University of Idaho
College of Agricultural and Life Sciences

Biocontrol pre-release studies on hoary cress in Idaho, adjacent states, and central Europe

PROGRESS REPORT
2002

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Table of Contents

Summary

1. The year 2002 was very successful for the Hoary Cress Consortium biocontrol effort. Total cash contributions for foreign exploration and biocontrol pre-release studies increased to approximately $147,000. These funds allowed us to fully fund the foreign exploration work program that was outlined by the CABI Bioscience Switzerland Centre. In addition, funds were used for three graduate students. One Masters student Michael Cripps conducted his research overseas and assisted in the foreign exploration program at CABI Bioscience. The other graduate students, one Masters and one PhD, started their research programs in Idaho and adjacent states.

2. We were able to accomplish a lot of work during 2002. The foreign exploration results are presented in the CABI Bioscience Annual Report. In this report we will only briefly summarize the foreign exploration work. In addition to the exploration for biological control agents, the two Masters students started a comparison of the biology and herbivory on hoary cress infestations between Europe and the western United States. Preliminary results of this work indicate that 1) the weed grows much more aggressively in North America, 2) with one probable exception no host-specific insect herbivores are found on the plants in the U.S., 3) in the U.S., hoary cress is an important early refuge for crop insect pests, particularly those damaging alfalfa and CANOLA.

3. During 2002, the following new partners joined the Hoary Cress Consortium: Idaho Fish and Game, USDI – BLM Vale, OR, and the USDI - BIA.

4. Insect surveys in Idaho, Oregon, Washington, and Wyoming revealed that one native North American weevil, *Ceutorhynchus americanus* Buchanan (Coleoptera, Curculionidae) feeds on hoary cress. This weevil species usually occurs in the eastern United States. The biology of the weevil and the original host plant(s) are unknown. The weevil is very closely related to one of the potential biocontrol agents currently studied by CABI Bioscience. In 2003, we will start to investigate the biology, impact, and the potential to rear this species as native biocontrol agent for hoary cress.

5. A research partner was found to conduct molecular genetic studies on hoary cress species. Dr. John Gaskin at the USDA Northern Plain Agricultural Research Laboratory, Sidney, MT, reviewed taxonomic literature on the genus *Cardaria* and started genetic studies with samples including those collected by the University of Idaho and CABI Bioscience.

6. The test plant species list for the assessment of the host-specificity of biological control agents for hoary cress currently developed by Dr. Linda Wilson (University of Idaho) and Dr. Jeff Littlefield (Montana State University) is near to completion. The document has become fairly large and the list includes many plant species. However, it is intended to use this list also for potential biocontrol programs for perennial pepperweed (*Lepidium latifolium*) and dyers woad (*Isatis tinctoria*). The list will be sent to the Technical Advisory Group (TAG) and the U. S. Fish and Wildlife Service for comment and approval.

1 Introduction

The three known hoary cresses or whitetop species are no longer named *Cardaria.* New taxonomic studies conducted in the U.S. and Germany using molecular techniques revealed that the genus *Cardaria* is no longer valid. The genus was reunited with the genus *Lepidium.* In addition, there are only two and not three hoary cress species. *Cardaria* draba (L.) Desv. (heart-podded hoary cress) is now *Lepidium draba* L. The name *Cardaria pubescens* (C.A. Meyer)(globe-podded hoary cress) Jarmolenko has changed to *Lepidium appelianum* Al-Shehbaz. *Cardaria chalepensis* (lens-podded hoary cress) is no longer an independent species. It is now considered a subspecies of heart-podded hoary cress For a detailed review of the name changes, please refer to the CABI Bioscience annual report.

Hoary cress species currently infest large and valuable areas of pasture, rangeland and riparian habitat in Washington, Oregon, Idaho, Montana, Wyoming, Utah, California, and Alberta. In addition they are serious weeds of grain, alfalfa and some orchard crops. They also serve as an alternative host for the cabbage seed-pod weevil (*Ceutorhynchus constrictus*), a major pest of CANOLA and oilseed rape in Alberta. Hoary cresses are declared noxious weeds in 14 western states and three Canadian provinces.

Hoary cresses are deep-rooted, hard perennial mustards with stout stems that grow up to 60 cm tall. The root system consists of persistent vertical and lateral roots from which new rosettes and flowering shoots arise, thus allowing the plants to develop into thick stands. The root system makes cultural control efforts impractical. Established clones survive thatching treatments and repeated cutting or cultivation. Grazing is not a promising control technique because sheep do not graze established clones. Cattle avoid hoary cress and when forced to graze it, produce tainted milk. Successful control has been achieved with metsulfuron and 2,4-D, but chemical control is considered uneconomic because of the large areas infested and large size of individual infestations.

Hoary cress species are indigenous to southwestern and central Asia, southeastern Europe and the Mediterranean region. They were probably introduced to the New World in the late 19th century in contaminated alfalfa seed, and plants were first noted around seaports along both East and West coasts.

Mustard weeds are generally considered difficult candidates for biological control because they are closely related to many important crop plants. In addition, there is a large number of closely related North American Brassicaceae, some of which are considered threatened and endangered. However, the severity of the problems caused by hoary cress species, and the current difficulties to effectively manage the noxious weed species has led to a new biological control program. Wyoming Weed and Pest Districts, the Idaho State Department of Agriculture (ISDA), and the University of Idaho initiated this new biocontrol effort in 2001. During 2002, Idaho Fish and Game, USDI BLM, Vale, OR, and USDI BIA, Billings, MT joined the consortium.

2 CABI Bioscience work in 2002

Results of the foreign exploration conducted by CABI Bioscience are presented in a separate annual report included in this application. The following is a summary of the foreign exploration accomplishments.

A literature survey started in 2001 was completed in 2002. It revealed 211 phytophagous organisms to be associated with *L. draba*, and 289 when adding organisms recorded from other *Lepidium* species including perennial pepperweed and dyers woad, *Isatis tinctoria.* Most organisms, i.e., more than 90% reported were insects, dominated by beetles (Coleoptera) with more than 40% of species found, followed by bugs (Homoptera, Hemiptera). Eight species of beetles (Coleoptera) were recorded as mono to oligophagous, and four of these were selected as potential biological control agents, 1) the shoot-mining weevil *Ceutorhynchus merkli* Korotyaev, 2) the gall-former *C. cardariae* Korotyaev, 3) the seed-feeder *C. turbatus,* and 4) *Baris semistriata,* the larvae of which mine in the root-crown of hoary cress. During field surveys conducted in 2001 and 2002, approximately 80 insect species, one mite, and at least two fungal pathogens were sampled or reared from *Lepidium draba* and *L. latifolium.* Specimens collected during 2002, will be identified by specialists in 2003.

In 2002, investigations on the biology and host-specificity of the four preliminary selected biological control agents were started. *Ceutorhynchus merkli* is a univoltine species. Females laid eggs between mid/end March to mid May. Larvae mined in the shoots of *L. darba* during April and May. Development time from egg to emergence of beetles of the new generation took about 8-9 weeks. After the emergence, adults fed for a couple of weeks on hoary cress foliage. Then they aestivated throughout the summer in leaf litter. Feeding recommenced in late summer before the weevils overwintered. About a third of the female weevils that laid eggs in spring were still alive in fall. During preliminary host-specificity tests, most plant species offered in single-choice oviposition tests were accepted. However, no oviposition and feeding occurred on commercial *Brassica oleracea* varieties offered. Development to mature larva or adult occurred thus far only on three very closely related species, i.e. *Lepidium draba* ssp. *chalapense, L. campestre,* and *Brassica nigra*. No development was found on perennial pepperweed, *Lepidium latifolium* or *L. virginicum*, a weedy native North American species.

Ceutorhynchus cardariae is a gall-forming weevil species. Preliminary observations indicate that some females lay their eggs in late summer after the aestivation, the majority of females, however, lay their eggs in early spring. Galls are formed at the apical meristem of developing shoots or petioles. The growth of galled shoots was stunted. Mature larvae left the galls to pupate in the soil. For 2003, it is planned to clarify the life cycle of the species, develop methods for host-specificity tests, and start to quantify its impact in the field. Galls were formed on only one *L. draba* plant offered under confined conditions. Progress with this potential biocontrol agent will therefore depend on whether females will lay eggs under confined conditions.

Ceutorhynchus turbatus is another univoltine weevil species. Adults of this small weevil species emerged in spring from the beginning of April onwards. Oviposition commenced when pods were formed, i.e., end of May, and larvae mined during June in the developing seeds of

hoary cress. Each larva usually destroyed one, but sometimes also both seeds in a silicle. Larvae develop fast. The total larval development time was approximately 30 days. Mature larvae left the pods to pupate in the soil from the beginning of July onwards. Fully developed adults remain during the winter in their earthen cocoons and emerge during the following spring. Oviposition of this weevil species is depends on the availability and right size and phenostage of pods. Pods have to be large enough to support development of a larva, however, if pods have already ripened too much, females will not be able to lay eggs. This requirement will limit the number of plant species that can be exposed during host-specificity tests. In addition, females laid inconsistently eggs under confined conditions. We will try to improve rearing and testing methods in 2003.

In summary, all three species appear to be well adapted to the phenology of heart-podded hoary cress, which starts to bolt early in spring, reproduces and senesces in early summer and then starts to regrow from root buds during late summer.

Unfortunately it was not possible to collect data on the fourth potential biocontrol agent, the weevil *Baris semistriata* during 2002. Only few adults were collected and they died during summer. However, preliminary tests conducted by a research group at the Zoological Institute in St. Petersburg suggest that the species might not be sufficiently host-specific to be considered for further consideration.

In addition to the existing candidate species, two flea beetle species, *Psylliodes wrazei* and an as yet undetermined *Psylliodes* sp. from Romania, as well as two recently described gall midge species, *Contarinia cardariae* and *Dasyneura cardariae* were added to the list of potential biocontrol agents. Collections of individuals of these four insect species will be conducted in 2003. Thus, the number of potential biocontrol agents for hoary cress studied by CABI Bioscience has increased to eight insect species.

3 University of Idaho research in 2002

Studies at the University of Idaho in 2002 focused on the comparison of hoary cress growth vigor and insect herbivory impact between weed populations in their native range in Europe and introduced range in the U.S. We were interested in the abundance and diversity of insect community associated with hoary cress infestations between Europe and North America. Two Masters students started their research projects in 2002, Jessica McKenney studied hoary cress populations in North America and Michael Cripps used the exact same research methods to characterize populations in central and Eastern Europe. Sites sampled in Idaho are presented in Figure 1 (see also Appendix). In total 17 sites were visited in Idaho, Oregon, Washington and Wyoming during 2002.

Preliminary results from the first field season studying approximately 15 populations in Europe and in the U.S. (Figure 1) revealed that percentage cover and frequency of *L. draba* was lower at sites sampled in Europe compared to the sites investigated in the U.S. (Figure 2). In addition, the percentage cover of bare ground at European sites was only half of that observed at U.S. infestations. In contrast, the percentage cover of plant competitors was approximately twice as high at European sites (Figure 2). This preliminary data suggest that hoary cress grows in part larger in North America because plant competition is less intense and more space for invasion (bare ground) is available.

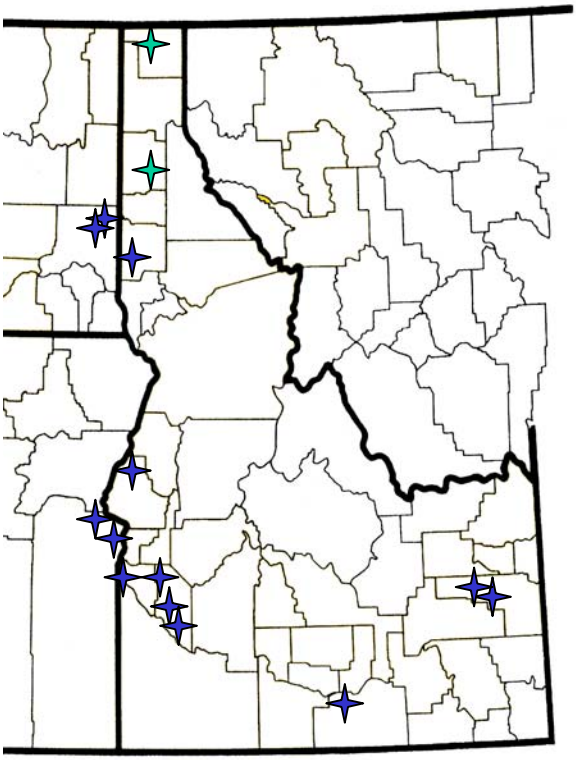

Figure 1
Hoary cress infestations sampled in 2002. Sites marked in green were only visited once in 2002, i.e., no harvest biomass was collected at these sites. Additional sites surveyed in Wyoming are not included in the map.

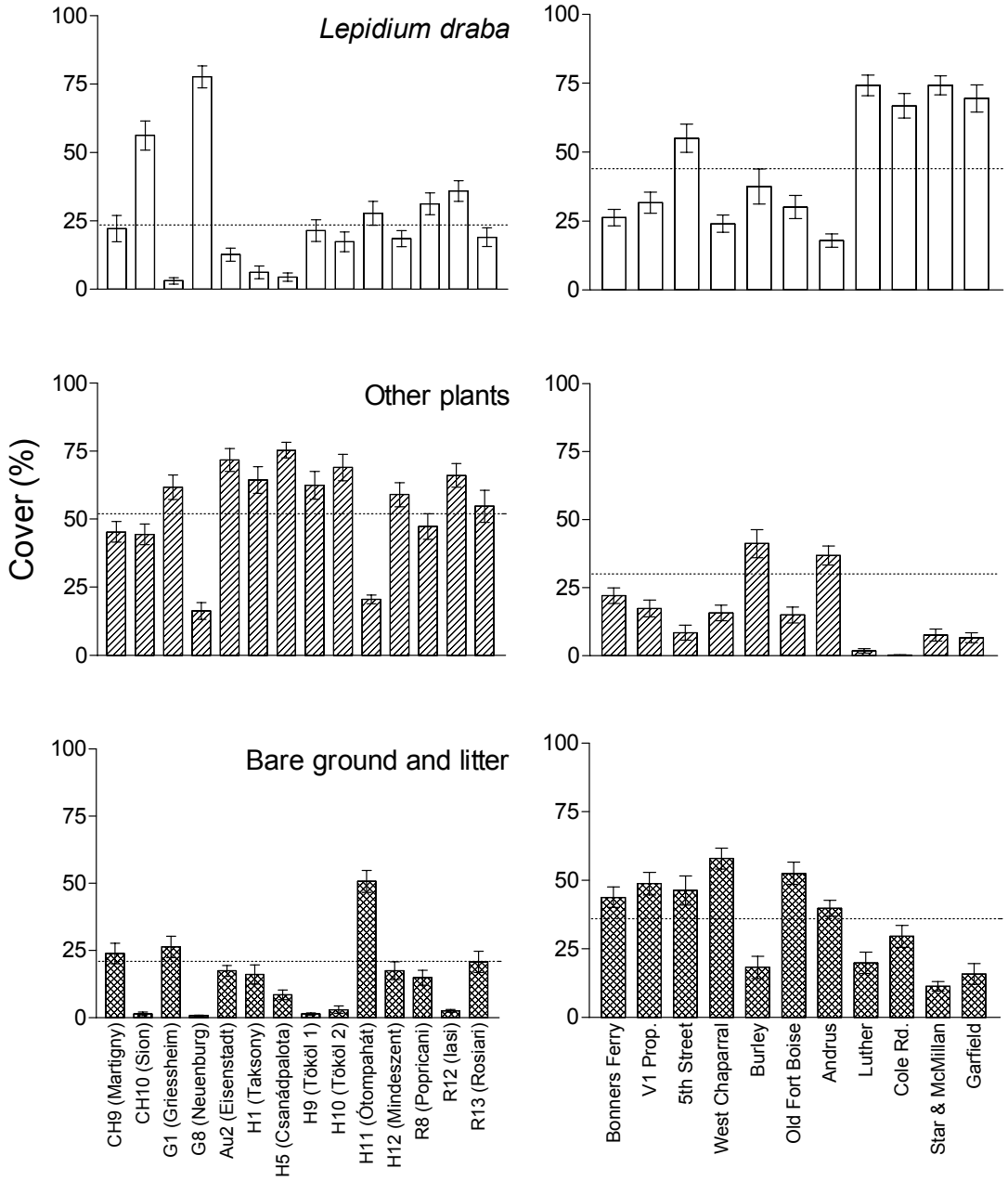

Figure 2 Percentage cover of *L. draba,* other plant species, and bare ground at field sites in Europe (left column) and the United States (right column) during 2002.

Hoary cress shoot density and biomass were smaller in Europe compared to the U.S., confirming that *L. draba* is growing more vigorously in its introduced range (Figures 3,4). On average, 21% of shoots were attacked by weevil larvae in Europe. The diversity of internally feeding species (e.g. weevils and flea beetles) was higher in Europe than in the U.S., where mites, thrips, and *Lygus* spp. accounted for the majority of specimens collected, sometimes in large numbers (Figure 5-10). The cabbage seed pod weevil, *Ceutorhynchus obstrictus,* an important pest of oilseed rape and CANOLA was comparably abundant on both continents (Figure 4). Nevertheless, it seems that hoary cress is used as a food source and/or early season refuge for this insect pest species (Figure 8).

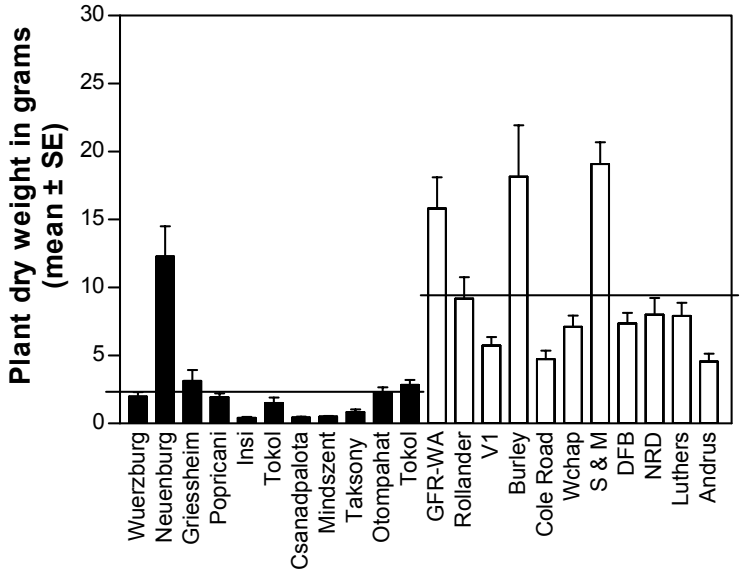

Figure 3
Hoary cress dry weight per 12.5cm by 25cm rectangle area at field sites in Europe (black bars) and in Idaho, Oregon, and Washington (white bars). The hoary cress biomass in North America is almost four times larger when compared to European sites (Europe, 2.56g ± 1.02g; U.S., 9.79g ± 1.60g; mean ± SE, $P < 0.001$).

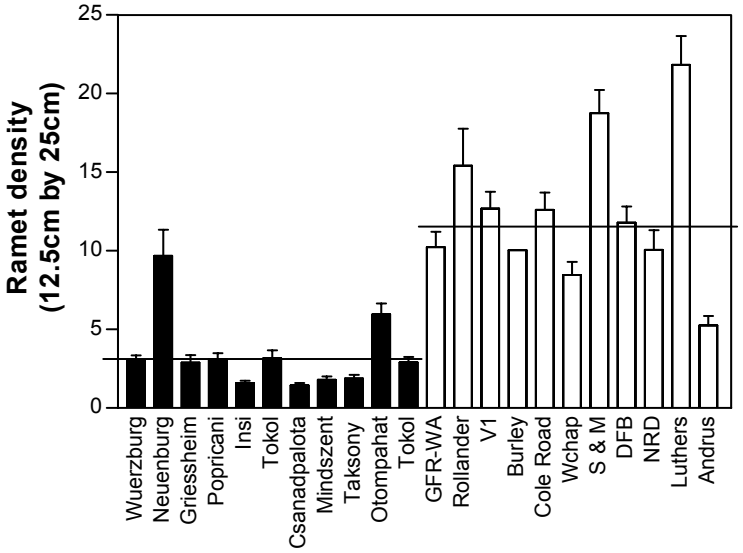

Figure 4
Hoary cress shoot density per 12.5cm by 25cm rectangle area at field sites in Europe (black bars) and in Idaho, Oregon, and Washington (white bars). The hoary cress density in North America is almost three times higher when compared to European sites (Europe, 3.40 ± 0.73; U.S., 12.48 ± 1.41; mean ± SE, $P < 0.001$).

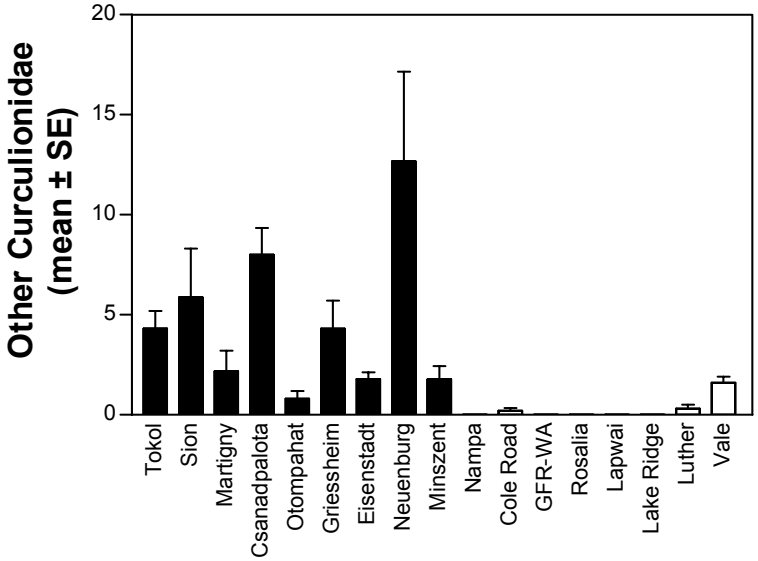

Figure 5
Abundance of other weevils and flea beetles at hoary cress infestations in Europe (black bars) and in Idaho, Oregon, and Washington (white bars)(Europe, 4.63 ± 1.26; U.S., 0.26 ± 0.19; mean ± SE; $P<0.001$).

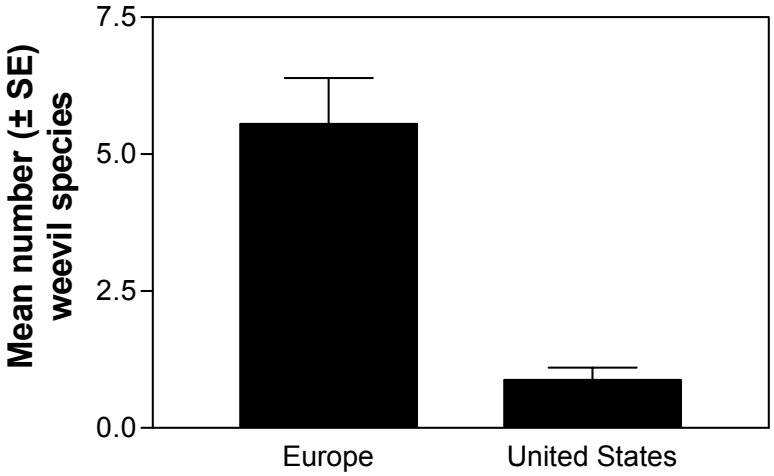

Figure 6
Comparison between the beneficial insect species diversity (weevils and leaf beetles) between the two continents. In Europe more beneficial insects species are found on hoary cress than in North America (Europe, 5.56 ± 0.83 species per site; U.S. 0.88 ± 0.22 species per site; mean ± SE; $P<0.001$).

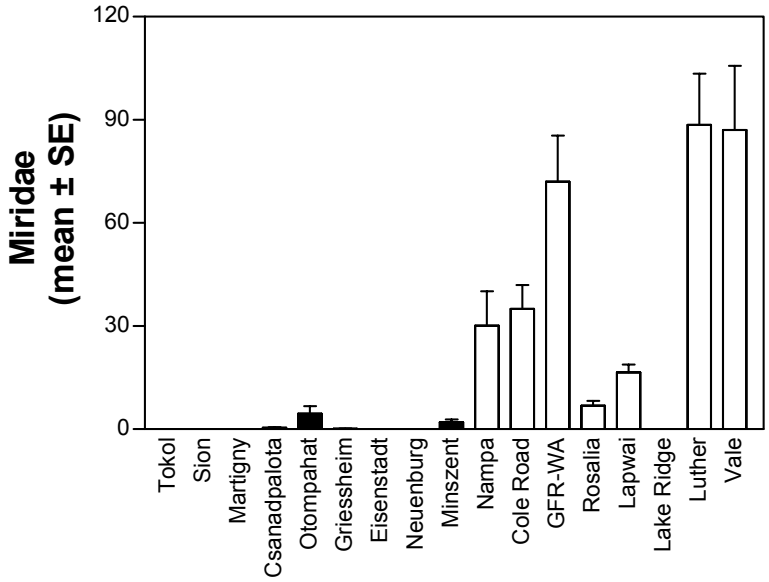

Figure 7
Abundance of *Lygus* spp. (plant bugs) at hoary cress infestations in Europe (black bars) and in Idaho, Oregon, and Washington (white bars)(Europe, 0.80 ± 0.53; U.S. 42.02 ± 12.64; mean ± SE; $P<0.001$).

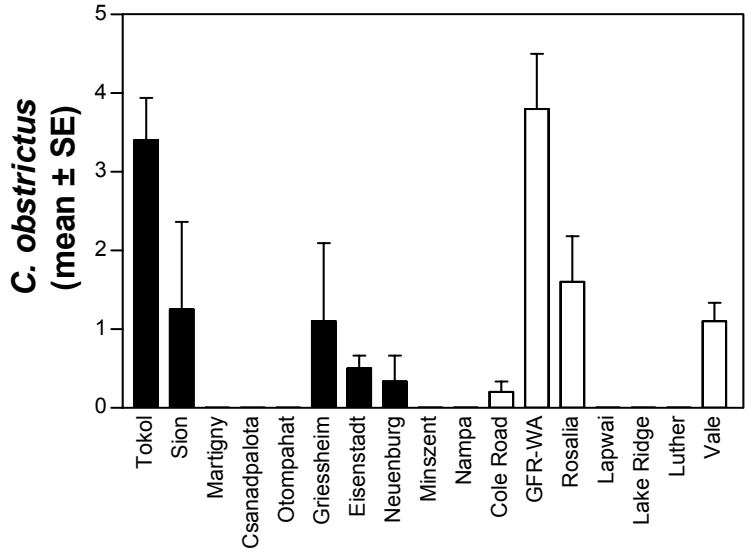

Figure 8
Numbers of cabbage seed pod weevils caught per ten 30 second sweeps at hoary cress infestations in in Europe (black bars) and in Idaho, Oregon, and Washington (white bars). There are no significant differences between continents (Europe, 0.73 ± 0.37; U.S., 0.83 ± 0.47; mean ± SE; n.s.).

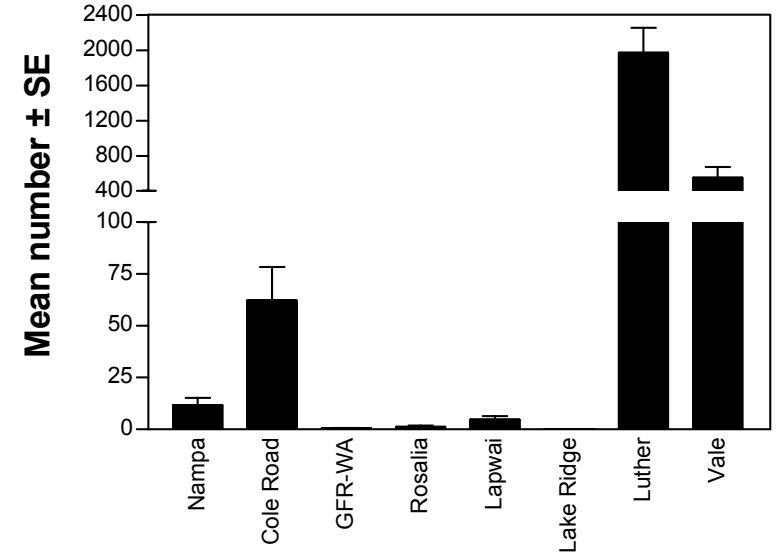

Figure 9
Abundance of thrips (Thripidae) at hoary cress infestations in Idaho, Oregon, and Washington (148.60 ± 66.67; mean ± SE, n = 8).

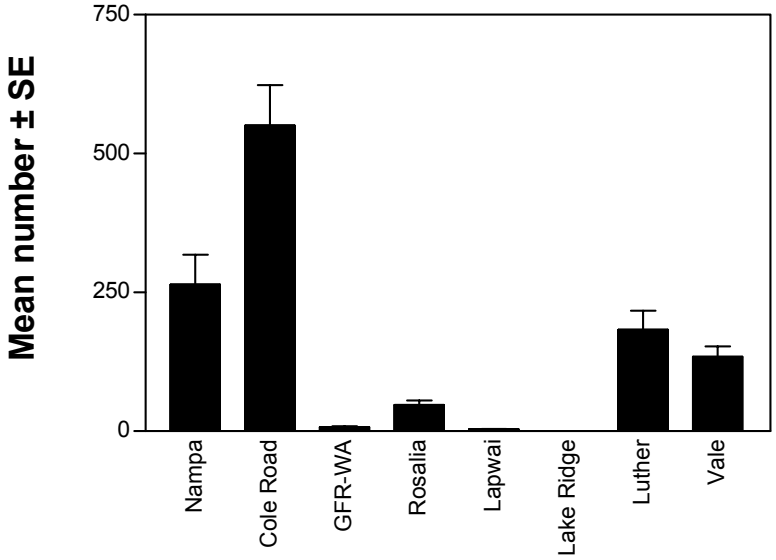

Figure 10
Abundance of mite pests at hoary cress infestations in Idaho, Oregon, and Washington (325.2 ± 244.5; mean ± SE; n = 8).

The data presented is only based on the 2002 field season and thus, preliminary. Data collection will be continued in 2003. In North America, we want to include sites in Wyoming and central Oregon and Washington. In Europe, surveys will extended further east, including the Ukraine. More comprehensive analyses of plant growth, insect diversity and abundance will be conducted after the second field season. With our research we anticipate to identify key factors responsible for the invasiveness and success of hoary cress in the U.S. and Canada. We also hope to receive competitive funding that would then allow us to test those identified key factors using manipulative experiments.

5 Conclusions

We had a successful second year with our efforts to develop a comprehensive biological control program for hoary cress in North America. All elements outlined in the strategic 5-year research plan have been addressed with the exception of the economic impact study of the problems caused by hoary cress. We are currently discussing the feasibility of a respective study as a graduate study project with faculty in the Agricultural Economics department at the University of Idaho.

There are eight potential biological control agents identified, some of which are already reared and studied for their biology at CABI Bioscience. Preliminary host-specificity tests with the first agents will be conducted in 2003. The test plant species list is nearly completed and although the list is long and comprehensive we anticipate positive feedback from the Technical Advisory Group (TAG) and the U.S. Fish and Wildlife Service. We intentionally developed a list that can also be used for biological control programs for perennial pepperweed and dyers woad.

The ecological pre-release studies are well underway and the transatlantic comparison provided impressive data in only one year. Our research has been acknowledged by an invitation to present the work at the 7th International Conference on the Ecology and Management of Alien Plant Invasions to be held in Ft. Lauderdale 3-7 November, 2003.

Genetic studies are underway at the USDA ARS NPARL in Sidney, MT. All populations studied during the transatlantic comparison study are included in the analyses. Thus, we will know which European hoary cress genotypes will match North American populations. In addition, colleagues at the University Wuerzburg, Germany will start to analyze the chemical compounds in the studied hoary cress populations. With this information, we may be able to avoid palatability problems between the potential biocontrol agents and North American hoary cress biotypes.

We also decided to include climatic data into our transatlantic habitat characterization studies in 2003. Climatic mismatch often directly affects the establishment of biocontrol agents. Knowledge of the molecular and chemical relatedness and the climatic growing conditions between European and North American hoary cress populations will hopefully reduce the risk for failure of establishment of biocontrol agents.

Appendix North American hoary cress infestations included in pre-release studies in 2002.

Name/Location	Coordinates	Elevation (m)	Habitat
North Road D, Vale, OR	N 44° 04.937' W 117° 18.320'	713.2	Roadside
Beaver Grade, Lapwai, ID	N 46° 23'49.9'' W 116° 48'40.2''	461.0	Open field
Farmington Rd., Garfield, WA	N 47° 0.471 ' W 117° 7.49	834.3	Wasteland
Star and McMillan Rd., Nampa, ID	N 43° 38.920' W 116° 29.615'		Open field
Cole Rd., Boise, ID	N 43° 29.368' W 116°16.469'	889.0	Pasture
Foothill Drive, Ontario, OR	N 44° 0.518' W 117° 0.6473'	670.8	Open field
Old Fort Boise, Parma, ID	N 43° 49'35.7'' W 117° 01'04.4''	673.0	Open field
West Chaparral Rd., Boise, ID	N 43°45'51.1'' W 116° 30'19.9''	794.0	Pasture
Rolland Rd., Idaho Falls, ID	N 43° 27.231' W 112° 2.720'	1,433.7	Pasture
Holmes Rd., Idaho Falls, ID	N 43° 30.879' W 112° 1.369'	1,452.0	Roadside
Route 71, Heath, ID	N 44° 45' 26.2" W 116° 51'49.6"	1,272.0	Open field
Route 410, Robertson, WY	N 41° 14.068' W 110° 21.934'	2,167.0	Roadside
Route 414, McKinnon, WY	N 41° 1.810' W 109° 57.789'	2,203.7	Pasture
County Rd. 44, Bonners Ferry, ID	N 48° 53.126' W 116° 21.826'	636.7	Pasture

Appendix Sponsors and funding provided and used in 2002

Project Sponsors	CABI Bioscience Funding		University of Idaho Funding	
	Received	Used	Received	Used
Idaho State Department of Agriculture	$35,000	Foreign exploration in central & eastern Europe Preliminary studies on biology of potential agents, Switzerland	$17,000	Graduate Student, M.S., Comparison study U.S.
Wyoming Weed and Pest Districts	$35,000			
Idaho Fish and Game	$3,000			
USDI–BLM Vale, OR	$2,500			
USDI–BIA			$10,000	Graduate Student, M.S., Comparison study Switzerland, Europe
Univ. of Idaho Stipend			$14,500	
Univ. of Idaho USDA-NRI Grant			$30,000	Graduate student, Ph.D., Pre-release studies in U.S.
Total	**$75,500**		**$71,500**	