conversation plantings we will work with agency partners to identify and prioritize plantings for survey. Plantings will be selected throughout the state, but there will be an emphasis on the southern border region due to concerns about Palmer amaranth introduction from Iowa. We will develop a survey protocol based on walking a pattern in the planting. Presence/absence survey data will be entered into EDDMapS. If Palmer amaranth is found, data will be displayed at a county level due to landowners' sensitivity about Palmer amaranth.

Aerial Image Analysis
Six field specialists will analyze images collected from drone flights in Zooniverse, a U of M image analysis platform. They will look at images and mark areas of infestation then enter a confidence level for each finding. They can also enter comments. By having the field specialists review and mark Palmer on images, we gain their analysis. We also gain data about analysis patterns that may inform machine learning/artificial intelligence development for future image analysis.

Control
If Palmer amaranth is found, the project team will determine the best course of action. Extension weed scientists will be consulted when appropriate. Indications to date are that incinerating plants in fall 2016 with propane torches was effective at reducing seed. We will continue torching plants as needed. Additionally, prescribed fire will be used at all known Palmer sites in spring 2018 to reduce Palmer and improve the native plant competition. Data from management activities will be entered into ISMTrack.

ENRTF BUDGET: $ 271,300

Outcome	Completion Date
1. Infestations will be monitored during the growing season a minimum of three times per year. Palmer plants will be controlled prior to seed development. Currently there are 30 locations to monitor in Lyon and Yellow Medicine Counties.	06/30/21
3. Investigate potential infestation reports from the public and agency partners.	06/30/21
4. Utilize prescribed fire and flame weeding to control Palmer amaranth.	06/30/22
5. Analyze aerial images	06/30/22

First Update January 31, 2019
New infestations detected and report follow up
Four Palmer amaranth plants were found one location by a farmer in Redwood County in fall 2018. Similarly, a farmer found one plant in Jackson County in the fall of 2018. The reports originally went to Extension who forwarded them to MDA. Both finds were confirmed with genetic testing. Shane followed up by surveying

within a five mile radius of the fields where the Palmer amaranth was found. No additional Palmer plants were found. MDA's seed and weed teams are investigating possible pathways. One possible pathway is contaminated sunflower screenings. Samples collected from sunflower screenings testing positive for Palmer amaranth.

Shane followed up on potential Palmer amaranth reports that came to MDA via County Agriculture Inspectors and Arrest the Pest. These reports were not Palmer amaranth but were often similar looking pigweeds.

Monitoring existing sites

No Palmer amaranth was found at any conservation planting in 2018, including plantings where it had been found in 2017. Most plantings were monitored twice during the growing season.

Site Name	Date	Acres
Douglas 02	7/2/2018	145.61
Todd 01	7/2/2018	143.57
Dodge 01	7/4/2018	89.89
Yellow Medicine 03	7/23/2018	11.27
Yellow Medicine 04	7/23/2018	15.98
Yellow Medicine 06	7/23/2018	9.28
Douglas 01	7/24/2018	3.43
Douglas 02	7/24/2018	145.61
Yellow Medicine 05	7/24/2018	3.54
Yellow Medicine 07	7/24/2018	63.82
Yellow Medicine 10	7/24/2018	38.64
Yellow Medicine 02	7/25/2018	11.41
Lyon 01	7/30/2018	53.69
Lyon 02	7/30/2018	2.80
Yellow Medicine 01	7/30/2018	4.82
Yellow Medicine 04	7/30/2018	15.98
Yellow Medicine 11	7/30/2018	53.12
Douglas 02	8/2/2018	145.61
Cottonwood 01	8/11/2018	93.20
Pennington 01	8/12/2018	154.00
Pennington 02	8/12/2018	848.24
Pennington 03	8/12/2018	61.04
Marshall 01	8/14/2018	38.29
Marshall 02	8/14/2018	116.12
Red Lake 01	8/14/2018	275.00
Red Lake 02	8/14/2018	184.66
Roseau 01	8/15/2018	79.29
Redwood 01	9/14/2018	165.00
Lyon 01	9/23/2018	53.69
Yellow Medicine 06	9/25/2018	9.28
Yellow Medicine 07	9/25/2018	63.82
Lyon 03	9/26/2018	3.67
Yellow Medicine 04	9/26/2018	31.97
Yellow Medicine 05	9/26/2018	3.54
Todd 01	10/1/2018	143.57

Site Name	Date	Acres
	Total	**3,282.46**

Survey

There were new Palmer finds in Jackson and Redwood counties.

Site Name	Date	Acres
Jackson 01	10/4/2018	2.16
Redwood County	11/13/2018	10.00
	Total	**12.16**

Control

Weed torching was conducted in fall 2018 on all plantings located in Todd County. We were not able to burn these Todd County plantings in spring 2018 due to burn restrictions throughout much of the spring. Torching ensured that all seedheads on Palmer plants from fall 2017 were burned.

Second Update July 31, 2019

New infestations detected and report follow up

Shane has been doing extensive follow up on potential new Palmer amaranth finds. This involves contacting landowners, collecting samples and submitting them for genetic testing, surveying the area for additional suspect plants and documenting these activities. We are awaiting genetic testing results of a potential new find.

Monitoring existing sites

No Palmer amaranth was found at any conservation plantings listed below in 2019, including plantings where it had been found in 2017. All plantings listed below have been surveyed once in 2019. You will notice that there are plantings missing because they have not been surveyed yet but will be surveyed by the end of August 2019.

Site Name	Date	Acres
Houston 01	4/25/2019	54.1
Redwood 01	7/02/2019	165.00
Dodge 01	7/15/2019	89.89
Todd 01	7/16/2019	143.57
Douglas 01	7/16/2019	3.43
Douglas 02	7/16/2019	145.61
Pennington 01	7/22/2019	154.00
Pennington 02	7/22/2019	848.24
Pennington 03	7/22/2019	61.04
Marshall 01	7/22/2019	38.29
Marshall 02	7/22/2019	116.12
Red Lake 01	7/23/2019	275.00
Red Lake 02	7/23/2019	184.66
Roseau 01	7/23/2019	79.29
	Total	**2,358.24**

Control

There was no Palmer amaranth control work. All recent Palmer finds have been a few Palmer plants in the row crop setting. In these cases, there were on a few Palmer plants and they were hand pulled by the farmer.

Third Update January 31, 2020

New infestations detected and report follow up

Shane has been doing extensive follow up on potential new Palmer amaranth finds. This involves contacting landowners, collecting samples and submitting them for genetic testing, surveying the area for additional suspect plants and documenting these activities. Palmer amaranth was detected at two unrelated sites in Houston County within agricultural fields. The first site is roughly a half acre that was planted for wildlife. The source is unknown, but management activities have been put into place to eradicate the infestation. The first management activity being propane weed torching. The second site was in a bean field where the farmer noticed two palmer amaranth plants, picked them before harvest and contacted his local agronomist. Both sites are being monitored in the 2020 season and management practices will be enforced if needed.

Monitoring existing sites

No Palmer amaranth was found at any conservation plantings listed below in 2019, including plantings where it had been found in 2017. Most plantings listed below were surveyed twice in 2019.

Site Name	Date	Acres
Redwood 01	7/02/2019	165.00
Jackson 01	7/02/2019	23.00
Dodge 01	7/15/2019	89.89
Todd 01	7/16/2019	143.57
Douglas 01	7/16/2019	3.43
Douglas 02	7/16/2019	145.61
Pennington 01	7/22/2019	154.00
Pennington 02	7/22/2019	848.24
Pennington 03	7/22/2019	61.04
Marshall 01	7/22/2019	38.29
Marshall 02	7/22/2019	116.12
Red Lake 01	7/23/2019	275.00
Red Lake 02	7/23/2019	184.66
Roseau 01	7/23/2019	79.29
Douglas 01	7/24/2019	3.43
Dodge 01	7/25/2019	89.89
Cottonwood 01	8/08/2019	93.20
Redwood 01	8/14/2019	165.00
Nicollet 01	8/14/2019	3.46
Lyon 01	8/21/2019	53.69
Lyon 02	8/21/2019	2.80
Yellow Medicine 02	8/21/2019	11.41
Yellow Medicine 06	8/21/2019	9.28
Yellow Medicine 07	8/21/2019	63.82
Yellow Medicine 10	8/21/2019	38.64
Yellow Medicine 03	9/04/2019	11.27
Yellow Medicine 04	9/04/2019	31.97
Yellow Medicine 05	9/04/2019	3.54
Yellow Medicine 11	9/04/2019	53.12
Lyon 03	9/05/2019	3.67
Yellow Medicine 01	9/05/2019	4.82
Hennepin 01	9/16/2019	22.64

Site Name	Date	Acres
Redwood 01	10/02/2019	165.00
Jackson 01	10/02/2019	23.00
	Total	**3,180.79**

Control

Weed torching was conducted September 17-18, 2019 at the new find in Houston county, site Houston 01. At Houston 02, the plants were hand-pulled by the farmer. These plants were collected by MDA and were autoclaved.

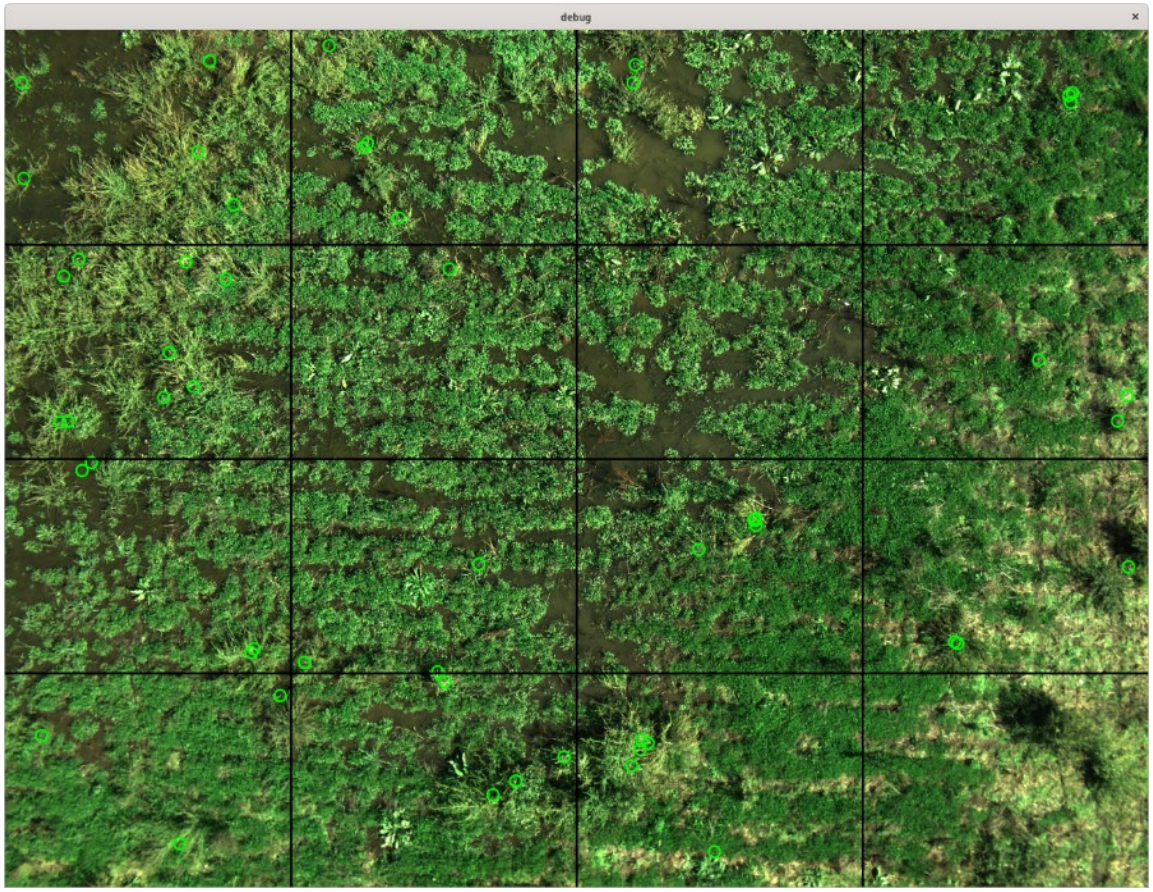
Palmer amaranth seedheads at Houston 01

Torching Palmer amaranth plants at Houston 01

Fourth Update July 31, 2020

This update period was heavily impacted by the COVID-19 virus. Travel restrictions and work-from home rules meant we needed to make some quick shifts in strategy and focus. Field operations for CCM crews were also suspended. To make the best of this situation, we scrambled and created a crowdsource weed identification project at zooniverse.org. Zoouniverse is a volunteer citizen-science website that connects science projects with human volunteers willing to help search though images and identify important features. We were able to set up two projects and upload several aerial data sets. CCM crews working individually from home could scan our aerial image sets and help identify Palmer amaranth. In addition to setting up a method to crowdsource weed identification tasks, this provided meaningful work for CCM crews during the time they were unable to travel and do outside field work. They reviewed 4,094 images. In contrast to a related project looking at oriental bittersweet images, it turned out to be difficult to identify Palmer amaranth. We realized that we need higher quality images and ordered a larger aircraft, a hexacopter, that can carry a large sensor/camera yet still have the maneuverability needed.

Site overview of a commercial lot near Council Bluffs, IA that is heavily infested with Palmer amaranth.



A single aerial image overlaid with points the CCM crews identified as potential Palmer amaranth plants.

A crop consultant found and reported Palmer amaranth in two row crop fields. Shane Blair was able to do a site visit the day of the report (06/24/20) and helped to scout the fields. There were only 10 Palmer plants and they were small (1-12" tall) this early in the season. The plants were hand pulled and sent to University of Illinois' Plant Clinic for genetic testing for species. Testing confirmed that the plants were Palmer. The fields will be monitored this season for additional Palmer plants. The fields are 16.2 and 67.7 acres in Winona County. A media release was issued about this find. We plan to use aerial survey to look for additional Palmer.

After visiting an existing Palmer site in Houston County, Shane and CCM organized and implemented torching Palmer plants in a hayfield.

There have been many reports of suspect Palmer that turned out to be waterhemp.

To date, Palmer amaranth management has gone better in Minnesota than many other states. This project has been an important component of that success. Many stakeholders asked that we publish what occurred with Palmer management in Minnesota so it can be used as an example. Eric Yu began documenting by compiling a timeline. Shane Blair and Extension contributed to the timeline. Eric then drafted a paper that is currently being reviewed internally.

Fifth Update January 31, 2021

New infestations detected and report follow up

Shane has been doing extensive follow up on the new Palmer amaranth finds. This involves contacting landowners, collecting samples and submitting them for genetic testing, surveying the area for additional suspect plants and documenting these activities. Palmer amaranth was detected at three sites in Winona County within agricultural fields. The source is unknown, but management activities were initiated to eradicate the infestation. The first management activity was hand pulling. Shane worked with the agronomist and landowner to ensure that Palmer amaranth was not present during the harvest of the bean fields. All three sites were monitored in the 2020 season and management practices will be enforced if needed in 2021.

Monitoring existing sites

No Palmer amaranth was found at any conservation plantings listed below in 2020, including plantings where it had been found in 2016, 2017 and 2018. All plantings below were surveyed once in 2020.

Site Name	Date	Acres
Redwood 01	7/22/2020	165.00
Jackson 01	7/22/2020	23.00
Lincoln 01	7/16/2020	25.00
Todd 01	8/06/2020	143.57
Houston 01	6/24/2020	.515
Houston 02	6/24/2020	17
Houston 01	7/07/2020	.515
Houston 01	7/14/2020	.515
Houston 01	7/23/2020	.515
Houston 01	8/12/2020	.515
Douglas 02	8/06/2020	145.61
Pennington 01	7/09/2020	154.00
Pennington 02	10/07/2020	848.24
Pennington 03	10/07/2020	61.04
Marshall 01	7/09/2020	38.29
Marshall 02	7/09/2020	116.12
Red Lake 01	7/09/2020	275.00
Red Lake 02	7/09/2020	184.66
Roseau 01	7/08/2020	79.29
Winona 01	6/24/2020	102.7
Winona 01	7/07/2020	102.7
Cottonwood 01	7/22/2020	93.20

Site Name	Date	Acres
Houston 01	8/24/2020	.515
Nicollet 01	10/08/2020	3.46
Lyon 01	8/13/2020	53.69
Houston 01	9/01/2020	.515
Houston 01	9/23/2020	.515
Houston 02	9/23/2020	17
Winona 01	7/23/2020	102.7
Winona 01	8/12/2020	102.7
Winona 01	8/25/2020	102.7
Yellow Medicine 11	9/04/2019	53.12
Yellow Medicine 01	8/13/2020	4.82
	Total	**3,018.73**

Control

Weed torching was conducted July 14th, 2020 at the Houston county site, site Houston 01. Hand pulling was conducted 7/23, 8/12, 8/24 and 9/1/2020. Hand pulling was also conducted at the new site within Winona county, in all three bean fields. Hand pulling was conducted on 06/24, 07/07, 7/23, 08/12 and 08/25/2020. The plants from both Houston 01 and Winona county were hand pulled, bagged and incinerated.

Sixth Update July 31, 2022

New infestations detected and report follow up

Shane has been doing extensive follow up on the new Palmer amaranth finds. This involves contacting landowners, collecting samples, and submitting them for genetic testing, surveying the area for additional suspect plants and documenting these activities. Palmer amaranth was detected at one site in Polk County within an area where screenings were being composted. A screenings sample was collected during a routine seed inspection, which led to a positive find for Palmer amaranth seed within the screenings. After further investigation Palmer amaranth cadavers from 2020 were found in a 2 acre "green" space that the company is using to compost screenings that contain 10 percent foreign matter or higher. The company has agreed to manage the site and to ensure that no potential contaminated screenings leave the area. Further monitoring will be conducted in the 2021 season and management practices will be enforced if needed in 2021.

Palmer amaranth was also detected at one site in Clay county. A University of Minnesota Extension employee noticed, what he believed to be, Palmer amaranth. He collected plant samples and collected samples of chicken feed, to which he believed to be the pathway. The Minnesota Department of Agriculture has confirmed the plants to be Palmer amaranth via a genetic test and pigweed seeds have been identified within the chicken feed. Further testing is being conducted currently to genetically identify the seeds.

Palmer amaranth has also been detected in Goodhue county. There are three agriculture fields in total, two of which belong to one farmer and the remaining field belongs to another farmer. The source for these three fields is currently unknown currently and they are not believed to be linked. Multiple pathways are being investigated and management practices are being put into practice. Multiple surveys have been conducted at the two initial sites where many Palmer amaranth plants have been found. With each survey, the number of Palmer amaranth plants found is decreasing. The remaining field, that is farmed by a separate farmer, has been surveyed and 3 plants have been identified. All plants that have been found in all three sites, have been hand pulled and destroyed, to ensure that no parts of any plant can produce seed. Aerial surveys have been conducted at all three of these locations, potentially helping us identify problem or overlooked areas of the field. All three of these fields were initially found by local agronomists who were conducting field inspections. They collected pictures and samples and notified both the Minnesota Department of Agriculture and the University of Minnesota Extension.

Many Palmer amaranth calls and emails come in weekly. All suspect plants are either confirmed by photo or the plants have been sent to a lab to be genetically identified.

Monitoring existing sites

Palmer amaranth has been found at one site, which is the Winona county site which is in an agricultural setting. The remaining sites, Palmer amaranth has not been found. Including plantings where it had been found in 2016, 2017 and 2018. All plantings are listed below with dates and acreage.

Site Name	Date	Acres
Houston 01	4/22/2021	.515
Houston 02	4/22/2021	16.8
Houston 01	5/06/2021	.515
Houston 01	5/19/2021	.515
Houston 02	5/19/2021	16.8
Houston 01	6/02/2021	.515
Winona 01	6/08/2021	154.00
Houston 01	6/14/2021	.515
Redwood 01	6/15/2021	160.00
Houston 01	6/22/2021	.515
Jackson 01	6/23/2021	23.00
Lincoln 01	6/23/2021	25.00
Houston 01	7/01/2021	.515
Houston 01	7/06/2021	.515
Winona 01	7/15/2021	154.00
Houston 01	7/22/2021	.515
	Total	**393.72**

Control

All sites this season where Palmer amaranth has been found, including all the new sites, Palmer amaranth has been hand pulled, bagged and incinerated.

Seventh Update January 31, 2022

Palmer amaranth new infestations detected and report follow up

Many Palmer amaranth calls and emails come in weekly. Shane did extensive follow up on the new Palmer amaranth finds. This involved contacting landowners, collecting samples, and submitting them for genetic testing, surveying the area for additional suspect plants and documenting these activities. Palmer amaranth was detected at one new site in Goodhue County (site name: Goodhue 04) within a feedlot operation. Plants were found growing near the feed bunk for cattle, which encompasses about a half an acre. Multiple samples of feed were collected, as well as the entire property surveyed. No additional plants were found other than the plants found near the feed bunk. Further monitoring will be conducted in the 2022 season, as well as more samples of feed collected to help determine the source. Management practices will be enforced if needed in 2022.

A routine seed inspection led to the positive find of Palmer amaranth in a specific seedlot of pearl millet that was sold in Minnesota as well as to other states. A stop sale was issued, and all seed was recalled. Unfortunately, the pearl millet was already planted in 5 counties within 6 sites in Minnesota. The county/site names with acreages are Houston 03 (6.03 ac), Wright 01(6.61 ac), Becker 01(9.495 ac), Polk 02(33.881 ac), Cottonwood 02a (5.819 ac) and Cottonwood 02b (126.272 ac). These sites have been surveyed and no Palmer amaranth has been found to date. We will continue to monitor these locations in the following seasons.

Monitoring existing Palmer amaranth sites

Palmer amaranth has been found at all three of the Goodhue County sites, as well as Polk 01, Winona 01a and Houston 01. The remaining sites, Palmer amaranth has not been found. All plantings where it had been found in 2016, 2017 and 2018 are deemed eradicated. All plantings that are being monitored are listed below with dates and acreage.

Site Name	Date	Acres
Goodhue 01a	8/03/2021	15.669
Goodhue 01b	8/03/2021	5.483
Douglas 01a	8/04/2021	.801
Douglas 01b	8/04/2021	2.107
Douglas 01c	8/04/2021	.497
Douglas 02a	8/04/2021	15.502
Douglas 02b	8/04/2021	27.325
Douglas 02c	8/04/2021	21.681
Douglas 02d	8/04/2021	5.201
Houston 01	8/11/2021	.515
Polk 01	8/11/2021	1.208
Goodhue 01a	8/12/2021	15.669
Goodhue 01b	8/12/2021	5.483
Polk 01	8/24/2021	1.208
Houston 01	8/30/2021	.515
Houston 02	8/30/2021	20.998
Goodhue 01a	9/14/2021	15.669
Goodhue 01b	9/14/2021	5.483
Goodhue 02	9/14/2021	72.041
Winona 01a	9/15/2021	16.272
Winona 01b	9/15/2021	67.727
Winona 01c	9/15/2021	18.706
Houston 01	9/16/2021	.515
	Total	**336.275**

Palmer amaranth control

All sites this season where Palmer amaranth has been found, including all the new sites, Palmer amaranth has been hand pulled, bagged, and incinerated.

Other priority target species

Control work was done on black swallow-wort at two sites, one in Hennepin and one in Chisago counties. Common teasel was treated at one site in Olmsted County. Cutleaf teasel was treated nine sites in southeastern Minnesota. Monitoring and spot treatment of Japanese hops was done for seven days on the Root River. Major progress was made with oriental bittersweet management this fall. Northern Minnesota crews worked in Winona for a week at time under the guidance of two very experienced field specialists based in Rochester. They spent almost 600 hours at five sites and accomplished much more than individual landowners could achieve singe-handedly. Poison hemlock was treated at two sites in Fillmore County. Knotweed were spot treated on the Zumbro River. Wabasha Soil Water Conservation District oversaw previous knotweed treatments but didn't have funds for 2021 treatments. Knotweeds spread rapidly along waterways as fragments on

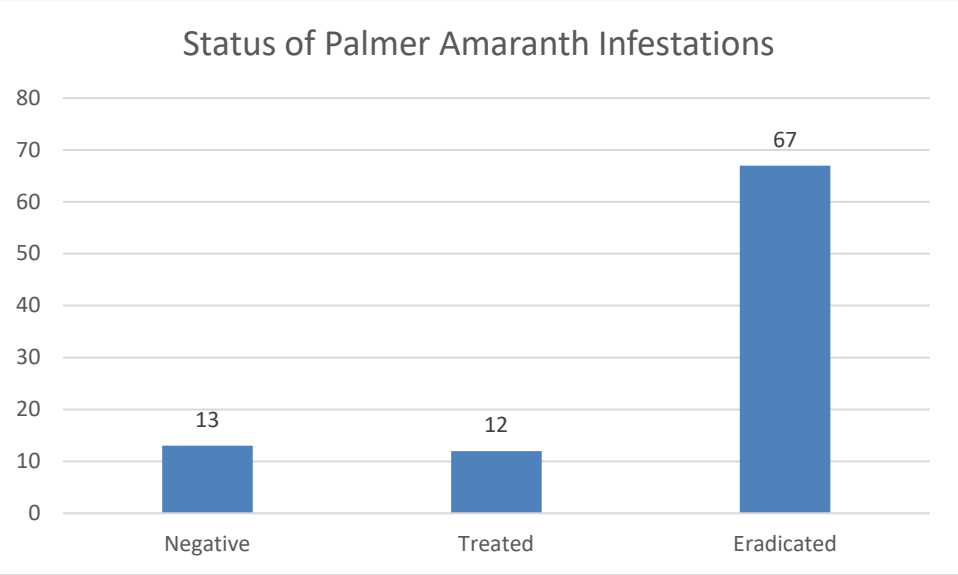
knotweeds can be moved downriver and start new infestations. It was hard for the field specialists to access the knotweeds along the river but they are skilled with canoes and did it.

Plant name	Acres Treated
Black swallow-wort	0.86
Common teasel	0.173
Cutleaf teasel	167.84
Japanese hops	43.58
Oriental bittersweet	80.7
Poison hemlock	113.83
Knotweeds	1
	407.98

Final Update August 15 2022

Palmer amaranth

This project was key to eliminating Palmer amaranth in conservation plantings in Minnesota. There have been no recent finds of Palmer amaranth in conservation plantings. From 2016 to the end of this project (06/30/22), 92 infestations or fields planted with infested seed mix were recorded. Of these, the majority (67) were eradicated meaning that no Palmer was found at the location for at least 3 years. There were 13 fields sown with infested seed mix but Palmer was not found in the field. There are 12 infestations that were treated and the control effort is ongoing. MDA is continuing to monitor these 12 active infestations.



Other priority target species

This project also addressed other priority target species including black swallow-wort, common teasel, cutleaf teasel, Japanese hops, oriental bittersweet, poison hemlock and knotweeds. Most recently, a cutleaf teasel infestation near the Munger Trail in Duluth was controlled. The infestation was found last fall and responding quickly prevented this infestation from spreading. To ensure finding and reporting these species are continues after this project, we held a workshop to train 92 current CCM members to identify them. Preventing the spread of these species has lasting benefits.

IV. DISSEMINATION:

Description: We will communicate about our activities and findings with the public, Cooperative Weed Management Areas, land managers, and weed scientists. Communication with the public will be via news media (print, television, and radio) and social media such as Facebook and Twitter. We will provide updates to the University of Minnesota Extension blog Minnesota Crop News for communication with the agricultural community. We will also provide updates to MDA's multi-agency/organization Noxious Weed Advisory Committee that meets a minimum of two times per year.

First Update January 31, 2019

Presentations and Events

- Blair, S. gave an update at a Todd County Palmer Amaranth Work Group meeting on July 19, 2018 in Staples.
- Blair, S. gave a Palmer amaranth identification and reporting presentation to 50 farmers and land managers on August 3, 2018 in Grey Eagle.
- Blair, S. gave a Palmer amaranth identification and reporting presentation at Central Lakes College Farm Forum to professors, farmers and land managers on August 24, 2018 in Staples.
- Chandler, M. gave a project update to MDA's Noxious Weed Advisory Committee on September 25th and December 19th 2018.
- Blair, S. gave an update on Palmer amaranth at the County Agricultural Inspector District 3 meeting on September 26, 2018 in Owatonna.
- Blair, S., C. Olson, M. Chandler, D. Opdahl, D. Looman, Z. Dieterman and A. Cortilet authored and Shane Blair presented "Palmer amaranth (*Amaranthus palmeri*) management in Minnesota conservation plantings" at the Upper Midwest Invasive Species Conference in Rochester from October 15-18, 2018.
- Blair, S. gave an update on Palmer amaranth at the County Agricultural Inspector District 4 meeting on October 31, 2018 in Redwood Falls.
- Blair, S. gave a Palmer amaranth identification and reporting presentation at Central Lakes College Farm Forum to professors, farmers and land managers on December 4, 2018 in Staples.
- Blair, S. and M. Merriman staffed a booth and answered many questions at the Minnesota Association of Soil and Water Conservation Districts annual meeting on December 10th and 11th, 2018 in Bloomington.
- The U of M's Minnesota Invasive Terrestrial Plants and Pests Center and MDA organized and hosted a Palmer Summit on January 22, 2019 in St. Paul. Representatives from Iowa, Minnesota, North Dakota, South Dakota and Wisconsin discussed the status of Palmer amaranth in each state, the challenges we face and how we can collectively reduce the spread of Palmer amaranth.

Articles and Media Coverage

- Blair, S. contributed the requested article "Palmer amaranth: Why the concern and where is it located in Minnesota?" to Mille Lacs County Soil and Water Conservation District for their newsletter. The article was dated January 24, 2019.

Second Update July 31, 2019

Presentations and Events

- Palmer amaranth was included in MDA's New County Agricultural Inspector training in St. Cloud February 12-13, 2019.
- Chandler, M. gave a project update to MDA's Noxious Weed Advisory Committee on February 27, 2019.
- Blair, S. presented Palmer amaranth identification and provided a status update at McCleod County's annual noxious weed meeting. Participants included county employees, farmers and producers, MnDOT and DNR. The meeting was on March 20, 2019.
- Blair, S. presented Palmer amaranth identification and provided a status update at Wadena County's annual noxious weed meeting. Participants included county employees, Extension, farmers and producers, and feedlot owners. The meeting was on April 2, 2019.
- Palmer amaranth identification was included in Weed 'Em Out workshops in Mankato (04/30/19) and Bemidji (05/02/19) for a total of 104 vegetation management professionals.
- Multiple MDA weed team members participated in spring 2019 MnDOT district meetings including weed identification training, including Palmer amaranth, and weed management discussions at the following locations: Bemidji (04/24), Detroit Lakes (04/25), Arden Hills (05/10), Mankato (05/13), Rochester (05/15) and Duluth (05/30).
- Blair, S. gave an update on Palmer amaranth to the Minnesota Association of County Agricultural Inspectors at their annual meeting in Baudette, MN on July 24, 2019.

Articles and media coverage

- Chasing Palmer: Minnesota tries to stop high-cost invasive weed https://www.mprnews.org/story/2019/07/19/chasing-palmer-amaranth-minnesota-tries-to-stop-invasive-weed-species The article was dated July 19, 2019.

Third Update January 31, 2020

- Blair, S. presented Palmer amaranth identification and provided a status update at the Minnesota Crop Production Retailers Trade Show. Participants included county employees, farmers and producers, retailers, manufacturers, distributors and custom applicators of crop production on December 12, 2019.
- Blair, S. provided a Palmer amaranth status updated at a County Agricultural Inspector, District 3 meeting on January 8, 2020.
- Blair, S. presented Palmer amaranth identification and provided a status update at the Northern Green Expo, in Minneapolis on January 15, 2020. Participants included green industry retailers, manufacturers, distributors and custom applicators of crop production.

Fourth Update July 31, 2020

COVID limited outreach opportunities.

Fifth Update January 31, 2021

- A project update was provided at MDA's Noxious Weed Advisory Committee meetings on September 29 (23 participants), November 17 (26 participants) and December 10 (24 participants).
- Olson, C., K. Sun, I. Laksminaryan, E. Yu, and D. Gebre-Egziabher presented a poster titled Improvements to Drone Technology for Effective Pest and Noxious Weed Management at the virtual Upper Midwest Invasive Species Conference November 2-6, 2020.
- Yu, E., S. Blair, M. Chandler, A. Cortilet and D. Thiede gave a presentation titled Timeline of Palmer Amaranth in Minnesota at the virtual Upper Midwest Invasive Species Conference November 2-6, 2020.

- An update was given to the Minnesota Association of County Agricultural Inspectors executive board on December 19 (16 participants).
- The following manuscript was submitted to the journal Weed Technology on January 19, 2021. Yu, E., S. Blair, M. Chandler, D. Thiede, A. Cortilet, J. Gunsolus and R. Becker. Timeline of Palmer amaranth (*Amaranthus palmeri*) in Minnesota.

Sixth Update July 31, 2021

- Monika Chandler and Emilie Justen provided a project update at MDA's Noxious Weed Advisory Committee meetings on May 5 (29 participants).
- How to identify Palmer amaranth and how to collect and preserve samples to be sent to the lab, was given to a group of crop consultants in Randolph, MN on June 17th (4 participants)
- How to identify Palmer amaranth and how to collect and preserve samples to be sent to the lab, was given to a crop consultant and their interns in Wanamingo, MN on July 27th (3 participants)
- An update was given to the Minnesota Association of County Agricultural Inspectors Short course on July 21st (35 participants)
- Our article Timeline of Palmer amaranth invasion and eradication in Minnesota documents what happened with Palmer in Minnesota. The article was published in Weed Technology and is available to all with open access. An abstract was published in April but the full article was published in July. To date, the article has been accessed via HTML by 102 and via PDF by 4,278.

Seventh Update January 31, 2022

- Updates were presented to the Noxious Weed Advisory Committee at meetings on 09/14/2022, 11/16/2022 and 12/14/2022.
- Cortilet, A. wrote an article titled "Palmer: What do I do now?" that was published in the Minnesota Department of Agricultures "Weed of the Month". (9/1/21)
- Blair, S. gave an update on Palmer amaranth to the Minnesota Association of County Agricultural Inspectors at their annual meeting via a virtual meeting. (12/08/21)
- Blair, S. gave an update on Palmer amaranth at a district 4 County Agricultural Inspectors meeting. (12/15/21).

Articles and media coverage
Chasing Palmer: Minnesota tries to stop high-cost invasive weed
https://www.mprnews.org/story/2019/07/19/chasing-palmer-amaranth-minnesota-tries-to-stop-invasive-weed-species The article was dated July 19, 2019.

Final Update August 15 2022

- Blair, S. gave an update on Palmer amaranth at a weed meeting in Todd County to train township officers/weed inspectors. (04/13/22)

Project Results Use and Dissemination

Presentations, articles, and a paper were the primary dissemination means. There were 40 presentations, trainings or updates about Palmer amaranth and this project. In trainings, we used resources developed for the ENRTF project Elimination of Target Invasive Plant Species including 3D printed models of Palmer amaranth seedlings, pressed plant samples, and large format printed displays. Two popular press articles were written and sent to outstate media. Our paper Timeline of Palmer amaranth invasion and eradication in Minnesota was open access published in Weed Technology. To date, it was accessed via HTML by 741 and via PDF by 4,580.

V. PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview: See attached spreadsheet

Explanation of Capital Expenditures Greater Than $5,000: N/A

Explanation of Use of Classified Staff: N/A

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

Enter Total Estimated Personnel Hours: 4,160	Divide by 2,080 = TOTAL FTE: 2.00

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

Enter Total Estimated Personnel Hours: 6,080 CCM: 4,000 U of M: 2,080	Divide by 2,080 = TOTAL FTE: 2.92

B. Other Funds:

SOURCE OF AND USE OF OTHER FUNDS	Amount Proposed	Amount Spent	Status and Timeframe
Other Non-State $ To Be Applied To Project During Project Period:			
	$	$	
Other State $ To Be Applied To Project During Project Period:			
In-kind Services To Be Applied To Project During Project Period: MDA: Overhead, field equipment, computing/software, GIS and data management, and project management for 2 years ($24,000); U of M: UAV Lab equipment for 2 years ($20,000); and CCM: Approximately $2.50/hr difference between actual cost per member and billing rate = $11,670.	$ 55,670	$ 55,670	Secured for length of project
Past and Current ENRTF Appropriation:			
2017 Palmer Amaranth Detection and Eradication	$ 173,000	$145,746	Emerging Issues funding through 06/30/2018
2017 Elimination of Target Invasive Plants - Phase 2 project M.L. 2016, Chp. 186, Sec. 2, Subd. 06e1 and Subd. 06e2	$ 750,000	$ 750,000	With respect to Palmer, this funding enabled us begin hiring a Palmer amaranth specialist before EI funds were available and to train people to identify and report Palmer.
Other Funding History:			

MDA Emergency Funds M.L. 2016, Chp. 17, Sec. 17.041, Subd. 1	$	$ 66,204	Spent

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Monika Chandler	Biological Control and Invasive Plant Management Coordinator	MDA	She will lead infestation monitoring, ground survey and report follow up. She will also provide overall project coordination
Demoz Gebre Egziabher	Professor	U of M	He will lead the development and utilization of aerial survey methods
Dustin Looman	Assistant Manager	CCM	He will manage crews and lead Palmer amaranth control activities

B. Partners NOT receiving ENRTF funding

Name	Affiliation	Role
Federal & state agencies	NRCS, FSA, BWSR and DNR	Identify sites to survey
Private landowners		Help manage Palmer infestations

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

Palmer amaranth eradication would have enormous positive ecological and economic implications. If Palmer amaranth becomes widespread in cropping systems, additional herbicides would be used. This could be detrimental to pollinators and water quality. Crop production costs would increase by an estimated $20-30 per acre for soybean and $15-20 for corn production. If half of Minnesota's 7.4 million acres of soybeans and 8.7 million acres of corn were infested, production costs would increase by approximately 165 million dollars annually. This burden would be borne by farmers and consumers and does not take into account the threat of non-target treatment impacts to surrounding agricultural natural areas. Additionally, Palmer amaranth is becoming problematic in prairie in Illinois and is outcompeting native vegetation. The stakes are high. There is not much Palmer amaranth in Minnesota. Now is the time to control it and keep it out of conservation plantings.

VIII. REPORTING REQUIREMENTS:

- The project is for 4 years, will begin on 07/01/2018, and end on 06/30/2022.
- Periodic project status update reports will be submitted January 31 and July 31 of each year.
- A final report and associated products will be submitted between June 30 and August 15, 2022.

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map

Aerial survey for Palmer amaranth detection

Palmer amaranth's long seedheads produce a lot of seed that enables spread.

Conservation Corps Minnesota burning Palmer amaranth in a conservation planting

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 Final Budget Spreadsheet

Project Title: Palmer Amaranth Detection and Eradication Continuation
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 06b
Project Manager: Monika Chandler
Organization: Minnesota Department of Agriculture
College/Department/Division: Plant Protection Division
M.L. 2018 ENRTF Appropriation: $431,000
Project Length and Completion Date: June 30, 2022
Date of Report: August 15, 2022

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	REVISED TOTAL BUDGET 02/10/22	TOTAL SPENT	TOTAL BALANCE
BUDGET ITEM			
Personnel (Wages and Benefits)	$149,579	$149,579	$0
MDA Personnel: One 2 year 100% time Plant Health Specialist position estimated salary $56,000 per year plus fringe benefits @ 36% for Activity 2			
Professional/Technical/Service Contracts			
Contract with Conservation Corps Minnesota for Palmer amaranth survey and management in conservation areas. Management methods include spot herbicide application, flame weeding and prescribed burning. Training and equipment (tools and personal protective equipment such as fire retardant clothing, gloves, hardhats, etc.) for crews (control and survey) and field specialists (survey) is included.	$98,000	$97,074	$926
Contract with University of Minnesota to develop and utilize aerial survey methods. Costs include a 50% time engineer $126,100 (salary $94,575 and fringe @ 25% $31,525), travel $15,800 (mileage $10,800 and meals and lodging $5,000), equipment $10,000 (airframe and sensors 2 @ $4,000 each and ground station $2,000) and other (repairs $2,000 and specialized pix4d software license $5,000)	$159,700	$159,700	$0
Equipment/Tools/Supplies			
MDA Supplies: Herbarium supplies, flagging materials, etc.	$298	$298	$0
Travel expenses in Minnesota			
MDA Travel: Mileage @ 53.50¢ for 17,000 miles ($9,000), approximately 40 days of lodging ($4,000) and 94 days of meals/yr ($3,200) per year.	$23,423	$23,423	$0

COLUMN TOTAL	**$431,000**	**$430,074**	**$926**