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

Date of Report: 10-15/2014

Date of Next Status Update Report: 1-1/2016

Date of Work Plan Approval:

Project Completion Date: 6-30/2018

Does this submission include an amendment request? _No_

PROJECT TITLE: Biological Control of Canada Thistle

Project Manager: Roger Becker

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Location: Statewide

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$300,000**
	Amount Spent:	**$0**
	Balance:	**$300,000**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 06c

Appropriation Language:
$300,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to develop a biological control for Canada thistle, an invasive plant species in Minnesota. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Biological Control of Canada Thistle

II. PROJECT STATEMENT: Canada thistle (*Cirsium arvense*) is native to Eurasia and has been introduced worldwide. It is considered as one of the worst weeds of agricultural and natural systems. In North American, Canada thistle is has been introduced into 42 states, 12 Canadian provinces and has a noxious weed status in 31 states. It is the most prevalent invasive plant in Minnesota and, with a prohibited noxious weed designation, control can be required by law. This results in considerable time and expense to control this weed on state lands. Absent biological control, currently available control options include herbicides, mowing, or tillage. These control methods can harm desirable plants and interfere with or alter wildlife management practices.

Canada thistle is a herbaceous perennial plant, with aboveground shoots dying back over the winter and underground roots surviving from year to year. Plants reproduce through seed dispersal and vegetatively via spreading underground lateral roots. Canada thistle plants are dioecious, with male and female flowers produced on separate plants. Flowers are pollinated by honeybees and other native pollinators. Seeds are attached to a plumose achene that can aid in dispersal.

In North America, the biological control agent and stem-mining weevil, *Ceutorhynchus litura*, was first introduced into Canada in 1965. It was subsequently introduced into the United States in 1972, with the first released in Montana. *C. litura* has since been established in Idaho, Montana, Nebraska, North Dakota, Oregon, Utah, Virginia, Washington and Wyoming. In 1998, *C. litura* was introduced into a limited area in Minnesota, with a resulting decline in Canada thistle populations long-term.

Ceutorhynchus litura adults overwinter in leaf litter, and begin to feed on Canada thistle leaf and stem tissue in early spring (April and May). Females oviposit in the mid-vein on the underside of leaves on rosette shoots. Larvae mine leaves, stems and crowns of Canada thistle plants throughout the spring and summer. Third instar larvae emerge from Canada thistle plants in late summer, pupate in the soil, and emerge as adults from July to October, depending on location. There is one generation per year.

There are conflicting reports about the efficacy of *C. litura* as a biocontrol agent against Canada thistle. Some have reported that *C. litura* did not control thistle stands, but could contribute to a decline in thistle populations when combined with other plant stressors, such as other insects or pathogens. It also has been reported that *C. litura* infestations did not reduce thistle stem counts, flowering or overwinter survival in Canada thistle stands on two South Dakota wildlife refuges over four years of study.

In contrast, others have found 75 to 92% of Canada thistle stems infested with *C. litura* larvae at four sites 15 years after release. Underground roots suffered higher winter mortality rates as a consequence of *C. litura* larval mining. Adults dispersed 9 km over 15 years. Significant declines in Canada thistle abundance were also documented after ten years when *C. litura* was released in combination with the gall forming fly, *Urophoa cardui*, and the seed-head weevil, *Larinus planus*. Total non-structural carbohydrates were 1.5 times lower on early season sampling in Canada thistle roots after attack by the three biocontrol insects mentioned previously, plus the leaf defoliator, *Cassida rubiginosa*. Similar reduced levels of free sugars and fructans were found in Canada thistle roots after spring larval mining. However, sugar levels recovered later in the summer. Lastly, competition from the native, cool-season, needle and thread grass (*Hesperostipa comata*) in addition to *C. litura*, has been shown to reduce Canada thistle root biomass. The combination of cool-season grass competition with *C. litura* may compliment restoration methods over each agent alone.

The host range of a weed biological agent is defined as the set of plant species attacked by the agent. In North America, *Ceutorhynchus litura* attacks Canada thistle (*Cirsium arvense*), although its host range includes the *Cirsium-Silybum-Carduus* complex of the Asteraceae subtribe Carduinae. In North America, there are no native *Carduus* or *Silybum* species, but there are at least 118 native species of *Cirsium.* Initial host range testing indicated that *C. litura* fed on the natives, *Cirsium brevistylum, Cirsium undulatum* and *Cirsium flodmanii*. Slotta

and colleagues found that the host range of Canada thistle biocontrol insects, *Larinus planus* and *Rhinocyllus conicus*, did not follow phylogenetic lines developed for *Cirsium* species derived from native *Cirsium* DNA sequences. Therefore, they recommend a more comprehensive list of *Cirsium* species should be included in host range testing of Canada thistle biological control insects.

In 1998, the stem-mining weevil, *C. litura,* was introduced into a limited area in Minnesota with a resulting decline in Canada thistle populations, generating interest in supporting a biological control effort with *C. litura*. Before we can support additional release of this biocontrol weevil in Minnesota, we need to determine whether *C. litura* will attack Minnesota's native thistles. If *C. litura* does not develop on our native thistles, a program to augment and support biological control of Canada thistle with *C. litura* can be implemented in Minnesota to provide cost-effective, long-term management of Canada thistle in Minnesota's natural areas. This project will determine the host range of *C. litura* on Minnesota's native *Cirsium* species. The first objective of our research is to determine whether *Cirsium* spp. native to Minnesota are attacked by *C. litura*. Specifically, we will investigate whether *C. litura* can feed, oviposit and complete development on native *Cirsium* spp. This project will help to define whether the host range of *C. litura* includes Minnesota's native *Cirsium* species. The second objective of this research is to determine the phenology of *C. litura* in Minnesota. This information will be invaluable for the implementation of a future Canada thistle biocontrol program.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 1, 2016:

Project Status as July 1 2016:

Project Status as of January 1, 2017:

Project Status as of July 1, 2017:

Project Status as of January 1, 2018:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Collect and develop the techniques to successfully grow Canada thistle and native thistles in phenological synchrony with each other and with *C. litura* to allow specificity testing.

Description: The University of Minnesota herbarium lists six thistles in the *Cirsium* genus as native to Minnesota (Table 1). A seventh species, *Cirsium x Iowense*, is also listed as native but it is now considered synonymous with *Cirsium altissimum* (tall thistle). We will collaborate with the Minnesota Biological Survey to locate sources for each of Minnesota's native thistles. *Cirsium* plants will need to be established the summer prior to host range testing as *C. litura* adults are active and oviposit in the spring. In spring and summer of 2015, we will collect roots or stems of perennial *Cirsium* species (Table 2). Two years prior to testing, seeds will be collected from biennial *Cirsium* species, planted and rosettes overwintered outside. Seedlings (for biennials) or plant parts (for perennials) will be planted into 3-gallon pots using a standard potting mix and greenhouse soil in a 1:1 ratio. Plants will be fertilized as necessary. Potted thistle plants will be overwintered using the pot-in-pot method to ensure winter survival. This technique is similar to that used by researchers to overwinter potted Canada thistle plants in Regina, Saskatchewan. Multiple plants of each species will be established so that replicated host-range field trials can be conducted. Scientist and technical staff at the University of Minnesota will conduct this work.

Table 1. Native Thistles (*Cirsium* spp.) of Minnesota

Scientific Name	Common Name	Life Cycle	Status
Cirsium altissimum	tall thistle	biennial	
Cirsium discolor	field thistle	biennial	
Cirsium flodmanii	Flodman's thistle	perennial	
Cirsium x lowense		perennial	(Considered synonymous with *Cirsium altissimum*)
Cirsium muticum	swamp thistle	biennial	
Cirsium pumilum var. Hillii	Hill's thistle	perennial	Species of Special Concern-MN
Cirsium undulatum	wavy-leaved thistle	perennial	Native to IA, ND, SD, WI,

Table 2. Time table for *Cirsium* species collection and host range testing. St. Paul, MN

Scientific name	Common name	Life-cycle	Seed collected	Roots/stems collected	Planted into pots	Host range testing
Cirsium altissimum	tall thistle	biennial	Fall 2014 (*pro bono*) Fall 2015		Spring 2015 (*pro bono*) Spring 2016	Spring 2016 Spring 2017
Cirsium discolor	field thistle	biennial	Fall 2014 (*pro bono*) Fall 2015		Spring 2015 (*pro bono*) Spring 2016	Spring 2016 Spring 2017
Cirsium muticum	Swamp thistle	biennial	Fall 2014 (*pro bono*) Fall 2015			Spring 2016 Spring 2017
Cirsium flodmanii	Flodman's thistle	perennial		Summer 2015	Summer 2015	Spring 2016
Cirsium pumilum var. *Hillii*	Hill's thistle	perennial		Summer 2015	Summer 2015	Spring 2016
Cirsium undulatum	wavy-leaved thistle	perennial		Summer 2015	Summer 2015	Spring 2016
Cirsium arvense	Canada thistle	perennial		Summer 2015	Summer 2015	Spring 2016

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Summary Budget Information for Activity 1:

ENRTF Budget: $ 60,000
Amount Spent: $ 0
Balance: $ 60,000

Outcome	Completion Date
1. Collect thistle plants and/or seeds. Thistle seed or vegetative propagules will need be located and collected at that appropriate time to ensure successful, replicated propagation. Propagation of Canada thistle is understood and collection sites are numerous. The native thistles are not common on the landscape and collection times will vary and will be defined to ensure consistent, replicated propagation under controlled conditions. We will work with Laura Van Riper (Terrestrial Invasive Species Coordinator), Welby Smith (State Botanist), and Dan Wovcha (Plant Ecologist) with the Minnesota Department of Natural Resources to locate potential sites for collection of native thistles. Hill's thistle poses the most potential difficulties to locate and successfully propagate to enable testing at the correct phenological synchrony to conduct valid host specificity testing. We will find suitable populations of Hill's thistle and develop techniques to do valid testing.	November 30, 2015
2. Develop techniques to successfully establish and overwinter each of the *Cirsium* species. We will document the growth and development phenology of each species. Despite public perceptions, growing native thistles and Canada thistle under controlled conditions to enable replicated, valid testing is not a simple task. For example, approx. two years of experimenting with overwintering techniques of container grown garlic mustard were required before we could repeatedly overwinter plants of the quality and phenological synchrony required for valid host specificity testing. We anticipate similar challenges with the various *Cirsium* species, and are currently beginning some techniques testing *pro bono* because we do not have two years to develop mass propagation techniques on this grant.	December 31, 2015
3. Overwinter thistle plants of each species of suitable quality in preparation for spring host range tests. We will be able to report on the success or challenges that need to be overcome by the first spring of the grant.	March 31, 2016

Activity Status as of January 1, 2016:

Activity Status as of July 1, 2016:

Activity Status as of January 1, 2017:

Final Report Summary:

ACTIVITY 2. Determine whether *Ceutorhynchus litura* attacks thistles native to Minnesota.

Overview *Ceutorhynchus litura* adults will be purchased from Biological Control of Weeds Inc., Bozeman, MT in the late summer or fall preceding the spring of host range testing. Weevils will be overwintered outside on caged Canada thistle plants. Two separate studies will be conducted with each native thistle species in replicated trials to include; sequential no-choice feeding and oviposition (egg-laying) and life-cycle completion experiments. All tests will also be conducted on Canada thistle as a control plant. Scientist and technical staff at the University of Minnesota will complete this work. The methodology of each test is described below.

Sequential no-choice feeding and oviposition tests. Tests will be conducted in the spring and early summer when *C. litura* females are laying eggs. Procedures are similar to those described by Esther Gerber at CABI, Delémont, Switzerland, for *Ceutorhynchus scrobicollis*. Prior to inclusion in oviposition tests, females will be tested to ensure that they are laying eggs. Only ovipositing females will be used in experiments. An excised Canada thistle or test plant leaf will be inserted into a hydrated piece of florist foam encased in a self-sealing plastic bag. Leaves will be a minimum of 5 cm in length as *C. litura* does not oviposit on leaves shorter than 5 cm. The leaf will be placed into a pint Mason jar and covered with nylon mesh. A mating pair of *C. litura* will be placed into the jar. After 3- to 4-days, leaves and stems will be dissected and checked for eggs. Feeding will be recorded. The test plant leaf will be replaced with a Canada thistle leaf to ensure *C. litura* females are ovipositing, and leaves will dissected after allowing 3- to 4-days for oviposition. A minimum of 10 replications will be completed.

Life-cycle completion tests. Prior to inclusion in these trials, females will be tested to ensure that they are laying eggs. Only ovipositing females will be used. In late March to early April, 5 marked female and 5 male *C. litura* will be placed on each potted thistle plant placed in a screen cage. After a period of two to three weeks, adults will be removed. In late summer, plants will be checked for F-1 adults. Number of adults collected from each plant will be recorded. All plants will then be dissected after adult emergence and checked for larval mining and tunneling. All plants will be grown outside and covered with nylon mesh bags to contain the *C. litura* during testing. Canada thistle plants will be used as a control plant species.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 120,000
Amount Spent: $ 0
Balance: $ 120,000

Outcome	Completion Date
1. Conduct host range studies. *Ceutorhynchus litura* adults will be purchased from Biological Control of Weeds Inc., Bozeman, MT and successfully overwintered outside on caged Canada thistle plants. Two separate studies will have been conducted with each thistle species in replicated trials including sequential no-choice feeding and oviposition (egg-laying) and life-cycle completion experiments. Results of all tests on Canada thistle as a control plant will also have been conducted. Scientist and technical staff at the University of Minnesota will complete this work. The methodology of each test is described above.	June 30, 2018

Activity Status as of January 1, 2016:

Activity Status as of July 1, 2016:

Activity Status as of January 1, 2017:

Project Status as of July 1, 2017:

Project Status as of January 1, 2018:

Final Report Summary:

ACTIVITY 3. Determine Phenology of *Ceutorhynchus litura* in Minnesota.

The phenology of *C. litura* will be followed for the three years of the study at the USFWS release sites at Lake Agassiz National Wildlife Refuge in northwestern Minnesota and at a caged site on the University of Minnesota, St. Paul campus. Canada thistle plants will be dissected at regular intervals during each growing season to determine the weevil's life cycle. At each site we will determine when weevils become active in the spring, when females lay eggs and when a new generation of adults emerge in late summer. If our testing shows a host range limited to Canada thistle, this information will be critical to implementing a Canada thistle biological control program in Minnesota. Scientist and technical staff at the University of Minnesota will complete this work.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 120,000
Amount Spent: $ 0
Balance: $ 120,000

Outcome	Completion Date
1. Complete phenology study- year 1, Lake Agassiz and St. Paul, MN. Data on the synchrony of Canada thistle and *C. litura* will have been collected.	December 31,2016
2. Complete phenology study-year 2, Lake Agassiz and St. Paul, MN. Second year of data collection on the synchrony of Canada thistle and *C. litura* will have been collected.	December 31, 2017
3. Complete phenology study-year effort, Lake Agassiz and St. Paul, MN. Complete data collection on the synchrony of Canada thistle and *C. litura.* Data analyzed, interpreted and reported in context of building a successful biological control program for Minnesota.	June 30, 2018

V. DISSEMINATION:

Description: The results of these studies will be presented at professional meetings, in University of Extension education efforts, and published in the appropriate scientific journal(s).

Project Status as of January 1, 2016:

Project Status as July 1 2016:

Project Status as of January 1, 2017:

Project Status as of July 1, 2017:

Project Status as of January 1, 2018:

Overall Project Outcomes and Results:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 291,717	Civil Service -part of 1 Project Senior Scientist ($123,000), 2 Project Technicians ($60,650), and 2 Junior Scientist $46,000/$49,400) collectively approx.0.9 FTE @ est. 36.8% fringe over 3 years. Student Labor approx. 0.38 FTE @ est., 7.57% fringe over 3 years (Full time summer, 1/4 time during school session - $12,167).
Professional/Technical/Service Contracts:	$3,600	Watering charges and other service charges for greenhouse and field space. Fees set by the University and amount listed based on past fee structures.
Equipment/Tools/Supplies:	$2,083	Temperature probes, field supplies: flags, netting, stakes, pots, potting medium, cages, insect purchases, etc.
Travel Expenses in MN:	$2,600	Travel within Minnesota to collect thistles and *C. litura*, to monitor phenology (development, staging, life-cycles) of the various thistles and *C. litura*, and travel to meet cooperators, sponsors, to present results within Minnesota. Estimate 75% mileage, 15% meals and 10% lodging.
TOTAL ENRTF BUDGET:	**$300,000**	

Explanation of Use of Classified Staff: N/A

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

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: a total of 3.84 FTEs over the 3 years of funding (approx. 0.9 Civil Service and 0.38 student labor FTEs per year for 3 years). 97.2% of this grant supports Minnesota jobs, 2.8% is spent on supplies and travel to conduct the research.

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

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
PI is not receiving any salary funding, 5% of PI's time = $22,455 salary and fringe.	$22,455	$	The time I spend on this effort is paid for from USDA CSREES funds
State			
University indirect costs $156,000.	$156,000	$	Indirect costs are used for U of M facilities expenses.
TOTAL OTHER FUNDS:	**$178,000**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners:

Project Partners Receiving Funds:

- Dr. Roger Becker, PI, Professor, Department of Agronomy and Plant Genetics, University of Minnesota.
- Dr. Elizabeth Katovich, Senior Scientist, Department of Agronomy and Plant Genetics, University of Minnesota.

Roger Becker and Elizabeth Katovich will lead the studies. Both cooperators have worked on previous and current LCCMR sponsored studies for purple loosestrife and garlic mustard biological control.

Project Partners Not Receiving Funds:

- Dr. Laura Van Riper, Terrestrial Species Coordinator, Minnesota Department of Natural Resources, will advise and assist where appropriate in working with the *C. litura* and will facilitate in identifying resources, expertise and MnDNR sites for thistle collections and *C. litura* work.
- Welby Smith, Minnesota Biological Survey, and Dan Wovcha. Minnesota Department of Natural Resources will provide native thistle locations and appropriate collection permits.
- Monika Chandler, Minnesota Department of Agriculture. Will advise and assist where appropriate in working with the *C. litura* and will facilitate procuring, releasing and recovering the weevils.

B. Project Impact and Long-term Strategy: Canada thistle is a common invasive plant in Minnesota impeding management goals in several ecosystems. Utilizing biological control on large infestations would prevent the need to apply herbicide, mow or till these sites reducing negative impacts by improving native forb diversity in prairies, and in general, forb diversity in several ecosystems increasing pollinator nectar and pollen source diversity and abundance.

This proposal is the first step in a long-term implementation strategy for biological control of Canada thistle in Minnesota. Before we can proceed, it is necessary to determine whether *C. litura* attacks native thistles. If the weevil only attacks Canada thistle, we will submit a future proposal to LCCMR for funding towards implementing a long-term Canada thistle biological control program. Activity 3 in this proposal is beginning that process through improved understanding of the phenology of *C. litura* in Minnesota to facilitate rearing and release should we proceed with this biological control effort.

C. Funding History: Have current LCCMR funding via MnDNR for garlic mustard biological control. Biological Control of Garlic Mustard $140,000 ending June 30 2016 and Monitoring Biological Control of Garlic Mustard

$52,214 award ended June 30 2014. These efforts inform and build expertise and capacity to conduct the Canada thistle work, but these funds can not be used directly for the Canada thistle work.

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS: N/A

IX. VISUAL COMPONENT or MAP(S): Please see attached visual.

X. RESEARCH ADDENDUM: Environment and Natural Resources Trust Fund: Please see attached research addendum.

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 1, 2016; July 1, 2016; January 1, 2017, July 1, 2017. A final report and associated products will be submitted between June 30 and August 15, 2018.

Environment and Natural Resources Trust Fund
M.L. 2015 Project Budget
Project Title: Biological Control of Canada Thistle
Legal Citation: *Fill in your project's legal citation from the appropriation language - this will occur after the 2015 legislative session.*
Project Manager: Roger Becker
Organization: University of Minnesota
M.L. 2015 ENRTF Appropriation: **$** 300,000
Project Length and Completion Date: 3 years, June 30 2018
Date of Report: Oct. 31, 2014

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	**Collect and grow thistle plants**			**Determine whether Ceutorhynchus litura attacks thistles native to MN**			**Determine weevil life-cycle and phenology in Minnesota**				
Personnel (Wages and Benefits) Overall	**$58,343**	**$0**	**$58,343**	**$116,687**	**$0**	**$116,687**	**$116,687**	**$0**	**$116,687**	**$291,717**	**$291,717**
Civil Service Senior Scientist, .0.4 FTE @ est. 36.8% fringe over 3 years. (Estimated at. $123,000)											
Civil Service Junior Scientist collectively approx.0.2 FTE @ est. 36.8% fringe over 3 years. (Estimated at. $46,000)											
Two Civil Service Technician approx.0.1 FTE each @ est. 36.8% fringe over 3 years. 0.2 FTE per year total. (Estimated at. $60,650)											
Civil Service Junior Scientist, .0.2 FTE @ est. 36.8% fringe over 3 years. (Estimated at. $49,400)											
Student Labor approx. 0.38 FTE @ est., 7.57% fringe over 3 years (Full time summer, 1/4 time during school session). (Estimated $12,167)											
Professional/Technical/Service Contracts											
Watering charges and other service charges for greenhouse and field space. Fees set by the University and amount listed based on past fee structures.	**$720**	**$0**	**$720**	**$1,440**	**$0**	**$1,440**	**$1,440**	**$0**	**$1,440**	**$3,600**	**$3,600**
Equipment/Tools/Supplies											
Temperature probes, field supplies: flags, netting, stakes, pots, potting medium, cages, insect purchases, etc.	**$417**	**$0**	**$417**	**$833**	**$0**	**$833**	**$833**	**$0**	**$833**	**$2,083**	**$2,083**
Travel expenses in Minnesota											
Travel within Minnesota to collect thistles and *C. litura* , to monitor phenology (development, staging, life-cycles) of the various thistles and *C. litura* , and travel to meet cooperators, sponsors, to present results within Minnesota. Estimate 75% mileage, 15% meals and 10% lodging.	**$520**	**$0**	**$520**	**$1,040**	**$0**	**$1,040**	**$1,040**	**$0**	**$1,040**	**$2,600**	**$2,600**
COLUMN TOTAL	**$60,000**	**$0**	**$60,000**	**$120,000**	**$0**	**$120,000**	**$120,000**	**$0**	**$120,000**	**$300,000**	**$300,000**

Biological Control of Canada Thistle

Photos R. Becker

Canada thistle is:

- the most common weed in natural areas, road-sides and rights-of-ways
- a Mn prohibited noxious weed
- control can be required by state law

Stem-mining weevil, *Ceutorhynchus litura* for biological control of Canada thistle

Laura Parsons

Adult *C. litura*

C. Litura larvae

Norman E. Rees

Biological control can:

- reduce herbicide use in natural areas
- increase diversity of native plants and pollinator food sources
- help protect water quality

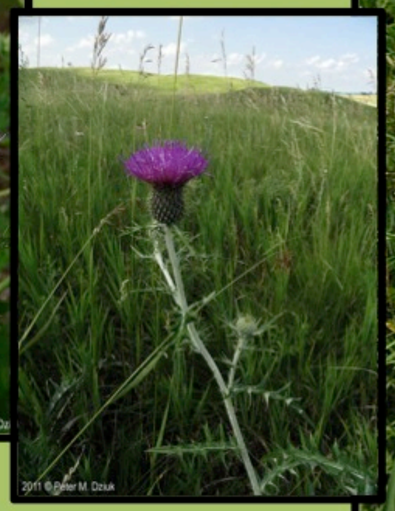
Seven thistles are native to Minnesota

Not common. Important for:

- Diversity
- Pollinators
- Preservation

Swamp thistle

Tall thistle



Flodman's thistle

Hill's thistle
(species of concern)

Field thistle

Wavyleaf thistle

Hybrid *C. altissimum* × *discolor* not shown

Photos Peter Dziuk and K. Chayka, Minnesota Wildflowers except wavyleaf thistle, Joseph M. DiTomaso