Target Invasive Plants and Biocontrol Agents Undergoing Screening

The B.C. Ministry of Forests, Lands and Natural Resource Operations and Rural Development (MFLNRO), through contributed funding, enables research by Centre for Agriculture and Biosciences International (CABI) and Agriculture and Agri-Food Canada (AAFC)'s Weed Biological Control program into potential new biocontrol agents for the province on an annual basis. Research on these agents is additionally funded by a consortium of interested partners, including other Canadian provincial and federal government departments, U.S.A. county, state and federal agencies, U.S.A. and Canadian Universities, and NGOs. Specific funding and research partners vary with each plant targeted.

The invasive plants currently targeted by British Columbia, as of March 2020, and their consortia objectives, are:

- Common reed (*Phragmites australis*)
- Common tansy (*Tanacetum vulgare*)
- Dalmatian and yellow toadflax (*Linaria dalmatica* and *L. vulgaris*)
- Flowering rush (*Butomus umbellatus*)
- Himalayan balsam aka: Policeman's helmet (*Impatiens glandulifera*)
- Hoary cresses (*Lepidium draba*, *L. chalepense* and *L. appelianum*)
- Knotweed (*Fallopia/Polygonum* spp.)
- Oxeye daisy (*Leucanthemum vulgare*)
- Russian olive (*Elaeagnus angustifolia*)

**Common reed (*Phragmites australis*)**

No biological control agents exist in B.C. to date for this perennial wetland grass. Investigation into potential biological control for invasive common reed in North America began in 1998. Participation in the project mainly involved agencies from the U.S.A. and eastern Canada and in 2013, B.C. joined the project to assist with completion of work on the two candidate biological control agents as the province has several populations of this invasive plant. Laboratory and field tests of host range in Europe confirmed that the two shoot-mining noctuid moths, *Lenisa (Archanara) geminipuncta* and *A. neurica* are specialists on Phragmites.

Both moth species were approved for release in Canada in April 2019. Rearing populations are kept at CABI, Switzerland and at AAFC, Lethbridge, Alberta. Releases experiments are planned in 2020 to assess the best insect stage: moths vs larvae vs eggs to release in order to get successful establishment of the biocontrol agents.
Common tansy (*Tanacetum vulgare*)

No biological control agents exist in B.C. to date for this perennial herbaceous flowering plant. The chemical variability of common tansy populations in Europe and North America has been described, particularly with respect to the varying proportions of the species' toxic compounds; the essential oil components such as alpha-thujone. This variability may influence host plant acceptance by biocontrol agent candidates.

Currently, tests are on-going with three insects: the stem-mining weevil *Microplontus millefollii*; the shoot and flower-head mining moth *Platyptilia ochrodactyla*; and the leaf-feeding chrysomelid *Chrysolina eurina*. Tests began in Switzerland for *M. millefollii*, however, the studies are now conducted in Russia, the weevil’s place of origin, to better synchronize the collection of weevils to be used in testing with their natural oviposition period. The weevil is showing a narrow host range so far. A preliminary impact experiment showed reduced stem length, plant biomass and number of flower heads on the target common tansy. Studies on *P. ochrodactyla* in Switzerland have shown under natural field conditions the moth has a narrow host range. Studies on *C. eurina* are continuing, yet it is proving difficult to rear the moth to sufficient numbers for tests. Single-choice tests were accomplished in 2019, results are pending.

Dalmatian and yellow toadflax (*Linaria dalmatica* and *L. vulgaris*)

There are five species of biological control agents that were purposely introduced in the province for each of Dalmatian and yellow toadflax, two of which attack both these short-lived perennial herbs with snapdragon-like flowers. The most recent agent, *Rhinusa pilosa*, was successfully released and established on yellow toadflax in B.C. in 2014 while studies on additional potential agents continue. Studies of the stem-boring weevil *Mecinus laeviceps* associated with *L. genistifolia/L. dalmatica* are near completion whereas studies for an additional *Mecinus* species, *M. peterharrisi*, investigated for control of *L. dalmatica* in northern regions, will be on-going for a few more years. Most studies are complete for *M. heydeni* targeting *L. vulgaris*. Studies for the *L. dalmatica* stem-galling weevil *R. rara* are completed and a petition for field release is being developed.
Flowering rush (*Butomus umbellatus*)

Currently no biological control agents exist in B.C. for this perennial rush-like aquatic plant. Investigation into potential biological control of flowering rush began in 2013. There are currently only three documented infested water bodies in the province, however, surveys for the plant in B.C. lakes are ongoing and the plant may prove to be more widespread. Currently manual treatments are used to control this extremely aggressive and damaging plant, yet, the long-term effectiveness of this method is not yet known. A literature search was conducted for phytophagous arthropods and fungal pathogens associated with flowering rush in Europe which identified five potential agents: two weevil species, *Bagous nodulosus* and *B. validus*; and two fly species, *Phytoliriomyza ornata* and *Hydrellia concolor*, all of which feed on the stems and leaves of flowering rush; and a fungus, *Doassansia niesslii*.

Host range testing work by CABI has focussed on *B. nodulosus* and *P. ornata*. Testing of adult *B. nodulosus* has demonstrated the weevil to be very host specific. Currently tests are being completed on the host-choice of beetle larvae as they emerge from flowering rush plants and disperse in the water. Impact testing results to date indicate a preference for and higher biomass reduction of North American versus European flowering rush. Host range testing of *P. ornata* is not as advanced as for *B. nodulosus* but in plant species tests so far, the fly is proving to be very host specific to flowering rush. Studies of the fungal pathogen have also been initiated. Different fungal life stages affect both the submerged and emerged portions of the plant. Attack of the emerged plant parts has led to significant infection and plant death. Three strains of fungus have been tested on the multiple North American flowering rush genotypes and one fungal strain was effective against the unique BC genotype that occurs in Bouchie Lake, B.C.

Hawkweed complex (*Pilosella* spp.; syn. *Hieracium* spp.)

To date, two biological control agents have been imported into B.C. for several species of these invasive perennial herbs. Studies for additional biocontrol agents of several hawkweed species are ongoing. Since 2000, seven biocontrol candidates have been considered for potential release in Canada, of which three were immediately dropped due to lack of specificity or effectiveness. The stolon-tip gall wasp *Aulacidea subterminalis* was the first agent to be approved by CFIA for release in Canada, and first released in B.C. in 2011. It targets mouse ear hawkweed (*Pilosella officinarum*), whiplash hawkweed (*P. flagellaris*), a stable hybrid of mouse-ear and meadow hawkweed, kingdevil hawkweed (*P. floribunda*) and the less preferred orange hawkweed (*P. aurantiaca*). The root-feeding hoverfly *Cheilosia urbana* was approved for import in spring of 2016 and first released in 2017. A hoverfly matching the description of *C. urbana* was observed on hawkweed plants at the release site in spring 2018, but its identity was not confirmed. A small number of adult flies were subsequently reared from some additional 2017 infested plants that were overwintered at AAFC-Lethbridge, and these were shipped to B.C. for release at the same site in June 2018. The fly primarily targets meadow (*P. caespitosa*) and orange hawkweeds. More flies may be released from AAFC’s population in 2020. Work on the rosette-feeding hoverfly *C. psilophthalma* has been postponed; studies on the stem-
galling wasp *A. hieracii* have been terminated due to it rarely being found in Europe on the hawkweed species being targeted for control in North America; and attempts to maintain a colony of the rust, *Puccinia hieracii* var. *piloselloidarum* have proven difficult, thus work on the rust has ceased. Research by CABI and AAFC, Lethbridge continues on two genetically and biologically divergent forms (biotypes) of another gall wasp *A. pilosellae*; one biotype is only found on *P. officinarum* in Europe, and the second occurs on several hawkweed species, including *P. caespitosa*, *P. glomerata*, *P. floribunda*, *P. piloselloides*, infrequently on *P. aurantiaca*, but not on *P. officinarum*. AAFC, Lethbridge also continues studies on the impact of *A. pilosellae* on B.C.’s invasive hawkweeds, which is part of the screening process for candidate biocontrol agents. In tests completed do far, both biotypes look to be very host specific on the invasive hawkweeds, versus on native North American hawkweeds.

**Himalayan balsam (aka: Policeman's helmet) (*Impatiens glandulifera)*

No biological control agents are currently available in Canada for this annual non-native plant often purposely grown as an ornamental. Investigation into potential biological control agents for Himalayan balsam began in the U.K. in 2006. British Columbia joined the project in 2012 with the development of a North American test plant list. Screening work is being conducted by CABI in the United Kingdom. Canadian test plant species collected in BC are provided to the UK lab for host-range testing of the fungus *Puccinia komarovii* originally observed in the Indian region of the Himalayas. In 2014, the fungus was permitted for release in the UK and released on field sites in England, the first ever fungal biological control agent in Europe. Field monitoring in the UK indicated that UK populations of Himalayan balsam were variably susceptible to the fungus. Research is continuing to match fungal strains with Himalayan balsam genotypes in both the UK and British Columbia. All Canadian non-target species tested were not affected by the available fungus strains. Molecular analysis of seven B.C. Himalayan balsam populations has revealed two haplotypes that are similar to the most common ones invading the UK. Additional fungal strains have been collected that may be better matched to the Canadian Himalayan Balsam populations and are being propagated and screened in containment.
Hoary cresses (*Lepidium draba, L. chalepense and L. appelianum*)

No biological control agents exist in B.C. to date for the three species of this perennial clonal mustard. Work on hoary cresses (or whitetops) was initiated by the U.S.A. in 2001 and B.C. joined the project in 2011. Seven phytophagous insect species were chosen for study, four of which have undergone initial screening and have been removed because of a lack of specificity. The focus has narrowed to two species; the gall-forming weevil *Ceutorhynchus cardariae* and the seed-feeding weevil *C. turbatus*.

The U.S.A. and CABI submitted a petition to the USDA, APHIS TAG in 2011 to request permission to release the *C. cardariae* weevil in the United States. APHIS responded with a request for supplementary testing for a few non-target plant species. This work has been completed and a supplemental release petition for the USA was submitted for review in January 2020. Host range testing studies at CABI are continuing on *C. turbatus*. This weevil has also been host-specific to the target hoary cress species compared to the non-target species that have been tested.

Knotweed (*Fallopia/Polygonum*)

To date, a single biological control agent has been imported into Canada targeting three knotweed species in British Columbia: Japanese knotweed (*Fallopia japonica* or *Polygonum cuspidatum*); Giant knotweed (*F. sachaliensis* or *P. sachalinense*) and the hybrid between these two species, Bohemian knotweed (*F.*
The sap-sucking psyllid, *Aphalara itadori* was permitted for release in 2014 and research for establishment and field impact studies by AAFC in B.C., Alberta and Ontario and by CABI in the UK are ongoing. The selection of release sites in multiple provinces was to cover large variations in climatic conditions and to assess overwintering capabilities of the psyllid. Adult psyllids have successfully overwintered in all three provinces and there has been completion of at least one generation in the field for multiple years following releases. However, to date, no sustained psyllid populations at any single location across all release years have been confirmed. Collections of additional psyllid lines were conducted in 2019 and screening work involving testing these psyllid lines against closely-related North American test-plants is also continuing.

Additional screening studies of a knotweed pathogen as a potential biocontrol agent have been conducted by CABI in the UK. Research has been focussed on two strains of the leaf spot fungus *Mycosphaerella polygoni-cuspidati* and shown the fungus affects all three knotweed species. In host range testing of non-target species however the pathogen was found to infect a related North American test-plant species. Thus, screening of these pathogen strains as classical biocontrol agents was stopped.

**Oxeye daisy (Leucanthemum vulgare)**

No biological control agents exist in B.C. to date for this rhizomatous perennial herb. In 2008, B.C. initiated funding on oxeye daisy with CABI and a test plant list was drafted. Studies have also been conducted into oxeye daisy’s phylogeny and its potential relationship to other desirable daisies. Neither native North American species nor ornamental daisies are found within the same subtribe *Leucantheminae* as oxeye daisy with the exception of Shasta daisy. Ploidy analysis has found a diploid and a tetraploid species of oxeye daisy in North America. The tetraploid *Leucanthemum ircutianum* is more common in Europe while the diploid *L. vulgare* is more common in North America. Both are found in B.C. The potential biological control agents investigated to date can be found on both species of oxeye daisy in Europe. Initial literature and field surveys prioritized eight potential biological control agents, but with testing four were discontinued due to lack of host specificity or impact. Currently, work at CABI concentrates on: the root-mining tortricid moth *Dichrorampha aeratana*; the shoot-mining moth *D. consortana*; and the root galling tephritid fly *Oxyna nebulosa*. Tests on *D. aeratana* are complete and the moth appears to be host specific and effective as shown in an impact study that resulted in a decrease of below ground biomass of potted oxeye daisy plants and number of flowers by 62%. The research is being summarized and a petition will be initiated in 2020 for review by Canadian and U.S.A. regulatory authorities. A shipment of the moths was sent to the AAFC quarantine facility in Lethbridge for use in a host-specificity test involving a native Yukon daisy, and for rearing in anticipation of approval to release. No-choice tests and efficacy experiments continue on *O. nebulosa*. This fly was found to decrease flower heads and reduce height and above-ground biomass of attacked oxeye daisy plants. Similar to *D. aeratana*, a population of *O. nebulosa* was shipped to the AAFC Lethbridge quarantine by CABI in 2019 for testing with the native Yukon daisy and to initiate a rearing colony. Studies to date on *D. consortana* have resulted in low larvae survival. This will be investigated further in 2020.
Russian olive (Elaeagnus angustifolia)

No biological control agents exist in B.C. to date for this flowering shrubby tree. The Russian olive screening project was initiated in 2007 and has been funded by U.S.A. agencies. B.C. began contributing to the project in 2014. This tree has been purposefully grown and sold in North America for a variety of purposes including as a source of nectar for honey bees, but it has since spread aggressively, causing particular problems in riparian habitats. Therefore, the focus has been on finding biological control agents that attack the reproductive capacity of the tree so as to not disrupt use of existing trees. Three potential agents continue to be studied: the shoot-galling mite Aceria angustifoliae; the fruit-attacking moth Anarsia eleagnella; and a recently found shoot-galling mite Aceria eleagnicola. Host specificity tests have been completed for A. angustifoliae and a petition for import and release has been submitted in the U.S. and Canada in November 2019. Initial studies on effectiveness of this agent look promising with a significant reduction in seed production. However, initial host specificity tests of Anarsia eleagnella may indicate a broader host range than required. A lack of survival of some test plant species and difficulty in obtaining an export permit from Iran for further mites has caused a temporary suspension of this work. Initial studies on Aceria eleagnicola have shown the mite has little impact on Russian olive. No further work is planned for this mite. Surveys for additional potential agents are on-going.
REFERENCES

