Western Region IPM Grants Program
Final Project Report

A. Grant Data

Title: Mechanisms and Impacts of Integrated Pest Management for Sustainable Dalmatian Toadflax Control in the Western US (WYO-00576 2005-34103-16009)

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- States involved: Colorado, Wyoming
- First year funded and number of years funded: 2005, funded for two years with a one year extension to 2008
- Total funding amount: $95,000

B. Nontechnical Summary.

Dalmatian toadflax is a highly invasive weed that threatens rangelands throughout the Western U.S.; this exotic forb is classified as a noxious weed in almost every western state and impacts both private and government land managers. Dalmatian toadflax is very difficult to control. Cultural control is largely ineffective and impractical on many invaded rangelands. Chemical control has shown promise, though herbicides can have detrimental effects on non-target plants. Biological control of Dalmatian toadflax with the weevil, *Mecinus janthinus*, has also shown promise but suppression is slow or insufficient under some conditions. Very little is known about IPM (integrated pest management) of Dalmatian toadflax, though this approach is clearly warranted. We sought to evaluate IPM strategies for Dalmatian toadflax control using commercial or reduced-rate applications of the herbicides currently used for toadflax control (imazapic or picloram) and releases of the Dalmatian toadflax stem mining weevil (*Mecinus janthinus*). The overall objective of our approach is to minimize risk to non-target species, while achieving long-term and economical Dalmatian toadflax management.

C. Introduction.

Dalmatian toadflax, (*Linaria dalmatica* L. Mill.), is an invasive perennial forb that is currently designated as a noxious weed in almost every Western state. Dalmatian toadflax impacts many different stakeholders including USDA Forest Service, Bureau of Land Management, National Park Service, State Natural Resource Management Agencies, County Weed and Pest Districts, ranchers and conservation groups. Dalmatian toadflax invasion is of serious concern for several reasons. Established plants are highly competitive and may displace desirable vegetation. Additionally, infestations may reduce rangeland productivity since toadflax is typically avoided by domestic grazers. Finally, while many other rangeland weeds are easily controlled, Dalmatian toadflax is one of the most difficult weeds to control in the Western United States. Existing control strategies show variable efficacy at best and very little is known regarding IPM strategies for management of this species. Physical control methods such as prescribed fire, mowing, and grazing are all ineffective. Cultural control methods involving seeding nonnative forage grasses have been effective in suppressing Dalmatian toadflax. However, consistent establishment of seeded forage grasses on semiarid rangeland is limited and the economics of reseeding are often difficult to justify. Chemical control with picloram has shown promise, although efficacy has been variable and high application rates are needed. Additionally, picloram may also negatively impact non-target broadleaf vegetation and is a restricted use herbicide. Imazapic has also shown promise for controlling Dalmatian toadflax and has previously been used for leafy spurge control and prairie restoration. However, while not a restricted use herbicide, imazapic impacts on non-target vegetation still need clarification. Biological control of Dalmatian toadflax has had limited success as only the European stem-mining weevil (*Mecinus janthinus G*ermar) has both successfully established at many sites and significantly negatively impacted toadflax at some sites. However, control is still variable.

There have been relatively few studies that have examined the interactions between biological control agents and herbicides. Two key issues are at stake: one, the impact of the herbicide treatment on survival and fecundity of the agent and two, the combined impacts of biocontrol and herbicides on the target plant. In general, previous research has found that as long as an herbicide application does not kill the host plant prior to the completion of the agent's life cycle, there appears to be little negative effect of herbicides on biological control agents. Clearly, there is the potential to integrate biological and chemical controls of weeds, but the development of an optimal integrated strategy requires that we understand the impact of management strategies on biocontrol agent performance as well as the combined impact of these stressors on weed performance. Dalmatian toadflax is an excellent candidate for this type of study. Management using individual strategies produces variable and/or insufficient control, and herbicidal control at effective rates may have negative impacts on non-target plants. However, there are no published studies on IPM of Dalmatian toadflax using herbicides and biocontrol.

We propose an IPM strategy that combines reduced-rate applications the two most effective herbicides available for Dalmatian toadflax control (imazapic or picloram) and biological control releases of *Mecinus janthinus*. The strategy seeks to minimize risks to non-target plant species while achieving effective suppression of Dalmatian toadflax on rangeland. The overall approach of the proposed research is to gain both applied management information and mechanistic understanding of the impact of potential new IPM strategies for Dalmatian toadflax. The proposed project attempts to reduce risk to non-target organisms from pesticides through the development of an IPM strategy that combines biological control and reduced herbicide rates. The project thus promotes environmental stewardship by controlling a highly invasive plant in a manner that promotes biological diversity and productivity.

D. Objectives.

The overall objective of the proposed research is to develop sustainable, economically feasible, integrated strategies for Dalmatian toadflax management using the biological control agent *M. janthinus* and herbicide treatment. The specific aims include the following:

Objective 1: <u>Evaluate the effectiveness of an IPM strategy using biological control and reduced-rate herbicide applications on Dalmatian toadflax</u>. This objective has been achieved with two years of field data following release of the biocontrol agents and herbicide application.

Objective 2: <u>Evaluate the effect of the IPM strategy on diversity and rangeland productivity of the non-target plant community</u>. This objective has also been met with by using three diverse field locations and collecting data for two years following treatment.

Objective 3: Evaluate the *mechanisms* of IPM by investigating above- and below-ground responses of Dalmatian toadflax to IPM. This objective has been modified due to several unforeseen greenhouse problems. Dalmatian toadflax did not respond well to the greenhouse environment and plants were spindly and flowered abnormally. This would have resulted in questionable data if we continued in the greenhouse. Subsequently, we moved the rhizotron/minirhizotron studies outdoors and the plants responded very positively. However, we were unable to interact the biocontrol agent with herbicides due to the early problems. Therefore, our objective shifted to determining the individual impacts of *Mecinus* and herbicide treatment on Dalmatian toadflax root growth.

E. Approach.

In the spring of 2006, we established three study sites for the project. The sites are located near Cheyenne, Wyoming, Centennial, Wyoming, and Lyons, Colorado. The three sites differ greatly in their attributes including elevation, precipitation, and plant community composition. The experimental design is a complete factorial in a randomized complete block design with two biocontrol treatments (with or without *M. janthinus*) and five herbicide treatments: control (none), reduced-rate imazapic, commercial-rate imazapic, reduced-rate picloram and commercial-rate picloram. We used six replicate plots per treatment for a total of 60 plots per site. During the late spring of 2006, we collected baseline data on plant community composition and cover, forage productivity and Dalmatian toadflax density and cover from each plot (60 plots per site). In late May and June of 2006, we released the biological control agent *Mecinus janthinus* (30 insects per plot) into each plot receiving that treatment. We were successful in keeping the insects out of the untreated plots by applying the systemic insecticide imidaclopyrid. In October 2006, we applied the herbicide treatments picloram and imazapic at commercial and reduced rates to the newly emerged prostrate toadflax stems. During the spring and summer of 2007 and 2008, we collected data on *Mecinus* establishment, toadflax density, biomass and reproduction, and plant species richness, cover and herbaceous above ground net primary production.

In two separate studies, rhizotron and minirhizotrons were used to assess the impact of *Mecinus* and herbicides on Dalmatian toadflax root growth. Dalmatian toadflax was established in clear acrylic rhizotrons (dimensions: 30 by 15 by 122 cm). Twenty *Mecinus* adults were placed inside each treated rhizotron for two weeks in June 2005 and then removed. Root images were collected over the growing season (June-October) with a portable digital scanner placed on the side of each rhizotron at monthly intervals. Images were then analyzed using specialized software for root length and surface area. For herbicide impacts, Dalmatian toadflax was established in minirhizotrons (30 cm diameter by 60 cm height with one 5 cm diameter clear acrylic tube at a 45 degree angle in each). Plants were grown outdoors for the growing season and treated with the herbicides picloram or imazapic in early November 2007. A minirhizotron camera was used to capture digital images of roots both pre and post herbicide treatment and data were quantified in a similar fashion to the rhizotrons. All data were statistically analyzed with appropriate methods to test the specific hypotheses generated for each objective.

F. Results.

In general, the herbicides and biocontrol agent did not provide consistent impacts on Dalmatian toadflax across study sites and reduced herbicide rates coupled with *Mecinus* did not provide comparable control to commercial rates of either herbicide alone. However, there were very clear impacts that are of value. At the Centennial, WY site, *Mecinus* reduced Dalmatian toadflax cover by more than 50% over all treatment combinations. This effect was much greater for full rate herbicide treated plots than for those not treated with herbicides. Interestingly, there was no reduction in toadflax biomass at this site as a result of any of the treatment combinations. At the Cheyenne site 18 months after treatment, the reduced and commercial rates of picloram significantly reduced Dalmatian toadflax cover by 73% and 94%, respectively. However, imazapic did not significantly alter toadflax cover at this site at either rate. At the Centennial WY site, full rates of picloram or imazapic significantly reduced toadflax cover, but only when the biological control agent was also present, indicating that the presence of the biocontrol may be beneficial to improved herbicide efficacy in some cases. The combination of these herbicides and biological control reduced toadflax cover by more than 80%, but did not affect toadflax biomass. Unexpectedly, at the Lyons, CO site, Dalmatian toadflax cover significantly increased to 2.5 times that of untreated controls in plots treated with the commercial rate of picloram. Both rates of picloram resulted in toadflax biomass values that were 2 times that of the untreated controls. Lower rates of the herbicides also increased toadflax cover at this site, but were not significantly different from the untreated control plots. Imazapic had no effect on toadflax biomass at this site.

Other beneficial data indicated that there were no direct effects of either reduced or commercial herbicide rates on *Mecinus* survival the year of the application or the following year. However, *Mecinus* population size was correlated with the amount of toadflax present in a plot, and treatments that reduced toadflax cover also reduced *Mecinus* by a similar amount. While it is positive that the treatments did not directly negatively impact *Mecinus*, the reduction in density the following year did not allow for a buildup in the *Mecinus* population.

In terms of non-target vegetation impacts, as expected we found that picloram significantly reduced the cover of perennial forbs, subshrubs and shrubs and increased grass cover. Imazapic increased grass cover with less impact on perennial forb cover, subshrubs and shrubs than picloram. Interestingly, none of the herbicide treatments reduced forb biomass at Centennial and Cheyenne. At Lyons, forb biomass for both rates of picloram was the same as the untreated control. Forb biomass in plots treated with either rate of imazapic was twice that of the untreated controls at this site. Across all three sites, all herbicide treatments increased perennial cool season grass biomass slightly over the untreated controls, but there were no differences among herbicides or rates.

Mechanistically, the rhizotron study indicated that *Mecinus* had none to minor, short term negative impacts on total root length and root area over two years. Subsequently the minirhizotron study indicated strong allocation to root growth in the late fall. However, following treatment, root growth was not negatively impacted by either herbicide.

At one of the sites we found evidence that combined biological control and herbicide applications provide better Dalmatian toadlfax control (in terms of reduced cover) than either provide alone. However, this was only true for the commercial rate of the herbicide. These results do not provide enough support to recommend reduced rate applications in combination with biological control as an effective control approach. The site where *Mecinus* had its greatest effect was also the site where populations built up to highest levels the year following release. It is possible that as *Mecinus* populations continue to increase at these sites biological control impacts will increase as well. The variation between sites in herbicide effects could be due to differences in the vegetation community at each site. At the Cheyenne site (where the herbicides had their greatest effect), less than 1/10 of 1% of the vegetation cover is composed of non-toadflax forbs, subshrubs, or shrubs. At the Centennial site 7% of the vegetation cover is in these classes and at Lyons 11%. Because these vegetation classes are more susceptible to picloram than grasses (which dominate all of these sites), it may be that as forb-subshrub-shrub vegetation increases at a site, picloram will have a greater indirect and positive effect on toadflax (by reducing the densities of competing species) than it will have directly on toadflax performance.

G. Impacts.

We sought to evaluate IPM strategies for Dalmatian toadflax control using recommended- and reduced-rate applications of the herbicides imazapic or picloram combined with releases of the Dalmatian toadflax stem mining weevil (*Mecinus janthinus*). We hypothesized that the combination of biological control and herbicides would lead to enhanced suppression of Dalmation toadflax. If effective, the combination of biological control and reduced-rate herbicide applications would lead to reduced amount of pesticide applied per acre (by 50%) as well as reduce the impact of herbicide applications on native and/or desirable non-target plant species. Our results indicate that the impacts of herbicide applications, biological control and their combination varied considerably among the different sites. Overall, our results did not support the implementation of an IPM strategy combining reduced-rate herbicide applications with releases of *M. janthinus*. Herbicide application at recommended rates may, however, be effectively combined with biological control although net toadflax suppression is likely to vary greatly among sites and the benefits of reduced pesticide use and reduced impact on non-target plants may not be realized. Our results provide mixed support for adoption of these IPM strategies for Dalmatian toadflax management, so it is unclear to what extent land managers will adopt the IPM strategies we evaluated. Nevertheless, information on the use of biological control and herbicide application for Dalmatian toadflax management is useful as land managers can apply fall treatments to Dalmatian toadflax without direct injury to *Mecinus* which is very important.We have presented or plan to present this information in several meetings including the following:

Meiman, P. Converse County Weed and Pest Growers' Workshop, Converse Co, WY, December 2007. Time and Timing of Grazing. Attendance: 60.

Norton, A. Invasive Species in Natural Areas Conference. Missoula, MT, February, 2008. Evaluating weed control strategies in natural areas: the importance of non-target plants.

Collier, T. Wyoming Weed and Pest Council Annual Meeting. Riverton, WY, November 2008. Integrating Mecinus with herbicides for Dalmatian toadflax control: an update. Attendance: 150.

Collier, T. Integrating Mecinus with herbicides for Dalmatian toadflax control. Riverton, WY, November 2008.

Enloe, S. Integrated biocontrol and herbicide approaches for Dalmatian toadflax control. Weed Science Society of America, Orlando, FL, February, 2009.

H. Appendices. Please attach to your report any of the following that will enhance public understanding of your project and its impacts and which you give permission to the Western IPM Center to use or post with attribution to your work:

- Printed fact sheets or other publications resulting from your work.

We have three papers in preparation and will provide reprints as soon as they are available.

Enloe, S., A. Norton, T. Collier, and P. Meiman. Integrated management of Dalmation toadflax with biological control and herbicides. To be submitted to Invasive Plant Science and Management.

Norton, A., T. Collier, S. Enloe, and P. Meiman. Mecinus establishment on Dalmatian toadflax as affected by herbicide applications. To be submitted to Biological Control.

Meiman, P. S. Enloe, A. Norton, and T. Collier. Impact of integrated herbicide applications and biological control on functional changes in grassland productivity. To be submitted to Rangeland Ecology and Management.