WIPM Center

A. Grant Data

- Grant Agreement #: K009607-MT4
- Title: Research and Extension on Integrated Biological and Cultural Management of Canada thistle
- Type: Addressing Critical Issues in IPM
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B. Nontechnical Summary. Canada thistle (*Cirsium arvense*) is an aggressive, creeping perennial weed that infests crops, pastures, rangelands, roadsides, and non-crop areas throughout the northern and western United States. In Montana, Canada thistle is a category one noxious weed that infests approximately 1.5 million acres. Several stakeholders, including organic growers and alfalfa seed growers have expressed their concern about the lack of viable management options for Canada thistle. The main goal of this project was to evaluate if the joint usage of pathogens, insects, and herbicides can provide efficient, economically durable, and environmentally benign management of Canada thistle. We concluded that there is an additive relationship between management practices suggesting that an integrated weed management approach yields greater Canada thistle control than singular practices.

C. Introduction. *Species description and impact*. Canada thistle (*Cirsium arvense*) is a highly competitive perennial species prevalent all over the state of Montana, infesting more than 1.5 million acres with the potential for much more (MT Dept. of Natural Resources and Conservation 2004). This category 1 noxious weed is particularly hard to control because of its deep, creeping, and reproductive root system, its colony-forming tendencies, and its high seed production potential (Holm et al. 1977). This weed threatens productivity in both crop and non croplands. In cropland, Canada thistle causes extensive yield losses through competition for light, nutrients, and moisture. It also increases harvesting problems due to seed and forage contamination. Heavy infestations are also commonly found in overgrazed pastures and ranges and may crowd out and replace native grasses and forbs, decreasing species diversity in an area. It has been found to facilitate the establishment of other exotic species, changing the composition and functioning of the belowground community (Pritekel et al. 2006).

Canada thistle management. The principle in Canada thistle management is to stress the plant to force it to use its stored root nutrients, weakening its regenerative capacity. This can be achieved through a sound management plan that integrates different control practices such as biological control agents and herbicides. Empirical studies and computer simulation models suggest that although each individual practice could have low efficacy, when combined in an integrated approach, synergistic interactions may effectively decrease weed populations (Liebman and Gallandt, 1997; Westerman et al. 2005).

Biological Control. Pseudomonas syringae (PST) is a bacterial pathogen with known efficiency as a biological control agent of Canada thistle (Johnson et al., 1996; Gronwald et al., 2002). Specific symptoms include reduced growth, apical chlorosis, stunting, and necrosis (Gulya 1992; Gronwald et al., 2004). The stem-boring weevil *Hadroplontus litura* attacks Canada thistle in early spring, before the plants have thoroughly established (Zwölfer and Harris 1966). Females lay eggs in the leaf midvein. The larvae tunnel down into the root crown, feeding on callus tissue and creating tunnels. These tunnels can coalesce into a woody gall which, when combined with the additional stress of producing callus tissue, can kill the plant. In Canada, *H. litura* had one of the best establishment rates out of 12 biocontrol agents released (Harris 1979).

Despite the potential benefits of designing integrated weed control programs that take advantage of synergistic interactions, little is known on how biological control agents and herbicides should be integrated to manage Canada thistle. In this study we evaluated the individual and joint weed control value of two biological control agents (PST and the stem-boring weevil, *H. litura)* and three different herbicides (2,4-D, Clopyralid, Glyphosate) on Canada thistle emergence and growth. Our hypothesis was that synergistic interactions between biological control agents and herbicide would result in greater Canada thistle control than simply adding each agent's individual effects. ssss

D. Objectives. Restate your project objectives. After each objective, provide a brief (1-3 sentence) narrative about whether you've achieved it; if it was modified, mention how.

1. Assess the individual and combined effect of stand density and two biological control agents (*Pseudomonas syringae pv. tagetis* and the stem gall fly, *Urophora cardui*) on the growth and reproductive output of Canada thistle.

   We have achieved this objective. However, instead of stand density, we used herbicide, and instead of using the stem gall fly, we used the stem-boring weevil *Hadroplontus litura*. We monitored Canada thistle emergence and growth, not reproductive output.

2. Evaluate if infestation of Canada thistle plants by *P. syringae* and the use of herbicides modifies the behavior and performance of the stem gall fly.

   We have achieved this objective by documenting all interactions between the two biocontrols and herbicide. As sated above, instead of the stem gall fly, we used the stem-boring weevil.

3. Develop and deliver extension material on the integrated management on Canada thistle.

   We have achieved this objective through numerous extension presentations throughout Montana as well as agricultural station field days detailing our experimental methods and results. We have been able to provide management recommendations for Canada thistle and have published some of that in a USDA Technical Bulletin.

E. Approach. The realization that individual control practices are not always effective at controlling Canada thistle infestations has spurred research into the integration of mechanical, cultural, biological, and chemical practices as an approach to manage this weed (Travnicek et al. 2005, Graglia et al. 2006, Collier et al. 2007). A method of conceptualizing this integration, introduced by Liebman and Gallandt (1997), is the idea of utilizing “many little hammers” to develop an ecologically-based weed reduction strategy. In this scenario, each little hammer refers to a weed control technique that may not be successful on its own, but may have a deleterious effect on the target organism. The interactions between practices can be synergistic, additive, complementary, or antagonistic (Kluth et al. 2003, Abdollahi and Ghadiri 2004, Collier et al. 2007), so it is crucial to carefully document each effect singularly and in factorial combination with the other proposed tactics. The goal of our greenhouse and field experiments was to combine two rates of glyphosate with *Hadroplontus litura* weevils and a pathogen, PST, in greenhouse and field settings to evaluate the existence of additive or synergistic interactions among these three factors in reducing the growth of Canada thistle. We hypothesized that, first, while each treatment would have a negative effect on Canada thistle growth, the integrated strategies would have higher impact than individual control methods. Second, a PST application following weevil infestation would be more effective than one prior to it, as the damage caused by the insects would provide new vectors of infection for the bacteria, increasing damage to the plants.

Two studies, one in the greenhouse and one in the field, were performed to evaluate our hypotheses. In the greenhouse, Canada thistle roots were planted in columns 43 cm tall and 15 cm in diameter. The experimental design was a randomized complete block design with glyphosate rate (none, one-sixth of the labeled rate – 0.63 kg ae/ha, or a full labeled rate – 3.78 kg ae/ha), insects (absent or present), and timing of PST application (none, early – before insect release, or late – after insect release) as the main factors. A total of three different trials were run. PST and insect applications were made 3-5 weeks after plant emergence. Glyphosate was sprayed on after Canada thistle flowering to facilitate translocation (Wilson and Michiels 2003). Plants were harvested, dried, and weighed approximately 90 days after herbicide application. The field experiment followed a randomized complete block design with four 30 x 10 m replicates and a total of 252 roots per replicate. Twenty plants from each replicate were randomly selected and assigned to either control, reduced rate of glyphosate (1/6 the labeled rate, 0.63 kg ae/ha), recommended rate of glyphosate (3.78 kg ae/ha), or the combination of pathogen (PST) and reduced rate of glyphosate. *H. litura* was not available at the time of treatment and was not included in the study. Near the end of the growing season, Canada thistle shoots were harvested, dried, and weighed. Emergence was noted for each treatment the following spring.

F. Progress. Describe, *in 1-2 paragraphs,* the progress made on your project during the past year on each objective.

We completed objectives one and two by performing one greenhouse and one field experiment to document the interactions between control agents and their effect on Canada thistle emergence, growth, and survivorship into the next growing season. As this was the last set of experiment to be performed, all the data was analyzed and written into a thesis format. Materials and data from this thesis and its corresponding research are in the process of being submitted for peer-reviewed publication. hitherto, we publised the following peer-reviewed article.

Collier, T., S. Enloe, J. Sciegienka, and F. Menalled. 2007. Combined impacts of *Ceutorhynchus litura* and herbicide treatments for Canada thistle suppression. Biol. Control. 43:231-236

We also made the following repsentations in profesional meetings:

Sciegienka, J. and F. Menalled. 2008. Reproduction and Integrated Management of Canada Thistle (*Cirsium arvense* (L.) Scop.). Fifth International Weed Science Society Congress, Vancouver, British Columbia, Canada. 23 – 27 June, 2008. Ecological Society of America Annual Meeting. Milwaukee, Wisconsin

Enloe S, Collier, T, Sciegienka, J and F. Menalled. 2007. Integrating the Stem Mining Weevil (*Hadroplontus litura)* with Herbicides for Canada Thistle Control: How useful is it? Western Society of Weed Science Annual Meeting. Portland, Oregon.

Sciegienka, JK, F. Menalled, Miller PR, Zidack NK, and Blodgett SL. 2007. Canada thistle growth and physiological response to a pathogen, insect, and herbicide. Western Society of Weed Science Annual Meeting. Portland, Oregon. 2nd prize in the graduate student contest. Category: weeds of agronomic crops.

For objective three, extension talks have been given all over the state of Montana with the goal of educating managers and laypeople in integrated weed management, using Canada thistle as an example. In addition, agricultural station field days have been held. These activities provide tours of experimental plots, details of experimental methods, and summaries of results that directly contribute to management recommendations. Finaly we published two technical bulletins

Jacobs, J., J. Sciegienka, and F. Menalled. 2007. Ecology and management of Canada thistle [*Cirsium arvense* (L.) Scop.] NRCS Technical Bulletin.

Smith, R. and F. Menalled. 2006. Integrated strategies for managing agricultural weeds: making cropping systems less susceptible to weed colonization and establishment. MT200601 issued 6/06.

G. Results. In accordance with Collier et al (2007), we detected additive but not synergistic interactions among management tactics aimed at controlling Canada thistle, contradicting our first hypothesis. We also found one antagonistic interaction between glyphosate and PST. It is possible that glyphosate could have reduced PST's efficacy by killing shoot tissue or that PST could have interfered with glyphosate's activity by perhaps metabolizing or degrading some of the herbicide's active ingredient (Boyette et al. 2008). Overall, glyphosate, PST, and insects each exhibited deleterious effects on Canada thistle. This effect increased with combinations of control agents. Contrary to our hypothesis, early and late PST applications had the same effect on shoot biomass and shoot number, and an early application of PST was more deleterious to Canada thistle root weight than a late application. The impact of the relative time of pathogen application on Canada thistle root could be due to the fact that PST is only active on newly forming tissue in the plant (Mathews and Durbin 1990, Steinberg et al. 1990, Johnson et al. 1996). Since the early application was sprayed on young, developing shoots, the debilitating effects of the infection could have been more pronounced. Root reserves would be forced to replenish shoot tissue in order to keep photosynthesis going. It is possible that by the time of the late application, the plants were large enough to overcome PST's negative effects.

Each treatment applied to fallow field-grown Canada thistle plants excelled at suppressing emergence the following spring. This suggests that when caught early in its lifetime and treated appropriately, Canada thistle can be successfully managed. It also indicates that even one sixth of the recommended labeled rate of glyphosate can do equally well in suppressing Canada thistle, whether it is paired with PST or not. However, only one year of this experiment was done, and caution should be taken with the conclusions made for this experiment. In addition, at the end of the first growing season, no difference was evident in shoot weight between treatments.

This study set a precedent of the importance of testing the existence of interactions between several control practices. Although previous studies have evaluated the combined used of two singular control methods for Canada thistle control, (Kluth et al. 2003, Travnicek et al. 2005, Ferrero-Serrano et al. 2008) the literature is lacking in detailing interactions between insects and herbicides and interactions between more than two control practices, especially an insect, herbicide, and pathogen. Although these results did not display synergism, there is a possibility that synergistic interactions could still develop in field conditions due to the added abiotic and biotic stressors that plants face (Bostock et al. 2001, Martone and Wasson 2008). Conversely, it is also important to determine whether interactions are antagonistic in field conditions to prevent unsuccessful management. This work adds to the growing body of research that emphasizes the use of integrated management over individual tactics (Swanton and Weise 1991, Elmore 1996, Buhler 2002). Our results show that integrated methods work equal to or more effectively than the best individual management practices.

H. Impacts.

Innovations: We tested a novel combination of agents to see how they would perform in an integrated weed management plan. Combinations of these agents could be used anywhere there is an infestation of Canada thistle, whether in agriculture, range, or smaller settings such as gardens.

Safeguarding human health and the environment: Our results show that a reduced rate of glyphosate had the same effect as a full rate on Canada thistle in a fallow field and had similar effects as a full rate in the greenhouse. This could encourage managers to decrease the use of herbicide and use it as part of an integrated weed management strategy that combines tactics for higher control efficacy. The insects and pathogen that were used actually decrease the impacts on human health from traditional chemical methods.

*Economic benefits:*While an economic assessment was not conducted on the management strategies used in our experiments, it is our belief that reducing herbicide rates and combining them with biological controls could prove to be more economical in the long run. The insects we used are cold-hardy and do not need reapplication each year. While PST is not currently available to the general public, we hope that this research has highlighted its use in an integrated weed management strategy and encourages mass production of this useful biological control.

Implementation of IPM: Through extension publications such as our USDA Technical Bulletin and extension presentations throughout Montana, we believe we have been able to reach a wide audience, with potential for even more exposure.

I. Appendices. If applicable, please attach to your report any of the following that will enhance our understanding of your project and its impacts:

- Photographs
- Any presentations, such as in PowerPoint, resulting from this project
- Printed fact sheets or other publications resulting from your work.

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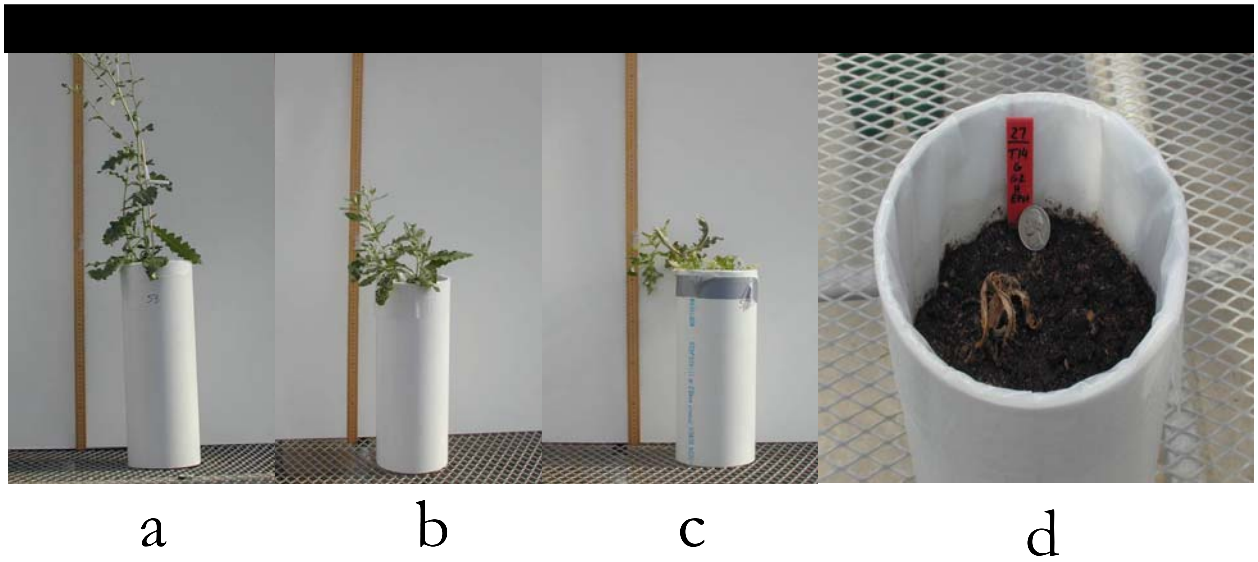

Growth of Canada thistle under the following management scenarios:

a) no control practice
b) *Pseudomonas syringae* (PST), a bacterial pathogen with known efficiency as a biological control agent of Canada thistle
c) The stem-boring weevil *Hadroplontus litura*
d) PST, stem-boring weevil, and reduced rate of glyphosate (1.2 L/ha)