Development of a Biological Control Program for Common Tansy: Final Report 2006 - 2009

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Prepared on behalf of the Alberta Invasive Plants Council by

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Summary

Common tansy (*Tanacetum vulgare*) is an aromatic, perennial European plant that was introduced into North America as a cultivated herb, but has now become an abundant, invasive plant across Canada and the northern USA. We have initiated a project, supported by a consortium of funding agencies and programs in Canada and the USA, to investigate the potential of European insects as biological control agents against common tansy in North America. Field survey sites in northern Germany, Russia, and Ukraine were selected, based on climatic matching, to maximize the chances that insects introduced as a result of this study will be preadapted to Canadian and northern US climates. Based on a literature review and previous field surveys, we identified several insects as potential biological control agents, including a stem-mining weevil, *Microplontus millefolii*, a leaf-feeding beetle, *Cassida stigmatica*, a flower-feeding moth, *Isophrictis striatella,* a stem-mining beetle, *Phytoecia nigricornis*, and a leaf- and flower-galling midge *Rhopalomyia tanaceticola.* In field surveys in Russia we also found a root-feeding beetle, *Longitarsus noricus*, that had not been previously reported from common tansy. All of these insects have been collected at field sites, and progress is being made in determining their life-histories and in developing rearing methods. A test plant list, including 56 species related to common tansy or with chemical similarities to it, was developed for use in host-specificity testing of the insects. The list has been approved by the review panels in Canada and the USA and almost all plant species required have been obtained. Host-specificity testing of *C. stigmatica* and *L. noricus* is under way. A Ph.D. project has been started to study the chemical diversity of common tansy and its effects on the host preferences of insects feeding on common tansy. We have also collaborated with researchers using molecular methods to study the systematics and genetic diversity of common tansy and related species. This project has resulted in the development of an effective consortium of stakeholders and researchers that is well placed to continue with the detailed studies on agent biology and host specificity required to gain approval for the release of biological control agents in Canada and the USA.

1 Introduction

Common tansy, *Tanacetum vulgare*, is an aromatic European plant that was first introduced into North America as a medicinal and culinary herb, but which is now an increasing weed problem in pastures, rights of way, waste places, and riparian areas across the northern USA and Canada. The overall goal of the project is to identify European insects that can be introduced into North America as biological controls for common tansy. A major component of the study is host specificity testing of the proposed insects, using an agreed list of test plants, to minimize any risk that they will cause unwanted damage to non-target plant species.

Field and laboratory studies on European insect species that are potential biological control agents for this weed were initiated in 2006 at the CABI Europe station in Delémont, Switzerland. Most of the species that were previously identified as potential biological control agents have now been collected from field sites in Germany, Russia, and Ukraine, and progress has been made in determining their life histories and setting up host specificity tests.

Major funding for the project was provided by the Advancing Canadian Agriculture and Agri-Food program (Project AB0025CO) and the Agriculture Development Fund, Saskatchewan (Project 20060126) for the period 2006 to 2009. This document serves as the final report for these funders, and is also being provided to all agencies funding this cooperative project through the Alberta Invasive Plant Council (AIPC), as well as other Canadian and US agencies funding the work on biological control of common tansy at CABI.

2 Objectives

The goals and objectives set out in our proposal were:

Goals:

- To form a consortium of Canadian and US agencies and stakeholders that will generate ongoing support for European studies on potential biological control agents for common tansy.
- To generate the biological data needed to support petitions for regulatory approval to introduce one or more insects from Europe as biological control agents against common tansy in Canada and the USA.

Objectives:

- To prepare a test plant list for use in host-specificity studies with potential biological control agents for common tansy, and obtain approval of this list from the TAG and BCRC .
- To determine suitable areas for field surveys of insects on common tansy in Europe and western Asia, based on climatic similarity with areas where common tansy is a problem in North America.

- To select potential biological control agents for common tansy from among insect species found feeding on this plant in Europe.
- To characterize the chemical variability of European and North American populations of common tansy and other Tanacetum species, so that plant material of known chemotypes can be used in biological studies and host specificity tests.
- To conduct field and laboratory studies on the biology, behaviour, life history and environmental requirements of the selected potential biological control agents.
- To assess the host-specificity of potential biological control agents through field and experimental studies with a list of other potential host plants.
- To assess the potential of candidate biological control agents for impact on common tansy by field and experimental observations.

The long-term goal of these studies is to use data from host-specificity, biology and impact studies to prepare submissions for regulatory approval for field release of promising biological control agents in Canada and the USA.

3 Results

3.1 Progress on overall goals

Work to develop a biological control program for common tansy has been supported by 11 agencies and programs in Canada and the United States. We have held annual meetings either in person or by conference call to review progress and plan work for the following season.

Plans for the project were discussed during a meeting in St. Paul, Minnesota, Nov. 9-10, 2006, attended by Dr. Alec McClay, Dr. Urs Schaffner (CABI), Monika Chandler, Natasha Northrop, and Antony Cortilet (Minnesota Dept. of Agriculture), and Tina Markeson (Minnesota Dept. of Transportation).

Progress on the project was discussed with Dr. André Gassmann (CABI) during a visit to CABI, Switzerland, by Dr. McClay on May 4, 2007, and during a visit by Dr. Gassmann to Lethbridge, AB, on February 9, 2008.

A meeting of consortium participants was held on October 31, 2008, in conjunction with the British Columbia Invasive Plant Council Research Forum, to review the progress of the project, plan future work, and consider future funding needs. Discussions at the meeting covered the history and background of the project, the current status of biological control agent studies at CABI, the status of the test plant list, genetic and molecular studies at USDA and the University of Minnesota, the Ph.D. project, work plans and priorities for 2009 and beyond, funding status, and studies needed in North America to document tansy populations.

A conference call including project participants and representatives of some of the funding agencies (Alberta Agriculture and Food Council, Saskatchewan Agriculture Development Fund) was held on November 23, 2009, again to review progress, plan future work, and discuss funding needs and status.

Progress reports on the project were provided to AIPC by CABI in quarterly station reports for September 2006, June 2007, September 2007, June 2008, September 2008, and June 2009, and in annual project reports for 2006, 2007 and 2008 (Gassmann et al. 2007; Gassmann et al. 2008; Gassmann et al. 2009). The September 2009 quarterly and 2009 annual reports are in preparation.

We have developed cooperative links with other researchers working on aspects of common tansy relevant to biological control. An M.Sc. student, Benjamin Clasen, working with Dr. Alan Smith in the Department of Horticulture, University of Minnesota, has been studying the genetic diversity and geographic structure of common tansy populations across Europe and North America. Dr. John Gaskin, a botanist with the USDA Agricultural Research Service in Sidney, MT, has been using molecular approaches to study the systematics and relationships of *Tanacetum* species and closely related genera in North America and Europe. These studies are not funded by the project, but we have been sharing information and materials. A Ph.D. student, Vera Wolf, supervised by Prof. Caroline Müller at the University of Bielefeld, Germany, has been studying the chemical and morphological diversity of European and North American populations of common tansy and their effects on insect feeding preferences.

Over the three years of the project, an effective consortium of funders and researchers has been developed that has made significant progress towards the overall goal of biological control of common tansy.

3.2 Progress on specific objectives

3.2.1 Develop test plant list and obtain approval by TAG and BCRC

Development of the test plant list is complete. Test plants were selected based on their phylogenetic closeness to common tansy, conservation status, economic importance, and chemical similarity to common tansy. The proposed list (Table 1) includes 56 plant species: six *Tanacetum* species in addition to *T. vulgare*, 32 other species in the tribe Anthemideae (to which *Tanacetum* belongs), 13 other species of the family Asteraceae (including a few economically important species such as sunflower, lettuce, safflower and globe artichoke), and 5 species in other plant families that have some chemical similarities with common tansy.

Currently only one North American native species of *Tanacetum* is recognized, *Tanacetum bipinnatum*, which occurs across northern North America from Alaska to Newfoundland (Flora of North America Editorial Committee 1993+). This includes forms such as *Tanacetum camphoratum*, *T. huronense*, and *T. douglasii* that had previously been described as separate species. However we will include populations that have been described under all these names in the host-specificity testing.

The test plant list was submitted for review in September 2007 to the Canadian Biological Control Review Committee (BCRC) and the USDA Technical Advisory Group for Biological Control Agents of Weeds (TAG). Comments on the proposed list from both groups were received in October 2008. In a letter the chair of the TAG commented that “In general the reviews were very complimentary of the petition”, and the chair of the BCRC said that “This is a very well-prepared petition and Dr. McClay is commended on the thoroughness of his submission”. Modifications to the test plant list suggested by some reviewers included the inclusion of the ornamental tansy variety *Tanacetum vulgare* var. *crispum*, additional species of *Artemisia* from Alaska, the arctic chamomile species *Tripleurospermum phaeocephalum*, additional congeners of threatened and endangered Asteraceae, and the minor crop species *Helianthus tuberosus* and *Tragopogon porrifolius*. Two other species suggested for addition were in fact already included on the list under different names.

Overall, the responses from TAG and BCRC indicated that the test plant list as submitted would be an adequate basis for assessing the host-specificity of proposed biological control agents for common tansy. All species on the list have now been obtained except for one North American native (*Hulteniella integrifolia*, an Arctic species), or should be easy to obtain from commercial sources.

3.2.2 Determine suitable areas for field surveys

Field survey areas in Europe were selected based on climate matching with areas of Canada and the USA where common tansy is a problem, using the CLIMEX® program (Sutherst et al. 2004). This should maximize the chances that agents introduced from these areas will be adapted to the climates they encounter at release sites. We used the Match Climates option in CLIMEX to select areas matching Edmonton, AB and Duluth, MN. Areas matching these climates are in northern and eastern Europe and Scandinavia, with areas matching Alberta being somewhat further east than those matching Minnesota (Figure 1).

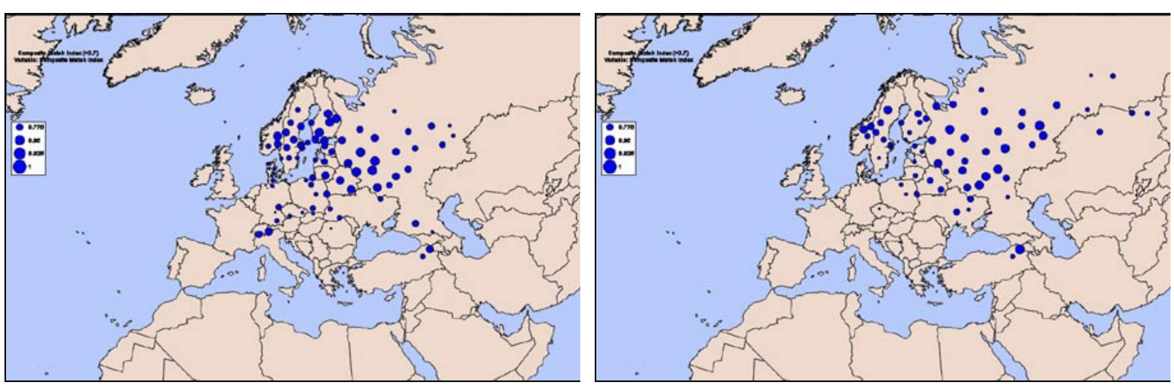

Figure 1. Areas in Europe and western Asia matching climates of Duluth, MN (left) and Edmonton, AB (right). Size of circles indicates closeness of climate match.

Specific survey sites were selected based on the climatic matching as well as logistics, accessibility and the knowledge and availability of local cooperators. The main collection areas were in northern Germany, around St. Petersburg and Moscow (Russia) and Kiev (Ukraine). Other collections were made in southern Germany and Armenia (Figure 2). Field work in Russia was carried out in cooperation with staff of the Russian Academy of

Sciences, St. Petersburg, and in Ukraine in cooperation with the M. G. Kholodny Institute of Botany, Kiev.

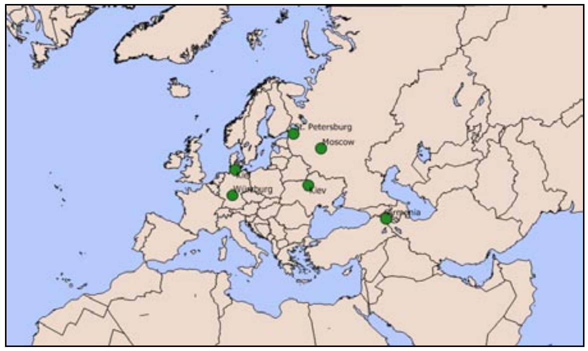

Figure 2. Location of main collection areas for insects on common tansy in Europe and western Asia.

3.2.3 Select potential biological control agents

Most of the insect species previously identified as potential biological control agents have been collected during this project. The stem-mining weevil *Microplontus millefolii* has been found in all areas surveyed, but most commonly around Kiev. The leaf-feeding beetle *Cassida stigmatica* was found in all areas surveyed. The flower- and stem-mining moth *Isophrictis striatella* has been found in northern and southern Germany but not so far at the Russian and Ukrainian study sites. Collection records for this species in the GBIF database extend north into Scandinavia and Finland, and there is a literature record from eastern Russia (Piskunov and Bolshakov 2005). The stem-mining beetle *Phytoecia nigricornis* was found at several sites but in the greatest numbers around Kiev.

Several species of root-boring moths in the genus *Dichrorampha* were proposed as possible biocontrol agents based on previous literature and field surveys. Some larvae were collected in our surveys, but all adults reared out were of species that are known to feed on other host plants. It will be logistically difficult to collect and dissect large amounts of root material to find these larvae and to separate out the several different species reported to feed on tansy. Thus this group of potential agents has been ranked as a lower priority for now. The gall midge *Rhopalomyia tanaceticola*, which attacks the leaves and flower heads, was found at sites in Germany and around St. Petersburg. However it does not appear to be very damaging to common tansy and has also been ranked as low priority. The root-mining jewel beetle *Meliboeus graminoides*, reported in the literature from common tansy, has not been found yet in our surveys.

A species which was not known from the earlier field and literature surveys was the root-feeding beetle *Longitarsus noricus*. It was initially identified as a similar species, *L. succineus*, which feeds on a number of species of Asteraceae, but was later identified as *L. noricus* by a chrysomelid specialist. This species has a wide distribution in Europe according to the literature, but in our surveys was found only around St. Petersburg, where it was quite common. There is no host plant information on *L. noricus* in the literature. *Longitarsus* species are often host-specific, and other species in the genus have been effective as biological control agents against other weeds (McEvoy and Cox 1991; Ireson et al. 2000; Schwarzländer 2000). This species has proved relatively easy to rear. Currently we consider *L. noricus* the most promising potential agent and it is the highest priority species for further study.

Information collected during this project has been valuable in selecting insect species with the greatest potential as biological control agents for common tansy.

3.2.4 Characterize the chemical variability of common tansy

This has been studied as part of the Ph.D. program of Vera Wolf. *Tanacetum vulgare* from 13 European and 9 North American populations was grown in a common garden experiment, their growth and morphological characters were recorded and chemotypes were analysed by GCMS of leaf terpenes. All populations were very chemically diverse. GCMS detected 84 different terpenes and 44 chemotypes were defined according to the two major components in each individual. There was more diversity in European than North American populations. This is consistent with the likelihood that there were multiple introductions of *T. vulgare* from Europe into North America. North American plants produced significantly more stems than European plants. Feeding tests have been started with *Cassida stigmatica* to look at chemotype effects on host plant preference but the sample size to date is small. The same chemotypes defined and utilized in this study will be used with other bioagent candidate species so that a variety of chemotypes are tested.

The only significant morphological difference between North American and European populations was a higher number of stems produced by North American plants.

These results are consistent with the findings of Ben Clasen in his M.Sc. thesis at University of Minnesota (Clasen 2009). Using ISSR markers he found that genetic diversity was high in both European and North American common tansy populations but slightly higher in Europe, suggesting multiple introductions of common tansy into North America. As with the chemotype data, most variation was within populations and only a small percentage between populations, suggesting little geographic structuring.

3.2.5 Biological studies on selected potential biological control agents

The life histories of all potential biological control agents selected for study are now better understood. The weevil *Microplontus millefolii* (Figure 3) has a single generation per year, and overwinters as adults. Eggs are laid in the shoot tips starting in early June and larvae feed in the stems. Field collected adults have been placed on common tansy plants in various caged conditions to develop a rearing method but oviposition rates so far have been low. The best results were obtained when plants were placed in an outdoor cage intermixed with natural vegetation. Further study will be needed to identify conditions required for oviposition to allow rearing and host-specificity tests with this species.

Figure 3. Adult *Microplontus millefolii.*

The tortoise beetle *Cassida stigmatica* (Figure 4) feeds on common tansy foliage in the larval and adult stages, and overwinters as an adult. Beetles collected in August 2006 in Germany had a mean fecundity of about 290 eggs in 2007, but fecundity in some other collections was much lower. Adults appear to be quite long-lived: a small percentage of each beetle generation survives more than two years in our rearing conditions and these beetles can remain active during the third year. This was confirmed in 2008 when a few beetles from the collections made in 2007 were still alive in mid October 2008.

Figure 4. Adult of *Cassida stigmatica* on tansy flower head.

Figure 5. Adult of *Isophrictis striatella.*

The moth *Isophrictis striatella* (Figure 5) has been confirmed to oviposit in mid to late summer on the flower heads of common tansy. Larvae feed in the flower heads and can be found in the flower heads in late fall. It appears that larvae then move into the stems in early spring and complete their development in the dry tansy stems the following summer, as adults emerge in late summer from dried stems collected in the spring. From our dissections, it seems that larvae can spend over 12 months in dry stems and that the moth can have a partial two-year life cycle. Thus, the biology of *I. striatella* is not yet fully resolved. It also appears that populations in northern Europe may behave differently from those in eastern France and southern Germany, and that larvae in the former area may complete some part of their development in newly growing shoots. Possibly there are biotype differences between these populations.

The stem-boring beetle *Phytoecia nigricornis* (Figure 6) has been collected in relatively small numbers and has not yet been reared through its full life cycle. Larvae are found in the stems and adults caged on potted *Tanacetum* plants laid eggs into the stems.

Figure 6. Adult *Phytoecia nigricornis.*

The gall midge *Rhopalomyia tanaceticola* has two generations per year, with adults flying in April – May and June – September. The first produces galls in the leaf axils or on the leaves, and the second makes conical green galls on the flower heads. Flower galls collected in late fall and early spring were empty, suggesting that larvae leave the galls to overwinter and pupate in the soil. Flower heads of common tansy with a high rate of attack by the seed-galling midge *Ozirhincus tanaceti* were reported by a CABI collaborator in Serbia; this species may also be a potential biological control agent.

Figure 7. Adult *Longitarsus noricus.*

The flea beetle *Longitarsus noricus* (Figure 7) feeds on foliage of tansy as adults and the larvae feed on the roots. Females collected from the field sites around St. Petersburg oviposited readily when provided with tansy foliage inserted into blocks of florists' sponge for feeding. Eggs are shiny, yellow-brownish and elongated. Egg hatch rate was 57% and larvae emerged 8 to 14 days after egg collection. When larvae were transferred to the roots of potted common tansy plants in July, adults emerged the following May. The sex ratio of adults checked after oviposition was strongly female biased.

3.2.6 Host-specificity testing

Host-specificity testing has been started with some of the insect species collected.

Larval transfer tests were carried out with larvae of *Cassida stigmatica* in 2007 using cut leaves and whole plants of *T. vulgare*. Larvae completed development on *T. vulgare* and the native *T. bipinnatifidum* ssp. *huronense*, and at a low rate on *Achillea millefolium*, but not on *T. corymbosum*, *T. parthenium*, *T. cinerariifolium*, *T. coccineum* or *T. macrophyllum*. Development on *T. bipinnatifidum* ssp. *huronense* was significantly slower than on *T. vulgare*. Further larval transfer tests were carried out in 2008 on potted plants. Survival to the adult stage was 20 – 30% on most tested populations of *T. vulgare*, except for two populations where no larvae developed to adults for unknown reasons. Survival on the native North American *T. huronense* and *T. camphoratum* was lower at about 10% for both species. No larvae developed to adults on *T. parthenium*, *T. cinerariifolium*, *Achillea alpina* or *Artemisia frigida*. The results to date suggest that the physiological host range is restricted to a few species in the genus *Tanacetum*. Further tests would be needed to assess the likelihood of attack on native North American *Tanacetum* species in the field.

In July 2007 no-choice oviposition and larval development tests were set up with *Longitarsus noricus*. Five males and five females were transferred onto three potted plants each of *T. vulgare* and three replicates of four test plant species, i.e. *T. huronense*, *T. coccineum*, *Leucanthemum vulgare* and *Jacobaea vulgaris* (=*Senecio jacobaea*). In May 2008 11 adults (4 ♂ and 7 ♀) emerged from two *T. vulgare* plants of European origin and one male emerged from *T. huronense*. In 2008 tests were set up by transferring newly-hatched 25 larvae per plant onto potted plants of 14 test plant species, mostly North American natives. Plants were kept over winter in an unheated greenhouse and emergence of adults was observed in 2009. Emergence of *Longitarsus* adults was recorded from all surviving test plants, including *T. camphoratum*, *Artemisia* spp., *Achillea* spp. and *Arctanthemum arcticum*. However all emerged adults will need to be identified to species, as a very similar local species, *L. succineus*, occurs in the CABI garden at Delémont, and is known to feed on several species of Asteraceae. Molecular approaches to identifying *L. noricus* are under development. In future testing it is planned to treat test plants in the fall before use with a non-persistent insecticide and keep them enclosed until use, in order to exclude contaminant *Longitarsus* species.

4 Other cooperation

We have cooperated with two other studies that are linked to this project, although not part of the project workplan itself.

4.1 Molecular systematics of species related to *Tanacetum*

Dr. John Gaskin at the USDA ARS Northern Plains Agricultural Research Laboratory in Sidney, Montana, has carried out studies using molecular methods to clarify the evolutionary relationships of *Tanacetum* and related European and North American plant species in the tribe Anthemideae, to which tansy belongs. Other North American genera such as *Artemisia*, *Achillea*, *Picrothamnus*, *Vesicarpa*, and *Sphaeromeria* are included in the study, some of which include species that were at one time classified in *Tanacetum*. The result of ITS sequencing indicated that species of *Artemisia, Arctanthemum, Picrothamnus, Sphaeromeria,* and *Vesicarpa* belong to the subtribe Artemisiinae and *Achillea* and *Matricaria* species belong to Matricariinae. All these genera are thus well separated from *Tanacetum*. The markers used to date were not very informative in separating species within *Tanacetum* and the next step will be to investigate more rapidly evolving cpDNA markers that may be informative for this group.

4.2 Genetic diversity of common tansy populations in North America

Dr. Alan Smith and his student Ben Clasen of the Department of Horticultural Science at the University of Minnesota, in a collaborative project with the Minnesota Department of Agriculture, have studied genetic diversity within introduced populations of common tansy in North America and native European populations (Clasen 2009). Measurements of genetic diversity using ISSR markers showed that North American populations had diversity levels (Shannon's I) ranging from 0.107 to 0.253. These are consistent with values seen in other self-incompatible invasive species, such as yellow toadflax and kochia. Most detected diversity was within, rather than between, populations but there was some evidence for geographic structuring, with a population in Ramsey County, MN being grouped separately from other North American populations. Further sampling of additional populations in Europe and North America showed that genetic diversity was similar in both ranges, but there appeared to be less differentiation between populations in Europe. The native species *T. huronense* and *T. camphoratum* appear to be closely related to *T. vulgare* based on ISSR molecular markers.

5 Communications

A number of poster and oral presentations on the project have been made, as listed below:

Presenter	Event	Type	Location	Date
Alec McClay	USDA-APHIS Technical Advisory Group on Biological Control of Weeds	Talk	Lethbridge, AB	Apr. 25, 2006

Alec McClay	North American Weed Management Association annual meeting	Field tour	Calgary, AB	Sept. 21, 2006
Urs Schaffner, CABI	Presentation to staff of Minnesota Dept. of Agriculture and other agencies	Talk	St. Paul, MN	Nov. 9, 2006
Alec McClay	Alberta Weed Advisory Committee	Talk	Edmonton, AB	Nov. 14, 2006
Monika Chandler	Midwest Invasive Plant Symposium	Talk	Milwaukee, WI	Dec. 13, 2006
Alec McClay	Alberta Invasive Plants Council "Year in Review" Workshop	Poster	Red Deer, AB	Apr. 12, 2007
Alec McClay	XII International Symposium on Biological Control of Weeds	Poster	Montpellier, France	Apr. 24, 2007
Alec McClay	Alberta Sustainable Resource Development, Regional Invasive Plant Workshop	Poster	Athabasca, AB	May 31, 2007
Karen Sundquist, AIPC	Alberta Agricultural Service Boards Summer Tour	Poster	Edson, AB	Jul. 9-11, 2007
Monika Chandler	Midwest Invasive Plant Network and Natural Areas Association Conference	Poster	Cleveland, OH	Oct. 9-11, 2007
Monika Chandler	South Dakota Weed and Pest Conference	Presentation	Huron, SD	February 21, 2008
Alec McClay	Weeds Across Borders 2008	Poster	Banff, AB	May 27-30, 2008
Alec McClay	Fifth International Weed Science Congress	Poster	Vancouver, BC	June 23-27, 2008
	British Columbia Invasive Plant Council Research Forum	Poster	Vancouver, BC	October 29-30, 2008
Monika Chandler	Invasive Plant Workshop,		St. Joseph, MO	January 6, 2009
Alec McClay	Strathcona County tansy workshop for landowners	Talk	North Cooking Lake, AB	April 20, 2009
Monika Chandler	Invasive Weed Workshops	Talk	Marshall, Grand Rapids, and Detroit Lakes, MN	April 23, May 5, and May 19, 2009
Ben Clasen	Microbial and Plant Genomics Institute Symposium	Poster	University of Minnesota	April 2009

Monika Chandler	Ramsey County Cooperative Weed Management Area Workshop	Talk	Arden Hills, MN	April 29, 2009
Alec McClay	Alberta Sustainable Resource Development Northeast Invasive Plant Workshop	Talk	Athabasca, AB	May 28, 2009
Ben Clasen	University of Minnesota	Thesis Defence Seminar	St. Paul, MN	August 2009
Vera Wolf	International Society for Chemical Ecology	Poster	Neuchâtel, Switzerland	August 23-27, 2009
Alec McClay	Entomological Society of Alberta	Talk	Vermilion, AB	November 6-7, 2009

An update on the project appeared in the Spring 2008 edition of the Alberta Invasive Plants Council newsletter *The Invader* (McClay 2008). Information on the project has been updated periodically on the Minnesota Department of Agriculture website at http://www.mda.state.mn.us/plants/badplants/tansy/tansycontrol.aspx and in the Minnesota Integrated Weed Management Group's newsletter *The Thicket.* An article by Monika Chandler on tansy was published in the Minnesota Shade Tree Advocate (Chandler 2008). Support from all project funders was acknowledged in these presentations.

6 Conclusions and recommendations

This project has provided a solid foundation for the further detailed studies on potential biological control agents for common tansy that will be required to obtain approval for field releases of agents in Canada and the USA. The first priority currently is to complete host-specificity testing with the root-feeding beetle *Longitarsus noricus.* Because of the presence of a very similar species in the field at CABI's location in Delémont, it will be necessary to accurately identify all adults emerging from tests with this species to ensure that they are *L. noricus*. During our November 2009 conference call we discussed possible molecular approaches to this question. Because of the close relationship between common tansy and the native *T. bipinnatifidum* it will be necessary to carefully assess possible impacts on this species by all potential agents. We propose to use open-field and multiple-choice tests to study the preferences of *Cassida stigmatica* for this native tansy species compared with common tansy. Further work with the weevil *Microplontus millefolii*, the moth *Isophrictis striatella*, and the beetle *Phytoecia nigricornis* needs to focus initially on further clarifying their life-histories and developing rearing methods so that host-specificity testing can be conducted. The root-feeding beetle *Meliboeus graminoides* is also still considered a potentially useful agent and further exploration will be conducted at field sites in Russia to attempt to collect material of this species for study. Further collaboration with researchers on the genetics and systematics of common tansy and related species will also be useful in interpreting the results of host-specificity tests.

7 Acknowledgments

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Table 1. List of proposed test plant species for biological control agents for *Tanacetum vulgare*

Higher taxa	Test plant species	Status in Europe*	Status in North America*	Notes
Genus *Tanacetum*				
	Tanacetum vulgare L.	N	I	Target weed (test acceptance with several different populations/chemotypes).
	Tanacetum bipinnatum (L.) Schultz-Bip.	N	N	Includes "*Tanacetum huronense* Nuttall", *"Tanacetum camphoratum* Lessing", *"Tanacetum douglasii* DC". All these are synonymized under *T. bipinnnatum* in the *Flora of North America*, but we plan to test populations that have been referred to under all of these species names.
	Tanacetum balsamita L.	N	I	Introduced weed in North America.
	Tanacetum parthenium (L.) Schultz-Bip.	N	I	Introduced weed in North America; cultivated as a source of herbal medicines (feverfew).
	Tanacetum cinerariifolium (Trevir.) Schultz-Bip.	N	I, H	Economic (source of pyrethrum); cultivated and occasionally naturalized.
	Tanacetum coccineum (Willd.) Grierson	-	I, H	From Asia Minor, Caucasus, and Iraq. Ornamental and sometimes grown as a source of pyrethrum.
	Tanacetum corymbosum (L.) Schultz-Bip.	N	I	Naturalized in Oregon.
Tribe Anthemideae				
Genus *Anthemis*				
	Anthemis arvensis L.	N	I	Introduced weed in North America
	Anthemis cotula L.	N	I	Introduced weed in North America
Genus *Matricaria*				
	Matricaria chamomilla L.	N, E	I, H	Grown for herbal use and sometimes becoming weedy.
	Matricaria discoidea DC	I	N	"pineapple weed"
	Matricaria occidentalis Greene	-	N	Native in California, very similar to *M. discoidea*
Genus *Achillea*				
	Achillea millefolium L.	N	N	Test native North American populations
	Achillea alpina L.	-	N	
	Achillea ptarmica L.	N	I	
Genus *Leucanthemum*				
	Leucanthemum maximum (Ramond) DC	N	I, H	Grown as ornamental (Shasta daisy)
	Leucanthemum vulgare Lamarck	N	I	Introduced weed in North America
Genus *Chamaemelum*				
	Chamaemelum nobile (L.) Allioni	N	I	Grown as ornamental
Genus *Santolina*				
	Santolina chamaecyparissus L.	N	I, H	Grown as ornamental
Genus *Glebionis*				
	Glebionis coronaria (L.) Cassini ex Spach	N, H	I, H	=*Chrysanthemum coronarium* L. Grown as a vegetable for Asian market ("shungiku").

Higher taxa	Test plant species	Status in Europe*	Status in North America*	Notes
	Glebionis segetum (L.) Fourreau	N	I	=*Chrysanthemum segetum* L.
Genus *Chrysanthemum*				
	Chrysanthemum × *morifolium* L.	-	H	Florist's chrysanthemum – test several cultivars
Genus *Ismelia*				
	Ismelia carinata (Schousboe) Schultz-Bip.	N	I	=*Chrysanthemum carinatum* Schousboe
Genus *Cotula*				
	Cotula coronopifolia L.	I?	I	
Genus *Leucanthemella*				
	Leucanthemella serotina (L.) Tzvelev	I	I	
Genus *Artemisia*				
Subgenus *Absinthium*				
	Artemisia frigida Willd.	N?	N	
	Artemisia scopulorum A. Gray	-	N	
Subgenus *Artemisia*				
	Artemisia biennis Willd.	I	N	
	Artemisia ludoviciana Nutt.	-	N	State listed as threatened in MI
	Artemisia vulgaris L.	N	N	
Subgenus *Dracunculus*				
	Artemisia campestris L.	N	N	Some subspecies state listed as threatened or endangered in OH, MA, ME, NY, OR, WA, NH, PA
	Artemisia dracunculus L.	N	N	State listed as endangered in IL
Subgenus *Tridentatae*				
	Artemisia tridentata Nutt.	-	N	
	Artemisia cana Pursh	-	N	
Genus *Sphaeromeria*				
	Sphaeromeria argentea Nutt.	-	N	=*Tanacetum nuttallii* Torrey & A. Gray
Genus *Picrothamnus*				
	Picrothamnus desertorum Nuttall	-	N	
Genus *Arctanthemum*				
	Arctanthemum arcticum (L.) Tzvelev	-	N,H	Grown as ornamental
Genus *Hulteniella*				
	Hulteniella integrifolia (Richards.) Tzvelev	-	N	
Genus *Tripleurospermum*				
	Tripleurospermum inodorum (L.) Schultz-Bip.	N	I	Introduced weed in North America
Tribe Astereae				
	Solidago canadensis L.	I	N	Or any other native North American species in the genus

Higher taxa	Test plant species	Status in Europe*	Status in North America*	Notes
Tribe Gnaphalieae				
	Anaphalis margaritacea (L.)	I,H	N	Or any other native North American species in the genus
Tribe Helenieae				
	Helenium autumnale L.	-	N	Or any other native North American species in the genus
Tribe Coreopsideae				
	Coreopsis tinctoria Nutt.	-	N	Or any other native North American species in the genus
Tribe Heliantheae				
	Helianthus annuus L.	I,E	N,E	Economically important
Tribe Eupatorieae				
	Eutrochium maculatum (L.) E. E. Lamont	-	N	=*Eupatorium maculatum* L. Or any other native North American species in the genus
Tribe Madieae				
	Arnica chamissonis Lessing	-	N	Or any other native North American species in the genus
Tribe Senecioneae				
	Senecio eremophilus Richardson	-	N	Or any other native North American species in the genus
Subfamily Cichorioideae				
Tribe Lactuceae				
	Lactuca sativa L.	N,E	I,E	Economically important
	Cichorium intybus L.	N,E	I,E	Minor crop
Subfamily Cichorioideae				
Tribe Cardueae				
	Cirsium flodmanii (Rydb.) Arthur	-	N	Or any other native North American species in the genus
	Carthamus tinctorius L.	N,E	I,E	Economic crop
	Cynara scolymus L.	N,E	I,E	Economic crop
Species with chemical similarities				
Family Lamiaceae				
	Salvia officinalis L.	N, H	I, H	Contains thujone, camphor, 1,8-cineole (Perry et al. 1999)
	Rosmarinus officinalis L.			Contains α-pinene, 1,8-cineole, camphor, verbenone, and borneol (Santoyo et al. 2005)
Family Cupressaceae				
	Juniperus occidentalis Hook.	-	N	Contains α-pinene, camphene, camphor, borneol (von Rudloff et al. 1980)
	Thuja occidentalis L.	-	N	Contains thujone (Naser et al. 2005)
Family Magnoliaceae				
	Magnolia grandiflora L.	-	N	Contains parthenolide (Castañeda-Acosta et al. 1995)

*N – native; I - introduced; H – horticultural; E – economic.

APPENDIX 1

Financial report

1. Income and expenses statement

Income and expenses for common tansy biological control through Alberta Invasive Plants Council (all amounts in Canadian $):

	To Oct 31 2007	Nov 1 2007 – Oct 31 2008	Nov 1 2008 – Oct 31 2009	Nov 1 2009 - Jan 31 2010	Totals to Jan 31 2010
INCOME					
Advancing Canadian Agriculture and Agri-Food	$25,000.00	$22,500.00	$20,000.00		$67,500.00
Agricultural Development Fund (Saskatchewan)	$20,000.00	$25,000.00	$25,000.00		$70,000.00
Enbridge Grant	$2,000.00		$1,000.00		$3,000.00
Encana Grant	$4,000.00	$4,000.00	$4,000.00		$12,000.00
Alberta Beef Producers		$5,000.00	$5,000.00		$10,000.00
Alberta Sustainable Resource Development	$10,000.00				$10,000.00
TOTAL INCOME	**$61,000.00**	**$56,500.00**	**$55,000.00**	**--**	**$172,500.00**
EXPENSES					
CABI Switzerland	$40,876.50	$45,000.00	$58,000.00	$9,145.72	$153,022.22
McClay Ecoscience	$14,901.83	$3,715.79	$7,723.41	$3,543.75	$29,884.78
Global Crossing (teleconferencing)			$93.00		$93.00
AIPC (admin expenses)			$2,000.00		$2,000.00
TOTAL EXPENSES	**$55,778.33**	**$48,715.79**	**$67,816.41**	**$12,689.47**	**$185,000.00**
BALANCE at Jan 31 2010					**($12,500.00)**

2. Funding provided to CABI from all sources for common tansy biological control

This table shows total amounts invoiced by CABI to date to all project sponsors for the common tansy biological control project. CABI invoices Canadian sponsors in Canadian dollars and US sponsors in US dollars. Because there have been substantial currency fluctuations over the period of the project, we have estimated totals in Canadian dollars by converting the US amounts at average exchange rates over each year of the project (from PACIFIC Exchange Rate Service, http://fx.sauder.ubc.ca).

	To Oct 31 2007	Nov 1 2007 – Oct 31 2008	Nov 1 2008 – Oct 31 2009	Nov 1 2009 - Jan 31 2010	Totals to Jan 31 2010
Canadian sources (C$)					
AIPC (see previous table)	$40,876.50	$45,000.00	$58,000.00	$9,145.72	$153,022.22
BC Ministry of Forests		$10,000.00	$15,000.00		$25,000.00
Canadian $ total	**$40,876.50**	**$55,000.00**	**$73,000.00**	**$9,145.72**	**$178,022.22**
US sources (US$)					
Minnesota Dept. Agriculture	$20,000.00	$20,000.00	$40,000.00		$80,000.00
UPM Blandin Paper Mill		$5,000.00			$5,000.00
Montana Noxious Weed Trust Fund		$20,000.00	$20,000.00		$40,000.00
US totals (US$)	**$20,000.00**	**$45,000.00**	**$60,000.00**	**--**	**$125,000.00**
Average exchange rate (US$1.00 =)	C$1.0968	C$1.0240	C$1.1650	--	
US totals in Canadian $[1]	**$21,936.00**	**$46,080.00**	**$69,900.00**	**$0.00**	**$137,916.00**
Total all sources in Canadian $	**$62,812.00**	**$101,080.00**	**$142,900.00**	**$9,145.72**	**$315,938.22**

3. <u>Expenditure of funding received from Agricultural Development Fund (Saskatchewan)</u>

		Totals to Jan 8, 2010
INCOME RECEIVED		**$70,000.00**
EXPENDITURES		
CABI Switzerland		
Salaries and benefits		
Student	$18,750.00	
Scientist	$30,000.00	
Technician	$13,500.00	
Total salaries		$62,250.00
Materials and supplies		$1,500.00
Field work		$5,250.00
Other expenses (CABI indirect costs)		$4,500.00
Other fees (McClay Ecoscience consulting)		$1,500.00
TOTAL EXPENDITURES		**$75,000.00**
BALANCE at Jan 8, 2010		**($5,000.00)**

I have reviewed and approved this financial statement on behalf of the Alberta Invasive Plants Council, and request payment of all remaining funding instalments.

(Signed)

______________________________ ______________________

Virginia Battiste
Administrative Coordinator
Alberta Invasive Plants Council

Date