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Biological Control

BIOLOGY AND BIOLOGICAL CONTROL OF TANSY RAGWORT

Rachel Winston, Carol Bell Randall, Jeff Littlefield,
Mark Schwarzländer, Jennie Birdsall, and Eric Coombs

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The Forest Health Technology Enterprise Team (FHTET) was created in 1995 by the Deputy Chief for State and Private Forestry, USDA Forest Service, to develop and deliver technologies to protect and improve the health of American forests. This book was published by FHTET as part of the technology transfer series.

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Biology and Biological Control of Tansy Ragwort

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CHAPTER 1: INTRODUCTION

Overview

Tansy ragwort (*Jacobaea vulgaris* Gaertner, formerly *Senecio jacobaea* L.) is an exotic biennial or short-lived perennial native to Europe, Siberia, and Asia. This weed was likely introduced to North America in contaminated ship's ballast. It was first recorded in North America in Nova Scotia, Canada in the 1850s and Pennsylvania, U.S. in 1876. By the early 1900's, tansy ragwort had invaded port regions along the western coast: Washington (1901), Oregon (1910), California (1912), and British Columbia (1913). Infestations spread inland via contaminated animal feed, logging equipment, and other human-mediated avenues. In the 1970's, the weed infested more than 3.6 million ha (9 million acres) in the state of Oregon alone. By 1979, the weed could be found in Montana, and it spread to Idaho in 1991. Though currently present in 14 states and 8 Canadian provinces (Figure 1a), tansy ragwort is most problematic in the western U.S. and in Canada.

Tansy ragwort grows under a variety of conditions but is most commonly established in pastures, sparse forests, rangeland, roadsides, burned areas, and other disturbed places (Figure 1b). This species is typically found growing from sea level to 1,500 m (5,000 ft) in elevation in North America and is present on all slopes and aspects, though it prefers southern exposure. Tansy ragwort rosettes can successfully overwinter in cold climates with heavy snow pack. Some of the largest infestations are found in climates with cool, wet weather. Dry summers limit the weed's establishment. Though it is found in a variety of soil types, tansy ragwort grows most aggressively in lighter, well-drained soil, and capitalizes on disturbance.

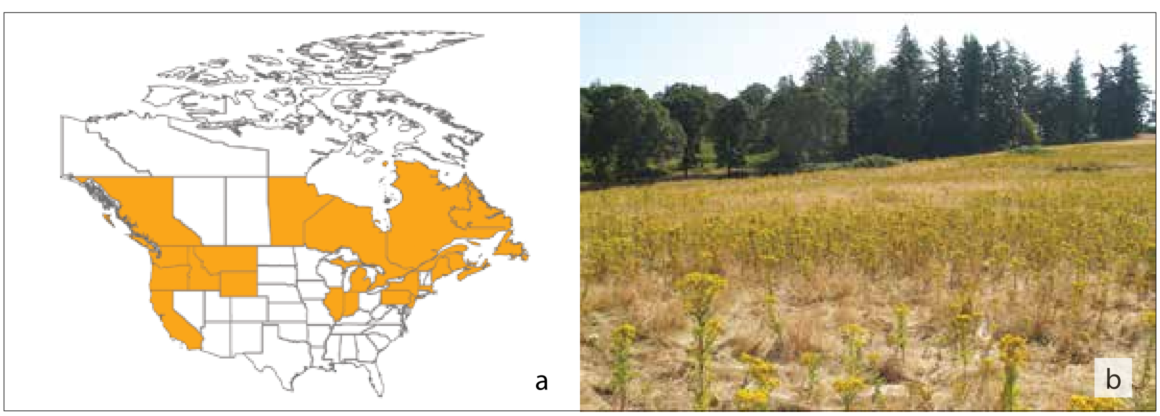


Figure 1 Tansy ragwort a. North American distribution (USDA PLANTS Database); b. Infestation in Oregon (Marianna Szücs, University of Idaho)

All parts of tansy ragwort contain pyrrolizidine alkaloids, substances that are broken down into compounds toxic to cattle, horses, goats and deer. These animals will largely avoid tansy ragwort, but will feed on the plant if not provided a better alternative. The plant becomes much more difficult for animals to detect in dried hay mixtures. Tansy ragwort toxicity is cumulative and, after repeated ingestion, can cause irreversible liver damage, often leading to death. Humans are susceptible to tansy ragwort poisoning as well.

Tansy ragwort infestations are often found on disturbed soils. Once tansy ragwort germinates and forms rosettes, the species is a strong competitor in pastures, rangelands, and natural areas, displacing native and/or more desirable forage species. At its peak densities in the 1970s, it was considered one of the leading causes of economic loss to Oregon agriculture. This was attributed to stock fatalities, detrimental effects of alkaloids on milk production, discoloration and taste-tainting of honey made from tansy ragwort nectar, and to the loss of pasture and rangeland. An aggressive management program was initiated against this weed in the 1900s. Because tansy ragwort invades a wide range of habitats, land managers realized the need for multiple control tools, and a vigorous biological control program was initiated. This manual discusses the biological control of tansy ragwort in the western U.S., within the larger context of an integrated tansy ragwort management strategy.

Classical Biological Control of Weeds

Most invasive plants in the U.S. are not native; they arrived with immigrants, through commerce, or by accident from different parts of the world. These non-native plants are generally introduced without their natural enemies, the complex of organisms that feed on the plant in its native range. The lack of natural enemies is one reason plant species become invasive pests when introduced in areas outside of their native range.

Biological control (also called "biocontrol") of weeds is the deliberate use of living organisms to limit the abundance of a target weed. In this manual, "biological control" refers to "classical biological control," which reunites host-specific natural enemies from the weed's native range with the target weed in its introduced range. Natural enemies used in classical biological control of weeds include different organisms, such as insects, mites, nematodes, and fungi. In the U.S., most weed biological control agents are plant-feeding insects, of which beetles, flies, and moths are among the most commonly used.

Biological control agents may attack a weed's flowers, seeds, roots, foliage, and/or stems. Effective biological control agents may kill the weed outright, reduce its vigor and reproductive capability, or facilitate secondary infection from pathogens—all of which reduce the weed's ability to compete with other plants. Root- and crown-feeding biological control agents are usually more effective against perennial plants that primarily spread by root buds. Alternatively, flower- and seed-feeding biological control agents are typically more useful against annual or biennial species that only spread by seeds.

There are advantages and disadvantages to biological control of weeds as a management tool (Table 1).

Table 1 Advantages/disadvantages of classical biological control as a weed management tool

ADVANTAGES	DISADVANTAGES
Target specificity	Will not work on every weed in every setting
Continuous action	Irreversible
Long-term cost-effective	Protracted time until impact is likely
Integrates well with other control methods	Not all exotic weeds are appropriate targets
Generally environmentally benign	Uncertain "non-target" effects in the ecosystem
Self dispersing, even into difficult terrain	Unpredictable level of control; does not eliminate weed

To be considered for release in North America, it is crucial that biological control agents are host specific, meaning they must feed and develop only on the target weed; or in some cases, on a few closely related plant species. They must never feed on any crop or any rare plant species. Tests are necessary in order to ensure that the biological control agents are effective and that they will damage only the target weed. Potential biological control agents often undergo more than five years of rigorous testing to ensure that host specificity requirements are met.

The United States Department of Agriculture's Animal and Plant Health Inspection Service Plant Protection and Quarantine (USDA-APHIS-PPQ) is the federal agency responsible for providing the testing guidelines and authorizing the importation of biological control agents into the United States. The Canadian Food Inspection Agency (CFIA) serves the same role in Canada. Federal laws and regulations are in place to minimize the risks to native plant and animal communities associated with introduction of exotic organisms to manage weeds. The Technical Advisory Group (TAG) for Biological Control Agents of Weeds is an expert committee with representatives from regulatory agencies, federal land management offices, environmental protection agencies from the U.S., and representatives from Canada and Mexico. TAG reviews all petitions to import new biological control agents into the U.S. and makes recommendations to USDA-APHIS-PPQ regarding the safety and potential impact of prospective biological control agents (for more information, please refer to the TAG manual cited in Chapter 1 References at the end of this manual). Weed biological control researchers work closely with USDA-APHIS-PPQ and TAG to accurately assess the environmental safety of potential weed biological control agents and programs. In addition, some states in the U.S. have their own approval process to permit field release of weed biological control agents. The Canadian counterpart to TAG is the Biological Control Review Committee (BCRC) which uses the North American Plant Protection Organization's (NAPPO) Regional Standards for Phytosanitary Measures (RSMP) number 7 (NAPPO RSMP NO.7) as their review/petition requirement.

Code of Best Practices for Classical Biological Control of Weeds

Biological control practitioners have adopted the International Code of Best Practices for Biological Control of Weeds. The Code was developed in 1999 by delegates and participants of the Tenth International Symposium for Biological Control of Weeds to improve the efficacy of and reduce the potential for negative impacts from biological control. In following the Code, practitioners reduce the potential for causing environmental damage through the use of biological control by voluntarily restricting biocontrol activities to those most likely to result in success.

International Code of Best Practices for Classical Biological Control of Weeds[1]

1. Ensure that the target weed's potential impact justifies release of non-endemic agents
2. Obtain multi-agency approval for target
3. Select agents with potential to control target
4. Release safe and approved agents
5. Ensure that only the intended agent is released
6. Use appropriate protocols for release and documentation
7. Monitor impact on the target
8. Stop releases of ineffective agents or when control is achieved
9. Monitor impacts on potential non-targets
10. Encourage assessment of changes in plant and animal communities
11. Monitor interaction among agents
12. Communicate results to public

[1] Ratified July 9, 1999, by the delegates to the X International Symposium on Biological Control of Weeds, Bozeman, MT

Although weed biological control is an effective and important weed management tool, it does not work in all cases and should not be expected to eradicate or completely remove the target weed. Ideally, biological control should be integrated with other chemical, mechanical, and/or cultural methods of weed control to improve overall weed control success.

Biological Control of Tansy Ragwort

One of the key desired characteristics of an introduced biological control agent is host specificity. As described above, this is determined by testing to ensure the potential biological control agent feeds only on the target weed and nothing else, or only a few additional species. The testing procedure has become more rigorous with time. The first testing usually involves species closely related to the target weed. For tansy ragwort, whose genus was recently changed from *Senecio* to *Jacobaea*, the most closely related species are other individuals in the same tribe (Senecioneae) which includes plants in the new *Jacobaea*, individuals remaining in *Senecio*, and individuals in the genus *Packera*. All plants in the genus *Jacobaea* are not native to North America. However, there are 46 species (and numerous subspecies and varieties) of native *Senecio* in North America. In addition, there are 54 species (and numerous subspecies and varieties) of *Packera* native to North America. Many of these could potentially be impacted by tansy ragwort biocontrol agents.

In order for any biological control agent to be approved for release in the United States or Canada, researchers must demonstrate that the agent will not feed and develop on these native species, or other related plants. Following a series of lengthy and involved host specificity testing, in 1959 the cinnabar moth *Tyria jacobaeae* (L.) became the first agent approved and released in the U.S. against tansy ragwort (Figure 2). Though this defoliating moth proved effective at reducing tansy ragwort stands at some locations in the Northwest, the tansy ragwort biocontrol program continued to expand with the subsequent identification and research of additional agents. By 1969, three species had been approved for release in the U.S. as classical biological control agents of tansy ragwort. As of 2011, an additional moth is approved in Canada, and four additional flea beetle species are present but not approved for redistribution on tansy ragwort in Canada (one of which is also present in the northwestern U.S.). Care must be taken to ensure any unapproved species is not inadvertently collected and distributed along with the approved agents. All five of these U.S.-unapproved insects are described in greater detail in Chapter 3.

Figure 2 Adult *Tyria jacobaeae* (Laura Parsons and Mark Schwarzländer, University of Idaho)

Integrated Weed Management

The most effective weed management programs often employ a variety of approaches and weed control methods at different times and at different sites (termed Integrated Weed Management or IWM) over a long period of time. Weed management activities available to managers include education and prevention, chemical (herbicides), mechanical (hand-pulling or mowing), cultural (grazing or fire), and biological control. IWM relies on the development of realistic weed management objectives, accurate weed identification and mapping, and post-treatment monitoring to answer the question: Are current weed-management activities meeting the weed-management objectives?

Land managers choose weed control methods that will enable them to achieve their weed management goals in the most cost-effective manner. No single weed control method will enable managers to meet their tansy ragwort management objectives in all environments or instances. Control method(s) employed in integrated weed management will depend on the size and location of the infested area and specific management goals (e.g., eradication vs. weed density reduction). Small patches of tansy ragwort may be eliminated with a persistent herbicide program, but large infestations will often require the use of additional control methods. A combination of control methods, such as biological control with supplemental cultural practices or chemical controls, consistently applied through time, is usually necessary to attain and maintain weed management goals for tansy ragwort, especially when it infests large acreages.

Is Biological Control of Tansy Ragwort Right For You?

When biological control is successful, biocontrol agents behave like a pest species of the target weed: they increase in abundance until they suppress (or contribute to the suppression of) the target weed. As local weed populations are reduced, biological control agent populations also decline due to starvation and/or dispersal to other target weed infestations.

As stated in Table 1, biological control is not always effective in every weed system or at every infestation. We recommend that you develop an integrated weed management program in which biological control is one of several weed control methods used. Here are some questions you should ask before you begin a biological control program:

Is my management goal to eradicate the weed or reduce its abundance?

Biological control does not eradicate target weeds, so it is not a good fit with an eradication goal. However, depending on the target weed, biological control agent used, and land use, biological control can be effective at reducing the abundance of a target weed to an acceptable level.

How soon do I need results: this season, one to two seasons, or within five to ten years?

Biological control takes time to work, so another weed management method may be a better choice if you need to show short-term results. Generally, it can take one to three years after release to confirm that biological control agents are established at a site, and even longer for agents to cause significant impacts to the target weed. In some weed infestations, 5-30 years may be needed for biological control to reach its weed-management potential.

What resources can I devote to my weed problem?

If you have only a small weed problem (few infested acres), weed control methods such as herbicides and/or hand pulling, followed by annual monitoring for re-growth, may be most effective. These intensive control methods may allow you to achieve rapid control and prevent the weed from infesting more area. However, if an invasive weed is well-established over a large area, and resources are limited, biological control may be your most economical weed control option. Other more costly weed control methods can be reserved for high priority treatment areas, such as travel corridors where the weed is more likely to readily disperse.

Is the weed the problem or a symptom of the problem?

Invasive plant infestations often occur where desirable plant communities have been disturbed. If the disturbance continues without restoration of a desirable, resilient plant community, biological control may not solve your weed problems.

The ideal biological control program:

1. Is based upon an understanding of the target weed, its habitat, land use and condition, and management objectives
2. Is part of a broader integrated weed management program
3. Has considered all weed control methods and determined that biological control is the best option based on available resources and weed management objectives
4. Has realistic weed management goals and timetables
5. Includes resources to ensure adequate monitoring of the target weed, the vegetation community, and populations of biological control agents

About This Manual

This manual provides information on tansy ragwort and each of its biological control agents. It also presents guidelines to establish and manage biological control agents as part of an integrated tansy ragwort management program.

Chapter 1: Introduction provides introductory information on tansy ragwort (including its distribution, habitat, and economic impact) and biological control.

Chapter 2: Getting to Know Tansy Ragwort provides detailed descriptions of the taxonomy, growth characteristics and features, invaded habitats, and occurrence of tansy ragwort in the United States. It also describes how to differentiate tansy ragwort from common tansy and other tansy ragwort-related plants which look alike.

Chapter 3: Biology of Tansy Ragwort Biological Control Agents describes biological control agents of tansy ragwort, including information on each agent's native range, original source of releases in North America, parts of plants attacked, life cycle, description, destructive stages, host specificity, known non-target effects, habitat preferences, and availability. This chapter is particularly useful for identifying biological control agents in the field.

Chapter 4: Elements of a Tansy Ragwort Biological Control Program includes detailed information and guidelines on how to plan, implement, monitor, and evaluate an effective tansy ragwort biological control program. Included are guidelines and methods for:

- Selecting and preparing biological control agent release sites
- Collecting, handling, transporting, shipping, and releasing biological control agents
- Monitoring biological control agents and vegetation

Chapter 5: An Integrated Tansy Ragwort Management Program discusses the role of biological control in the context of an integrated tansy ragwort management program.

The Glossary defines technical terms frequently used by those involved in tansy ragwort biological control.

Literature Cited lists the publications utilized to compile this manual.

Appendices:

I. Related Senecioneae Species Native to North America
II. Related Exotic Senecioneae Species Present in North America
III. Troubleshooting Guide: When Things Go Wrong
IV. PPQ Form 526: Interstate Transport Permit (Sample Form Only)
V. Sample Biological Control Agent Release Form
VI. Tansy Ragwort Qualitative Monitoring Form
VII. General Biological Control Agent Monitoring Form
VIII. Tansy Ragwort Quantitative Monitoring Form
IX. Tansy Ragwort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form

Chapter 2: Getting to Know Tansy Ragwort

Taxonomy

Tansy ragwort belongs to the sunflower family (Asteraceae) and the tribe Senecioneae. Until recently, the plant was known as *Senecio jacobaea* L. in the genus *Senecio*, one of the largest and most widespread genera in the world (1,000+ species). However, recent molecular work has resulted in a reorganization of the plants within this group. Though taxonomic relationships within the tribe are still uncertain, tansy ragwort is now recognized as a member of the genus *Jacobaea*, and is now *Jacobaea vulgaris* Gaertner.

The members of *Jacobaea* differ genetically from *Senecio*, however, there is no discernible difference in their botanical traits. Similar to *Senecio*, *Jacobaea* species range from annual forbs to subshrubs. They have single to clumped stems and alternate leaves with variable margins. Like all other members of the sunflower family, *Jacobaea* species produce flower heads, or capitula, that are an aggregation of many individual flowers (Figure 3a). These flowers, called florets, are clustered together and attached to a receptacle. There are two types of florets: disc and ray (Figure 3b, 3c). Some species produce only one type, while others (like tansy ragwort) produce both. The receptacle and florets are enclosed by modified leaves called involucral bracts. Each floret produces one seed (achene) from early to late summer. Seeds often have a tuft of whitish hairs (pappus) on one end, similar to those on dandelion seeds (Figure 3d).

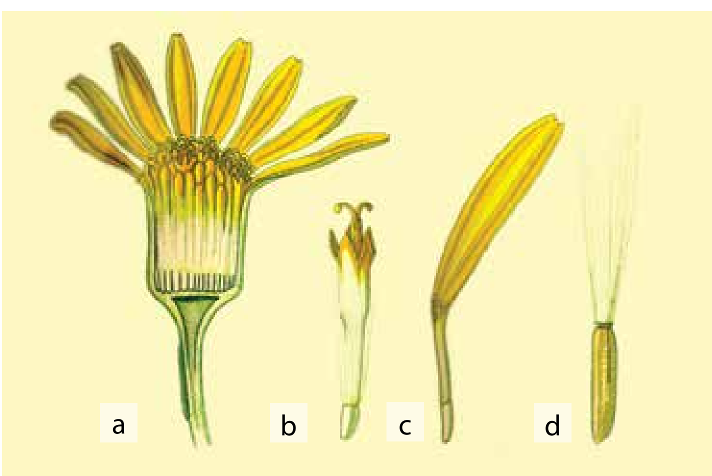


Figure 3 Tansy ragwort a. capitulum; b. disc floret; c. ray floret; d. seed with pappus (all Prof. Dr. Otto Wilhelm Thomé Flora von Deutschland, Österreich un der Schweiz 1885, Gera, Germany, www.biolib.de; © expired, permission granted by Kurt Stueber)

Related Species in North America

The tribe Senecioneae (which includes *Jacobaea*, *Packera*, *Senecio*, and ~117 other genera) is the best starting point for identifying North American species related to tansy ragwort. As of 2011, the USDA PLANTS database recognized 54 native *Packera* species, 46 native *Senecio* and 9 exotic *Senecio* as being established in North America (not including tansy ragwort; see Appendix 1 and 2, respectively). Both native and exotic *Packera* and *Senecio* species have numerous subspecies and varieties.

Tansy Ragwort

Scientific Name

Jacobaea vulgaris Gaertner (previously *Senecio jacobaea* L.)

Common Names

Tansy ragwort, ragwort, tansy, stinking Willy, tansy butterweed, fleur de St. Jacques

Classification

Kingdom	Plantae	Plants
Subkingdom	Tracheobionta	Vascular plants
Superdivision	Spermatophyta	Seed plants
Division	Magnoliophyta	Flowering plants
Class	Magnoliopsida	Dicotyledons
Subclass	Asteridae	
Order	Asterales	
Family	Asteraceae	Aster family
Tribe	Senecioneae	Groundsel
Genus	Jacobaea	
Species	Jacobaea vulgaris Gaertn.	Tansy ragwort

Description

At a Glance

Herbaceous biennial (winter annual or short-lived perennial under certain conditions) typically growing 30-90 cm (1-3 ft) tall. The root system consists of one to several soft, fleshy roots. Leaves are deeply lobed to pinnately toothed, alternate, and 7½-20 cm (3-8 inches) long. Stems arise singly or in clumps and branch near the top with multiple inflorescences. Flowering occurs from July to September. Flower heads consist of yellow disc (center) and ray (outer) florets. Ray flowers (usually 13) resemble petals and grow 8-20 mm (⅓-¾ inch) long (Figure 4). Seeds are topped by a fine pappus.

Roots

Roots of tansy ragwort may resemble taproots early in the life of the plant, though these typically give way at 1 to 2 months of age to a fibrous system consisting of a cluster of up to 100 roots/crown. Each root is soft, fleshy, white, and approximately 1-2 mm (up to 1/12 inch) in diameter (Figure 5). Roots may extend 30 cm (12 inches) deep with very fine and short root branches occurring at wide intervals.

Tansy ragwort is capable of re-sprouting from the root crown. Though this occurs primarily after injury, undamaged individuals may also sprout numerous stems from a single crown. Rotting of crown connective tissue enables each stem to form a distinctive plant, and up to 20 stems have been observed from one crown. Root fragments may also give rise to new plants; pieces as small as 1½ cm (⅔ inch) have regenerated under greenhouse conditions.

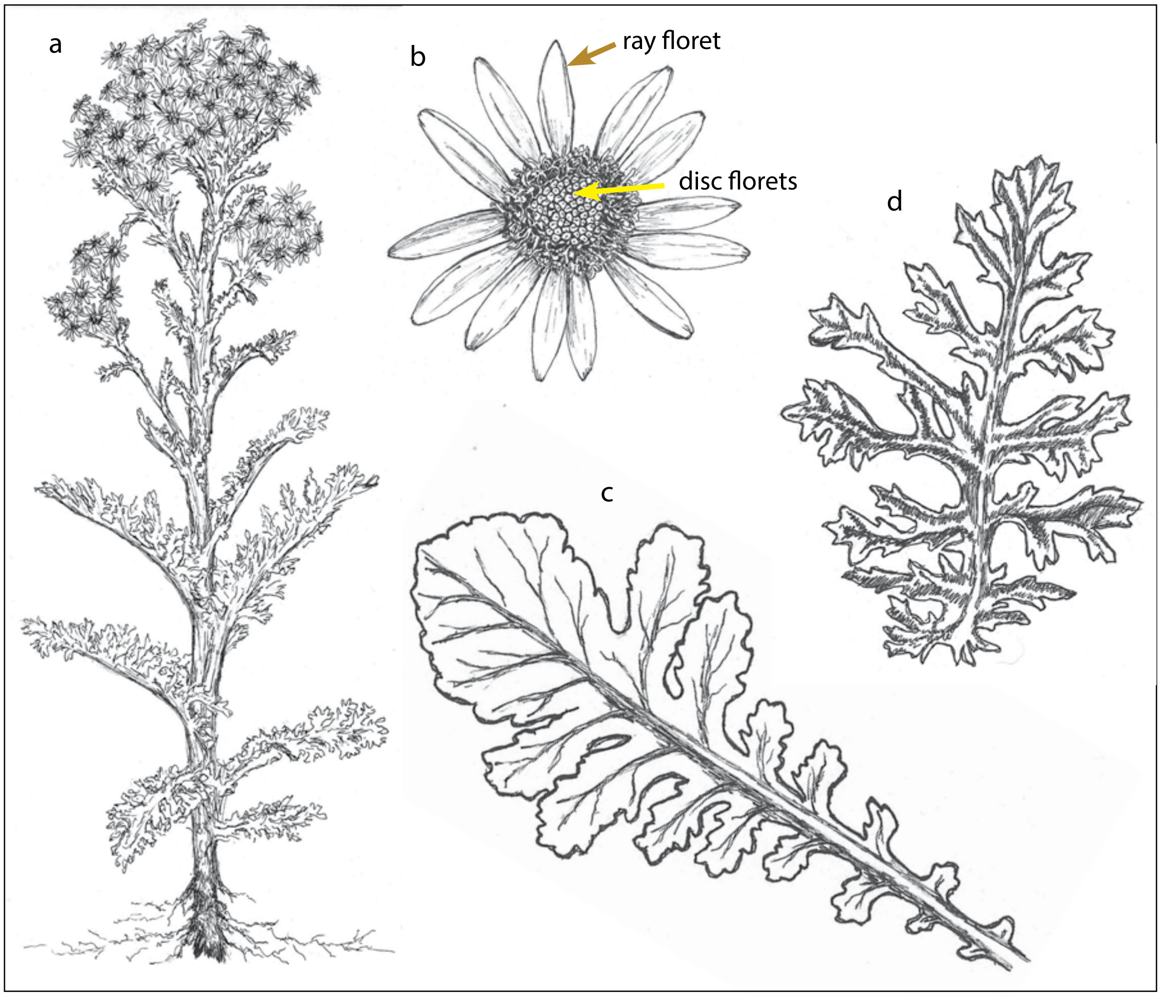


Figure 4 Tansy ragwort a. plant, b. flower, c. rosette leaf, d. stem leaf (Rachel Winston, MIA Consulting)

Figure 5 Tansy ragwort a. root system (Eric Coombs, Oregon Department of Agriculture); b. plant (Jeff Littlefield, Montana State University)

Leaves

Rosette leaves are stalked, deeply lobed with rounded partitions, and 7-20 cm (3-8 inches) long by 2-6 cm (¾-2½ inch) wide (Figure 6a). Rosette leaves often die back as the plant bolts and flowers. Stem leaves alternate along the stem, are bi- or tri-pinnately toothed (Figure 6b), and decrease in size as they approach the top of the stem. Midway up the stem, leaves no longer have petioles and clasp the stem (Figure 6c). The leaf surface is typically hairless, but may be slightly woolly during early development.

Stems

Plants may reach 1.8 m (6 ft) in height, though 30-90 cm (1-3 ft) is typical. Stems are rigid and grow singly or in clumps from a semi-woody crown. Only the upper half of stems branch, giving rise to inflorescences (Figure 7a). Stems are furrowed, and may be either hairless or lightly cottony (Figure 7b). Stems (especially near the base of plants) may occasionally be reddish-tinged (Figure 7c).

Flowers

Tansy ragwort inflorescences occur in clusters of 20-300 flower heads at the end of branch tips. Heads are 12-25 mm (½-1 inch) in diameter and consist of yellow ray and disc florets (Figure 8a). There may be 12-15 (but usually 13) ray flowers around the periphery, each 8-20 mm (⅓-¾ inch) long. Unopened ray flowers are rolled and extend straight up from the receptacle (Figure 8b). Disc florets (50-60) are cylindrical tubes found in the center of the flower head (Figure 8a). Bracts (typically 13) enclosing the receptacle are tipped in black (Figure 8c). Flowering occurs from July through October.

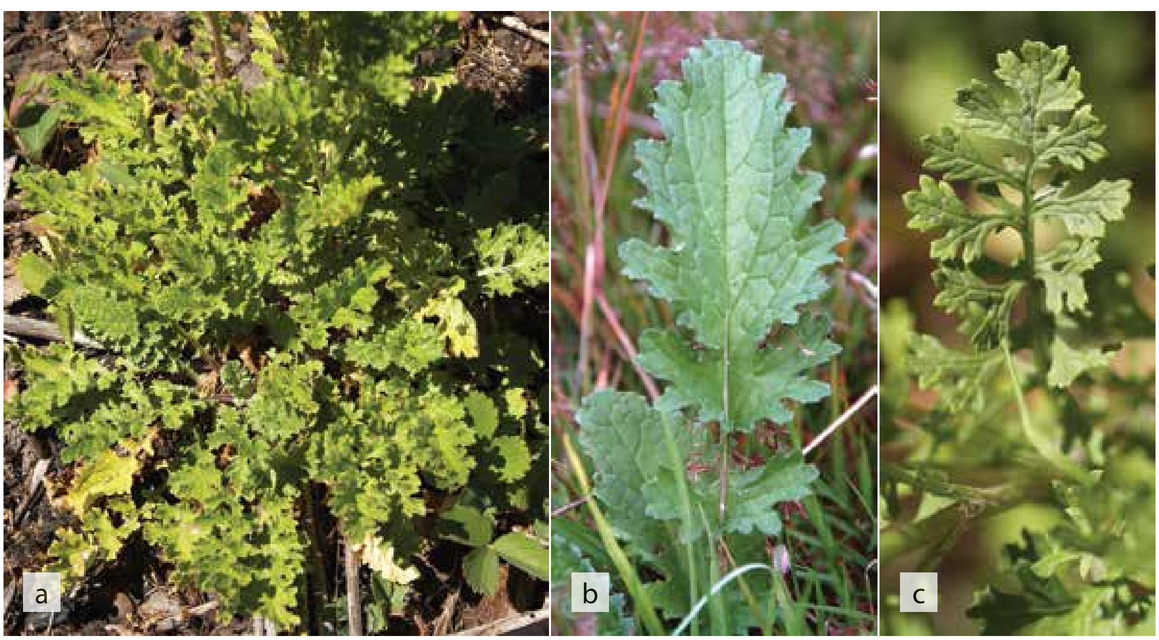


Figure 6 Tansy ragwort a. rosette; b. rosette leaf; c. stem leaf (all Marianna Szücs, University of Idaho)

Figure 7 Tansy ragwort a. plant (Marianna Szücs, University of Idaho); b. stem (H. Zell); c. red stem near base of plant (© 2009 Zoya Akulova)

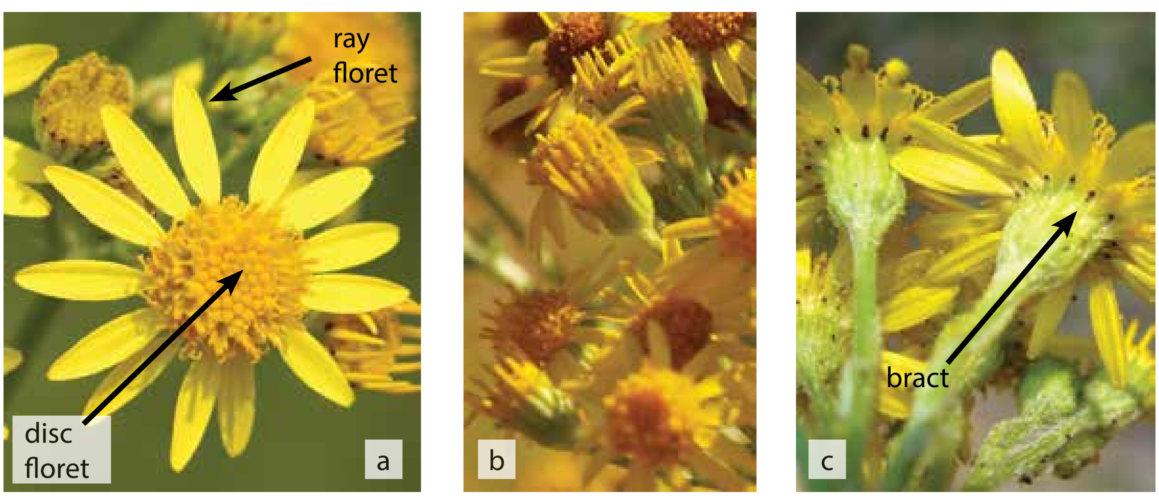


Figure 8 Tansy ragwort a. mature flower head (Strobilomyces); b. immature flower heads (Marianna Szücs, University of Idaho); c. bracts (© 2009 Zoya Akulova)

Fruits and Seeds

Fruits are single-seeded achenes that are brown, ribbed, and 2 mm (1/10 inch) long. Achenes of ray flowers are hairless while the ridges of disc flower achenes are lined with tiny hairs. Achenes of both are topped by a fine pappus that is 2-3 times as long as the seed and resembles that of dandelions (Figure 9a). The pappus readily detaches from ray flower achenes; consequently, achenes topped with persistent pappus have typically arisen from disc flowers. Seed production varies depending on environmental conditions, but one plant is capable of producing 3,500 to 150,000 seeds (up to 75 per seed head). Tansy ragwort is self-incompatible; it depends on pollination services (typically insects) for fertilization of seeds.

Biology and Ecology

Tansy ragwort seed can be dispersed short distances by wind (typically <5 m or 16 ft), and longer distances by humans, other animals, and water. Barbed pappus hairs of disc flower achenes are easily entangled in fur, feathers, clothing, and machinery. Disc achenes are released shortly after maturation, while ray achenes are often retained by the parent plant for months after maturity. Disc seeds do not have a long period of dormancy; germination has been documented within a few days of ripening. Germination of ray seeds can be somewhat longer. This difference in seed dispersal and germination rate by tansy ragwort achene type may contribute to the invasion success of this species worldwide. Both types of seeds may remain viable in the soil for up to eight years.

The life history of tansy ragwort varies depending on climatic conditions, with two life cycles predominant in the western U.S. In coastal zones of the Pacific Northwest, which are characterized by mild and wet winters, seed germination begins in autumn. Rosettes develop and put on considerable growth during the winter. The following spring, rosettes continue to grow and the root system expands. Plants often become dormant during the hot, latter part of summer. Flowering may occasionally occur the first year, but is usually delayed until the second. In this manner, tansy ragwort in the Coastal Pacific Northwest behaves as a biennial. Bolting typically occurs in early spring of the second year, followed by flowering from July to September. Plants senesce and release seed throughout the fall and winter (Figure 9b).

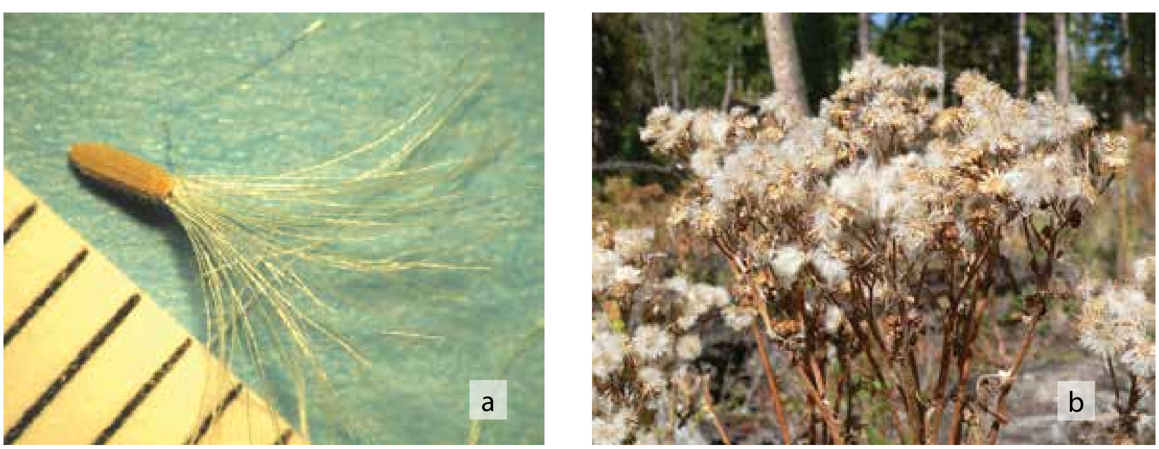


Figure 9 Tansy ragwort a. achene with pappus (© 2009 Zoya Akulova); b. senescing plant (Jeff Littlefield, Montana State University)

The Intermountain West (including Montana, northern Idaho, eastern Oregon, and eastern Washington) is characterized by shorter 6-month growing seasons and cold, snowy winters. Because of the short duration of the growing season in the Intermountain West, tansy ragwort plant growth is slower than in the Coastal Pacific Northwest, and it may act more like a perennial requiring three or more years to develop from a seedling to a flowering plant. Seed germination typically begins in spring following snowmelt. Seedlings increase in size throughout the summer months, and only those with at least 4-5 rosette leaves successfully overwinter. Growth is suspended in the winter months. Tansy ragwort plants typically bolt in early summer, and flowering takes place from July to October. Seeds are released throughout the fall and winter.

Seedlings (Figure 10) are highly susceptible to competition for light, nutrients, space, and moisture. Tansy ragwort rosettes in both climates grow horizontally, shading out and killing competing vegetation beneath rosette leaves. As plants bolt, rosette leaves die back, creating open space around stems that is readily inhabited by new tansy ragwort seedlings.

Figure 10 Tansy ragwort seedlings (Jeff Littlefield, Montana State University)

Vegetative reproduction of tansy ragwort is usually triggered by disturbance or damage to the parent plant (e.g. mowing or defoliation by the cinnabar moth). New stems sprout either from cut root fragments or from the root crown. Subsequent rotting of the crown connective tissue enables each stem to form a distinctive plant. It is therefore difficult to distinguish plants developed vegetatively from those arising via seed.

Distribution

Tansy ragwort is currently present in 14 states and 8 Canadian provinces (Figure 1a, repeated here in Figure 11a), tansy ragwort is primarily a problem weed in the western U.S. and in Canada. It is listed as noxious in nine states and two Canadian provinces (Figure 11b).

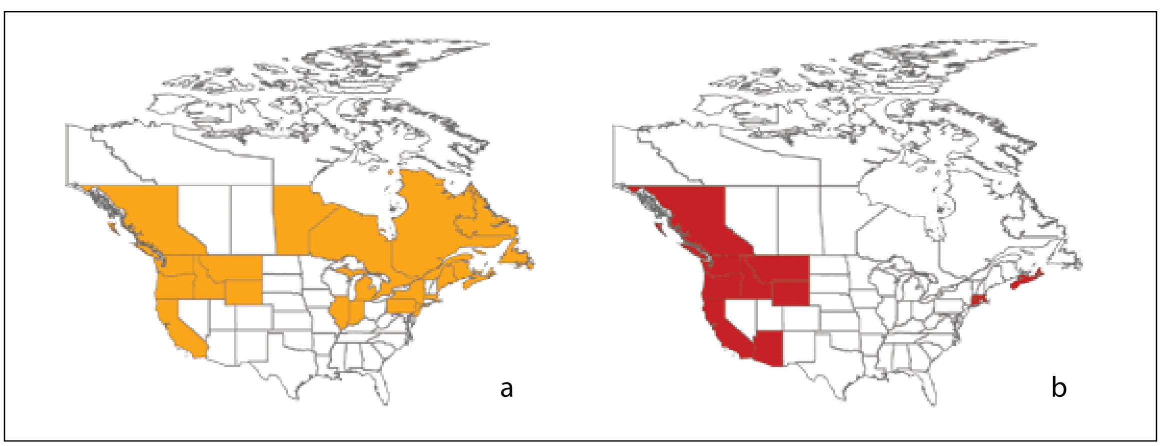


Figure 11 States and provinces where tansy ragwort is a. established; b. declared noxious (INVADERS, USDA PLANTS)

Commonly Confused Species

The species perhaps most frequently confused with tansy ragwort is common tansy (*Tanacetum vulgare* L.). Both are exotic weeds in the western U.S. and Canada, sometimes occurring side by side. Both species have dissected leaves, flower heads consisting of yellow florets, and both can form dense monocultures (Figure 12). Unlike tansy ragwort, common tansy leaves are more finely dissected with pointier teeth, has only disc florets (no showy ray florets) with a maximum head diameter of 1 cm (<½ inch), has a creeping root system, and has very aromatic foliage when crushed.

The sunflower family (Asteraceae) is one of the largest families in the world; there are numerous species in North America that have flowers similar to tansy ragwort. However, the combination of large, open, and yellow flower heads with disc and ray florets and thick leaves that are deeply lobed with rounded teeth helps differentiate tansy ragwort (Figure 13a-c) from look-alikes (Figure 13d-f). Of the 54 *Packera* species and 55 *Senecio* species present in the U.S. and Canada (see Appendix 1 and 2), many do not occur in the northwestern U.S. where tansy ragwort is problematic. Of those with ranges in this region, most do not have lobed or toothed leaves like tansy ragwort (Figure 14a-b), or they have very small and dissimilar flower heads (Figure 14 c-d). The *Senecio* or *Packera* species most closely resembling tansy ragwort are described in Tables 2 and 3.

Figure 12 Infestations of a. tansy ragwort (Joseph M. DiTomaso, University of California - Davis, Bugwood.org); b. common tansy (Steve Dewey, Utah State University, Bugwood.org)

Figure 13 Tansy ragwort a. plant (Jeff Littlefield, Montana State University, Bugwood.org); b. capitulum (Strobilomyces); c. leaf (Marianna Szücs, University of Idaho) (Figure 13 continued on next page)

Fig 13 (Continued from previous page) Common tansy d. plant (Steve Dewey, Utah State University, Bugwood.org); e. capitula (Steve Dewey, Utah State University, Bugwood.org); f. leaf (Mary Elen Harte, Bugwood.org)

Figure 14 North American *Senecio* differing from tansy ragwort due to dissimilar (a-b) leaves or (c-d) flower heads. a. *S. pudicus* and b. *S. soldanella* (Mary Elen Harte, Bugwood.org); c. *S. sylvaticus* (Richard Old XID Services, Inc., Bugwood.org); d. *S. vulgaris* (Joseph M. DiTomaso, University of California - Davis, Bugwood.org)

Table 2 Tansy ragwort look-alike native *Senecio* species in the U.S. and Canada. Top three photos credit Mary Elen Harte, Bugwood.org; bottom photo David Monniaux.

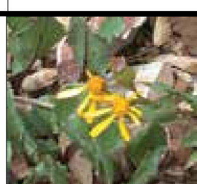
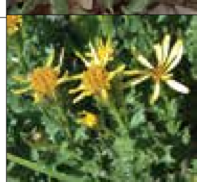
SPECIES	IMAGE	FEATURES DIFFERENT FROM TANSY RAGWORT
Showy alpine ragwort *S. amplectens* Native		Typically found in high alpine and very rocky surroundings (rockslides), which is habitat not often invaded by tansy ragwort though they may occasionally co-occur along trails or in moist clearings. The plant is lower growing than tansy ragwort (60 cm or 2 ft maximum) and has mostly basal leaves tinged in purple and nodding flower heads.
Dwarf mountain ragwort *S. fremontii* Native		Typically found in high alpine and very rocky surroundings (rockslides), which is habitat not often invaded by tansy ragwort though they may occasionally co-occur. *S. fremontii* is lower growing than tansy ragwort (40 cm or 1½ ft maximum) with stiffer succulent-like leaves. Flower heads of *S. fremontii* usually only possess 8 ray florets.
Tall ragwort *S. serra* Native		Capable of growing at far higher elevations than tansy ragwort (3,350 compared to 1,500 m) but in similar mesic habitat. Both species may co-occur. Leaves of *S. serra* are much longer and thinner with only very fine teeth. Flower heads of *S. serra* usually possess only 5-8 ray florets, rather than the 13 of tansy ragwort.
Arrowleaf ragwort *S triangularis* Native		Typically prefers more shade than tansy ragwort, but both can be found growing together. Leaves are strongly triangular in shape, with the widest portion near the stem. Margins are more finely toothed than tansy ragwort. Flower heads of *S. triangularis* usually possess only 8 ray florets and appear 2-3 weeks earlier in the growing season.

Table 3 Tansy ragwort look-alike *Packera* species in the U.S. and Canada. Photos top to bottom: Stan Shebs; Barry Breckling © 2009; Walter Siegmund; Douglas W. Jones; Susan McDougall, USDA PLANTS database; Dave Powell, USDA Forest Service, Bugwood.org

SPECIES	IMAGE	FEATURES DIFFERENT FROM TANSY RAGWORT
Lobeleaf grounsel *P. multilobata* Native		Typically grows in drier climates than tansy ragwort, but some populations may overlap. *P. multilobata* leaves are most dense basally and often have red midveins. While still lobed, they are thicker, more linear, and grayish compared to tansy ragwort. Flower heads are often similar, though ray florets of *P. multilobata* may curl downward.
Alpine groundsel *P. pauciflora* Native		Grows in subalpine and alpine regions but may overlap with tansy ragwort growing in mountain meadows. Basal leaves of *P. pauciflora* are more oval-shaped and not as wavy as tansy ragwort. Stem leaves are more deeply divided. All florets of *P. pauciflora* are often tinged with red or orange, and ray florets are more toothed or missing.
Balsam groundsel *P. paupercula* Native		Found in meadows, moist woods, foothills to moderate elevations in the mountains of northern North America, overlapping with tansy ragwort. Stems of *P. paupercula* are typically single and narrow. Basal leaves are toothed but more oval than tansy ragwort. Stem leaves are more deeply lobed but much smaller and more sparse.
Prairie groundsel *P. plattensis* Native		This species only overlaps with tansy ragwort growing in tallgrass prairie habitat of North America. Seed heads of *P. plattensis* are similar to tansy ragwort, and stems are slightly hairy. Leaves differ in that they are deeply lobed but so long and narrow as to appear fernlike.
Falsegold groundsel *P. pseudaurea* Native		May overlap with tansy ragwort growing in mountain habitat such as meadows, streambanks, and woodlands in northern and central North America. Capitula are similar; however, leaves differ. Basal leaves are oval and on long petioles. Stem leaves are deeply lobed but clasp the stem and are very small and linear.
Rocky Mountain groundsel *P. streptanthifolia* Native		May overlap with tansy ragwort growing in moist to moderately dry open areas, woods, and mountains from mid- to high elevations. Though capitula are similar, stems of *P. streptanthifolia* are more narrow and have very few leaves. Basal leaves are oval with slender petioles. Stem leaves are lobed but may clasp the stem and are sparse.

CHAPTER 3: BIOLOGY OF TANSY RAGWORT BIOLOGICAL CONTROL AGENTS

History

The tansy ragwort classical biological control program is one of the oldest in the United States. This project began in 1959 with the release of the cinnabar moth *Tyria jacobaeae* in California. This moth established successfully, and additional biocontrol agents were subsequently tested and released in the U.S. and Canada. By 1969, three insect species had been approved and introduced to the U.S. as classical biocontrol agents of tansy ragwort: a moth, a beetle, and a fly. As of 2011, another moth is approved in Canada, and four unapproved beetles are present but not approved for redistribution on tansy ragwort in Canada (one of which is also present in the northwestern U.S.). Care must be taken to ensure any unapproved insect or plant pathogen is not inadvertently collected and distributed along with the approved biocontrol agents.

Basic Insect Biology

Insects are the largest, most diverse class of animals. An understanding of basic insect biology and anatomy will help land managers recognize and identify the insects used as biological control agents of tansy ragwort. The insects used in this biological control program have complete metamorphosis, which means they exhibit a life cycle with four distinct stages: egg, larva, pupa, and adult (Figure 15a). Adult insects have an exoskeleton (a hard external skeleton), a segmented body divided into three regions (head, thorax, and abdomen), three pairs of segmented legs, and may have one or two pairs of wings (Figure 15b). The head of an adult insect has one pair each of compound eyes and antennae.

Immature insects have an exoskeleton that must be shed in order for them to grow to the next stage. The process of an insect shedding its "skin" in order to grow is called molting, and larval stages between molts are called "instars." Larvae generally complete three to five instars before they molt into the pupal stage (Figure 16). During the pupal stage, insects change from larvae to adults. Insects do not feed during the pupal stage.

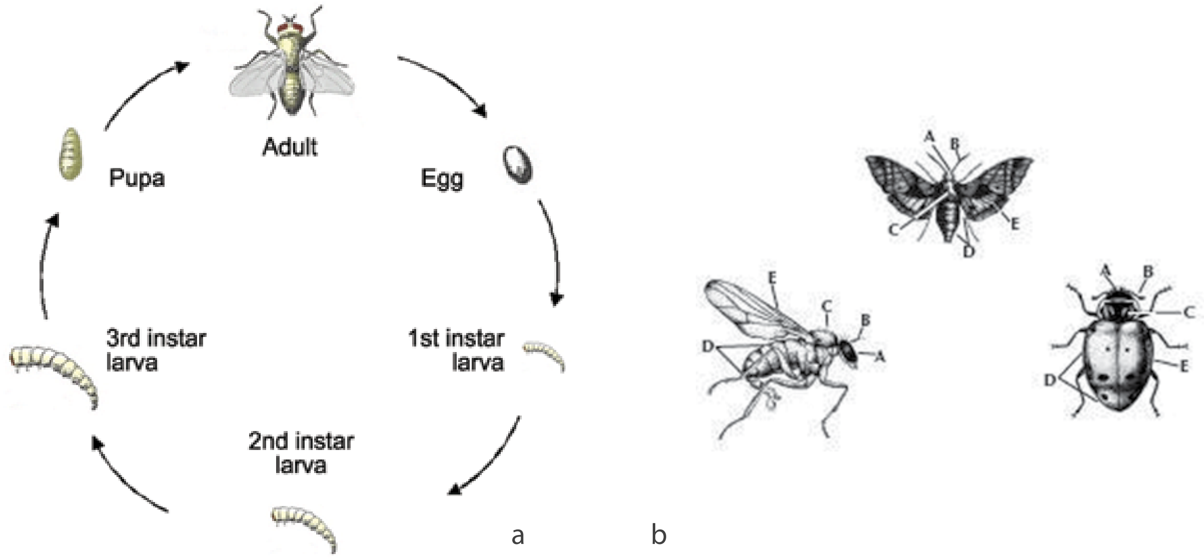


Figure 15 Basic entomology: a. complete metamorphosis of an insect (Linda Wilson); b. body parts of adult insects: A. head; B. antenna; C. thorax; D. abdomen; E. wing (Biocontrol of Weeds in the West)

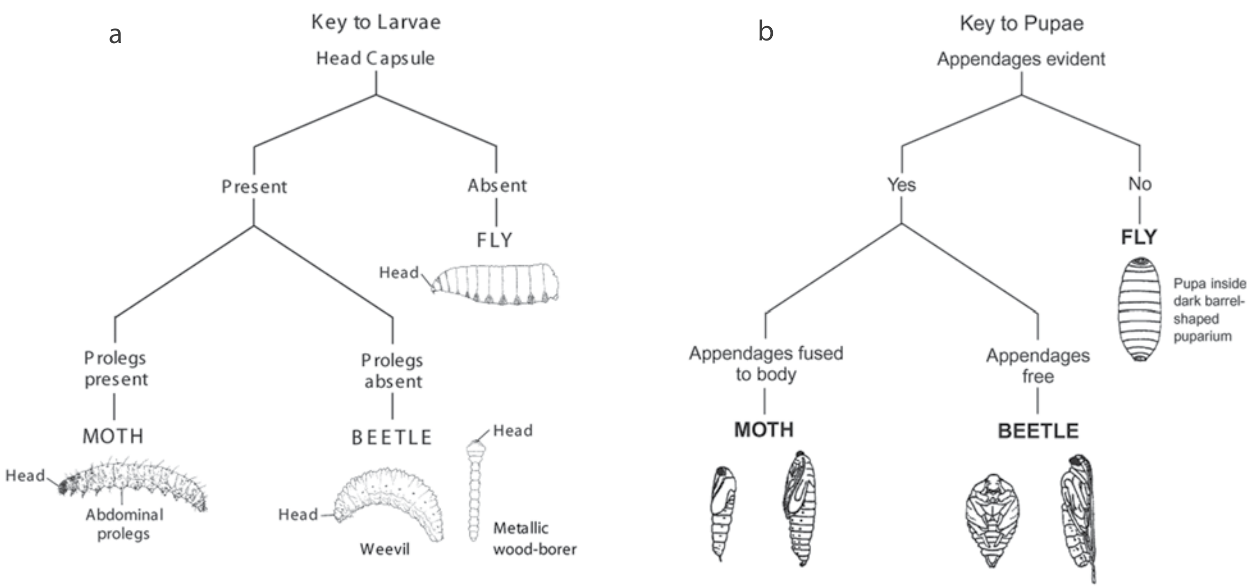


Figure 16 Simple identification key to differentiate tansy ragwort biological control agents by insect order as a. insect larvae; b. insect pupae (both Linda Wilson)

Butterflies and Moths (Order Lepidoptera)

Adult Lepidoptera have two pair of membranous wings, covered (usually completely) by minute powder-like scales. Antennae are prominent. The larvae (caterpillars) have a toughened head capsule, chewing mouthparts, and a soft body that may have hair-like or other projections, three pairs of true legs, and up to five pairs of abdominal prolegs. The pupal stage of Lepidoptera is known as a chrysalis and is often enclosed in a cocoon.

Beetles (Order Coleoptera)

Most adult beetles are hard-bodied with tough exoskeletons. They have two pairs of wings. The two front wings, called elytra, are thickened and meet in a straight line down the abdomen of the adult insect, forming a hard, shell-like, protective covering. The two hind wings are membranous and used for flight. These are larger and are folded under the elytra when not in use. Beetle larvae are grub or wormlike with three small pairs of legs. Most are pale white with a brown or black head.

Flies (Order Diptera)

Adult true flies are easily distinguished from other orders of insects by their single pair of membranous wings and typically soft bodies. Larvae of most true flies, called maggots, are legless and wormlike. Many insects have the word "fly" in their name, though they may not be true flies. In the common names of true flies, "fly" is written as a separate word (e.g., house fly) to distinguish them from other orders of insects that use "fly" in their name (e.g., butterfly in the order Lepidoptera and mayfly in the order Ephemeroptera).

Tansy Ragwort Biological Control Agents

The three tansy ragwort biocontrol species (one moth, one beetle, and one fly) permitted for release in both the U.S. and Canada are shown in brown boxes in Figure 17. These insects attack three distinct parts of tansy ragwort plants: foliage, roots, and seeds. One stem-boring moth is approved for release in Canada but not in the U.S. (Figure 17, gray box). Four root-feeding flea beetle species are reported on but not approved for redistribution on tansy ragwort in Canada (Figure 17, red box). and one of these has also been documented in the northwestern United States. Each approved species is described in greater detail, listed in the order of its release date within the United States. The species unapproved for release in the U.S. are summarized at the Chapter's end.

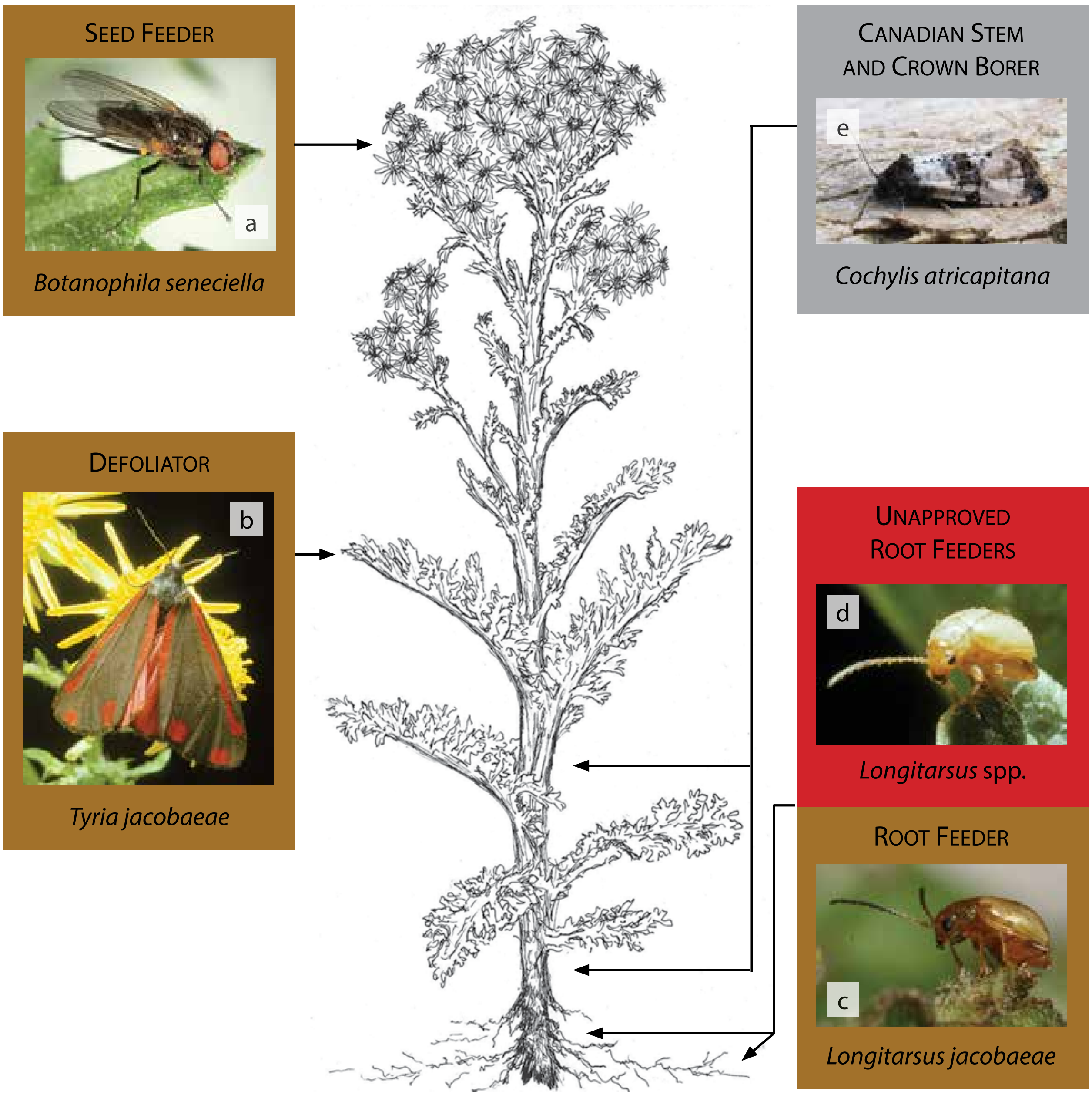


Figure 17 General location of attack for tansy ragwort biological control agents. Brown: tansy ragwort insects approved in both the U.S. and Canada; gray: insect approved in Canada but not in the U.S.; red: insects established in North America but not approved in Canada or the U.S. (Plant: Rachel Winston, MIA Consulting; a. © Malcolm Storey, www.bioimages.org.uk; b. Laura Parsons, University of Idaho; c. Eric Coombs, Oregon Department of Agriculture; d. Mark Schwarzländer, University of Idaho; e. © Geoff Riley)

Tyria jacobaeae

Cinnabar moth

ORDER	Lepidoptera
FAMILY	Arctiidae
NATIVE DISTRIBUTION	Eurasia
ORIGINAL SOURCE	France
FIRST U.S. RELEASE	1959 California
NONTARGET EFFECTS	*S. triangularis, S. seneca, S. vulagris, Packera pseudaurea*
ESTABLISHMENT	CA, MT, OR, WA

Figure 18 Adult *T. jacobaeae* (Laura Parsons, University of Idaho)

Description

Eggs are small (1 mm wide) and bright yellow when new, but turn black with age. Larvae generally develop through six instars. First instar larvae are light brown or orange, while third instars and later are banded orange and black. Mature larvae are up to 25 mm (1 in) long. Adults have black forewings with two red dots and red-lined borders. Hind wings are bright red (Figure 18). Wingspans may be up to 4 cm (1.5 inches), and coloring often fades with moth age.

Life Cycle

Pupae overwinter in loose soil or plant litter. Adults emerge in late spring, mate and lay eggs in clusters on the undersides of tansy ragwort rosette leaves (Figure 19a). Hatching larvae feed on the undersides of rosette leaves (Figure 19b). As tansy ragwort bolts, later instar larvae feed on stem leaves and developing buds, often in groups of 10-30 (Figure 19c). Final instar larvae leave plants in late summer and pupate in suitable locations before overwintering (Figure 19d). There is one generation per year (Figure 20).

Habitat Preference

This species does best in warm, sunny areas with dense tansy ragwort infestations. It is less successful in shady habitats, narrow canyons, saturated soils, locations with harsh winters and little protective snow cover, or over-grazed areas. Because pupae overwinter in shallow soil or plant litter, they are highly susceptible to trampling or predation by rodents or other insects.

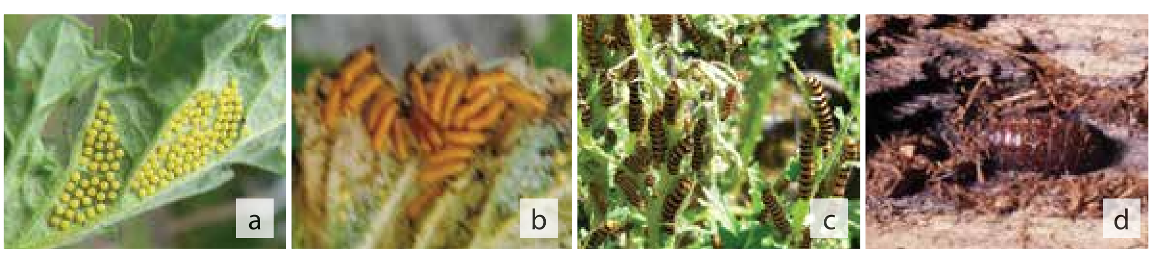


Figure 19 Cinnabar moth a. eggs; b. early instar larvae and mining tunnels; c. late instar larvae feeding gregariously; d. pupa (a, c Jeff Littlefield, Montana State University; b, d George Markin, U.S. Forest Service)

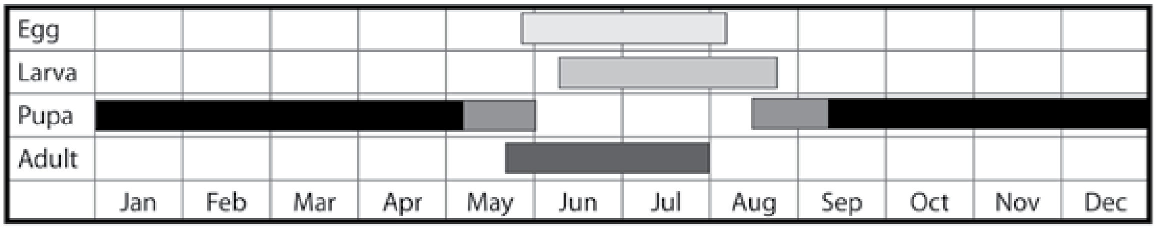


Figure 20 Life cycle of *T. jacobaeae*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the inactive overwintering period. Wide variation due to climate.

Impact

Larvae (Figure 21a) may completely defoliate tansy ragwort plants, leaving behind only bare stems. In milder climates such as the Coastal Pacific Northwest, the weed often re-grows in the autumn and recovers sufficiently to successfully overwinter and reproduce. In the colder, harsher climate of the Intermountain West, frosts usually kills tansy ragwort regrowth before the plants can fully recover, and the moth (Figure 21b) can be more effective in reducing tansy ragwort populations.

Availability

This moth is established at a number of sites throughout the western U.S., and populations can be readily collected from California, Oregon, Montana, and Washington, though tansy ragwort infestations and *T. jacobaeae* populations fluctuate markedly from year to year at most sites. This species should only be redistributed with caution (see Comments below).

Comments

The conspicuous colors of *Tyria* larvae serve as warnings to potential predators. Larvae are capable of sequestering alkaloids from their host for use as toxic defenses against birds and other animals. They are still, however, attacked by parasites, viruses, and pathogens; refer to page 45 in Chapter 4 for guidelines on avoiding the spread of infected individuals.

This moth has been documented attacking species related to tansy ragwort: in particular, the introduced *Senecio vulgaris* and *S. seneca* and the native *S. triangularis* and *Packera pseudaurea*. Tests in Montana demonstrated attack on native species only occurred if tansy ragwort was scarce; however, in Oregon, nontarget feeding occurred even when tansy ragwort was readily available. Consequently, interstate transport of this insect is not permitted. Furthermore, some states have prohibited its redistribution within their borders. Check with your state's department of agriculture, your county weed control authority, or your local extension agent for more information. Where this agent is approved for redistribution, it is imperative to refrain from making releases at sites where known related or susceptible species co-occur.

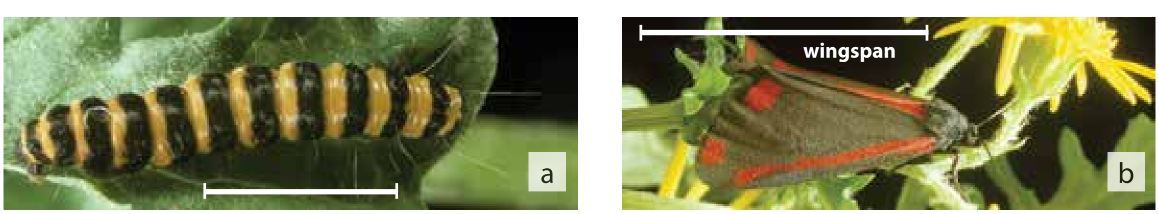


Figure 21 Cinnabar moth a. larva; b. adult (both Mark Schwarzländer, University of Idaho)

Botanophila seneciella

Ragwort seed head fly (= *Hylemyia seneciella*, *Pegohylemyia seneciella*)

ORDER	Diptera
FAMILY	Anthomyiidae
NATIVE DISTRIBUTION	Eurasia
ORIGINAL SOURCE	France
FIRST U.S. RELEASE	1966 California and Oregon
NONTARGET EFFECTS	None reported
ESTABLISHMENT	CA, ID, MT, OR, WA

Figure 22 Adult *B. seneciella* (Laura Parsons, University of Idaho)

Description

Eggs are small, oval in shape, and off-white in color. Maggots pass through three creamy-white instars (Figure 23a). Late instar maggots can be up to 6 mm (¼ inch) long. Pupal chambers are barrel-shaped and dark brown (Figure 23b). Adults (Figure 22) resemble house flies with reddish eyes, dark bodies, and slightly clouded wings that extend beyond their body (they are up to 6 mm or ¼ inch long). The abdomen of males is narrower than that of females.

Life Cycle

Pupae overwinter within loose soil or litter. Adults emerge in spring when tansy ragwort is in the rosette to late bolting stage. Adults lay eggs in young flower buds in late spring and early summer. Hatching larvae burrow into flower buds and feed on developing seeds (one larva per seed head). Attacked seed heads are easily identified—initially by a brown discoloration as florets die and later by the presence of frothy spittle (Figure 23c). Final instar larvae exit seed heads in late summer, leaving behind characteristic exit holes (Figure 23d) and pupate in the soil where they overwinter in puparia. There is one generation per year (Figure 24).

Habitat Preference

This species does well in meadows and forest clearings. Where it is established alongside the cinnabar moth, the ragwort seed head fly is often restricted to scattered tansy ragwort plants growing in habitats less suitable to the moth (e.g. shaded forests or narrow mountain valleys).

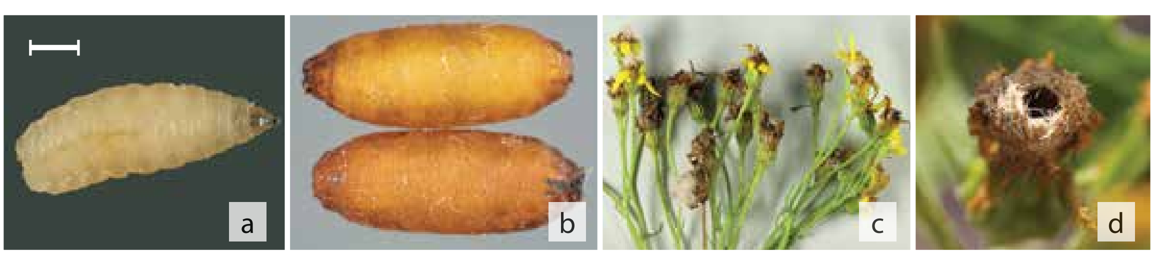


Figure 23 Seed head fly a. larva; b. pupae; c. infested seed heads; d. exit hole (a-c © Malcolm Storey, www.bioimages.org.uk; d Marianna Szücs, University of Idaho)

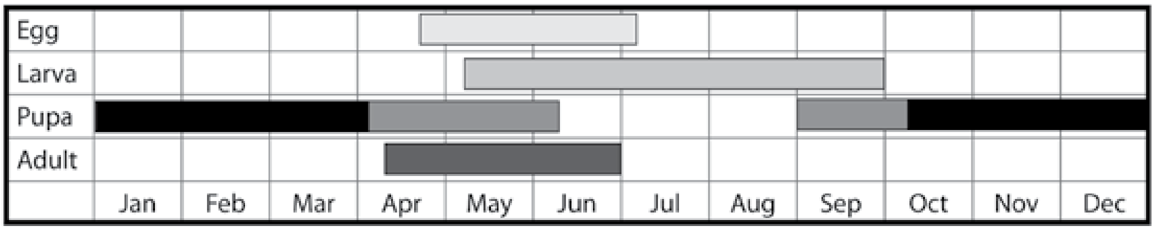


Figure 24 Life cycle of *B. seneciella.* Bars indicate the approximate length of activity for each of the life stages. Black bars represent the inactive overwintering period. Wide variation due to climate.

Impact

Maggots may destroy some or all seeds within attacked seed heads (Figure 25a). Infestation rates of up to 40% of available capitula have been documented in small, isolated tansy ragwort populations, though 5-10% attack rates are more typical. This agent is susceptible to resource competition from the cinnabar moth which also consumes tansy ragwort seed heads or tansy ragwort flea beetle-caused host mortality. Consequently, though the ragwort seed head fly (Figure 25b) is the most widely distributed, it is usually the least abundant and least effective of established tansy ragwort biocontrol agents.

Availability

This fly is established and can be readily collected from tansy ragwort infestations throughout the northwestern United States. Fly populations are smaller than populations of the other tansy ragwort biocontrol agents; the highest densities can be found in isolated tansy ragwort infestations less frequented by the other biological control agents.

Comments

This agent is a strong flier and disperses well after release. It can be found at nearly every tansy ragwort infestation and has been documented travelling 60-120 miles (100-200 km) from points of original distribution in 5-10 years. Despite its ease of dispersion, this agent is the least effective of the three tansy ragwort biological control agents established in the United States. Only the early seed heads are utilized; later-developing capitula generally escape attack. This agent is best used as a complement to the other two.

Figure 25 a. Tansy ragwort seed head attacked by *B. seneciella* and exhibiting typical damage; b. *B. seneciella* adult (both © Malcolm Storey, www.bioimages.org.uk)

Longitarsus jacobaeae

Tansy ragwort flea beetle

Figure 26 *Adult L. jacobaeae* (Eric Coombs, Oregon Department of Agriculture

ORDER	Coleoptera
FAMILY	Chrysomelidae
NATIVE DISTRIBUTION	Eurasia

Both Italian strains

ORIGINAL SOURCE	Italy
FIRST U.S. RELEASE	1968-1970 California
NONTARGET EFFECTS	None reported
ESTABLISHMENT	CA, MT, OR, WA

Swiss strain

ORIGINAL SOURCE	Switzerland
FIRST U.S. RELEASE	1969 CA; 2002 MT
NONTARGET EFFECTS	None reported
ESTABLISHMENT	ID, MT

Description

There are three strains of *L. jacobaeae* presently established in the U.S.: two Italian and one Swiss. All strains are morphologically identical (Figure 26). They differ genetically and in the timing of various stages in their life cycles. All strains have one generation per year. Eggs are small (<1 mm diameter) and whitish-yellow, turning orange with maturity (Figure 27a). Larvae develop through three instars. They are white and may be 1-4 mm (.04-.16 inch) long (Figure 27b). Last instar larvae have brown head capsules. Pupae are white, 2-4 mm (.08-.16 inch) long (Figure 27c). Adults are golden brown and 2-4 mm (.08-.16 inch) long. They have fully developed wings and are capable of flight, though they more often walk and may utilize their enlarged hindlegs to jump when disturbed.

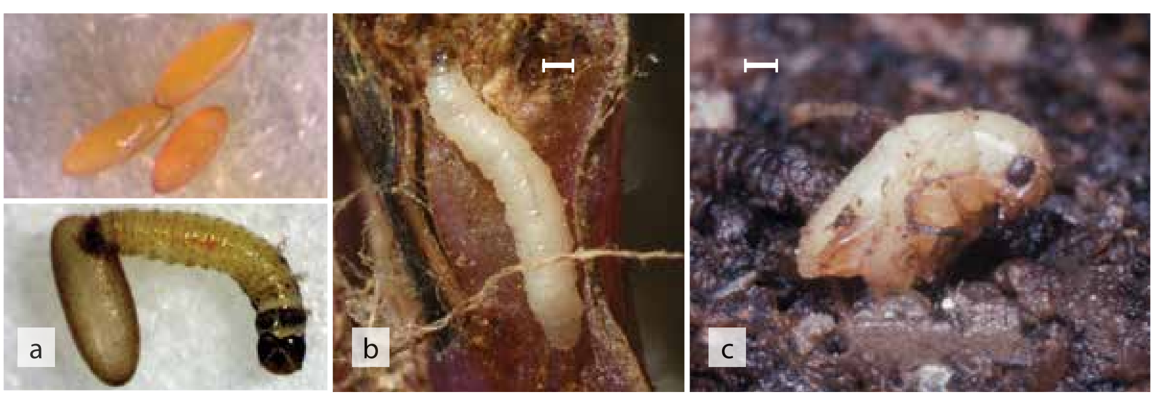


Figure 27 *L. jacobaeae* a. eggs and hatching larva (Ken Puliafico, Montana State University); b. late instar larva (Eric Coombs, Oregon Department of Agriculture); c. pupa (Laura Parsons, University of Idaho)

Life Cycle

Italian CPNW strain

At low elevations in the Coastal Pacific Northwest (CPNW), adult beetles emerge in late spring and feed briefly on tansy ragwort rosettes before entering aestivation (dormancy) for the summer. Adult beetles become active again and feed on tansy ragwort foliage in the cooler/wetter fall. After 2-3 weeks of feeding, adults mate and females lay eggs around the bases of tansy ragwort rosettes, sometimes laying eggs until early spring. Larvae hatch a couple weeks after eggs are laid and mine the leaf petioles and then root crowns of rosettes throughout winter and early spring. In spring, larvae leave root crowns to pupate in the soil (Figure 28).

Italian CAD strain

A cold-adapted strain of the Italian beetle (CAD) was identified by researchers at the University of Idaho. This strain is established in lower numbers at high elevation sites in Oregon and the Intermountain West of the U.S. At these locations, larvae do not aestivate; they continue feeding throughout summer. Pupation occurs in the soil in summer, and adults emerge soon after, laying eggs by late summer/early autumn. Eggs and larvae overwinter (Figure 29).

Swiss strain

Adult beetles emerge in mid- to late summer and feed on tansy ragwort foliage for 2-3 weeks prior to laying eggs around the bases of rosettes. Egg laying may extend into early fall. Eggs overwinter, requiring at least 60 days (80 is optimal) before hatching in the spring. Larvae feed at first in tansy ragwort leaf petioles prior to moving into the root crown. Pupation occurs in the soil in late spring or early summer (Figure 30).

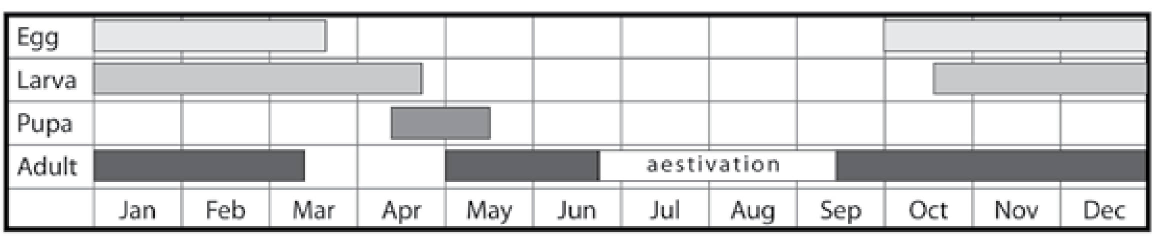


Figure 28 *Life cycle of L. jacobaeae* (Italian CPNW strain). Bars indicate the approximate length of activity for each of the life stages.

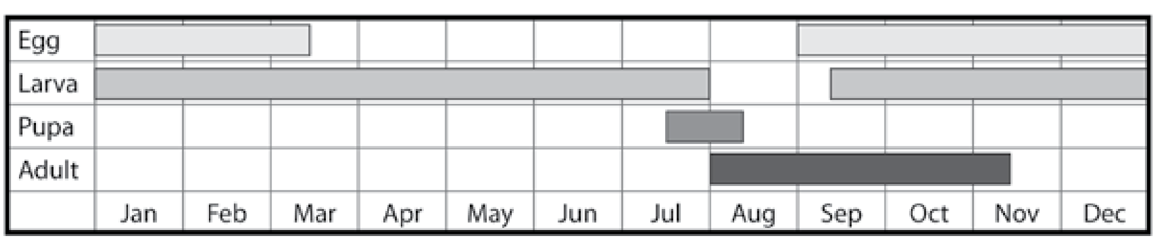


Figure 29 Life cycle of *L. jacobaeae* (Italian CAD strain). Bars indicate the approximate length of activity for each of the life stages.

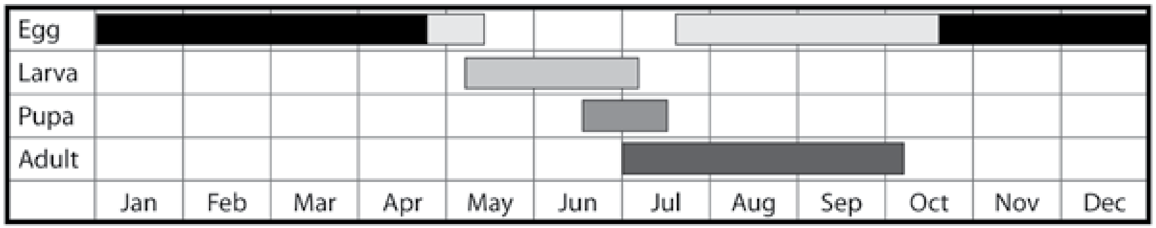


Figure 30 Life cycle of *L. jacobaeae* (Swiss strain). Bars indicate the approximate length of activity for each of the life stages. Black bars represent the inactive overwintering period.

Habitat Preference

All strains of this species do better in dense, unshaded tansy ragwort infestations. Flooding interferes with the larval and pupal stages of the beetle so tansy ragwort infestations in flood plains are less amenable to biological control by this agent. The Italian CPNW strain is best suited for low elevation sites (at or below 400 m or 1,300 ft) with climates characterized by warm summers and mild, moist winters. The Italian CAD strain, currently established at Mt. Hood Oregon and in the Intermountain West of the U.S., is hardier than CPNW populations and can survive at higher elevations (1,000-1,600 m or 3,200-5,200 ft). The Swiss strain does well at elevations higher than 400 m (1,300 ft) characterized by warm summers and cold winters with hard frosts and snow cover. It may be found up to 1,675 m (5,500 ft).

Impact

Adult feeding results in characteristic shot-holes in leaves (Figure 31a). This feeding interferes with photosynthesis and plant metabolism and may decrease the size of tansy ragwort plants. When beetle populations are high and plants are water-stressed, adult feeding can lead to death of tansy ragwort plants, especially seedlings and rosettes. The larval stage is generally the most destructive. Larval mining of the root crown (Figure 31b) depletes energy reserves, can reduce plant reproductive output, or cause death. This biological control agent is credited with the greatest reductions of tansy ragwort populations in the United States (Figure 31c).

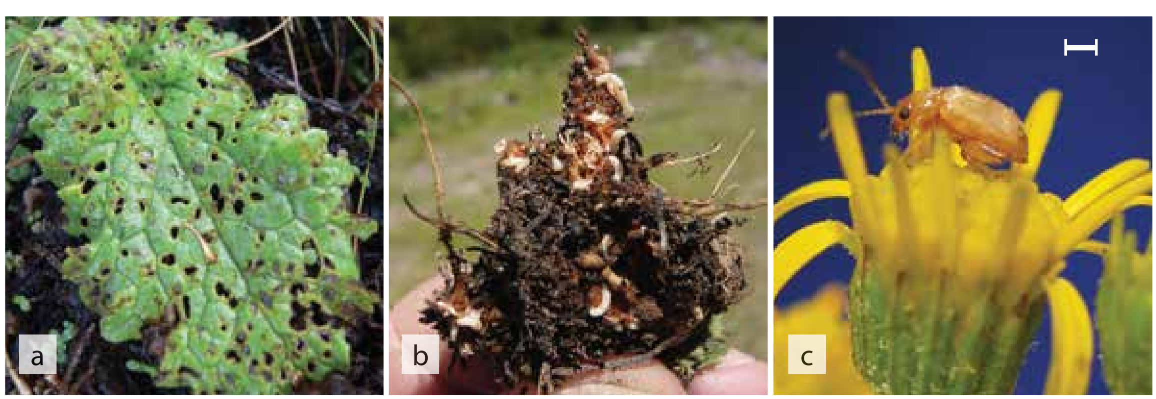


Figure 31 *L. jacobaeae* a. adult damage; b. larvae in roots; c. adult on capitulum (a, b Jeff Littlefield, Montana State University; c Marianna Szücs, University of Idaho)

Availability

The Italian CPNW strain is readily available from the coastal regions of California, Oregon, and Washington. The Italian CAD strain can be collected from the Mt. Hood region of Oregon and portions of Montana, though populations are not as large as those of Italian CPNW beetles. The Swiss strain is established in northern Idaho and western Montana and is rapidly increasing in both states, though populations are limited.

Comments

The flea beetle is the most effective of the three established tansy ragwort biocontrol agents, credited with decreasing plant densities by up to 90% in under 10 years. It disperses fairly well and has been found infesting scattered and small populations of tansy ragwort. The flea beetle does not directly compete with the moth, and both agents can complement each other. Four non-approved *Longitarsus* species have been identified in mixed populations of *L. jacobaeae* in Canada, and one of these in the northwestern U.S. Care should be taken in redistributing this species to ensure only *L. jacobaeae* is collected. See page 32-33 for more information.

Table 4 Traits of biological control agents introduced in the U.S. against tansy ragwort. (Photos: top, Laura Parsons, University of Idaho; middle, © Malcolm Storey, www.bioimages.org.uk; bottom, USDA ARS - European Biological Control Laboratory, Bugwood.org)

BIOLOGICAL CONTROL AGENT	GENERATIONS /YEAR	OVERWINTER	ADULT	EGG	LARVA	PUPA
Tyria jacobaeae Cinnabar moth	One	Pupa in soil		Bright yellow when new, but black with age; 1 mm wide; laid in groups in undersides of rosette leaves	First instar light brown or orange; late instars banded orange and black; up to 25 mm long; 5 (sometimes 6) instars	Pupal chambers dark brown; found in loose soil, litter, or rotting logs
Botanophila seneciella Ragwort seed head fly	One	Pupa in soil		Off-white; small and oval-shaped; laid singly on young buds	Creamy white; up to 6 mm long; three instars	Chambers are dark brown; barrel-shaped; found in soil or plant litter
Longitarsus jacobaeae Tansy ragwort flea beetle	One	Adult, larva, or egg (all o or in plant)		Whitish-yellow and less than 1 mm diameter; laid singly or in small groups on rosette bases	White with brown head capsules; 1-4 mm long; three instars	White; 2-4 mm long; found in soil or plant litter

Table 5 Comparison of U.S.-introduced tansy ragwort biological control agents according to tansy ragwort growth stage. CPNW = Coastal Pacific Northwest; IW = Intermountain West; CAD = Cold-Adapted

Month	Plant Life Stage (CPNW)	Plant Life Stage (IW)	Tyria jacobaeae	Botanophila seneciella	Longitarsus jacobaeae (Italian CPNW)	Longitarsus jacobaeae (Italian CAD)	Longitarsus jacobaeae (Swiss IW)
January	Overwintering rosettes continue to grow and expand root system	First-year and older plants overwinter as rosettes with little growth during this period	Pupae overwinter in soil, litter, or rotting wood	Pupae overwinter in soil or litter	Adults continue laying eggs over winter; hatching larvae feed on root crowns	Eggs and larvae overwinter on snow-covered plants (eggs at bases of rosettes, larvae within roots)	Eggs overwinter at bases of rosettes
February							
March							
April	First-year rosettes continue to grow throughout season; second-year rosettes begin bolting	Seed germination begins; second-year and older rosettes resume growth		Adults emerge (may feed on nectar of nearby plants)	Late instar larvae exit plants and pupate in soil	Larvae continue feeding on rosette leaf petioles and root crown tissue	
May			Adults emerge, mate, and lay eggs on undersides of rosette leaves	Adults lay eggs on immature buds	Newly emerged adults feed on foliage then aestivate		Larvae hatch and feed in rosette leaf petioles
June		First-year rosettes form; some second-year and older rosettes continue to grow; some rosettes bolt/early flower		Egg laying continues; maggots burrow into buds and feed on developing seeds, causing brown discoloration			Larvae feed on root crowns; pupation begins in soil
July	First-year rosettes continue to grow throughout season; second-year plants flower		Egg laying continues; larvae feed on lower leaf tissue		Adults in aestivation	Larvae exit roots to pupate in soil	Adults emerge, feed on foliage, and lay eggs at rosette bases
August		First-year and some older rosettes continue to grow; bolted stems in full flower and begin to set seed; some seed germination may occur	Larvae move up as plants bolt, feeding on foliage and capitula	Maggots continue feeding on seeds, frothy exudate is apparent; maggots begin exiting seed heads to pupate		New adults emerge, feed on new foliage, and lay eggs at rosette bases	Adults continue feeding and laying eggs at rosette bases
September			larvae begin to drop down and pupate in suitable locations				
October	Seed germination begins; flowering plants seed		Pupae overwinter in loose soil, litter, or rotting wood	Pupae overwinter in soil or litter	Adults resume activity, feed on foliage, and lay eggs at rosette bases throughout winter; hatching larvae feed in leaf petioles and stem bases over winter	Hatching larvae feed in root crowns of rosettes	Eggs overwinter at bases of rosettes
November	New rosettes develop and continue to grow over the winter; seeding plants senesce	First-year and some older rosettes overwinter with little growth during this period; bolted stems seed and senesce				Eggs and larvae overwinter on/in snow-covered plants (eggs at bases of rosettes, larvae within roots)	
December							

Unapproved (U.S.) Tansy Ragwort Insects

In addition to the three species described above, one more biocontrol agent is approved for redistribution in Canada but not in the U.S., the moth *Cochylis atricapitana*. Since the 1970s, four more species of *Longitarsus* have been observed in Canada as either adventive species or as successfully established populations after accidental introductions in contaminated releases of *L. jacobaeae*, likely from Europe. These include *L. flavicornis*, *L. ganglbaueri*, *L. gracilis*, and *L. succineus*. *Longitarsus ganglbaueri* has also been observed in the northwestern United States. None of these additional *Longitarsus* flea beetles are approved for redistribution in Canada or the United States. Care must be taken to ensure any unapproved agent is not inadvertently collected and distributed along with the approved agents.

Cochylis atricapitana

Ragwort stem and crown boring moth

ORDER	Lepidoptera
FAMILY	Cochylidae
NATIVE DISTRIBUTION	Europe
INTRODUCED TO CANADA	1990
NONTARGET EFFECTS	None reported
ESTABLISHMENT IN CANADA	BC, NB, NS

Figure 32 Adult *C. atricapitana*, © Geoff Riley

Description and Life Cycle

There are 2-3 generations per year. Overwintering larvae resume activity in spring, feeding on tansy ragwort stems and root crowns. Larvae develop through five instars, are creamy-white to tan, and can be up to 8 mm (0.3 inch) long. Pupation occurs either in the stem or in surrounding soil litter. Pupae are yellowish-brown 7-8 mm (0.27-0.3 inch) long, and enclosed in a white cocoon. Adults emerge in late spring (May-June) as tansy ragwort is bolting and lay creamy-white eggs on the crown or on the underside of tansy ragwort leaves. Adults are small and tent-winged with a wingspan of 12-16 mm (0.5-0.6 inch). The forewings have irregular brown marks flecked with black and grey on a white or yellowish-white background (Figure 32). Females are more pink than males. Hatching larvae mine leaves and petioles while older larvae mine stems and roots crowns. Pupation of the new generation occurs in the plant. Emerging adults lay eggs in similar locations in mid to late summer (July-August). Newly hatching larvae may overwinter, or a third generation may emerge from eggs laid in autumn and overwinter in plant stems.

Comments

Following its 1990 release, this agent established readily in New Brunswick, Nova Scotia, and coastal British Columbia. It was documented spreading up to 15 km in five years after release in Nova Scotia and controlling tansy ragwort at the release site within the same five years. Larval mining suppresses flower formation, stunts plant growth, and may kill plants outright. Further study is required to know the current distribution and impact of this species.

This agent is not approved for release in the U.S. When redistributing U.S.-approved biocontrol agents, particularly from infestations near the Canadian/U.S. border, care should be taken to ensure adults or egg-infested leaves are not accidentally collected.

Additional *Longitarsus* species

Accidental or adventive tansy ragwort flea beetles

ORDER	Coleoptera
FAMILY	Chrysomelidae
NATIVE DISTRIBUTION	Europe
INTRODUCED TO CANADA	1970s
NONTARGET EFFECTS	None reported
ESTABLISHMENT IN CANADA	BC, MB, NS, NL

Figure 33 Adult *L. flavicornis* (Mark Schwarzländer, University of Idaho)

Description and Life Cycle

The accidental or adventive tansy ragwort flea beetles (*L. flavicornis*, *L. ganglbaueri*, *L. gracilis*, and *L. succineus*) very closely resemble and are frequently mistaken for *L. jacobaeae*, especially *L. flavicornis* which differs only in the size of the male genitalia. Though less is known about the biology of the latter three flea beetles, *L. flavicornis* is a highly studied and successful tansy ragwort biological control agent in Australia. It has one generation per year. Larvae mine the petioles, lower leaves, and then root crowns of tansy ragwort where they overwinter. Larvae develop through three instars. They are white with brown head capsules, and may be 1.5-4 mm (.06-.16 inch) long. Pupation occurs in the soil in late spring or early summer. Pupae are white, 2-4 mm (.08-.16 inch) long. Adults emerge in early summer (May-June), feed on tansy ragwort leaves, and lay small yellowish eggs (<1 mm diameter) at the base of ragwort rosettes in late summer. Adults are coppery brown and 2.5-3.5 mm (.10-.14 inch) long (Figure 33). They have fully developed wings and are capable of flight, though they more often utilize their enlarged hindlegs to jump. Newly hatching larvae feed on ragwort stems, root crowns, and roots where they overwinter; occasionally the egg stage overwinters in Canada.

Comments

Longitarsus flavicornis is established in coastal British Columbia in mixed populations with *L. jacobaeae*. It is presumably limited by its need for warmer temperatures and a milder climate. Though this agent has been effective in controlling tansy ragwort in Australia, it reportedly does not have a significant impact on tansy ragwort densities in Canada. *Longitarsus ganglbaueri* has been collected from Manitoba and Nova Scotia and documented in California, Oregon, and Washington. Longitarsus gracilis has been confirmed as established in Nova Scotia and the Okanagan Valley of British Columbia, and *L. succineus* has been documented only in Newfoundland. These four flea beetles are not recommended for redistribution in Canada or the U.S. due to their broad host range. Care should be taken to ensure adults or eggs of these unapproved species are not accidentally collected. Check with your local biological control experts for help with identifying flea beetle species.

CHAPTER 4: ELEMENTS OF A TANSY RAGWORT BIOLOGICAL CONTROL PROGRAM

Before You Begin

The results of using biological control to treat tansy ragwort may vary greatly from site to site for a variety of reasons. Land managers should develop treatment programs that complement management activities and objectives unique to the area. This is accomplished by first understanding the scope of the tansy ragwort problem, defining overall goals for the tansy ragwort management program, and understanding the control methods available for accomplishing the goals.

Determining the Scope of the Problem

The first step should be to develop a distribution map of tansy ragwort at a scale that will allow you to address the problem in a manner consistent with your overall land-management objectives and your weed management resources. The most appropriate scale may encompass a large landscape with many different land owners/ managers, land uses, and site characteristics (Figure 34a). In large management areas with significant tansy ragwort infestations and limited resources, aerial mapping of large patches of tansy ragwort may be sufficient to identify priority areas for additional survey and weed management activities. In other management areas with small, discrete tansy ragwort infestations, or where an infestation's characteristics affect your ability to meet management objectives, your weed-management strategy might have to include more extensive mapping and analysis of the scope of the infestations (e.g. size, density, cover, and location in relation to roads and waterways over time) (Figure 34b).

Defining Goals and Objectives

Defining your weed management goals and objectives is crucial to the development of a successful biological control program. By defining what you want to achieve, you will be able to determine if, when, and where you should use biological control.

As precisely as possible, you must define what will constitute a successful tansy ragwort management program. For example, the goal of ". . . a noticeable reduction in tansy ragwort density over the next ten years. . ." might be achievable, but is subjective and open to observer bias. Alternatively, the goal of " . . . a 50 percent reduction in tansy ragwort stems over the next three years . . ." is more precise and measurable. If your goal is to reduce the abundance of tansy ragwort, then biological control might be an appropriate weed-management tool; however, by

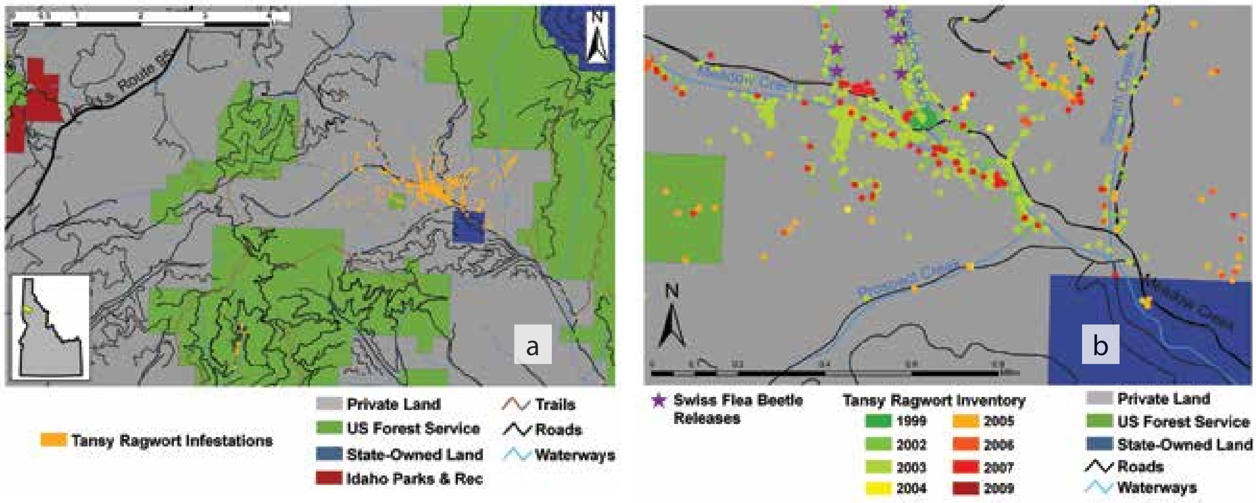


Figure 34 Tansy ragwort inventory. a. Large-scale spanning private, state, and federal land in the Palouse Cooperative Weed Management Area in northern Idaho; b. Fine-scale depicting population proximity to roads/waterways over time and biocontrol releases (data courtesy Potlatch Corporation and Palouse CWMA)

itself biological control will not completely remove tansy ragwort from the landscape. If your goal is to eradicate this weed, then you should plan to employ other weed control techniques instead of, or in addition to, biological control (see Chapter 5 for more details).

Understanding Tansy Ragwort Management Options

Once you determine the scope of your tansy ragwort infestations and define your overall program goals, review the weed management methods available (herbicides, mechanical treatments, cultural practices, and biological control) and determine the conditions (when, where, if, etc.) under which it might be appropriate to use each tool or combination of tools (see Chapter 5). Consult your agency or university biological control expert, cooperative weed management area, or county weed coordinator/supervisor to learn about other tansy ragwort management activities (herbicide use, grazing and mowing programs) underway or planned for your area, and the level and persistence of control that might be achieved by each.

Identify the resources that will be available for weed management activities, and determine if they will be consistently available until you meet your weed management program objectives. If resources are not available, or will not be available consistently, identify what will happen at the treatment site if planned management activities are not implemented. This information will help you determine the best management tools to use as you initiate and continue your integrated tansy ragwort management program.

With a map of tansy ragwort infestations in your management area, an understanding of your land management objectives, and a list of the weed management methods available with the level of control you can realistically expect from each, you can identify the sites where biological control would be a good fit.

Developing, Implementing, and Managing a Tansy Ragwort Biological Control Program

When biological control is deemed suitable for treating your tansy ragwort infestations, there are several important factors to consider. These include selecting appropriate release sites, obtaining and releasing insects, and monitoring the success of the program. These items are discussed in their own sections below. If problems are encountered following the initiation of a biological control program, refer to the troubleshooting guide in Appendix III for potential solutions.

Selecting Biological Control Agent Release Sites

Establish goals for your release site

You must consider your overall management goals for a given site when you evaluate its suitability for the release of biological control agents. Suitability factors will differ depending on whether the release is to be a

- general release, where biological control agents are simply released for tansy ragwort management,
- field insectary (nursery) release, primarily employed for production of biological control agents for distribution to other sites, or
- research release, used to document biological control agent biology and/or the agent's impact on the target weed and nontarget plant community.

A site chosen to serve one of the roles listed above may also serve additional functions over time (e.g., biological control agents might eventually be collected for redistribution from a research release).

Determine site characteristics

Tansy ragwort biological control agents vary in their habitat and climatic preferences. Consider these preferences when determining the location of your release (see Table 6, page 40). In addition, if your biological control program goals involve establishing permanent monitoring sites, which in turn will require regular inspections, consider the site's ease of accessibility, terrain, and slope.

For practical purposes, no tansy ragwort infestation is too large for biocontrol releases; however, it might not be large enough (Figure 35). Very small, isolated patches of tansy ragwort may not be adequate for biological control agent populations to build up and persist and may be better treated with other weed control tactics, such as herbicides or mechanical control. An area with at least 0.40 hectares (1 acre) of tansy ragwort is the minimum size to better ensure a successful biological control agent release site, but larger infestations are more desirable, especially if the land manager hopes to someday use the

Figure 35 Infestation of tansy ragwort not suitable for biocontrol (too small and near a road where land use practices are likely to interfere); Faith Duncan, Forest Service, Bugwood.org

release site as a field insectary. The tansy ragwort infestation should be contiguous, rather than scattered in distant patches, so that biological control agents may disperse more easily. While the tansy ragwort seed head fly is capable of survival in more sparse, scattered tansy ragwort infestations, the cinnabar moth and flea beetle both do best in dense tansy ragwort stands.

Note land use and disturbance factors

Preferred release sites are those that experience little to no regular disturbances. Fallow sites and natural areas are good choices for biological control agent releases. If a site must be disturbed (e.g., mowed or heavily grazed), the activities should not take place during the spring and summer months (and sometimes winter) when most biological control agents are active above ground. Sites where insecticides are used should not be utilized for agent releases. Such sites include those near wetlands that are subject to mosquito control efforts, where grasshopper outbreaks routinely require chemical control, or near agricultural fields that are sprayed regularly. Avoid sites prone to seasonal flooding. Roadside infestations along dirt or gravel roads should also be avoided; dust makes plants less palatable to biocontrol agents and silica may kill larvae. Do not use sites where significant conversion will take place, such as road construction, cultivation, building construction, and mineral or petroleum extraction. Do not use sites where burning or heavy herbicide use occurs regularly.

Survey for presence of biological control agents

Examine your prospective release sites to determine if tansy ragwort biological control agents are already present. If an agent you are planning to release is already established at a site, you can still release it at that site to augment the existing population, but it may be better to release it at another site. You should re-evaluate the release of the planned species if a different species of biological control agent is present.

Record ownership and access

In general, release sites on public land are preferable to sites on private land. If you must release biological control agents on private land, it is a good idea to select sites on land likely to have long-standing, stable ownership and management. Stable ownership will help you establish long-term agreements with a landowner, permitting access to the sites to sample or harvest biological control agents and collect insect and vegetation data for the duration of the project. This is particularly important if you are establishing a field insectary site, because five years or more of access may be required to complete insect harvesting or data collection. General releases of biological control agents to control tansy ragwort populations require less-frequent and short-term access; you may need to visit such a site only once or twice after initial release. When releasing biocontrol agents on private land, it may be a good idea to obtain the following:

- written permission from the landowner allowing use of the area as a release site,
- written agreement with the landowner allowing access to the site for monitoring and collection for a period of at least six years (three years for establishment and buildup and three years for collection), and
- permission to put a permanent marker at the site
- written agreement with the landowner that land management practices at the release site will not interfere with biological control agent activity

The above list can also be helpful for releases made on public land where the goal is to establish an insectary. In particular, an agreement should be reached that land management practices will not interfere with biological control agent activity (e.g. spraying or mechanically destroying the weed infestation). It is often useful to visit the landowner or land manager at the release site annually to ensure they are reminded of the biological control endeavors and agreement.

You may wish to restrict access to release locations, especially research sites and insectaries, and allow only authorized project partners to visit the sites and collect insects. The simplest approach is to select locations that are not visible to or accessible by the general public. To be practical, most if not all of your sites will be readily accessible, so in order to restrict access you should formalize arrangements with the landowner or manager. This will require you to post no-trespassing signs, install locks on gates, etc. (Figure 36).

Another consideration is physical access to a release site. You will need to drive to or near the release locations, so determine if travel on access roads might be interrupted by periodic flooding or inclement weather. You might have to accommodate occasional road closures by private landowners and public land managers for other reasons, such as wildlife protection.

Choosing the Appropriate Biological Control Agents for Release

You should consider several factors when considering which biological control agent to release at a site, including agent efficacy, availability, and site preferences (Table 6).

Agent efficacy

Efficacy refers to the ability of the biological control agent to directly or indirectly reduce the population of the target weed below acceptable damage thresholds or cause weed mortality resulting in control. It is preferable to release only the most effective biocontrol agents rather

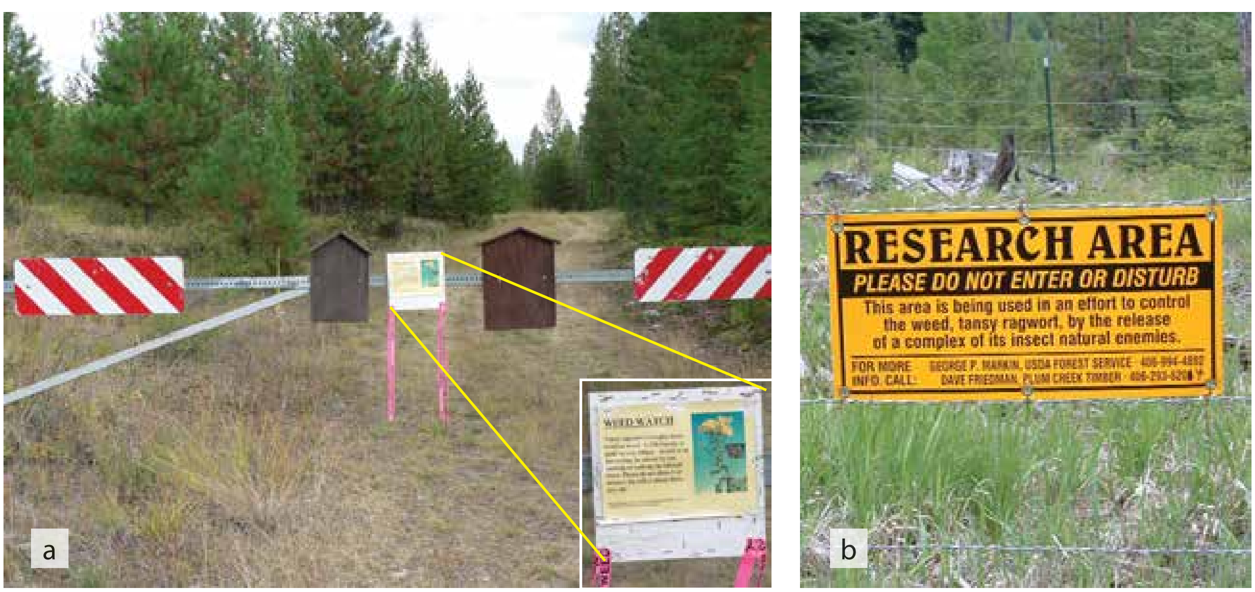


Figure 36 a. Access road closed to the public due to tansy ragwort infestation; b. tansy ragwort biocontrol release research area fenced off from the public (both Jeff Littlefield, Montana State University) than releasing all agents that might be available against a target weed. Consult with local weed biological control experts, neighboring land managers, and landowners to identify the agent(s) that appear(s) more effective given local site characteristics and management scenarios.

Agent availability

All three of the U.S.-approved biological control agents described in this manual are established in the continental U.S. However, availability varies greatly between species and sites. The ragwort seed head fly is the most widely distributed but the least common of the three agents, often found restricted to small tansy ragwort populations under conditions not favored by the cinnabar moth.

Table 6 Summary of general characteristics and site preferences of tansy ragwort biological control agents released in the United States (through 2011)

Agent Characteristics				Site Characteristics	
Species	Part Attacked	Efficacy	Availability	Favorable Conditions	Unfavorable Conditions
Tyria Jacobaeae Cinnabar moth*	Foliage and buds	High if plants cannot recover prior to winter	Widespread and readily available; not permitted for interstate transport; not approved for use in some states where already established (Idaho)	Warm, sunny areas; dense tansy ragwort	Shady areas; narrow valleys;; saturated soils; harsh winters without snow cover; heavily grazed areas
Botanophila seneciella Ragwort seed head fly	Seeds	Low	Widespread, though densities often low' populations fluctuate highly	Meadows and forest clearings; survives in sparse infestations and shady areas	Infestations highly defoliated by cinnabar moth
Longitarsus jacobaeae Tansy ragwort flea beetle	Roots and foliage	High	Widespread; different strains only available in certain locations	Open areas; Italian CPNW is best suited to low elevations and mild, moist winters; Italian CAD survives higher elevations and colder temperatures; Swiss is best suited to high elevations and cold winters with snow cover	Saturated soils or areas prone to flooding; heavily grazed areas

*Be sure to check with your local weed control authority of state department of agriculture to ensure this is a permitted biological control agent in your area

The tansy ragwort flea beetle is well-established throughout northwestern North America, and populations are still expanding in the Intermountain West of the U.S. The Italian CPNW strain is restricted to lower elevation sites in the Coastal Pacific Northwest characterized by warm, dry summers and mild, wet winters in California, Oregon and Washington. The Italian CAD strain is established at high-elevation sites in Oregon and Montana. The Swiss strain is thus far established at high-elevation sites characterized by cold winters with heavy snowpack in Montana and Idaho.

Due to concerns with nontarget attack, the cinnabar moth is restricted from interstate transport. Furthermore, this insect may not be permitted for redistribution in certain states where it is already established; check with your state's department of agriculture, your county weed control authority, or your local extension agent for more information. In states where the insect is already established and is permitted for redistribution, the intense defoliation of the cinnabar moth results in both tansy ragwort and cinnabar moth populations varying dramatically across sites and through time. This agent should not be used where known related or susceptible species co-occur (see Tables 2 and 3 and Appendices I and II for related species).

Federal and state agencies and commercial biological control suppliers may be able to assist you in acquiring agents that are not available but permitted for use in your state (see Obtaining and Releasing Tansy Ragwort Biological Control Agents, below). State departments of agriculture, county weed managers, extension agents, or federal and university weed biological control specialists should be able to recommend in-state sources. In addition, when redistributing approved U.S. biocontrol agents, particularly from infestations near the Canadian/U.S. border, care should be taken to ensure accidentally released agents (*Longitarsus* spp.) or species only approved in Canada (*Cochylis atricapitana*) are not inadvertently collected.

Release site characteristics

General physical site and biological preferences for each agent have been developed from anecdotal observations and experimental data. These are listed in Table 6 to help land managers ensure that insects are released in sites with suitable conditions.

Obtaining and Releasing Tansy Ragwort Biological Control Agents

You can obtain tansy ragwort biological control agents either by collecting them yourself, having someone collect them for you, or by purchasing them from a commercial supplier. Typically, the last two methods will require packaging and shipping from the collection site to your release location (see Collecting Tansy Ragwort Biological Control Agents, page 42).

Factors to consider when looking for sources of biological control agents

You do not need to take a "lottery approach" and release all three biological control agents at a site in the hopes that one of them will work. In fact, some biological control agents will not be available even if you want them, and some have shown to have little or no effectiveness in certain areas. The best strategy is to release the best agent! Ask the county, state, or federal biological control experts in your state for recommendations of agents for your particular region.

If available, biological control agents from local sources are best. Using local sources increases the likelihood that agents are adapted to the abiotic and biotic environmental conditions present, and are available at appropriate times for release at your site. Local sources may include neighboring properties or other locations in your county and adjacent counties. Remember: Interstate transport of biological control agents requires a USDA-APHIS-PPQ permit (see Regulations Pertaining to Tansy Ragwort Biological Control Agents, page 51). Get your permits early to avoid delays.

Some states, counties, and universities have "field days" at productive insectary sites (Figure 37). On these days, land managers and landowners are invited to collect or receive freshly collected tansy ragwort biological control agents for quick release at other sites. These sessions are an easy and often inexpensive way for you to acquire biological control agents. They are good educational opportunities as well, because you can often see first-hand the impacts of various agents on tansy ragwort plant communities.

Typically, field days are conducted at several sites in a state and on several dates. Although designed for intrastate collection and redistribution, out-of-state participants may be welcome to participate (remember that USDA permits are required for interstate movement and release of biological control agents). Contact county weed supervisors, university weed or biological control specialists, or federal weed managers for information about field days in your region.

Collecting Tansy Ragwort Biological Control Agents

Planning and timing of collection is critical. For all species, it is usually most efficient to scout the potential collection site well in advance to ensure your desired species is present and at suitable densities. The species of biological control agent and weather characteristics at your collection and release site will determine the best time in the season to collect. Ensure that all necessary collection supplies are on hand. Also, accurate identification of the biological control agents is essential. General guidelines for collecting U.S.-approved tansy ragwort biological control agents are listed below and in Table 7. For all species, collect only on a day with good weather; insects are usually not active in rainy and very windy conditions.

Figure 37 Field collection day for the tansy ragwort flea beetle; a. collecting; b. collected material; sorting agents from collected material (all Jeff Littlefield, Montana State University)

Table 7 Recommended timetable and methods for collecting tansy ragwort biological control agents in the United States. CPNW = Coastal Pacific Northwest; CAD = Cold-Adapted; IW = Intermountain West.

TYPE	SCIENTIFIC NAME	INSECT STAGE	PLANT STAGE	TIMING	METHOD
Moth	*Tyria Jacobaeae**	Larva	Rosette (early instar) or bud (late instar)	Summer (Jun-Aug)	Hand tapping plants over open pan
Fly	*Botanophila seneciella*	Larvae in seed heads (collection only - not for redistribution)	Late bud or flowering	Late summer (Jul-Sep)	Stand bouquets of infested plants in water surrounded by fine sand until maggots burrow into sand to pupate; store at 4-8 °C (39-46 °F) to overwinter (then see below)
		Pupae in soil	Overwintering rosette	Early spring (Apr-May)	Transfer pupae in sand to new patches
Beetle	*Longitarsus jacobaeae* (Italian low-CPNW)	Adult	Mature or early overwintering	Fall (late Oct-Dec)	Sweep net or insect vacuum
	Longitarsus jacobaeae (Italian CAD)	Adult	Mature or early overwintering	Late summer (Aug-Sep)	Sweep net or insect vacuum
	Longitarsus jacobaeae (Swiss IW)	Adult	Flowering	Late summer (Aug-Sep)	Sweep net or insect vacuum

*Be sure to check with your local weed control authority or state department of agriculture to ensure this is a permitted biological control agent in your area.

Collection methods

Sweep netting:

A sweep net is made of cotton or muslin on a hoop 10 to 15 inches in diameter (25 to 38 cm) attached to a handle 3 feet (0.9 m) long (Figure 38a). They can be purchased from entomological, forestry, and biological supply companies or you can construct them yourself. As their name implies, these are heavy duty nets used to “sweep” insects off tansy ragwort.

A sweep is made by swinging the net through the plant canopy. If insects are suitable for aspiration (see below for a description of aspiration and aspirators), it is best to alternate between sweeping insects off the weed and aspirating them out of the net. Sweep no more than 25 times before aspirating hard-bodied beetles or as few as five times for fragile adult moths and flies. Aspirating or removing insects at regular intervals reduces the potential harm that could result from knocking biological control agents around with debris and reduces the opportunity for predator insects swept up with the biological control agents from finding and devouring the agents.

Sweep netting is an easy and efficient method for collecting insects from the above-ground portion of plants, and is a plausible method for collecting adult flea beetles. The best time for sweeping is during the warmest part of the day (between 1 and 6 p.m.) as this is when the beetles are most active. As stated above, the adult cinnabar moth and ragwort seed head fly are very delicate, and collecting them with sweep nets can be damaging or fatal. Consequently, it is best to use other methods for collecting those species.

Aspirating:

Use an aspirator (Figure 38b) to suck the insects (usually flea beetles) directly from tansy ragwort or the sweep net. This provides selective sorting (no unwanted or unknown material is inadvertently collected). A variety of aspirators can be purchased from entomological, forestry, and biological supply companies, or you can construct them yourself. For the latter, make sure that tubing reaching your mouth is covered by fine-mesh screening, so that insects and small particles are not inhaled.

Hand-picking or tapping:

Simply pick the insects from foliage by hand, or tap them into a net or tray using a tool such as a racquet. Forceps or tweezers may be helpful. Hand-picking works best for stationary or slow-moving insects, such as cinnabar moth larvae.

Vacuuming:

A leaf blower with reverse capability can be equipped with a nylon mesh strainer on the inside mouth of the blowing tube (held in place with a rubber band or bungee cord, Figure 38c) and put in reverse to suck up insects. This method is particularly useful for collecting adult flea beetles from tansy ragwort rosettes. Rocks or debris vacuumed up may harm collected adults; consequently, this method should be restricted to collecting agents from foliage only. Adding rosette leaves to the net gives beetles substrates to crawl and hide on and reduces the strength of the vacuum. Sack contents should subsequently be aspirated to separate adult flea beetles from unwanted material.

Methods by species

Moths:

The cinnabar moth, *Tyria jacobaeae*, is best collected in the larval stage by tapping or shaking plants over an open pan. Hand-picking can be very time consuming, while sweeping collects unwanted material extensively and damages the soft-bodied larvae. Early-instar larvae can be

Figure 38 Collection tools: a. sweep net; b. aspirator; c. insect vauum (a-b: Laura Parsons, University of Idaho; c. Eric Coombs, Oregon Department of Agriculture)

collected (via tapping/shaking) from tansy ragwort rosette leaves in early summer. Late instar larvae are most easily collected from bolted plants in midsummer. Collecting early instar moth larvae is recommended because high densities of the moth larvae may strip all suitable foliage from tansy ragwort plants, leading to starvation during the late-instar larval stage. Adult moths are extremely fragile and should not be collected as all methods may result in injury.

Some populations of the cinnabar moth on the West Coast of the U.S. are infested with a virus and a *Nosema* pathogen. Larvae with pinkish colored droppings are infected by the pathogen and should not be collected. It is best to collect rosette leaves with egg masses attached. Leaves/eggs should be surface-sterilized (5 parts bleach to 95 parts water for 1 minute before running water for 5 minutes) prior to their transfer to new, uninfested tansy ragwort populations. Keep in mind that this species is not approved for use at all locations (see Choosing Appropriate Biological Control Agents for Release above).

Flies:

Sweeping adult ragwort seed head flies is possible, though is generally not the best way to collect flies for redistribution. Adult flies are fragile and can be damaged during sweeping or aspiration. Moving bouquets of fly-infested tansy ragwort seed heads into uninfested tansy ragwort patches is an effective means of redistributing the agent. However, moving seed heads from one site to another may inadvertently spread new tansy ragwort seeds (from potentially different genotypes) and make the tansy ragwort problem worse. The safest means of collecting and redistributing *B. seneciella* is to collect pupae. Bouquets of infested plants can be kept alive in flasks of water (small-mouth jars prevent emerging maggots from falling in the water and drowning). Flasks are placed in open buckets amid a thick layer of very fine sand or loose peat moss during late summer. After maggots exit seed heads and burrow into the sand, the sand is transferred to a cooler and stored at 4-8 °C (39-46 °F) to overwinter. Sand with pupae can then be placed into uninfested patches of tansy ragwort in early spring.

Beetles:

Tansy ragwort flea beetles, *Longitarsus jacobaeae*, are best collected in the adult stage either via sweeping (with or without an aspirator) or with an insect-collecting vacuum. Utilizing a sieve to sift beetles from debris helps make sorting easier. The Italian CPNW strain is best collected in the fall, while both the Italian CAD strain and the Swiss strain can be collected in late summer.

Containers for Tansy Ragwort Biological Control Agents

The manner in which biological control agents are handled during transportation to the release site will affect whether they will survive and multiply at the new site. To reduce mortality or injury, it is best to redistribute the agents the same day they are collected.

Following collection, insects need to be transferred to containers intended to protect them and prevent them from escaping. Containers should be rigid enough to resist crushing but also ventilated to provide adequate air flow and prevent condensation. Unwaxed paperboard cartons are ideal for cinnabar moth larvae and ragwort flea beetles. They are rigid, permeable to air and water vapor, and are available in many sizes.

As an alternative, you can use either light-colored, lined or waxed-paper containers (e.g., ice cream cartons are particularly suitable, see Figure 39) or plastic containers, providing they are ventilated. Simply cut holes in the container or its lid, and cover the holes with a fine mesh screen.

Figure 39 Field collected cinnabar moths in transport container (George Markin, Forest Service)

Untreated paper bags (lunch bags) work well for transporting agents short distances. However, they are fragile and offer little physical protection for the agents within, must be sealed tightly to prevent the agents from escaping, and some biological control agents are capable of chewing through them. Do not use glass or metal containers; they are breakable and make it difficult to regulate temperature, air flow, and humidity.

Fill the containers two-thirds full with crumpled paper towels or tissue paper to provide a substrate for insects to rest on and hide in and to help regulate humidity. Include a few fresh sprigs of tansy ragwort foliage (as food) before adding the agents. Tansy ragwort sprigs should be free of seeds, flowers, dirt, spiders, and other insects. Do not place sprigs in water-filled containers; they may crush the insects, or if the water leaks, it will likely drown your biological control agents. Seal the container lids either with masking tape or label tape. If you are using paper bags, fold over the tops several times and staple them shut. Be sure to label each container with (at least) the biological control agent(s) name, the collection date and site, and the name of the person(s) who did the collecting.

Transporting Tansy Ragwort Biological Control Agents

Keep the containers cool at all times

If you sort and package the agents while in the field, place the containers in large coolers with frozen ice packs. Do not use ice cubes unless they are contained in a separate, closed, leak-proof container. Wrap the ice packs in crumpled newspaper or bubble wrap to prevent direct contact with containers. Place extra packing material in the coolers to prevent the ice packs from shifting and damaging the biological control agent containers. As an alternative to coolers with ice packs, electric car-charged coolers can be utilized, provided the cycle is set to cool and not warm. Always keep coolers out of the direct sun, and only open them again when you are ready to remove the biological control agent containers to place them in a refrigerator for overnight storage or to release the agents. If you sort and package your agents indoors, keep them in a refrigerator (no lower than 4.4 °C or 40 °F) until you transport or ship them.

Transporting short distances

If you can transport your biocontrol agents to their release sites within 3 hours after collection, and release them the same day or early the next, you need not take any measures other than those already described.

Shipping long distances

Figure 40 Commercially made shipping container (University of Idaho, Bugwood.org)

You might need to use a bonded carrier service with overnight delivery (e.g., USPS, FedEx, UPS, or DHL) if your release sites are far from your collection sites or you have to deliver your biological control agents to several sites. In such cases, the containers should be placed in insulated shipping containers with one or more ice packs, depending on the size of the packs. Some specially designed foam shippers have pre-cut slots to hold agent containers and ice packs (Figure 40). This construction allows cool air to circulate but prevents direct contact between the ice and the containers. Laboratory and medical suppliers sell foam "bioshippers" that are used to transport medical specimens or frozen foods. If neither foam product is available, you can use a heavy-duty plastic cooler.

Careful packaging is very important regardless of the shipping container you use. Ice packs need to be wrapped in crumpled newspaper, wrapping paper, or bubble wrap, and should be firmly taped to the inside walls of the shipping container to prevent them from bumping against and possibly crushing the insect containers during shipping.

Empty spaces in the shipper should be loosely filled with crumbled or shredded paper, bubble wrap, packing "peanuts," or other soft, insulating material. Use enough insulation to prevent agent containers and ice packs from shifting during shipment but not so much that air movement is restricted. Tape the container lids shut. Enclose all paperwork accompanying the agents (including any needed permits) before sealing the shipping container. For additional security and protection, you may place the sealed shipping containers or coolers inside cardboard boxes.

Other factors to consider:

- Make your overnight shipping arrangements well before you collect your biological control agents, and make sure the carrier you select can guarantee overnight delivery.
- Plan collection and packaging schedules so that overnight shipments can be made early in the week. Avoid late-week shipments that may result in delivery on Friday through Sunday, potentially delaying release of the agents for several days.
- Clearly label the contents of containers and specify that they are living insects.
- Check with a prospective courier to make sure that they can accept this type of cargo and will not treat the packages in ways that could harm the biological control agents. If the courier cannot guarantee that such treatments will not occur, choose a different carrier.
- Contact personnel at the receiving end, tell them what you are shipping and when it is due to arrive, provide a tracking number, verify that someone will be there to accept the shipment, and instruct them not open the container prior to releasing the agents.

COMMON PACKAGING MISTAKES

Crushing - Secure all material included in the package so that blue ice, bundles of plant material, etc., do not become loose and move around en route, crushing insects.

Excess Heat - Do not expose biological control agents to direct sunlight or temperatures above 27 °C (80 °F).

Exhaustion - Provide sprigs of the target weed along with crumpled paper towels on which insects may crawl and hide.

Excess moisture - Remove spilled or excess water in the container. Utilize crumpled paper towels to help absorb moisture.

Lack of ventilation - Provide adequate ventilation; use only air-permeable containers.

Starvation - Provide sufficient food, and do not store containers with biological control agents more than three days.

Purchasing Tansy Ragwort Biological Control Agents

A number of commercial suppliers provide tansy ragwort biological control agents. County weed managers, extension agents, or university weed or biological control specialists may be able to recommend one or more suppliers. Make sure that a prospective supplier is reputable, can provide the species you want, and can deliver it to your area at a time appropriate for field release (you will want to know where and when the agents were collected). Interstate shipments of tansy ragwort biological control agents by commercial suppliers also require a USDA permit (see page 51 and Appendix IV). Confirm in advance that there is a permit in place for the species you are acquiring as well as the region in which the release will occur. DO NOT purchase or release unapproved, non-permitted biological control organisms.

Releasing Tansy Ragwort Biological Control Agents

Establish permanent location marker

Place a steel fence post or plastic/fiberglass pole at least 1.2 m (4 ft) tall as a marker at the release point (Figure 41a). Avoid wooden posts; they are vulnerable to weather and decay. Markers should be colorful and conspicuous. White, bright orange, pink, and red are preferred over yellow and green, which may blend into surrounding vegetation. Sometimes, conspicuous posts are not practical or suitable at your release site, due to too much human or large animal traffic or a high risk of vandalism, etc. In such cases, mark your release sites with short, colorful plastic tent/surveyor's stakes or steel plates that can be tagged with release information and located later with a metal detector and GPS.

Record geographical coordinates at release point using GPS

Map coordinates of the site marker should be determined using a global positioning system (GPS) device (Figure 41b). GPS coordinates should complement (not replace) a physical marker. Accurate coordinates will help re-locate release points if markers are damaged or removed. Along with the coordinates, be sure to record what coordinate system and datum you are using, e.g., Latitude/Longitude in WGS 84 or UTM in NAD83.

Prepare map

The map should be detailed and describe access to the release site, including roads, trails, and relevant landmarks. The map should complement (not replace) a physical marker and latitude and longitude or UTM coordinates. Maps are especially useful for long-term biological control programs in which more than one person will be involved or participants are likely to change. Maps are often necessary to locate release sites in remote locations or are physically difficult or confusing to access.

Complete relevant paperwork at site

Your county weed superintendent, extension office or local State or Federal land management agency may have standard biocontrol agent release forms for you to complete. Typically, the information you provide includes a description of the release site's physical location, including GPS-derived latitude, longitude, and elevation; a summary of its biological and physical characteristics and land use; the name(s) of the biological control agent(s) released; date and time of the release; weather conditions during the release; and the name(s) of the person(s) who released the agents (see Sample Biological Control Agent Release Form in Appendix V). The best time to record this information is while you are at the field site; do not wait until you are back in the office to do it. Once back in the office, submit the information to your local weed control authority, county extension agent, university, or state department of agriculture. Keep a copy for your own records.

Figure 41 a. Permanent marker for biological control agent release site (Rachel Winston, MIA Consulting); b. GPS (Howard F. Schwartz, Colorado State University, Bugwood.org)

Set up photo point

A photo point is used to visually document changes in tansy ragwort infestations and the plant community over time following release of biological control agents at a site. Use a permanent feature in the background as a reference point (e.g., a mountain, large rocks, trees, or a permanent structure) and make sure each photo includes your release point marker. Pre- and post-release photographs should be taken from roughly the same place and at the same time of year (Figure 42). Label all photos with year and location.

Release as many agents as possible

As a general rule of thumb, it is better to release many individuals of a biocontrol agent species at one tansy ragwort infestation than it is to spread those individuals too thinly over multiple tansy ragwort infestations. Concentrating the release will help ensure that adequate numbers of males and females are present for reproduction and reduce the risks of inbreeding and other genetic problems. Minimum release sizes have not been determined for most agents, but releases of 200 individuals or more are generally suitable.

Adult tansy ragwort flea beetles and ragwort seed head fly pupae should be released in a group at the marked release point instead of scattering the biological control agents throughout the tansy ragwort infestation. The cinnabar moth is best released in groups of 10 larvae per plant on plants 1 meter (3.2 ft) apart, but first be sure to check with your local weed control authority or state department of agriculture to confirm the cinnabar moth is permitted for redistribution in your area. Releases of all biocontrol agents should be made under moderate weather conditions (mornings or evenings of hot summer days, mid-day for cold season releases). Avoid making releases on rainy days. If you encounter an extended period of poor weather, however, it is better to release the insects than wait three or more days for conditions to improve as the agents' vitality may decline with extended storage. Avoid transferring biocontrol agents to areas with a number of ant mounds or ground dwelling animals which may predate the biological control agents.

Figure 42 Photo point for tansy ragwort infestation a. before and b. nine years after tansy ragwort flea beetle releasese (Eric Coombs, Oregon Department of Agriculture, Bugwood.org)

REGULATIONS PERTAINING TO TANSY RAGWORT BIOLOGICAL CONTROL AGENTS

U.S., intrastate

Generally, there are few if any restrictions governing collection and shipment of biological control agents within the same state; however, you should check with your state's department of agriculture or agriculture extension service about regulations governing the release and intrastate transport of your specific biological control agent. The state of California regulates release permits at the county level.

U.S., interstate

The interstate transportation of biological control agents is regulated by the U.S. Department of Agriculture (USDA), and a valid permit is required to transport living biological control agents across state lines. You should apply for a Plant Protection Quarantine (PPQ) permit from the Animal and Plant Health Inspection Service (APHIS) as early as possible—but at least six months before actual delivery date of your biological control agent. You can check the current status of regulations governing interstate shipment of weed biological control agents, PPQ Form 526 (Appendix II), at the USDA-APHIS-PPQ website http://www.aphis.usda.gov/plant_health/permits/organism/index.shtml. A recently initiated ePermit process can be accessed at http://www.aphis.usda.gov/permits/ppq_epermits.shtml; this allows the complete online processing of biological control agent permit requests.

Canada

Canada requires an import permit for any new or previously released biological control agent. Permits are issued by the Plant Health Division of the Canadian Food Inspection Agency. Redistribution of tansy ragwort biological control agents within a province is generally not an issue; however, you should consult with provincial authorities and specialists prior to moving biological control agents across provincial borders.

Documenting, Monitoring, and Evaluating a Biological Control Program

The need for documentation

The purpose of monitoring is to evaluate the success of your tansy ragwort biological control program and to determine if you are meeting your weed management goals. Monitoring activities utilize standardized procedures over time to assess changes in populations of the biocontrol agents, tansy ragwort, other plants in the community, and other biotic and abiotic components of the community. Monitoring can help tell you:

- If the biological control agents have become established at the release site
- If biological control agent populations are increasing or decreasing and how far they have spread from the initial release point

- If the biological control agents are having an impact on tansy ragwort
- If/how the plant community or biotic/abiotic factors have changed over time

Monitoring methods can be simple or complex. Basic assessments can be done with a minimum amount of time each year, while more involved assessments can be conducted with extensive effort. The duration of monitoring can also vary. A single year of monitoring may demonstrate whether or not the biocontrol agents established, while multiple years of monitoring may allow you to follow the population of the biocontrol agents, the decline of tansy ragwort, changes in the plant community, and other biotic and abiotic (e.g. climate, soil) changes.

Documenting outcomes—both successes and failures—will help generate a more complete picture of biological control impacts, guide future management strategies, and serve education and public relations functions. Similarly, monitoring can provide critical information for other land managers by helping them predict where and when biological control might be successful, helping them avoid releasing ineffective agents or the same agent in an area where they were previously released, and/or helping them avoid land management activities that would harm local biocontrol agent populations or worsen the tansy ragwort problem.

Information databases

Many federal and state agencies have electronic databases for archiving information from biological control releases. We have included a standardized biological control agent release form that, when completed, should provide sufficient information for inclusion in any number of databases (see Appendix V).

At the federal level, the USDA Animal and Plant Health Inspection Service (APHIS) maintains the Cooperative Agricultural Pest Survey (CAPS) database, which is part of the National Agricultural Pest Information System (NAPIS). Biological control agent release information is entered into CAPS by a number of state and federal agency personnel who serve on the state's CAPS survey committee. Contact your local APHIS officials or state department of agriculture for more information on participation.

The USDA Forest Service maintains a database of biological control agent releases on federal and non-federal lands. As of the writing of this document, weed biocontrol agent releases made on Forest Service lands are entered into the Forest Service ACtivity Tracking System (FACTS) database. Other agencies may maintain their own databases for this information. Many of the databases maintained by state and federal agencies have safeguards in place to prevent undesirable uses of the information they contain.

Monitoring methods

There are three main components to measure in a tansy ragwort monitoring program: biological control agent populations, tansy ragwort populations, and the rest of the plant community (including nontarget plants). More detailed monitoring might also examine effects on other biotic community components (such as other insects, birds, mammals, etc.) or abiotic factors (such as erosion, soil chemistry, plant architecture, etc.). Only the three main monitoring components are discussed in this manual.

Assessing biological control agent populations

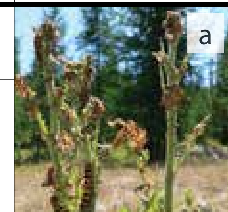
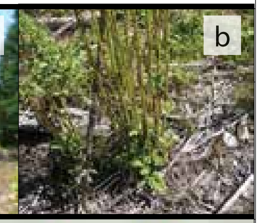
All biological control agents go through a population cycle of gradual increase, peak, and decline during the season. It is easier to assess insect establishment when populations peak, so we recommend you make multiple visits to a site throughout the season and sample when populations appear highest. Populations of some biological control agents take two to three years to reach detectable levels. Thus if no agents are detected a year after release, it does not mean that the insects failed to establish. Revisit the site at least once annually for three years. If no evidence of insects is found, either select another site for release or make additional releases at the monitored site. Consult with your county extension educator or local biological control of weeds expert for assistance.

General biological control agent surveys: If you wish to determine whether or not a tansy ragwort biological control agent has established after initial release, you simply need to find the biological control agents or evidence of their presence. The easiest way to confirm agent establishment in the years following release is to find one or more of the insect's life stages at the release site (Table 8). Begin looking for biological control agents where they were first released and then expand to the area around the release site. Sometimes, biological control agents do not like the area where they were released and move to patches of tansy ragwort nearby. Damage characteristic of individual biocontrol agents can also indicate successful establishment (Table 8).

Example monitoring methods: To determine the density of biological control agents at the release site, a systematic monitoring approach is needed. During peak densities of your insect of interest, visit the tansy ragwort infestation and count the number of adults swept (flea beetles), number of adults or larvae observed (cinnabar moth, Figure 43), or number of infested seed heads observed (seed head fly) in a 3 minute period. Repeat this activity six times and find the average. Over 500 adult flea beetles, 60 adult or 200 larvae of cinnabar moths, or over 60 fly-infested tansy ragwort seed heads are all indicative of very high agent populations that should have a visible effect on the tansy ragwort population in the near future. Repeating this activity consistently each year will help you track the changes in insect population over time and help you predict the impact of your biocontrol agents. See Appendix VI for a sample form on which you can record agent counts along with plant monitoring data.

Figure 43 Cinnabar moth larvae (Jeff Littlefield, Montana State University)

Table 8 Life stages/damage to look for to determine establishment of U.S. tansy ragwort biological control agents. a, b: defoliation and damage/regrowth by *T. jacobaeae* larvae; c. capitula infested with *B. seneciella* larvae; d-f: *L. jacobaeae* all strains; d, e: shothole feeding by adults; f: mining by larvae (Photos: a, b, d, e: Jeff Littlefield, Montana State University; c: © Malcolm Storey, www.bioimages.org.uk; f: Eric Coombs, Oregon Department of Agriculture)

SCIENTIFIC NAME	LIFE STAGE	WHERE TO LOOK	WHEN TO LOOK	DAMAGE	DAMAGE APPEARANCE
Tyria jacobaeae	Adults	Flying up from foliage during the heat of the day	Spring/summer (May-Jun)	Adults do not damage host plants	 a  b
	Larvae	Early instar: rosette leaves; late instar: buds, stem tips	Summer	Young leaves skeletonized; older leaves and inflorescences defoliated; bare stalks	
Botanophila seneciella	Adults	Immature buds	Spring/summer (Apr-Jun)	Adults do not damage host plants	 c
	Larvae	In seed heads	Spring - early fall (May-Sep)	Seed heads with dark discoloration and then later with frothy spittle	
Longitartus jacobaeae (Italian low-PNW)	Adults	Foliage, actively feeding or laying eggs near rosette bases	Early summer; fall/winter (May-Jun; Sep-Dec)	Foliage with shot-hole feeding damage	 d
	Larvae	Leaf petioles, root crown tissue, roots	Fall - spring (Oct-Apr)	Stems wilty, stunted, and with decreased reproductive output	
Longitartus jacobaeae (Italian cold-IW)	Adults	Foliage, actively feeding or laying eggs near rosette bases	Fall (Aug-Nov)	Foliage with shot-hole feeding damage	 e
	Larvae	Leaf petioles, root crown tissue, roots	Fall - summer (Sep-Jul)	Stems wilty, stunted, and with decreased reproductive output	
Longitartus jacobaeae (Swiss)	Adults	Foliage, actively feeding or laying eggs near rosette bases	Summer (Jul-Sep)	Foliage with shot-hole feeding damage	 f
	Larvae	Leaf petioles, root crown tissue, roots	Spring/ early summer (May-Jun)	Stems wilty, stunted, and with decreased reproductive output	

Assessing the status of tansy ragwort and co-occurring plants

The ultimate goal of a biological control program is to permanently reduce the abundance of the target weed and enable the recovery of more desirable vegetation on the site. To determine the efficacy of biocontrol efforts, there must be monitoring of plant community attributes, such as target weed distribution and density. Ideally, monitoring begins before biological control efforts are started (pre-release) and at regular intervals after release. There are many ways to qualitatively (descriptively) or quantitatively (numerically) assess tansy ragwort populations and other plant community attributes at release sites.

Qualitative (descriptive) vegetation monitoring: Qualitative monitoring (Appendix VI) uses subjective measurements to describe tansy ragwort and the rest of the plant community at the management site. Examples include listing plant species occurring at the site, estimates of density, age and distribution classes, visual infestation mapping, and maintaining a series of photos from designated photo points. Qualitative monitoring provides insight into the status or change of tansy ragwort populations (Figure 44). However, its descriptive nature does not generally allow for detailed statistical analyses. Data obtained in qualitative monitoring may trigger more intensive monitoring later.

Figure 44 Photo point for tansy ragwort infestation a. during; b. 4 years after; c. 7 years after cinnabar moth release. As tansy ragwort decreased, so too did populations of the cinnabar moth. In recent years, seeds in the seed bank resulted in a new crop of tansy ragwort (d). It is presumed the cinnabar moth population will increase again in response to the increase in tansy ragwort (all photos George Markin, Forest Service).

Quantitative vegetation monitoring: The purpose of quantitative monitoring is to measure changes in the tansy ragwort population as well as the vegetative community as a whole before and after a biological control agent release. It may be as simple as counting flowering tansy ragwort plants in an area (Figure 45a) or as complex as measuring plant height, flower and production, biomass, species diversity, and species cover (Figure 45b). If designed properly, quantitative data can be statistically analyzed and give quantitative information on population or community changes. Pre- and post-release monitoring should follow the same protocol and be employed at the same time of year. Post-release assessments should be planned annually for at least three to five years after the initial biocontrol agent release. When the goal of the quantitative monitoring is to maximize the research potential for your site, consider involving a university.

See Appendix VII for a sample data form where you can record quantitative plant monitoring data along with biological control agent counts. Additional examples of quantitative vegetation monitoring protocols can be found in Appendix VIII. The Standardized Impact Monitoring Protocol (SIMP) used by the state of Idaho for weed and vegetation monitoring is described in Appendix IX. It is a combination of qualitative and quantitative elements and can be easily modified to meet your personal or agency needs.

Assessing impacts on nontarget plants

To address possible nontarget attacks on species related to tansy ragwort, you must become familiar with the plant communities present at and around your release sites. As stated in Chapters 1 and 2, there are 109 closely related species present in North America, 9 of which are exotic. You may have to consult with a local botanist, if available, for advice on areas where these plants might be growing and how you can identify them. Herbarium records at a university or other research institution may provide guidance about their local or statewide distribution of potential nontarget hosts.

Figure 45 Monitoring a. the target and nontarget impacts of the cinnabar moth on *Senecio* in Montana (George Markin, Forest Service); b. measuring the combined effects of biological control agents on tansy ragwort and co-occurring species/cover (Jeff Littlefield, Montana State University).

The host ranges of the tansy ragwort seed head fly and flea beetle are for the most part restricted to tansy ragwort with no nontarget effects reported in North America (see Chapter 3). The cinnabar moth, however, has been documented feeding on the native *Senecio triangularis* (Figure 46) and *Packera pseudaurea*. Tests in Montana demonstrated attack on native species only occurred if tansy ragwort was scarce. However, at sites in Oregon, nontarget feeding occurred even when tansy ragwort was readily available. Care should be taken in the management of your tansy ragwort biological control program to ensure that all closely related native species are identified and monitored along with tansy ragwort.

Figure 46 Cinnabar moth on the North American native *Senecio triangularis* (Eric Coombs, Oregon Department of Agriculture)

If you observe approved biological control agents feeding on and/or developing on native species, the vegetation sampling procedures described above can be easily modified to monitor changes in density and/or cover of these native species. Concurrently, you may wish to collect additional data, such as the number of agents observed on native relatives of tansy ragwort, the amount of foliar feeding observed, or the presence of characteristic biological control agent damage. Collecting this data for subsequent years can help determine if there is a population level impact or if the nontarget feeding is temporary or of minor consequence to the nontarget species.

If you observe approved biological control agents feeding on and/or developing on native species, collect samples and take them to a biological control specialist in your area. Alternatively, you may send the specialist the site data so he or she can survey the site for nontarget impacts. Be sure not to ascribe any damage you observe on native species to any specific insect and thus bias the confirmation of attack and the identification of the species causing the attack.

CHAPTER 5: AN INTEGRATED TANSY RAGWORT MANAGEMENT PROGRAM

Introduction

Classical biological control has been applied to many invasive weed species, and there are several examples in which both single- and multiple-biocontrol agent introductions have successfully controlled the target weeds. Where ideally suited, biological control can maintain tansy ragwort densities below economically significant levels, enabling land managers to live with the weed; however, it may take three to five years or more for biological control to reduce weed populations to such manageable levels. Furthermore, tansy ragwort occurs across a wide range of habitats (Figure 47). Some habitats are unsuitable to biocontrol insects, so biological control is not going to work against this weed every time at every site. Integration with other weed control methods or resorting to other control measures entirely may be required to attain tansy ragwort management objectives. A wide variety of successful weed control methods have been developed and may be useful for in helping meet management goals for tansy ragwort. The most successful tansy ragwort management efforts have a number of common features, including:

- Education and Outreach
- Inventory and Monitoring
- Prevention (keeping uninfested areas uninfested, often in conjunction with Early Detection and Rapid Response [EDRR] activities)
- Weed Control Activities: A variety of tansy ragwort control activities which are identified based on characteristics of the target infestation and planned in advance to use the most appropriate method or combination of methods at each site, including:
    - Biological control (insects)
    - Physical or mechanical treatment (tilling, mowing, etc.)
    - Cultural practices (grazing, reseeding, etc.)
    - Chemical treatment

Programs which incorporate all of these activities are called Integrated Weed Management (IWM) programs, and they address several aspects of land management, not just weed control. Land managers or landowners engaged in IWM take the time to educate themselves and others about the threat invasive plants pose to the land. They get out on their land and look for potential threats, including tansy ragwort. When an infestation is found, they map it and make plans to address it utilizing control methods most appropriate for their particular infestation. After initiating control activities, they monitor if the control was successful. If re-treatment or additional treatments are necessary, these are applied in a timely manner with appropriate post-treatment monitoring to ensure that management objectives are being met.

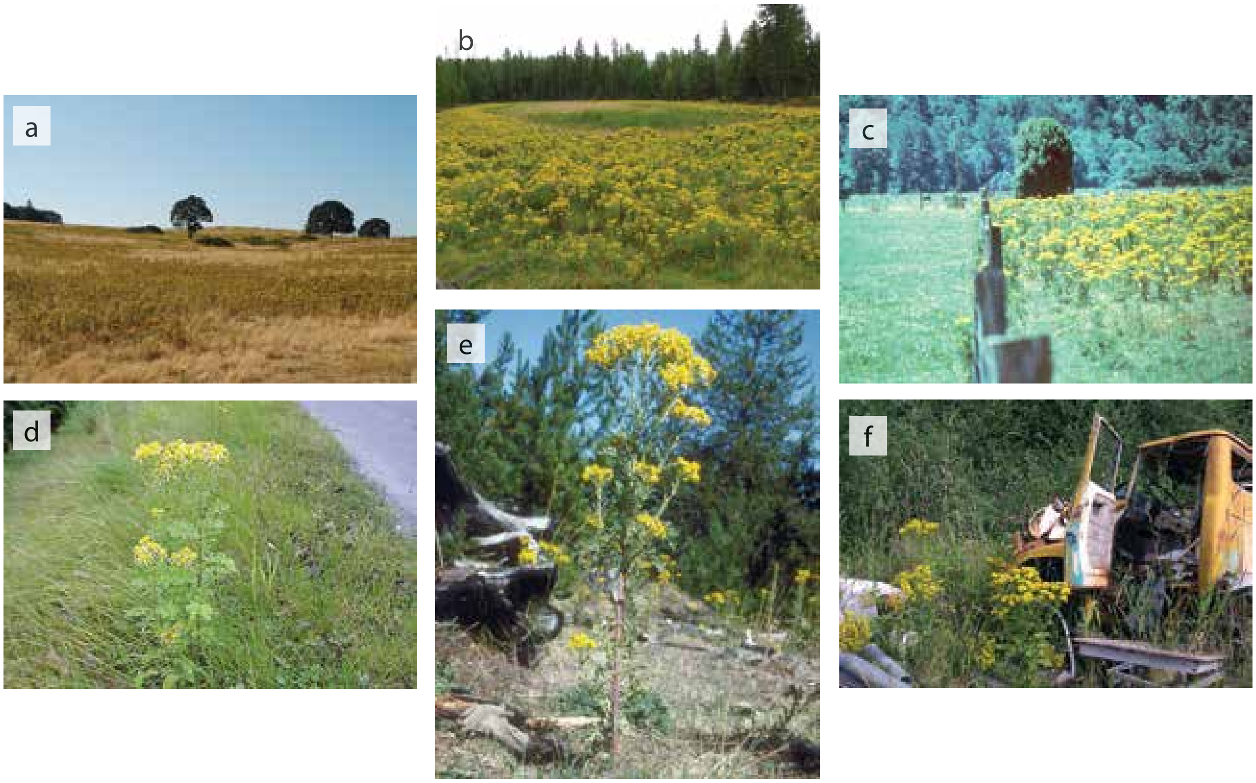


Figure 47 Various habitats where tansy ragwort can thrive: a. open range hillside (Marianna Szűcs, University of Idaho); b. forest opening around wetland (Jeff Littlefield, Montana State University); c. pasture (Utah State University); d. roadside (Faith Duncan, USDA Forest Service); e. slashpile (Eric Coombs, Oregon Department of Agriculture); f. abandoned land (Tom Heutte, USDA Forest Service; c.-f. Bugwood.org).

Integrated Weed Management programs undertaken on a large scale can at times prove logistically difficult, expensive, and time-consuming. The concept of Cooperative Weed Management Areas (CWMA) was created in order to make this thorough approach to weed management more feasible and successful. CWMAs consist of federal, state and local land managers, as well as concerned private landowners, within a designated zone who join efforts against exotic plants, pooling and stretching limited resources and manpower for managing invasive species and protecting/restoring habitat. Cooperation between neighboring CWMAs helps transfer knowledge and experience between heavily treated regions and places not yet as impacted by tansy ragwort. Numerous CWMAs exist throughout the western states of the U.S. and are excellent sources of information, experience, and resources for treating tansy ragwort infestations with an IWM approach.

The components of tansy ragwort IWM are described individually below. Because the focus of this manual is the biological control of tansy ragwort, the potential to integrate biocontrol with other weed control methods is described at the end of each control method's section. Long-term management is greatly improved when control methods are identified according to infested habitat type, land use, ownership, and available resources and then integrated when appropriate. The final section of this chapter takes these variables into consideration and offers suggestions for an IWM approach under different weed management scenarios (see page 72).

Components of Successful Integrated Weed Management Programs to Manage Tansy Ragwort

Education & Outreach

Education and outreach activities increase public awareness of noxious weeds, the problems they cause, their distribution, and ways to manage them (Figure 48). Ideally, education and outreach activities also foster cooperation and collaboration across land ownership boundaries to facilitate the development of a landscape-level weed management response. Education efforts should be an important component of any weed management plan, regardless of the target weed or weed control method employed.

By educating land managers and landowners, recreationalists and the public about the threat of tansy ragwort and other important noxious weeds and enabling them to identify infestations, it becomes possible to assess the problem at the landscape scale. This landscape-level understanding of the weed problem greatly improves the ability of land managers to cooperatively develop successful weed management responses for the entire affected area.

Figure 48 Tansy ragwort weed education sign (Montana Tansy Ragwort Cooperative Project, Jeff Littlefield, Montana State University)

Inventory & Mapping

Inventory and mapping are key elements of a successful weed management program. It is imperative that the extent of a weed population be understood before control activities are identified, prioritized, and implemented because the best treatment methods are often determined by the size and location of the infestation. Education and outreach activities which foster collaboration between adjacent landowners are particularly useful when developing landscape-level maps of weed infestations. As land managers and landowners gain an appreciation for the threat tansy ragwort poses to their land, they are often more willing to participate to ensure that their land is inventoried and accurate maps of tansy ragwort are developed so the best control activities can be implemented. Small populations of tansy ragwort are best treated with weed control methods which are likely to eradicate (remove entirely) the population immediately [see early detection and rapid response (EDRR) described below]. Larger, more established populations of tansy ragwort can be treated with biological, physical or mechanical, cultural and/or chemical controls, depending on the size, location, and density of the infestation.

Tansy ragwort infestations are often mapped by foot, vehicle, horse, or airplane using a global positioning system (GPS) unit and a geographical information system (GIS), though hard copy maps made by hand are suitable for some locations. Inventory efforts should document the following for each infestation: location, boundaries, estimated density, land usage, treatment history, and date. Photos of the infestation and a list of co-occurring species are also useful. Documenting inventory and mapping efforts enables land managers to determine if all known infestations have been treated, and makes post-treatment monitoring possible. In turn, this allows land managers to judge the effectiveness of various treatment methods. See Chapter 4 for suggested techniques of monitoring infestations given certain treatments.

Prevention

Prevention activities focus on areas not currently infested by tansy ragwort with the goal of keeping these areas weed-free. Though tansy ragwort is already present throughout much of northwestern North America, there are many areas where it has not yet established and other areas where it remains at low densities. Inventory efforts help identify the precise borders of these locations. Preventing further introduction and spread to uninfested areas is more environmentally desirable and cost-effective than is the subsequent treatment of large-scale infestations.

Tansy ragwort is spread by the movement of seed-contaminated hay, wind, motorized equipment, wildlife, root-fragments, or water dispersal into uninfested areas. Preventing the spread of tansy ragwort requires cooperation among all landowners and land managers. In areas where this weed is not yet present, it is important to ensure that possible invasion avenues are identified and management actions taken to reduce the risk of spread. This includes minimizing soil disturbances and regularly monitoring uninfested sites to ensure they remain uninfested.

Cultivation, soil erosion, road grading, recreational activities (e.g. riding dirt bikes or four wheelers) and overgrazing weaken existing plant communities, decrease plant cover, and cause disturbance, conditions that favor tansy ragwort establishment and persistence. Such activities should be avoided in tansy ragwort-prone areas. Where grazing is inevitable, proper livestock management, such as alternating the season of use, changing stocking numbers and species, and rotating livestock, will allow grazed vegetation to recover and competitive plants to increase which, in turn, will help prevent the establishment of tansy ragwort. During the seed formation stage, livestock should be kept off weed-infested land. If it is not possible to avoid driving vehicles and machinery (e.g. logging and construction equipment) through tansy ragwort infestations, it is crucial that a thorough cleaning take place before equipment leaves the contaminated area.

Prevention and exclusion activities are typically paired with education efforts. Examples of exclusion efforts include weed-free forage programs, state seed laws, and mandatory equipment cleaning when leaving infested sites and before entering uninfested sites. Weed-free hay programs, alone, were responsible for significantly reducing new tansy ragwort populations in Oregon.

An early detection and rapid response (EDRR) program is a specific protocol for tracking and responding to new infestations. It relies heavily on education and outreach activities to be effective. An EDRR program targets areas where tansy ragwort may spread. It consists of two complementary activities: 1) educating land managers and the public to aid in immediate and thorough detection of the weed and 2) initiating rapid response eradication efforts at all verified locations of the weed.

Weed Control Activities

Biological Control

Biological control involves the use of living organisms, usually insects, mites, or pathogens, to control a weed infestation and recreate the balance of plant species with their natural predators and pathogens. Classical biological control focuses on the introduction of select natural enemies from the invasive weed's site of origin. This method of tansy ragwort management is most suitable for larger (tens to thousands of acres) infestations. For new infestations, or satellite outbreaks of the weed (new populations outside the fringe of existing tansy ragwort infestations), more rapid control methods should be utilized (chemical treatment with or without physical control). Refer to Chapter 3 for detailed descriptions of the biological control agents currently approved for use against tansy ragwort and Chapter 4 for how to implement a biological control program in your area.

Physical or Mechanical Treatment

Physical treatment utilizes hand pulling, hoeing, tilling, or mowing to remove or disrupt the growth of weeds and is the oldest method of weed control. Physical methods have had variable success in controlling tansy ragwort and are labor-intensive and not suitable for much of the remote or rough-terrain areas tansy ragwort has invaded. These methods are most applicable for small and easily accessible tansy ragwort infestations where repeated treatments are possible.

Hand pulling

Hand pulling may be successful on small and new populations of tansy ragwort if applied persistently. Hand pulling should be done wearing gloves as a precaution against the large-scale handling of alkaloid-ridden tansy ragwort. It is important to remove as much of the root as possible, while minimizing soil disturbance. As plants age, hand pulling can result in increased tansy ragwort populations due to regeneration from the severed roots of pulled plants. In addition, the seedbank in established tansy ragwort infestations is capable of producing new tansy ragwort stands for years to come. To account for this, infestations should be hand-pulled when the soil is moist (to ensure all root components are removed) and several times a year for multiple years. Efforts made to clip flowering plants may reduce seed production initially, but this often causes tansy ragwort to quickly produce new seed heads and also to behave as a perennial. persisting even longer on the landscape. All tansy ragwort plant parts should be bagged and removed from the area to prevent possible tansy ragwort vegetative growth or seed dispersal from pulled material. Holes remaining after plant removal are often filled with mulch or plant litter, a process that creates an unsuitable habitat for new tansy ragwort seedling growth by removing necessary light. In particularly dry climates, however, mulching holes can hold the moisture in, thus creating a more favorable environment for seedling growth. Re-seeding open space newly devoid of tansy ragwort using more desirable species can provide sufficient competition to decrease tansy ragwort seedling germination and persistence.

Tilling

Tansy ragwort is not usually a problem in cultivated crops because tilling will control this weed if done on a timely basis and if roots are cut often and below the soil surface (Figure 49). Control is enhanced when an herbicide treatment is used in conjunction with tilling as well as sowing competitive pasture species or crops and adding fertilizer. If performed infrequently or as the sole control method, this technique can result in the vegetative spread of the weed from root crown fragments. Tilling is generally not practical or desirable in wildlands and nature preserves.

Figure 49 Tilling treatment (Howard Schwartz, Colorado State University)

Tilling is not usually compatible with biological control efforts. Tilling and disking damage biological control agents pupating in the soil and can kill tansy ragwort flea beetle larvae in the plant roots.

Mowing

Cutting back the above-ground portion of a plant will remove top growth and can reduce tansy ragwort reproductive output if undertaken just before flowering. It is important that mowing events occur prior to tansy ragwort seed formation because mowing can increase seed dispersal. Mowing is often not very effective in controlling or reducing tansy ragwort populations. Rosettes are often low-growing and occur below the blades of conventional mowers. A single mowing treatment of flowering plants does not injure the root system so will not eliminate the tansy ragwort infestation. Plants are capable of immediate regrowth from the remaining root crown, and mowing typically encourages the plants to persist as perennials. Consequently, control with mowing is not possible unless done often enough so that root carbohydrates are depleted sufficiently and roots die. Frequent mowing, however, might be too costly or infeasible for larger or remote infestations. Mowing may prove useful in combination with herbicides in dense plant growth where the purpose of the mowing is only to reduce the amount of seed input to the soil seedbank and to decrease competing vegetation such that tansy ragwort plants are more exposed to subsequent roadside herbicide applications.

Prior to mowing, it is important to consider the life cycles of the biological control agents and when and where they will be on the plant. For example, mowing plants in mid to late summer just prior to seed formation can destroy larvae of the cinnabar moth and the ragwort seed head fly. Likewise, mowing plants during the fall can harm adults or larvae of the tansy ragwort flea beetle. In mild climates of the Coastal Pacific Northwest, tansy ragwort rosettes continue to grow during the winter. Mowing plants during this period does not interfere with the cinnabar moth and ragwort seed head fly pupae which are overwintering in the soil.

Cultural Practices

Cultural methods of weed control, including seeding with competitive species, burning, and grazing, can enhance the growth of desired vegetation, which may slow the invasion of noxious weeds onto a site. Regardless of which method is used, all cultural control techniques are more successful when combined with other control methods, such as tilling prior to re-seeding or grazing prior to applying herbicides.

Seeding competitive species

Tansy ragwort plants are sensitive to competition for light and resources during early growth stages or after they have been suppressed by cultivation, chemical control, or biocontrol insects. Healthy or closed plant communities with little to no soil disturbance are typically not successfully invaded by tansy ragwort. Where this weed is established and then suppressed by one or more control methods, reinvasion by tansy ragwort or other undesirable species is likely if the ecological niche it occupied remains unfilled. Successful long-term management requires the establishment and maintenance of desirable competitive species to avoid reinvasions.

Seeding can be used to help establish competitive native (or exotic but more desirable) species, such as grasses and forbs, in a tansy ragwort infestation. Some of the most competitive grasses in northwestern North America include wheatgrass and wildrye while competitive forbs include clover and yarrow (Figure 50a). The selection of the most suitable plant species to use for competition with tansy ragwort depends on habitat, site conditions, climate, management goals, and future land use. Utilizing ecologically equivalent species (those with root and growth patterns similar to tansy ragwort) may provide the best competition for this weed. Inventorying nearby sites that are uninvaded by tansy ragwort may yield the best replacement species. Consult your local county extension agent or Natural Resource Conservation Service (NRCS) representative for additional help in determining the best alternatives in your area. Further suggestions for ecoregions throughout the U.S. can be found on the The Native Seed Network website (please see Chapter 5 References for the URL). Likewise, the "links" section of the USDA PLANTS website offers numerous revegetation guideline manuals specific to different regions of both the U.S. and Canada. This site also provides access to a program and fact sheets that utilize soil, plant, and climate data to select plant species that are site-specifically adapted, suitable for the selected practice, and appropriate for the goals and objectives of the revegetation project.

Control of tansy ragwort prior to seeding more desirable species is important because established ragwort plants are highly competitive. In order to create a suitable site for re-seeding, either an area should be tilled, chained, or harrowed to provide an acceptable seed bed and/or herbicides applied to reduce competition from tansy ragwort. The disturbance caused by tillage leaves an ideal setting for tansy ragwort seedlings to sprout from the existing seedbank. Consequently, planted seeds should contain a mix of species, some of which should be quick to germinate while others should provide more long-term competition to tansy ragwort seedlings. Because high populations of rodents can reduce the success of re-seeding, erecting a raptor perch/pole may discourage rodent habitation and help ensure seeded species successfully germinate and establish.

Incorporating biocontrol agents with re-seeding has been difficult, primarily because the methods used to establish a productive stand of competitive species are not always compatible with the establishment and survival of biological control agents. Tilling can disrupt and destroy insects residing in soil litter and plant roots, and heavy herbicide use will reduce the tansy ragwort shoots on which the tansy ragwort flea beetle and cinnabar moth feed, thus hindering establishment of these species. Many successful revegetation programs establish competitive species first, using biological control agents after the seeded species have become established and tansy ragwort re-grows.

Prescribed fire

Utilizing fire to treat tansy ragwort must be implemented with care as fire used incorrectly may lead to healthier, more problematic tansy ragwort infestations. Flamethrowers (Figure 50b) can kill over 90% of flowering plants and decrease the viability of attached seeds. Fire simultaneously decreases excess plant litter and recycles nutrients in the soil, which increases the density and vigor of competitive grass species. Fire may sometimes be used in combination with other control methods to suppress tansy ragwort.

Fire disturbs land cover and may result in the creation of new openings favorable to tansy ragwort seedling germination. The same removal of plant litter and nutrient recycling that favors growth of competitive species following a fire can also favor the growth of tansy ragwort. In Montana, the largest tansy ragwort population discovered to date established and thrived

Figure 50 Cultural practices: a. seeding competitive species like yarrow (Richard Old, XID Services, Inc, Bugwood.org); b. using prescribed fire such as flamethrowers on tansy ragwort plants (George Markin, Forest Service)

following large-scale fires. Follow up monitoring of burned areas previously infested by or threatened by tansy ragwort is strongly recommended. Re-seeding following a burn is the most important priority.

The time of controlled burns must be planned to enable biological control agents to survive. Generally, soil-inhabiting agents are able to survive fast-moving, low- or moderate-intensity fires. If a fire event occurs while the biological control agents are in the adult stage, they may escape the fire by flying off and readily re-establishing on recovering tansy ragwort not killed during the fire. Cinnabar moth and ragwort seed head fly adults are better suited to surviving controlled fires than tansy ragwort flea beetles, which largely disperse by jumping rather than flying large distances.

Grazing

All parts of the tansy ragwort plant contain pyrrolizidine alkaloids, substances that are broken down into compounds toxic to cattle, horses, goats and deer. Toxicity is cumulative, and after repeated ingestion, can cause irreversible liver damage, often leading to death. Most grazing animals will not willingly consume tansy ragwort. However, poor range/pasture conditions may make this weed more desirable. Tansy ragwort is often consumed by livestock in dried hay mixtures as the weed is more difficult for animals to detect when dried. In the Pacific Northwest, the majority of livestock poisoning occurs in late winter and early spring when tansy ragwort rosettes are growing among pasture grass. Cattle cannot easily discriminate the weed in this setting and stage, and small amounts of tansy ragwort are frequently consumed, leading to chronic toxicity.

Grazing cattle avoid tansy ragwort and instead target competing grass species. When too many cattle graze in an area, they reduce the vigor of grass plants and disturb the soil, creating new openings for tansy ragwort seedling establishment. Consequently, cattle grazing is not recommended on land infested by tansy ragwort.

Sheep appear to be tolerant to the toxicity of the pyrrolizidine alkaloid metabolites of tansy ragwort, so this weed is rarely problematic in dense grassland pastures grazed heavily by sheep (Figure 51). Sheep seek out the foliage of tansy ragwort, which effectively prevents flowering and reduces tansy ragwort plant density when grazed continuously. When sheep are moved out of tansy ragwort-infested pastures during rotational grazing, tansy ragwort may recover, bolt and spread. Continuous sheep grazing, though most effective against tansy ragwort, should be monitored carefully. Heavily grazing other herbaceous species present in tansy ragwort-infested pastures can create openings ideal for tansy ragwort germination from the seedbank. Sheep grazing is most useful in infested pastures with high grass densities, though overgrazing can be damaging to grass populations as well. In rugged or remote rangeland where physical, cultural, or chemical control measures are expensive or infeasible, a successful grazing management strategy may provide reasonable control.

Grazing sheep for tansy ragwort control is incompatible with the feeding activities of the cinnabar moth and the ragwort seed head fly. Sheep grazing may complement and enhance the weed control effect of the larval feeding of the tansy ragwort flea beetle, provided sheep are rotated out of the pasture before flea beetles reach the adult stage.

Chemical Control

Herbicides are important tools for controlling noxious weeds and are available for tansy ragwort control in a variety of environments (Figure 52). Herbicide usage is most effective on small infestations, including newly established populations and recently established satellite patches arising from nearby older, larger tansy ragwort infestations. Herbicides are also excellent for use on the leading edge of large advancing tansy ragwort infestations. In travel corridors or

Figure 51 Pasture grazed by sheep (Eric Coombs, Oregon Department of Agriculture)

high use areas (e.g. roads, campgrounds, logging operations), herbicides are ideal for treating tansy ragwort infestations, thus preventing the further spread of this weed via vehicles, machinery, or people.

Figure 52 Spraying herbicides (Steve Manning, Invasive Plant Control, Bugwood.org)

Herbicides are often too costly to be of practical use in treating extensive infestations of tansy ragwort and are also impractical in hard-to-access and environmentally sensitive areas. Repeated herbicide applications are usually required to keep tansy ragwort in check, especially at sites with an extensive seedbank as seeds can remain viable for up to eight years. Potential nontarget damage to associated vegetation must also be considered when using herbicides, especially in natural areas. For these reasons, herbicides are best used as part of a larger, integrated weed management program which employs other weed control methods in areas where herbicides are less likely to be cost effective or the most appropriate control choice.

When herbicides are used against tansy ragwort, it is important that the applicator adhere to all label instructions to ensure the usage, surfactant requirement, application rate, application timing and location of herbicide application are ideal. Not all herbicides are registered for use against tansy ragwort in agricultural and rangeland settings, or for use in each state of the U.S. and in Canada. Many herbicides are restricted use and can only be applied by a certified and licensed applicator, and then only under specific conditions. Please consult your county weed control authority or county agricultural extension agent to learn which herbicides work best and when to apply them in your area.

Herbicides are generally applied in one of two ways: spot or broadcast applications. Spot treatments are used for individual tansy ragwort plants or small patches. In spot applications, an appropriate herbicide is applied to the foliage of target plants only. Broadcast treatments spray an appropriate herbicide over an entire area to treat larger weed infestations. Broadcast treatments should be used with caution as many herbicides may also impact plants that land managers may want to retain. Selective herbicides are those that target selected species while leaving other species virtually unharmed. Utilizing selective herbicides helps reduce the nontarget impacts of broadcast applications.

Most herbicides currently registered for use against tansy ragwort work best when applied while the weed is actively growing, especially when the weed in the seedling or rosette stage either in the spring or mid-fall. Herbicides are less effective against tansy ragwort after plants have bolted or are producing flowers. For specific recommendations in the states of Idaho, Oregon and Washington, refer to the Pacific Northwest Weed Management Handbook (please see Chapter 5 References), an annually revised Extension publication from the Extension Services of Oregon State University, Washington State University and the University of Idaho. Some of the most widely used products to combat tansy ragwort in these states and also Montana include:

- **2,4-D** is most effective on seedlings in the fall or spring. It can also be broadcast sprayed on actively growing rosettes in the fall or spring to kill aboveground growth of tansy ragwort. This compound has been used successfully in combination with dicamba on pre-bolting tansy ragwort individuals. 2,4-D alone and in combination with dicamba is less effective against flowering plants.
- **Aminopyralid** can be applied in the spring or early summer on rosettes or bolting plants or, alternately, in the fall on rosettes. Aminopyralid can be very damaging to desirable forbs, especially legumes. However, this herbicide can be applied near some tree species where dicamba and picloram cannot be used. This herbicide does not kill grasses. It has a soil residual period, which will reduce regrowth of tansy ragwort seedlings in subsequent years.
- **Clopyralid** is best used when applied on fall- or spring-emerged tansy ragwort rosettes. It is often mixed with other herbicides to increase weed control results. It will provide good control of tansy ragwort, but has less soil residual than picloram or dicamba, so follow up monitoring and timely re-treatments are often required. Though this herbicide is more selective than aminopyralid, it may still kill desirable legume species and other forbs, so its use should be limited when used in conjunction with broadleaf revegetation efforts. This herbicide does not kill grasses.
- **Dicamba** should be applied when tansy ragwort is in the rosette stage. It is often mixed with other herbicides to increase weed control results. This herbicide provides good control of tansy ragwort, but has a shorter soil residual period than picloram, so follow up monitoring and timely re-treatments (alone or in combination with 2,4-D) may be needed to prevent reinvasion by tansy ragwort seedlings. There is some residual activity of dicamba, and this herbicide may kill desirable legume species, so its use should be limited when combined with forb revegetation efforts. It does not kill grasses.
- **Glyphosate** is best used on new tansy ragwort growth during fall (in the Intermountain West) when plants are storing reserves in the roots for winter. It is a non-selective herbicide and should only be used in situations where loss of non-target vegetation is acceptable. Glyphosate use should be accompanied by revegetation of desirable species.
- **Metsulfuron** should be applied post-emergence to actively growing tansy ragwort plants. It is best to use a nonionic or organosilicone surfactant with metsulfuron. Restrictions apply for its use on some grasses; this strong herbicide may result in stunting or death of some desirable species of plants in treatment areas. Spot spraying metsulfuron on individual plants or dense patches of tansy ragwort is preferable to a broadcast treatment.
- Use **picloram** on new tansy ragwort growth from fall or spring emergence. This herbicide can be used throughout active growth stages, but is best pre-bolting. Picloram requires a high usage rate but has a long soil residual period, which will reduce regrowth from remaining tansy ragwort roots or seedlings. This herbicide's use is restricted near water by law (as is the use of some other compounds), and picloram will kill desirable legume species.

If land usage of treated areas includes grazing practices, it is important to remove animals from pastures sprayed with herbicides until after the herbicide's label requirements for reentry are satisfied. Some herbicides may increase the palatability of tansy ragwort to grazing animals.

Herbicide use may directly interfere with the feeding activities of the cinnabar moth and ragwort seed head fly as well as the adult stage of the tansy ragwort flea beetle. Plants partially or fully defoliated by leaf-feeding biological control agents may not absorb enough herbicide to kill them. The actions of herbicides and the root-feeding larvae of the tansy ragwort flea beetle may be complementary in certain locations or habitats, though hard evidence is lacking. In order to guarantee that biological control agent populations remain viable as the tansy ragwort infestations are reduced, some of the infested area should not be treated with herbicides to serve as "refuges" for biological control agents.

The advantages and disadvantages of tansy ragwort control methods are summarized in Table 9.

USE HERBICIDES SAFELY!

Read the herbicide label, even if you have used the herbicide before. Follow all instructions on the label.

Wear protective clothing and safety devices as recommendedon the label.

Bathe or shower after each herbicide application.

Be cautious when you apply herbicides. Know your legal responsibility as a herbicide applicator. You may be liable for injury or damage resulting from herbicide use.

Follow all storage and disposal instructions on the herbicide label.

Peter M. Rice

Table 9 Comparison of tansy ragwort management options

CONTROL METHOD	ADVANTAGE	DISADVANTAGE	COMMENTS
Biological Control	Can be very selective Agents generally do not have to be reintroduced once established Public acceptance is generally higher than with other weed control methods	Some risk of undesirable effects on native plants Not successful in all situations Permanent; cannot be undone Measurable changes in weed densities may take many years	Most economical option for large infestations and will control tansy ragwort in a variety of environments in which the weed occurs
Physical Control	Fast acting Useful along transportation vectors (roads, waterways)	Time intensive Not appropriate for many infestation locations	Areas must usually be treated multiple times or ragwort will rapidly recover
Revegetation	Can be used to re-seed natives Competitive species are self-perpetuating and weaken tansy ragwort	May be ineffective if existing ragwort stand is dense Expensive for larger infestations	Seeding methods not always compatible with biocontrol agents; best used when an area is being reclaimed
Grazing	Allows use of the land even with heavy tansy ragwort infestations Can be used in combination with biological or chemical control methods	Cannot be used in many natural areas such as national parks and wilderness areas Improper management can result in livestock poisoning Non-selective Expensive Can exacerbate the problem	Will remove top-growth only, and does not reduce the root mass. The same areas must be grazed continuously or tansy ragwort will rapidly recover
Herbicides	Fast acting High success rate for reducing tansy ragwort densities	Expensive for large areas May harm desirable vegetation, especially broadleaf species Many natural areas are inaccessible to spray equipment Public resistance to chemical controls	Best used on small patches when tansy ragwort foliage first emerges, or on the edges of a large infestation to keep it from spreading while other methods, such as biological control, have time to establish

Integrated Weed Management—Putting It All Together

Integrated weed management (IWM) is a system for the planning and implementation of a weed management program using an interdisciplinary approach to identify and, where appropriate, incorporate multiple methods for containing or controlling an undesirable plant species or group of species. IWM has two interdependent goals:

1. The development of a long-term plan to manage all land in a designated area, with all affected landowners and land managers working together in a coordinated manner to control weed populations.
2. The implementation of the most effective and economical weed control method(s) for the target weed, regularly assessed and adjusted as needed based on regularly updated weed distribution maps, treatment efficacy data and available resources.

Any IWM plan depends upon an understanding of the weed, an understanding of the threatened and invaded sites, and an understanding of all available weed control methods. In any IWM program, it is important to recognize that tansy ragwort and other noxious weed infestations are often symptoms- not just problems. If the weed management program only seeks to remove tansy ragwort from the landscape without taking measures to ensure the causes of the weed's initial establishment (e.g. soil disturbance, weed-infested hay/other vectors, and land management activities damaging to competing species) are stopped, other noxious weeds are likely to replace tansy ragwort. Earlier we mentioned the importance of education and outreach, inventory and mapping, and preventive actions and land usage changes. Treatment of tansy ragwort infestations are complicated by the plant's persistent growth characteristics and the seed, which can remain viable in the soil for many years. A control program that integrates multiple control methods—such as biological control agents, herbicide, and cultural practices across the landscape in an integrated manner—is far more likely to achieve long-term success against tansy ragwort than any single control method used alone.

Depending on the size and location of the tansy ragwort infestation, different weed control methods complement each other. When used successfully, biological control and sheep grazing can both stress tansy ragwort plants by depleting root reserves and photosynthetic ability. Weakened plants are more susceptible to herbicides and competition from more desirable grasses and forbs. Burning and mowing can reduce plant litter such that tansy ragwort plants are more exposed to herbicide applications. A reduction of litter may also be more conducive to healthier growth of competitive grasses and forbs. Competitive species should be planted for areas newly opened due to burning or physical control. Finally, herbicide applications may help reduce tansy ragwort prior to a fall or early spring seeding of grasses.

Tansy ragwort control methods are only complementary when applied with careful consideration to the requirements and pitfalls of all other control methods being used as well as a thorough understanding of the scope of the tansy ragwort problem. For example:

- Herbicide use can decimate a population of biological control agents by depleting the tansy ragwort food source when the biological control agents need to feed if all plants are killed outright and untreated refuges are not preserved
- Herbicide treatment can also increase the likelihood of cattle, horses and goats utilizing tansy ragwort (resulting in poisoning) by temporarily increasing its palatability if land managers do not alter grazing plans to accommodate the herbicide applications

- Mowing and tilling often do not kill tansy ragwort plants and may instead result in larger, more robust plants whose growth was stimulated by the physical injury
- Mowing and tilling may also encourage the spread of tansy ragwort by moving seed and root material to areas not currently infested unless managers ensure that proper monitoring and equipment decontamination is conducted
- Cultural practices may harm biocontrol agent populations by removing needed host material
- All removal methods can result in an increase of germination of tansy ragwort or other exotic weeds on the site post treatment from residual weed seed in the soil and if more desirable competitive species are not planted

Successful tansy ragwort IWM programs divide infestations across a landscape into treatment classes based upon the characteristics of the tansy ragwort infestation. This manual proposes three tansy ragwort treatment classes for a landscape:

Exclusion: For areas with no tansy ragwort present
Eradication: For new or small tansy ragwort infestations
Management: For treatment of entrenched tansy ragwort infestations

The control methods employed within each treatment class will differ depending on the land use and characteristics of the infestation. Likely scenarios are described below, with emphasis on four common settings where tansy ragwort is problematic in northwestern North America: agricultural fields, pastures or rangeland, roadsides/trails, and forest clearings or slash piles.

Exclusion of Tansy Ragwort from Uninfested Sites

Though tansy ragwort is distributed widely throughout northwestern North America, there are many susceptible sites which are not yet invaded by this weed. Maintaining these areas as tansy ragwort-free requires a combination of activities summarized in Table 10. In addition, aggressively treating core tansy ragwort-infested areas in neighboring regions will help decrease the likelihood of the weed's spread into your uninfested areas.

Table 10 Necessary components for an integrated approach to exclusion of tansy ragwort

METHOD	ADVANTAGES	DISADVANTAGES
Education/Outreach	Informs all stakeholders of threat of weed invasion; educated collaborators will be better able to assist in rapid weed identification	Can be time consuming; should be continuing
Prevention	Reducing disturbance maintains or improves habitats; cleaning equipment/ utilizing weed-free hay helps protect area from other weeds in addition to tansy ragwort	Land use changes can interfere with current usage practices; e.g., ceasing disturbance may interfere with agricultural practices or road usage
Inventory/Monitoring	Allows for the fast discovery and immediate treatment of new populations of tansy ragwort and other species of concern	Can be time consuming and costly; requires repeat visits

Education and outreach activities inform all land managers, landowners, and land users in the designated area about the threat of tansy ragwort and educate them on how to identify and report new infestations. Once tansy ragwort is identified as a potential threat, land owners, managers, and weed control authorities should work together to develop an early detection and rapid response (EDRR) protocol to follow when new infestations are identified. Education and outreach efforts should communicate the EDRR protocol to all interested parties.

Land use practices in sites designated exclusion areas should be geared towards maintaining the area tansy ragwort-free (prevention). Activities that disturb the soil and weaken existing plant communities (e.g., cultivation, road grading, off-road recreational activities, and overgrazing should all be limited or avoided). Using weed-free hay and washing construction or fire-fighting equipment prior to moving between infested and uninfested sites can further prevent the spread of tansy ragwort. Finally, the designated area should be inventoried and monitored regularly to ensure that any tansy ragwort discovered is treated immediately.

Agricultural fields

Ensure agricultural equipment is free of tansy ragwort, or clean equipment before allowing it into uninfested fields. Utilize only tansy ragwort-free seed when planting crops.

Pastures or rangelands

Ensure that animals which have been grazing in infested areas are weed seed-free prior to allowing them to move into uninfested pastures or range land. Ensure that animals are managed in such a manner as to minimize soil and site disturbance, limit use of off road vehicles and ensure such vehicles are weed-free before allowing them in clean areas.

Roadsides and trails

Manage vegetation along roadsides in a way which reduces site susceptibility to tansy ragwort infestation. For low-access roads or trails, ensure all vehicles, pack animals and their hay, and human equipment are cleaned and checked for seed or plant material prior to utilizing the road or trail.

Forest clearings and slash piles

Regularly monitor forest clearings (including camp grounds) and slash piles, especially after management activities or camping/hunting seasons to ensure no tansy ragwort infestations become established.

Eradication of New or Small Tansy Ragwort Infestations

New or discrete infestations [<1/10 hectare (¼ acre) in size] of this weed should be treated immediately with the goal of eradicating, or permanently removing, the population. Tansy ragwort is a difficult species to eradicate once it is well entrenched in infestations of 0.2 hectares (0.5 acres) or more. To ensure eradication, the land manager must commit to follow up monitoring and re-treatment of the infested area often for a minimum of three years, but ideally for eight to ten years (the length of time tansy ragwort seeds are thought to remain viable in the soil seedbank). Regular inventory of the land area designated as an eradication zone will help ensure new infestations are documented and treated immediately. The management approach and control methods used in an eradication zone will be more intensive than those used at larger established infestations. Biological control and cultural techniques are helpful in reducing tansy ragwort populations. Physical methods and herbicides are the most appropriate for rapid removal with the goal of eradication of tansy ragwort (Table 11). Physical control methods should be applied when plants are young to ensure roots are not sufficiently large to leave regenerating fragments behind. Herbicides should be applied during the rosette stage. Both techniques may require repeat visits, and both may be used to follow-up on escapees of other methods. The best approach for treatments and timing will vary depending on the size and location of the infestation.

Agricultural fields

When tansy ragwort infests cropland currently under production, control with cultivation is feasible. If cultivation occurs when tansy ragwort plants are young and is done repeatedly, tansy ragwort plants can be completely eradicated, though monitoring should be conducted annually to ensure tansy ragwort infestations do not come back. Cultivation should be deep enough to ensure sufficient damage to tansy ragwort's root system, and should be done when soil is dry to promote desiccation of the tansy ragwort root fragments. Cultivation should not be done when tansy ragwort plants are older than seedlings unless it can be repeated frequently to kill new germinants and sprouts from severed root fragments (usually not an acceptable practice when tansy ragwort co-occurs with crops grown in the western U.S.). Hand-pulling tansy ragwort plants can be effectively used on sporadic individuals recovering from cultivation. Herbicides may kill tansy ragwort completely, especially if applied on fall or spring rosettes. Repeat visits and treatments of the physical and chemical methods described above will likely be required.

Table 11 Treatment options for an integrated approach to eradicating tansy ragwort

METHOD	APPLICABILITY	ADVANTAGES	DISADVANTAGES
Cultivation	Ideally for young infestations in agricultural fields	Can eliminate young infestations in single visit if no seed bank	Established tansy ragwort can regrow from root fragments and require multiple visits; disturbs soil
Hand-pulling	Single or flowering plants are most obvious and can be pulled and bagged, followed by hand-pulling seedlings and young rosettes—the stages where hand-pulling is most effective	Inexpensive and can eliminate young infestations quickly; can be a useful option in environmentally sensitive areas	Time consuming for large infestations; requires repeat visits; if root fragments remain, plants will resprout
Herbicides	Spot-treatment of individual plants or small infestations of dense tansy ragwort	Can eliminate young infestation in single visit if no seed bank; has residual control effects; may encourage growth of competitive species	Established tansy ragwort often requires repeat visits; can have non-target effects for multiple years; only applicable in certain locations and habitats

Pastures or range lands

The typically uneven terrain and difficult accessibility of rangeland and some pastures make tansy ragwort infestations in these situations difficult to treat with physical control methods. Herbicides are the most effective means of eradicating new or small tansy ragwort infestations in these locations. Some herbicides can temporarily increase the palatability of tansy ragwort for cattle, horses, and goats, thus increasing poisoning incidences in these animals. Follow herbicide label instructions for livestock re-entry guidelines to avoid poisoning. Repeat visits and applications will likely be required.

Roadsides and trails

It is imperative that new tansy ragwort infestations along roadsides and other transport corridors (such as trails and waterways) be eradicated as soon as possible to prevent the spread of the weed. The accessibility and terrain of roadsides make them more conducive to physical control methods such as mowing or hand-pulling. Physical control methods should be performed frequently throughout the growing season. These methods may exacerbate tansy ragwort by stimulating recovery growth from single-treatments, or by moving seed to uninfested locations. Herbicides are the best control option for eradicating tansy ragwort from small roadside (or other travel corridor) infestations. Repeat visits and applications will likely be required.

Forest clearings and slash piles

The often remote locations and rough terrain of forest clearings and slash piles make these settings unsuited for physical control methods such as hand-pulling or mowing that require regular and thorough follow-up applications in order to be effective. Herbicide use is the best control option for eradicating a small tansy ragwort infestation in these settings in order to prevent its spread into surrounding forest land. Repeat visits and applications will likely be required.

Management of Entrenched Tansy Ragwort Infestations

Sites with well established infestations of tansy ragwort are difficult to control because they have a large seed bank, and the tansy ragwort plants often have well developed root systems which, when damaged, result in regenerative root fragments. Reducing the abundance of tansy ragwort at entrenched infestations often requires the use of multiple treatment methods (biological control, physical, cultural, and herbicides) with multiple applications over time. The goal for these large, well established infestations is to prevent the further spread of the population and to maintain tansy ragwort densities below a pre-determined economically significant level. The treatment methods used, and whether they are applied alone or in combination with other methods, will vary depending on the size, location, and density of the established tansy ragwort infestation as well as the physical characteristics of the site and the composition of the vegetative community at the site. A thorough inventory of the management zone will help land managers categorize the infestation, the rest of the plant community, and any challenges the site may pose for treatment operations (excessive slope, soil concerns, sensitive species concerns, aspect, elevation). With this information, land managers will be able to develop an IWM plan, which will account for all factors that may influence treatment and give land managers the best possible opportunity to reach their weed management goals for the infested area.

Agricultural fields

In no-till agricultural fields, tansy ragwort populations often build up and become more problematic than in cultivated fields. In no-till settings, tansy ragwort populations may be treated with biological control. Ensure that releases are made only in crops where the harvesting and maintenance processes do not interfere with the life stages of the targeted biocontrol agents. For example, harvesting methods including mowing or swathing would likely destroy larvae of the cinnabar moth or the tansy ragwort seed head fly if performed when the larvae utilize above-ground portions of tansy ragwort. Destructive harvest practices are best integrated with biological control during late fall to early spring when the biocontrol agents are less likely to be found in the top portions of tansy ragwort plants. Tilling and disking damage biological control agents pupating in the soil and can kill tansy ragwort flea beetle larvae in the plant roots. In tilled fields, cultivation of older tansy ragwort plants should be done with care as it may increase the abundance and promote the spread of tansy ragwort through heightened regrowth from damaged root crowns. Cultivation should ideally not be done when tansy ragwort plants are older than seedlings unless it can be repeated frequently to kill new germinants and sprouts from severed root fragments (usually not an acceptable practice for tansy ragwort infestations among most crops grown in the western U.S.). Hand-pulling tansy ragwort plants can be effectively used on sporadic individuals recovering from cultivation. Herbicides may kill tansy ragwort completely, especially if applied on fall or spring rosettes. This method can be utilized over the entire area, or used to spot-treat tansy ragwort individuals that recover from physical control. The residual action of some herbicides makes them unsuitable for use in crop settings under rotational farming with legumes and other broadleaf species, so be sure to read the label fully and select only those compounds safe to use in your situation. Burning fields following harvest may kill tansy ragwort still growing or could be used to decrease surrounding litter, thus increasing access to tansy ragwort leaf surface area for herbicide uptake. A summary of integrated control methods available for use against tansy ragwort in an agricultural setting is listed in Table 12.

Pastures or rangeland

The obvious first choice for tansy ragwort control in pastures or rangeland is to graze with sheep, the only domestic livestock tolerant of the toxic effects of pyrrolizidine alkaloids. Without continuous grazing that prevents bolting and reproduction, tansy ragwort will quickly recover, bolt, flower and set seed. However, continuous grazing is controversial in that it is often considered a cause of the tansy ragwort problem by disturbing the soil and negatively impacting desirable, competing pasture species. Grazing of tansy ragwort should be augmented by other forms of control, especially when grazing programs are ended. Biological control is very applicable to pasture and rangeland infestations of tansy ragwort. The agents are self-perpetuating so are capable of dispersing to remote and rugged rangeland locations. Insects may also complement control in areas which are not grazed continuously. Though hand-pulling can be effective in very small and young tansy ragwort populations, this method is not applicable in large pasture and rangeland settings. Other forms of physical control may also not be suitable for pasture or rangeland terrain. Herbicides can be used in this setting, but are often infeasible or too expensive for the vast rangelands where tansy ragwort is problematic. Chemical control also frequently kills nontarget desirable vegetation such as clovers, alfalfa, and some grasses. Some herbicides increase the palatability of tansy ragwort, so where chemical control is applied, animals should be removed and not returned until the label deems reentry

Table 12 Treatment options for an integrated approach to managing tansy ragwort in an agricultural setting

METHOD	TECHNIQUE	ADVANTAGES	DISADVANTAGES	INTEGRATION
Biological	Release cinnabar moth larvae* in summer; seed head fly pupae in early spring; flea beetle adults in fall or summer (see Table 7 in Chapter 4 for strains)	Self perpetuating; cost effective; may weaken plants, making other control methods more effective	Slow initially; many introductions may be needed; cinnabar moth may have some nontarget effects	Supplement with well-timed mowing/ crop harvesting, grazing, herbicides that do not kill all ragwort plants
Hand-pulling	Immediately for seedlings and young rosettes; multiple times during growing season if possible; on moist soil to ensure all root is removed	Inexpensive and can quickly eliminate young infestations or sporadic individuals	Time consuming for large infestations; requires repeat visits; if root fragments remain, plants will re-sprout	Supplement with spot-spraying herbicides or biocontrol if in a no-till setting
Cultivation	Immediately for seedlings and young rosettes; multiple times during growing season if possible; deeply and on dry soil to ensure dessication of root fragments	May eliminate young infestations in single visit if no seed bank	Established tansy ragwort can regrow from root fragments and require multiple visits; disturbs soil profiles	Supplement with hand-pulling or spraying individuals that recover or sprout after cultivation
Burning	In fall or spring on fields with plant litter or of flowering plants on field perimeters	Can kill plants and attached seeds; by removing litter, fire better exposes new tansy ragwort plants to herbicides	Nutrient cycling and removal of litter can encourage sprouting of tansy ragwort; may cause air quality or erosion issues; fire can escape control	Follow with herbicide treatment or cultivation
Herbicides	On actively growing rosettes in fall or spring; broadcast over entire field or spot-treatment of individual plants	Can eliminate young infestation in single visit if no seed bank; has residual control effects	Expensive; established tansy ragwort often requires repeat visits; can have non-target effects for multiple years; unsuitable for many crops	Supplement with hand-pulling or biocontrol if not all plants are sprayed and field is not tilled

*Be sure to check with your local weed control authority or state department of agriculture to ensure this is a permitted biological control agent in your area.

as safe. Herbicides may interfere with the cinnabar moth and the ragwort seed head fly, but may complement the effects of the tansy ragwort flea beetle if plants (especially roots) are not all killed outright. Planting competitive species is more applicable in pastures than remote rangeland, but is a useful approach for managing tansy ragwort in both locations (native species are preferred, especially in rangeland situations). Burning may temporarily kill some tansy ragwort individuals, but is more useful in increasing stands of competitive grasses and increasing the potential exposure of tansy ragwort plants to herbicides. Likewise, grazing with cattle may temporarily decrease nontarget vegetation that would otherwise intercept herbicide spray intended for tansy ragwort. Keep in mind that cattle usage is only applicable when sufficient forage is available so that the toxic tansy ragwort can be safely avoided. A summary of integrated control methods available for use against tansy ragwort growing in pastures or rangeland is listed in Table 13.

Roadsides and trails

Roadways and trails with well established infestations of tansy ragwort pose a unique control problem. Due to continuous disturbance from traffic and/or construction machinery, conditions are nearly always optimal for reoccurring tansy ragwort establishment and spread. Varied and repeated treatments are likely to be required to reduce and contain infestations in this setting. Biocontrol efforts may not be as effective on roadside infestations as in other tansy ragwort environments, but releases are still warranted, especially where infestations may be spreading away from the road and into different land use zones. Biocontrol agents may weaken and suppress the established weed populations. Mowing is applicable because, by design, most major roads are accessible by mowing machinery. Repeated mowing can weaken tansy ragwort and encourage the growth of more competitive species. Mowing should only be done prior to tansy ragwort seed maturation lest the problem be made worse by distributing seeds. Tansy ragwort flea beetles can be successfully integrated with mowing. Check biocontrol agent populations prior to mowing as adult flea beetles, as well the larvae of the cinnabar moth and the ragwort seed head fly will be killed by mowing. Roadside and trail infestations of tansy ragwort can be controlled with herbicides, especially if chemical is applied to the susceptible rosettes in fall and spring. Aboveground kill (achieved with herbicides such as 2,4-D) can be compatible with larvae of the tansy ragwort flea beetle. However, complete destruction of all plants adversely impacts biocontrol populations because it removes their required food. The residual action of many herbicides can preclude colonization by legumes and other competitive broadleaf species. Herbicides used in conjunction with continuous mowing can weaken the root reserves of tansy ragwort, leading to eventual plant death. Planting competitive species can complement the effects of herbicides, biocontrol, and mowing, provided the new species are resistant to repeated cutting and the herbicides used. Burning roadsides may kill some tansy ragwort individuals, but is more useful in increasing stands of competitive grasses and increasing tansy ragwort exposure to herbicides. Integrated control methods available for use on tansy ragwort infestations along roadsides are summarized in Table 14.

Forest clearings and slash piles

Because tansy ragwort seed is easily spread via contaminated machinery and people, and because this weed favors disturbed soils for its establishment, logging slash piles and campgrounds provide an ideal habitat for tansy ragwort. Herbicides are a good choice to use in these situations, but must be applied with caution given the wide variety of nontarget species likely present in

Table 13 Treatment options for an integrated approach to managing tansy ragwort in pastures or rangeland

METHOD	TECHNIQUE	ADVANTAGES	DISADVANTAGES	INTEGRATION
Biological	Release cinnabar moth larvae* in summer; seed head fly pupae in early spring; flea beetle adults in fall or summer (see Table 7 in Chapter 4 for strains)	Very effective; can often find isolated or hard-to-access populations; self perpetuating; cost effective	Slow initially; many introductions may be needed; cinnabar moth may have some nontarget effects	Supplement with grazing, herbicides that do not kill all ragwort, competitive planting
Hand-pulling	Immediately for seedlings and young rosettes; multiple times in growing season if possible; on moist soil to ensure all root is removed	Inexpensive and can quickly eliminate young infestations or sporadic individuals	Time consuming; not applicable for large, remote, inaccessible patches; requires repeat visits; if root fragments left, plants will re-sprout	Supplement with spot-spraying herbicides
Planting Competitive Species	Broadcast or drill seed of grasses or forbs in spring or fall (dependent on species)	Ragwort seedlings susceptible to competition; good for reclamation	Can be expensive and time-consuming; difficult or can fail when tansy ragwort dense; may introduce unwanted species	First apply herbicides; follow with biocontrol
Burning	In fall or spring on pastures with plant litter	Can kill plants and attached seeds; by removing litter, fire better exposes ragwort plants to herbicides	Nutrient cycling and removal of litter can encourage sprouting of tansy ragwort; may cause air quality or erosion issues; not applicable for vast areas; fire can escape control	Follow with herbicides and planting of competitive species
Grazing	Use sheep continuously in the growing season or as a pre-conditioner before cattle; cattle to be used only when healthy forage available and for the purpose of increasing ragwort exposure to herbicides	Efficient; may find remote or dificult-to-access infestations; increases ragwort exposure to herbicides	Continuous grazing required which is time-consuming and can be hard on the environment; nontarget effects on desirable broadleaf species; marketing issues may discourage high stocking rates	Supplement with biocontrol; may follow with burning or chemicals only if animals removed
Herbicides	On actively growing rosettes in fall or spring; broadcast over entire pasture/range or spot-treat plants	Can kill young infestations in single visit if no seed bank; has residual control effects	Expensive; established ragwort often requires repeat visits; can have non-target and negative environmental effects for multiple years	Supplement with hand-pulling; follow with planting

*Be sure to check with your local weed control authority or state department of agriculture to ensure this is a permitted biological control agent in your area.

Table 14 Treatment options for an integrated approach to managing tansy ragwort along roasises and trails

METHOD	TECHNIQUE	ADVANTAGES	DISADVANTAGES	INTEGRATION
Biological	Release moth larvae* in summer; seed head fly pupae in early spring; flea beetles in fall/summer (see Table 7 in Chapter 4 for strains)	Very effective; self perpetuating; can access spreading populations; can be cost effective	Slow initially; multiple introductions may be needed; cinnabar moth can have some nontarget effects	Supplement with planting, herbicides that don't kill all plants, and mowing when insects not active above-ground
Mowing	On plants prior to seed formation; plants will recover so multiple mows likely needed	Reduces spread of population; weakens plants after multiple cuttings; easy in flat terrain	Time consuming; tansy ragwort can regrow quickly and requires multiple visits; may negatively affect some competing species	Supplement with herbicides, flea beetle biocontrol, planting competitive species
Planting Competitive Species	Broadcast seed of grasses or forbs in spring or fall (dependent on species)	Ragwort seedlings susceptible to competition; good for site reclamation	Can be expensive and time-consuming; difficult or can fail when tansy ragwort dense; may introduce unwanted material	First apply herbicides; follow with biocontrol; maybe mowing
Burning	In fall or spring when other plants have senesced and released seed	Can kill plants; by removing litter, fire better exposes ragwort plants to herbicides	Nutrient cycling and removal of litter can encourage sprouting of tansy ragwort; may cause air quality or erosion issues; fire can escape control	Follow later with herbicide treatment
Herbicides	On actively growing rosettes in fall or spring; broadcast over entire pasture/range or spot-treat plants	Can kill young infestation in single visit if no seed bank; has resiual control effects	Expensive; established ragwort often requires repeat visits; can have nontarget and negative environmental effects for multiple years	Precede with burning; follow with planting competitive species

*Be sure to check with your local weed control authority or state department of agriculture to ensure this is a permitted biological control agent in your area.

the immediate area. Herbicide treatments in forest clearings are usually done on a small scale as spot treatments with backpack or ATV sprayers. Their success is dependent upon the thorough identification of all tansy ragwort plants in the vicinity. Well-timed herbicide applications can help treat new tansy ragwort (and other weed species) sprouting from the soil seedbank and help promote competing vegetation. Biological control agents have proven beneficial on slash piles in the Intermountain West by successfully dispersing to disjunct slash piles, patches, and scattered plants that otherwise may not have been located by people. Supplemental releases at widely spaced tansy ragwort infestations increase the insects' dispersal abilities and efficacy. The variable conditions under which the three agents can thrive have made them successful in shaded, partially shaded, or full sun infestations. Given the difficulty in locating all tansy ragwort plants in a region, and the higher dispersal ability of the insects, herbicides and biocontrol integrate well within a slash pile/forest clearing tansy ragwort management program. During revegetation efforts, the most effective species to be planted to compete with tansy ragwort are natives already growing in the area. Restoring the plant community to its pre-logging status and decreasing the soil disturbance will help tip the ecological balance away from tansy ragwort and other similar weeds. Integrated control methods available for use on tansy ragwort infestations in forest clearings and slash piles are summarized in Table 15.

Table 15 Treatment options for an integrated approach to managing tansy ragwort in forest clearings/slash piles

METHOD	TECHNIQUE	ADVANTAGES	DISADVANTAGES	INTEGRATION
Biological	Release cinnabar moth larvae* in summer; seed head fly pupae in early spring; flea beetle adults in fall or summer (see Table 7 in Chapter 4 for strains)	Very effective; self perpetuating; can access isolated populations; can be cost effective	Slow initially; many introductions may be needed; cinnabar moth can have some nontarget effects	Supplement with herbicides that don't kill all plants or planting native species (including trees)
Planting Competitive Species	Broadcast seed of native occurring species in spring or fall (dependent on species)	Ragwort seedlings susceptible to competition; good for site reclamation	Can be expensive and time-consuming; difficult or can fail when tansy ragwort dense; may introduce unwanted material	First apply herbicides; follow with biocontrol
Herbicides	On actively growing rosettes in fall or spring; spot-treat plants	Can kill young infestation in single visit if no seed bank; has residual control effects	Expensive; time-consuming; difficult to locate all tansy ragwort individuals in area; often requires repeat visits; can have nontarget and negative environmental effects for multiple years	Supplement with biocontrol; follow with planting competitive species

*Be sure to check with your local weed control authority or state department of agriculture to ensure this is a permitted biological control agent in your area.

GLOSSARY

abdomen	The last of the three insect body regions; usually containing the digestive and reproductive organs
achene	A small, one-seeded fruit that does not split at maturity
adventive	Species that arrived in the geographical area from elsewhere by any means, but is not self-sustaining and whose numbers are only increased through non-reproductive means, unlike a naturalized species
aestivation	A period of dormancy to survive predictable, unfavorable environmental conditions, such as temperature extremes, drought or reduced food availability
alternate	Where leaves appear singly at stem nodes, on alternate sides of the stem
antenna (pl. antennae)	In arthropods, one of a pair of appendages on the head, normally many jointed and of sensory function
aspirator	An apparatus used to suck insects into a container. Can be as simple as in a mouth aspirator, or mechanical as in a gasoline- or battery-powered vacuum aspirator
basal	Located at the base of a plant or plant part
biennial	A plant that flowers and dies between its first and second years and does not flower in its first year
biological control	The reduction in the abundance of a pest through intentional use of its natural enemies (predators, parasitoids, and pathogens)
bolting	Plant stage at which the flower stalk begins to grow
bract	A small, leaf-like structure below a flower
broadcast application	The spreading of pesticides over an entire area
capitulum (pl. capitula)	Seed head of a plant in the sunflower family
complete metamorphosis	An insect life cycle with four distinct stages (egg, larva, pupa, adult)
compound eyes	Paired eyes consisting of many facets, or ommatidia, in most adult Arthropoda
coordinates	A set of numbers used to specify a location
crown	Location of where a plant's stems meets its roots

density	Number of individuals per unit area
dissemination	Dispersal. Can be applied to seeds or insects
elytron (pl. elytra)	Hardened front wing of a beetle
emergence	Act of adult insect leaving the pupal exoskeleton, or leaving winter or summer dormancy
exoskeleton	Hard, external skeleton of the body of an insect
exotic	Not native
floret	One of the small, closely clustered flowers forming the head of a composite flower in the sunflower family
flower head	A special type of inflorescence consisting of numerous florets that actually look like one flower
forb	Herbaceous plant (does not have solid woody stems)
genus (pl. genera)	A taxonomic category ranking below family and above species and consisting of a group of species exhibiting similar characteristics. The genus name is followed by a Latin adjective or epithet to form the name of a species
grub	A soft, thick-bodied, C-shaped beetle larva
head	Insect segment with the mouthparts, antennae, and eyes
head capsule	Hardened covering of the head of an immature insect
herbivory	Feeding on plants
host	The plant or animal on which an organism feeds; the organism utilized by a parasitoid; a plant or animal susceptible to attack by a pathogen
host specificity	The highly-evolved, often obligatory association between an insect and its host (i.e. weed). A highly host-specific insect feeds only on its host and on no other species
inflorescence	The flowering part of a plant
instar	The phase of an insect's nymphal or larval development between molts
integrated weed management	A system for the planning and implementation of a program, using an interdisciplinary approach, to select a method for containing or controlling an undesirable plant species (or group) using all available methods
involucre	A circle of bracts under an inflorescence
larva (pl. larvae)	Immature insect stage between the egg and pupa (examples include grubs, caterpillars and maggots)
lobed	A leaf with shallow or deep, rounded segments, as in a thistle rosette leaf
membranous	Thin and transparent
molting	Process of insect development that involves shedding its exoskeleton and producing another for the next instar
NAD 83	North American Datum, the official datum used for the UTM geographic coordinate system in North America
node	Part of the stem of a plant from which a leaf, branch, or aerial root grows

nontarget effect	When control efforts affect a species other than the species they were enacted to control (can be positive or negative)
oviposit	To lay or deposit eggs
pappus	A tuft of hairs, scales, or bristles at the base of an achene in flowers of the sunflower family
perennial	A plant that lives three or more years
petiole	Leaf stalk that attaches it to a plant stem
proleg	A fleshy, unsegmented, abdominal walking appendage of some insect larvae, common among caterpillars
pupa (pl. pupae) (v. pupate)	Non-feeding, inactive insect stage between larva and adult
qualitative	Measurement of descriptive elements (e.g., age class, distribution)
quantitative	Measurement of quantity; the number or amount (e.g., seeds per capitula)
receptacle	Part of the stem to which the flower is attached
rosette	A compact, circular, and normally basal cluster of leaves
seed head	Synonym for capitulum of a plant in the sunflower family. Consists of a receptacle and florets
senescence	Final stage in a plant's life cycle
species	A fundamental category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding
spot application	Applying pesticides on one plant or on small patches
synchrony	Occurring at the same time (e.g. plant flowering and insect oviposition)
taxonomy	The classification of organisms in an ordered system that indicates natural relationships. The science, laws, or principles of classification; systematics
thorax	Body region of an insect behind the head and abdomen, bearing the legs and wings
transect	A straight line of varying length along which plants are periodically sampled individually or in quadrants
UTM	Universal Transverse Mercator, a grid-based geographic coordinate system
WGS 84	The World Geodetic System, a datum for latitude/longitude geographic coordinate systems

SELECTED REFERENCES

Chapter 1: Introduction

Bain, J.F. 1991. The biology of Canadian weeds. 96. *Senecio jacobaea* L. Can. J. Plant Sci. 71: 127-140.

Balciunas, J.K. 1999. Code of best practices for classical biocontrol of weeds. In: N.R. Spencer (ed.). Proceedings of the X International Symposium on Biological Control of Weeds. Montana State University, Bozeman, Montana, USA.

Coombs, E.M., H. Radtke, D.L. Isaacson, and S.P. Snyder. 1996. Economic and regional benefits from the biological control of tansy ragwort, *Senecio jacobaea*, in Oregon. Pp. 489-494. In: V.C. Moran and J.H. Hoffmann (eds.). Proceedings of the IX International Symposium on Biological Control of Weeds. University of Cape Town, Stellenbosch, South Africa.

Coombs, E.M., J.K. Clark, G.L. Piper, and A.F. Cofrancesco, Jr. (eds.). 2004. Biological Control of Invasive Plants in the United States. Oregon State University Press, Corvallis. 467 p.

Greenman, J.M. 1915. Monograph of the North and Central American species of the Genus *Senecio* - Part II. Annals of the Missouri Botanical Garden 2: 573-626.

Harper, J.L., and W.A. Wood. 1957. Biological flora of the British Isles, *Senecio jacobaea* L. Journal of Ecology 45: 617-637.

Isaacson, D.L. 1976. The role of biological control agents in integrated control of tansy ragwort. Pp. 189-192. In: T.E. Freeman (ed.). Proceedings of the IV International Symposium on Biological Control of Weeds. Gainesville, Florida, USA.

Julien M.H. and M.W. Griffiths. 1998. Biological control of weeds: A world catalogue of agents and their target weeds, 4th edition. Wallingford, UK: CAB International Publishing

Macel, M., K. Vrieling, P.G.L. Klinkhamer. 2004. Variation in pyrrolizidine alkaloid patterns of *Senecio jacobaea*. Phytochemistry 65: 865-873.

McFadyen, R.E.C. 1998. Biological control of weeds. Annual Review of Entomology 43: 369-393.

van der Meijden, E. 1974. The distribution of *Senecio jacobaea* L. and *Tyria jacobaeae* L. in relation to soil properties. Acta Botanica Neerlandica 23: 681-690.

NAPPO RSMP NO. 7. 2008. North American Plant Protection Organization, Regional Standards for Phytosanitary Measures, Number 7. Guidelines for Petition for First Release of Non-indigenous Phytophagous Biological Control Agents. Ottowa, Ontario, Canada.

Pelser, P.B., Veldkamp, J.-F. & van der Meijden, R. 2006. New combinations in *Jacobaea* Mill. (Asteraceae-Senecioneae). Compositae Newsletter 44: 1-11.

Pelser, P.B., B. Nordenstam, J.W. Kadereit, and L.E. Watson. 2007. An ITS phylogeny of Tribe Senecioneae (Asteraceae) and a new delimitation of *Senecio* L. Taxon 56: 1077-1104.

Pemberton, R.W., and C.E. Turner. 1990. Biological control of *Senecio jacobaea* in northern California, an enduring success. Entomophaga 35: 71-77.

Poole, H.S. 1915. *Senecio jacobaea* and *Callimorpha jacobaeae* (the cattle killing ragwort and the cinnabar moth). Proceedings of the Nova Scotian Institute (Halifax) 13: 279-288.

Rice, P.M. 2011. INVADERS Database System (http://invader.dbs.umt.edu). Division of Biological Sciences, University of Montana, Missoula, MT 59812-4824. Accessed 18 January, 2011.

Turner, C.E., and P.B. McEvoy. 1995. Tansy ragwort. Pages 264-269 in J.R. Nechols, L.A. Andres, J.W. Beardsly, R.D. Goeden, and C.G. Jackson, editors. Biological Control in the Western United States: Accomplishments and Benefits of Regional Research Project W-84, 1964-1989. Univ. CA, Div. Agric. and Nat. Res., Berkeley & Oakland, CA.

USDA, APHIS. 2000. Reviewer's Manual for the Technical Advisory Group for Biological Control Agents of Weeds Guidelines for Evaluating the Safety of Candidate Biological Control Agents. Animal and Plant Health Inspection Service, Plant Protection and Quarantine. 02/2003.

USDA, NRCS. 2011. The PLANTS Database (http://plants.usda.gov, 26 April 2011). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Wardle, D.A. 1987. The ecology of ragwort (*Senecio jacobae*a L.) - A Review. New Zealand Journal of Ecology 10: 67-76.

Chapter 2: Getting to Know Tansy Ragwort

Andersson, S. 2001. The genetic basis of floral variation in *Senecio jacobaea* (Asteraceae). The Journal of Heredity 92(5): 409-414.

Bain, J.F. 1991. The biology of Canadian weeds. 96. *Senecio jacobaea* L. Can. J. Plant Sci. 71: 127-140.

Cameron, E. 1935. A study of the natural control of ragwort (*Senecio jacobaea* L.). Journal of Ecology 23: 265-322.

Coombs, E.M., T.E. Bedell, and P.B. McEvoy. 1991. Tansy ragwort (*Senecio jacobaea*): importance, distribution and control in Oregon. Pp. 419-428. In: L.F. James, J.O. Evans, M.H. Ralphs, and R.D. Child (eds.). Noxious Range Weeds. Westview Press, Inc., Boulder, CO.

Coombs, E.M., J.K. Clark, G.L. Piper, and A.F. Cofrancesco, Jr. (eds.). 2004. Biological Control of Invasive Plants in the United States. Oregon State University Press, Corvallis. 467 p.

Flora of North America. 2008. *Senecio*. FNA Volume 20, pp. 544. (www.efloras.org) Accessed 19 January, 2011.

Harper, J.L., and W.A. Wood. 1957. Biological flora of the British Isles, *Senecio jacobaea* L. Journal of Ecology 45: 617-637.

Markin, G.P. and J.L. Birdsall, 1999. Biological control of tansy ragwort in Montana: status of research as of December 1999 (unpublished report). USFS Rocky Mountain Research Station, Bozeman, MT. 21 pp.

McEvoy, P.B. 1984a. Dormancy and dispersal in dimorphic achenes of tansy ragwort, *Senecio jacobaea* L. (Compositae). Oecologia 61: 160-168.

McEvoy, P.B. 1984b. Seedling dispersion and the persistence of ragwort *Senecio jacobaea* (Compositae) in a grassland dominated by perennial species. Oikos 42: 138-143.

McEvoy, P.B. and C.S. Cox. 1987. Wind dispersal distances in dimorphic achenes of ragwort, *Senecio jacobaea*. Ecology 68(6): 2006-2015.

Pelser, P.B., B. Gravendeel, and R. van der Meijden. 2002. Tackling speciose genera: species composition and phylogenetic position of *Senecio* sect. Jacobaea (Asteraceae) based on plastid and nrDNA sequences. Amer. J. Bot. 89: 929-939.

Pelser , P.B., B. Nordenstam, J.W. Kadereit, and L.E. Watson. 2007. An ITS phylogeny of Tribe Senecioneae (Asteraceae) and a new delimitation of *Senecio* L. Taxon 56: 1077-1104 .

Poole, A.L. and D. Cairns. 1940. Botanical aspects of ragwort (*Senecio jacobaea* L.) control. Bull. N.Z. Dep. Sci. Indust. Res. 82: 1-66.

Rice, P.M. 2011. INVADERS Database System (http://invader.dbs.umt.edu). Division of Biological Sciences, University of Montana, Missoula, MT 59812-4824. Accessed 18 January, 2011.

Sheley, R.L. and J.K. Petroff. 1999. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, OR.

USDA, NRCS. 2011. The PLANTS Database (http://plants.usda.gov, 26 April 2011). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Wardle, D.A. 1987. The ecology of ragwort (*Senecio jacobaea* L.) - A Review. New Zealand Journal of Ecology 10: 67-76.

Chapter 3: Biology of Tansy Ragwort Biological Control Agents

Andreas, J., E.M. Coombs, G.L. Piper, M. Schwarzländer, and J. Milan. 2010. Biological Control. Pp. 4-7. In: R.D. William, D. Ball, T.L. Miller, R. Parker, J.P. Yenish, T.W. Miller, D.W. Morishita and P.J.S. Hutchinson (eds.). Pacific Northwest Weed Management Handbook. Extension Services, Oregon State University, Corvallis, OR.

British Columbia Biocontrol Development Website. 2011. British Columbia Ministry of Forests, Lands, and Natural Resources. http://www.for.gov.bc.ca/hra/Plants/biocontrol/index.htm. Accessed 30 April 2001.

Brown, R.E. 1989. Biological control of tansy ragwort (*Senecio jacobaea*) in western Oregon, U.S.A., 1975-87. Pp. 299-305. In: E.S. Delfosse (ed.). Proceedings VII International Symposium on the Biological Control of Weeds. Rome, Italy.

Coombs, E.M., J.K. Clark, G.L. Piper, and A.F. Cofrancesco, Jr. (eds.). 2004. Biological Control of Invasive Plants in the United States. Oregon State University Press, Corvallis. 467 p.

DeClerck-Floate, R., U. Schaffner, and S. Turner. Request for renewal of permit to field release the Swiss biotype of *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae) as a biological control agent for tansy ragwort, *Jacobaea vulgaris* (Compositae: Asteraceae) in Canada. CFIA Release Petition. May, 2010. 36 pp.

Dempster, J.P. 1982. The ecology of the cinnabar moth, *Tyria jacobaeae* L. (Lepidoptera, Arctiidae). Advan. Ecol. Res. 12: 1-36.

Diehl, J.W. 1988. Feeding, colonization and impact of the cinnabar moth, *Tyria jacobaeae*, on *Senecio triangularis*, a novel, native host plant. A thesis submitted to Oregon State University. 85 pp.

Frick, K.E. 1969. Attempts to establish the ragwort seed fly in the United States. J. Econ. Entom. 62: 1135-1138.

Frick, K.E. 1970. Ragwort flea beetle established for biological control of tansy ragwort in northern California. California Agriculture 24: 12-13.

Frick, K.E. 1971. Longitarsus jacobaeae (Coleoptera: Chrysomelidae), a flea beetle for the biological control of tansy ragwort. II. Life history of a Swiss biotype. Annals of the Entomological Society of America 64: 834-840.

Frick, K.E. and J.K. Holloway. 1964. Establishment of the cinnabar moth, *Tyria jacobaeae*, on tansy ragwort in the western United States. J. Econ. Entomol. 57: 152-154.

Frick, K.E. and G.R. Johnson. 1972. *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae), a flea beetle for the biological control of tansy ragwort. 3. Comparison of the biologies of the egg stage of Swiss and Italian biotypes. Annals of the Entomological Society of America 65: 406-410.

Frick, K.E. and G.R. Johnson. 1973. *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae), a flea beetle for the biological control of tansy ragwort. 4. Life history and adult aestivation of an Italian biotype. Annals of the Entomological Society of America 66: 358-366.

Fuller, J.L. 2002. Assessing the safety of weed biological control: a case study of the cinnabar moth *Tyria jacobaeae*. A thesis submitted to Oregon State University. 66 pp.

Ireson, J.E., R.J. Holloway, W.S. Chatterton, and S.M. Leighton. 2000. Establishment and redistribution of *Longitarsus flavicomis* (Stephens)(Coleoptera: Chrysomelidae) for the biological control of ragwort (*Senecio jacobaea* L.) in Tasmania Australian Journal of Entomology 39: 42-46.

James, R.R., P.B. McEvoy, and C.S. Cox. 1992. Combining the cinnabar moth (*Tyria jacobaeae*) and the ragwort flea beetle (*Longitarsus jacobaeae*) for control of ragwort (*Senecio jacobaea*): An experimental analysis. Journal of Applied Ecology 29: 589-596.

Julien, M.H. and M.W. Griffiths. 1998. Biological control of weeds: A world catalogue of agents and their target weeds, 4th edition. Wallingford, UK: CAB International Publishing.

Littlefield, J.L., G.P. Markin, K.P. Puliafico, and A.E. deMeij. 2008. The release and establishment of the tansy ragwort flea beetle in the Northern Rocky Mountains of Montana. Pp. 573-576. In: M.H. Julien, R. Sforza, M.C. Bon, H.C. Evans, P.E. Hatcher, H.L. Hinz and B.G. Rector (eds.). Proceedings of the XII International Symposium on Biological Control of Weeds. La Grande Motte, France.

Markin, G.P. and J.L. Birdsall. 1999. Biological control of tansy ragwort in Montana: status of research as of December 1999 (unpublished report). USFS Rocky Mountain Research Station, Bozeman, MT. 21 pp.

Markin, G.P. and J.L. Birdsall. 2001. Biological control of tansy ragwort in Montana: status of research as of December 2001 (unpublished report). USFS Rocky Mountain Research Station, Bozeman, MT. 20 pp.

Markin, G.P. and J.L. Littlefield. 2008. Biological control of tansy ragwort (*Senecio jacobaeae* L.) by the cinnabar moth, *Tyria jacobaeae* (CL) (Lepidoptera: Arctiidae), in the northern Rocky Mountains. Pp. 583-588. In: M.H. Julien, R. Sforza, M.C. Bon, H.C. Evans, P.E. Hatcher, H.L. Hinz and B.G. Rector (eds.). Proceedings of the XII International Symposium on Biological Control of Weeds. La Grande Motte, France.

McLaren, D.A. 1992. Observations on the life history and establishment of *Cochylis atricapitana* (Lep: Cochylidae), a moth used for biological control of *Senecio jacobaea* in Australia. Entomophaga 37: 641-648.

McLaren, D.A., J.A. Ireson, and R.M. Kwong. 2000. Biological control of ragwort in Australia. Pp. 67-79. In: Neal R. Spencer (ed.). Proceedings of the Xth International Symposium on Biological Control of Weeds. Montana State University, Bozeman, Montana, USA.

Naumann, C., T. Hartmann, and D. Ober. 2002. Evolutionary recruitment of a flavin-dependent monooxygenase for the detoxification of host plant-acquired pyrrolizidine alkaloids in the alkaloid-defended arctiid moth *Tyria jacobaeae*. PNAS: 6085-6090.

Potter, K.J.B., J.E. Ireson, and G.R. Allen. 2004. Oviposition of the ragwort flea beetle, *Longitarsus flavicornis* (Stephens) (Coleoptera: Chrysomelidae), in relation to the phenology of ragwort, *Senecio jacobaea* L. (Asteraceae). Biological Control 30: 404-409.

Puliafico, K.P. 2003. Molecular taxonomy, bionomics and host specificity of *Longitarsus jacobaeae* (Waterhouse) (Coleoptera: Chrysomelidea): The Swiss Population Revisited. Master of Science Thesis, Montana State University, Bozeman, MT. 129 pp.

Puliafico, K.P., J.L. Littlefield, G.P. Markin, and U. Schaffner. 2008. Field and laboratory observations of the life history of the Swiss biotype of *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae). Pp. 200-205. In: M.H. Julien, R. Sforza, M.C. Bon, H.C. Evans, P.E. Hatcher, H.L. Hinz and B.G. Rector (eds.). Proceedings of the XII International Symposium on Biological Control of Weeds. La Grande Motte, France.

van Zoelen, A.M. and G.J. Kusters. 1986. Termination of diapause in the cinnabar moth (*Tyria jacobaeae*) by chilling. Entomol. Exp. Appl. 45: 185-192.

Chapter 4: Elements of a Tansy Ragwort Biocontrol Program

Coombs, E.M., J.K. Clark, G.L. Piper, and A.F. Cofrancesco, Jr. (eds.). 2004. Biological Control of Invasive Plants in the United States. Oregon State University Press, Corvallis. 467 p.

Frick, K.E. and G.R. Johnson. 1973. *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae), a flea beetle for the biological control of tansy ragwort. 4. Life history and adult aestivation of an Italian biotype. Annals of the Entomological Society of America 66: 358-366.

Markin, G.P. and J.L. Birdsall. 1999. Biological control of tansy ragwort in Montana: status of research as of December 1999 (unpublished report). USFS Rocky Mountain Research Station, Bozeman, MT. 21 pp.

Markin, G.P. and J.L. Birdsall. 2001. Biological control of tansy ragwort in Montana: status of research as of December 2001 (unpublished report). USFS Rocky Mountain Research Station, Bozeman, MT. 20 pp.

Markin, G.P. and J.L. Littlefield. 2008. Biological control of tansy ragwort (*Senecio jacobaeae* L.) by the cinnabar moth, *Tyria jacobaeae* (CL) (Lepidoptera: Arctiidae), in the northern Rocky Mountains. Pp. 583-588. In: M.H. Julien, R. Sforza, M.C. Bon, H.C. Evans, P.E. Hatcher, H.L. Hinz and B.G. Rector (eds.). Proceedings of the XII International Symposium on Biological Control of Weeds. La Grande Motte, France.

Puliafico, K.P., J.L. Littlefield, G.P. Markin, and U. Schaffner. 2008. Field and laboratory observations of the life history of the Swiss biotype of *Longitarsus jacobaeae* (Coleoptera: Chrysomelidae). Pp. 200-205. In: M.H. Julien, R. Sforza, M.C. Bon, H.C. Evans, P.E. Hatcher, H.L. Hinz and B.G. Rector (eds.). Proceedings of the XII International Symposium on Biological Control of Weeds. La Grande Motte, France.

Chapter 5: An Integrated Tansy Ragwort Management Program

Bain, J.F. 1991. The biology of Canadian weeds. 96. *Senecio jacobaea* L. Can. J. Plant Sci. 71: 127-140.

Bedell, T.E., R.E. Whitesides, and R.B. Hawkes. 1981. Pasture management for control of tansy ragwort. Pacific Northwest Cooperative Extension Publication No. 210.

Brewster, B.D., M.P. Rolston, and A.P. Appleby. 1978. Control of tansy ragwort in western Oregon pastures with 2,4-D. Oregon State University Agricul. Exper. Stat. Circular 665.

Coombs, E.M., T.E. Bedell, and P.B. McEvoy. 1991. Tansy ragwort (*Senecio jacobaea*): importance, distribution and control in Oregon. Pp 419-428. In: L.F. James, J.O. Evans, M.H. Ralphs, and R.D. Child (eds.). Noxious Range Weeds. Westview Press, Inc, Boulder, CO.

Coombs, E.M., H. Radtke, D.L. Isaacson, and S.P. Snyder. 1996. Economic and regional benefits from the biological control of tansy ragwort, *Senecio jacobaea*, in Oregon. Pp. 489-494. In: V.C. Moran and J.H. Hoffmann (eds.). Proceedings of the IX International Symposium on Biological Control of Weeds. University of Cape Town, Stellenbosch, South Africa.

Goodwin, K., G. Marks, and R. Sheley. 2006. Revegetation guidelines for western Montana: considering weeds. Montana State University, Extension EB 170. 44 pp.

Harper, J.L., and W.A. Wood. 1957. Biological flora of the British Isles, *Senecio jacobaea* L. Journal of Ecology 45: 617-637.

Jacobs, J. and S. Sing. 2009. Ecology and management of tansy ragwort (*Senecio jacobaea* L.). NRCS Invasive Species Technical Note MT-24

Native Seed Network. http://www.nativeseednetwork.org. Accessed 26 April 2011.

Pacific Northwest Weed Management Handbook. 2011. Compiled by E. Peachey, D. Ball, R. Parker, J.P. Yenish, T.W. Miller, D.W. Morishita, and P.J.S. Hutchinson. Oregon State University Agricultural, Corvallis, OR. 451 pp. http://pnwhandbooks.org/weed/

Poole, A.L. and D. Cairns. 1940. Botanical aspects of ragwort (*Senecio jacobaea* L.) control. Bull. N.Z. Dep. Sci. Indust. Res. 82: 1-66.

Sharrow, S.T. and W.D. Mosher. 1983. Sheep as a biological control agent for tansy ragwort. Journal of Range Management 35: 480-482.

Sheley, R.L., J. Mangold, K. Goodwin, and J. Marks. 2008. Revegetation Guidelines for the Great Basin: Considering Invasive Weeds. Agricultural Research Service Publication. ARS-168.

Suter, M.S. Siegrist-Maag, J. Connolly, and A. Luscher. 2007. Can the occurrence of *Senecio jacobaea* be influenced by management practice? Weed Research 47: 262-269.

Trainor, M.A. 2003. Quantifying tansy ragwort (*Senecio jacobaea*) population dynamics and recruitment in northwestern Montana. Masters thesis. Montana State University, Bozeman, Montana.

VanBebber, R. 2003. CWMA Cookbook: A recipe for success. Idaho State Department of Agriculture, Boise, ID. 22 pp.

van der Meijden, E. and R.E. van der Waals-Kooi.1979. The population ecology of *Senecio jacobaea* in a (Netherlands) sand dune system: 1. Reproductive strategy and the biennial habit. Journal of Ecology 67: 131-153.

Wardle, D.A. 1987. The ecology of ragwort (*Senecio jacobaea* L.) - A Review. New Zealand Journal of Ecology 10: 67-76.

USDA, NRCS. 2011. The PLANTS Database (http://plants.usda.gov, 26 April 2011). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

APPENDICES

Appendix I: Related Senecioneae Species Native to North America

SCIENTIFIC NAME	COMMON NAME	DURATION	HABIT	DISTRIBUTION
Packera anonyma	Small's ragwort	Perennial	Forb	AL, AR, DC, DE, FL, GA, IN, KY, LA, MD, MS, NC, NJ, NY, OH, PA, SC, TN, VA, WV
P. antennariifolia	Shale barren ragwort	Perennial	Forb	MD, PA, VA, WV
P. aurea	Golden ragwort	Perennial	Forb	AL, AR, CT, DC, DE, FL, GA, IA, IL, IN, KY, MA, MD, ME, MI, MN, MO, MS, NC, NH, NJ, NY, OH, OK, PA, RI, SC, TN, TX, VA, VT, WI, WV; LB, MB, NB, NF, NS, ON, PE, QC; SPM
P. bernardina	San Bernardino	Perennial	Forb	CA
P. bolanderi	Bolander's ragwort	Perennial	Forb	CA, OR, WA
P. breweri	Brewer's ragwort	Biennial Perennial	Forb	CA
P. cana	Woolly groundsel	Perennial	Forb Subshrub	CA, CO, ID, KS, MN, MT, ND, NE, NM, NV, OR, SD, UT, WA, WY; AB, BC, MB, SK
P. cardamine	Bittercress ragwort	Perennial	Forb	AZ, NM
P. castoreus	Beaver Mountain ragwort	Perennial	Forb	UT
P. clevelandii	Cleveland's ragwort	Perennial	Forb	CA
P. contermina	Northwestern groundsel	Perennial	Forb	MT; AB, BC, NT, YT
P. crocata	Saffron ragwort	Perennial	Forb	CO, MT, UT, WY
P. cymbalaria	Dwarf arctic ragwort	Perennial	Forb	AK, ID, MT, WA; AB, BC, NF, NT, QC, YT
P. cynthioides	White Mountain ragwort	Perennial	Forb	AZ, NM
P. debilis	Weak groundsel	Perennial	Forb	CO, ID, MT, WY
P. dimorphophylla	Splitleaf groundsel	Perennial	Forb	CO, ID, MT, NM, NV, OR, UT, WY
P. eurycephala	Widehead groundsel	Perennial	Forb Subshrub	CA, NV, OR
P. fendleri	Fendler's ragwort	Perennial	Forb	CO, NM, WY
P. fletti	Flett's ragwort	Perennial	Forb	OR, WA
P. franciscana	San Francisco Peaks ragwort	Perennial	Forb	AZ
P. ganderi	Gander's ragwort	Perennial	Forb	CA
P. glabella	Butterweed	Perennial	Forb	AL, AR, FL, GA, IA, IL, IN, KS, KY, LA, MD, MO, MS, NC, NE, OH, OK, SC, SD, TN, TX; ON
P. greenei	Flame ragwort	Perennial	Forb	CA
P. hartiana	Hart's ragwort	Perennial	Forb	AZ, NM, TX, UT
P. hesperia	Western ragwort	Perennial	Forb	OR
P. hyperborealis	Northern groundsel	Perennial	Forb	AK, MT; AB, BC, NT, NU, YT
P. indecora	Elegant groundsel	Perennial	Forb	AK, CA, ID, MI, MN, MT, WA, WI, WY; AB, BC, LB, MB, NT, NU, ON, QC, SK, YT
P. ionophylla	Tehachapi ragwort	Perennial	Forb	CA

Appendix I (continued): Related Senecioneae Species Native to North America

SCIENTIFIC NAME	COMMON NAME	DURATION	HABIT	DISTRIBUTION
Packera layneae	Layne's ragwort	Perennial	Forb	CA
P. macounii	Siskiyou Mountain ragwort	Perennial	Forb	CA, OR, WA; BC
P. malmstenii	Podunk ragwort	Perennial	Forb	UT
P. millefolium	Piedmont ragwort	Perennial	Forb	GA, NC, SC, VA
P. millelobata	Uinta ragwort	Perennial	Forb	NM, TX
P. moresbiensis	Cleftleaf ragwort	Perennial	Forb	AK; BC
P. multilobata	Lobeleaf groundsel	Annual Perennial	Forb	AZ, CA, CO, ID, NM, NV, UT, WY
P. neomexicana	New Mexico groundsel	Perennial	Forb Subshrub	AZ, CO, NM, TX, UT
P. obovata	Roundleaf ragwort	Perennial	Forb	AL, AR, CT, DC, FL, GA, IL, IN, KS, KY, LA, MA, MD, MI, MO, MS, NC, NH, NJ, NM, NY, OH, OK, PA, RI, SC, TN, TX, VA, VT, WV; ON, QC
P. ogotorukensis	Ogotoruk Creek ragwort	Perennial	Forb	AK
P. pauciflora	Alpine groundsel	Perennial	Forb	AK, CA, CO, ID, MI, MN, MT, NV, WA, WY; AB, BC, LB, NF, NT, ON, QC, YT
P. paupercula	Balsam groundsel	Perennial	Forb	AK, AL, CO, CT, DE, FL, GA, IA, ID, IL, IN, KY, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NH, NJ, NM, NY, OH, PA, RI, SD, TN, UT, VA, VT, WA, WI, WV, WY; AB, BC, LB, MB, NB, NF, NS, NT, NU, ON, PE, QC, SK, YT
P. plattensis	Prairie groundsel	Biennial Perennial	Forb	AR, AZ, CO, IA, IL, IN, KS, KY, LA, MI, MN, MO, MT, NC, ND, NE, NM, OH, OK, PA, SD, TN, TX, VA, VT, WI, WV, WY; AB, BC, MB, NT, ON, SK
P. porteri	Porter's groundsel	Perennial	Forb Subshrub	CO, OR
P. pseudaurea	Falsegold groundsel	Perennial	Forb	CA, CO, IA, ID, IL, IN, KS, MN, MO, MT, ND, NE, NM, NV, OR, SD, WA, WI, WY; AB, BC, MB, SK
P. quaerens	Mogollon Mountain ragwort	Perennial	Forb	AZ, NM
P. quercetorum	Oak Creek ragwort	Perennial	Forb	AZ, NM
P. sanguisorboides	Burnet ragwort	Biennial Perennial	Forb	NM
P. schweinitziana	Schweinitz's ragwort	Perennial	Forb	ME, NC, NH, NY, TN, VT; NB, NS, PE, QC
P. spellenbergii	Carrizo Creek ragwort	Perennial	Forb	NM
P. streptanthifolia	Rocky Mountain groundsel	Perennial	Forb	AK, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY; AB, BC, MB, NT, SK, YT
P. subnuda	Buek's groundsel	Perennial	Forb	CA, ID, MT, OR, WA, WY; AB, BC, NT, SK

Appendix I (continued): Related Senecioneae Species Native to North America

SCIENTIFIC NAME	COMMON NAME	DURATION	HABIT	DISTRIBUTION
Packera tampicana	Great Plains ragwort	Annual	Forb	KS, LA, MO, MS, NM, OK, TX
P. tomentosa	Woolly ragwort	Perennial	Forb	AL, AR, DE, FL, GA, LA, MD, MO, MS, NC, NJ, OK, SC, TX, VA
P. tridenticulata	Threetooth ragwort	Perennial	Forb Subshrub	CO, KS, ND, NE, NM, OK, SD, TX, WY; MB, NT, SK
P. werneriifolia	Hoary groundsel	Perennial	Forb	AZ, CA, CO, ID, MT, NM, NV, UT, WY
Senecio actinella	Flagstaff ragwort	Perennial	Forb	AZ, NM
S. amplectens	Showy alpine ragwort	Perennial	Forb	CO, MT, NM, NV, UT, WY
S. ampullaceus	Texas ragwort	Annual	Forb	AR, MO, TX
S. aphanactis	Chaparral ragwort	Annual	Forb	CA
S. arizonicus	Arizona ragwort	Perennial	Forb	AZ, NM
S. aronicoides	Rayless ragwort	Biennial Perennial	Forb	CA, OR
S. astephanus	San Gabriel ragwort	Perennial	Forb	CA
S. atratus	Tall blacktip ragwort	Perennial	Forb	CO, NM, UT, WY
S. bigelovii	Nodding ragwort	Perennial	Forb	AZ, CO, NM, UT, WY
S. blochmaniae	Dune ragwort	Perennial	Forb Subshrub	CA
S. californicus	California ragwort	Annual	Forb	CA
S. cannabifolius	Aleutian ragwort	Perennial	Forb	AK
S. clarkianus	Clark's ragwort	Perennial	Forb	CA
S. congestus	Marsh fleabane	Annual Biennial	Forb	AK, IA, MI, MN, ND, SD, WI; AB, BC, LB, MB, NT, NU, ON, QC, SK, YT
S. crassulus	Thickleaf ragwort	Perennial	Forb	CO, ID, MT, NM, NV, OR, SD, UT, WY
S. elmeri	Elmer's ragwort	Perennial	Forb	WA; BC
S. eremophilus	Desert ragwort	Perennial	Forb Subshrub	AK, AZ, CO, MA, MT, ND, NM, NY, SD, UT, WY; AB, BC, MB, NT, ON, SK, YT
S. ertterae	Ertter's ragwort	Annual	Forb	OR
S. flaccidus	Threadleaf ragwort	Perennial	Forb Subshrub	AZ, CA, CO, KS, NM, NV, OK, TX, UT
S. fremontii	Dwarf mountain ragwort	Perennial	Forb	CA, CO, ID, MT, NM, NV, OR, UT, WA, WY; AB, BC
S. hydrophiloides	Tall groundsel	Biennial Perennial	Forb	CA, ID, MT, NV, OR, UT, WA, WY; AB, BC
S. hydrophilus	Water ragwort	Biennial Perennial	Forb Subshrub	CA, CO, HI, ID, MT, NV, OR, SD, UT, WA, WY; BC
S. integerrimus	Lambstongue ragwort	Biennial Perennial	Forb	CA, CO, IA, ID, KS, MN, MT, ND, NE, NM, NV, OR, SD, UT, WA, WY; AB, BC, MB, SK
S. lemmonii	Lemmon's ragwort	Perennial	Forb Subshrub	AZ

Appendix I (continued): Related Senecioneae Species Native to North America

SCIENTIFIC NAME	COMMON NAME	DURATION	HABIT	DISTRIBUTION
Senecio lugens	Small blacktip ragwort	Perennial	Forb	AK, MT, WA, WY; AB, BC, NT, YT
S. lyonii	Island senecio	Perennial	Subshrub	CA
S. megacephalus	Rocky ragwort	Perennial	Forb	ID, MT; AB, BC
S. mohavensis	Mojave ragwort	Annual	Forb	AZ, CA, NV
S. multidentatus	Huachuca Mountain ragwort	Perennial	Forb	AZ
S. musiniensis	Musinea ragwort	Perennial	Forb	UT
S. neowebsteri	Olympic Mountain ragwort	Perennial	Forb	WA
S. parryi	Mountain ragwort	Perennial	Forb Subshrub	AZ, NM, TX
S. pattersonensis	Mono ragwort	Perennial	Forb	CA, NV
S. pseudoarnica	Seaside ragwort	Perennial	Forb	AK, ME; BC, LB, NB, NF, NS, NT, QC; SPM
S. pudicus	Bashful ragwort	Annual Perennial	Forb	CO, NM, UT
S. quaylei	Quayle's ragwort	Annual	Forb	TX
S. rapifolius	Openwoods ragwort	Perennial	Forb Subshrub	CO, ID, SD, WY
S. sheldonensis	Mt. Sheldon ragwort	Perennial	Forb	BC, NT, YT
S. soldanella	Colorado ragwort	Perennial	Forb	CO, NM
S. spartioides	Broom-like ragwort	Perennial	Forb Subshrub	AZ, CA, CO, NE, NM, NV, SD, TX, UT, WY
S. sphaerocephalus	Ballhead ragwort	Perennial	Forb	CO, ID, MT, NV, OR, UT, WY
S. squalidus	Oxford ragwort	Perennial	Forb	CA; NB, NS
S. taraxacoides	Dandelion ragwort	Perennial	Forb	CO, NM, OK
S. triangularis	Arrowleaf ragwort	Perennial	Forb Subshrub	AK, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY; AB, BC, NT, YT
S. warnockii	Warnock's ragwort	Perennial	Subshrub	NM, TX
S. wootonii	Wooton's ragwort	Perennial	Forb Subshrub	AZ, CO, NM, TX

Appendix II: Related Exotic Senecioneae Species Present in North America

SCIENTIFIC NAME	COMMON NAME	DURATION	HABIT	DISTRIBUTION
Senecio aquaticus	Water ragwort	Biennial Perennial	Forb	NJ
S. cannabinifolius	Hempleaf ragwort	Perennial	Forb	AL, FL
S. cineraria	Dusty miller	Perennial	Forb Subshrub	AL, CA, MD, NY, OR, UT
S. elegans	Redpurple ragwort	Annual	Forb	CA
S. erucifolius	Hoary ragwort	Perennial	Forb	PA
S. madagascariensis	Madagascar ragwort	Annual Biennial	Forb	HI
S. sylvaticus	Woodland ragwort	Annual	Forb	CA, HI, LA, MA, ME, MI, NJ, OH, OR, PA, WA, WI; BC, NB, NF, NS, PE, QC
S. viscosus	Sticky ragwort	Annual	Forb	AK, CT, ID, IL, MA, ME, MN, NH, NJ, NY, PA, RI, WI; AB, BC, MB, NB, NF, NS, ON, PE, QC, SK; SPM
S. vulgaris	Old-man-in-the-spring	Annual/ Biennial	Forb	AK, AL, AR, AZ, CA, CO, CT, DC, DE, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VA, VT, WA, WI, WV, WY; AB, BC, LB, MB, NB, NF, NS, NT, ON, PE, QC, SK, YT; GL; SPM

Appendix III: Troubleshooting Guide: When Things Go Wrong

This guide is intended to assist those who encounter problems when establishing a biological control program. It identifies the probable cause of typical problems and offers solutions.

PROBLEM	PROBABLE CAUSE	SOLUTION
Biological control agents unhealthy or dead when received	Physical damage to agents in transport	Provide adequate packing material to minimize movement of containers and ice packs.
	Drowning	Do not put water in containers during transport; prevent accumulation of excess moisture; too much plant material causes condensation.
	Excess or prolonged heat or cold	Keep containers cool at all times; use coolers and ice packs; avoid exposure to direct sunlight while in transit.
	Starvation	Put tansy ragwort foliage (no flowers, seeds, or roots) in containers.
	Redistribution time	Transport or ship agents immediately after collection.
		Release agents at new site immediately upon arrival or receipt of agent.
	Parasitism and/or disease	Check source agents. Ensure the insect population is disease-free when collecting or receiving shipment.
Reproductive problems	Agents past reproductive stage	Collect at peak activity (i.e. insects are mating and ovipositing).
	Sex ratio: not enough males or females	Collect at peak activity; observe mating among target agents before collecting; males often emerge earlier than females.
	Agents not synchronized with the tansy ragwort growth stage	Biological control agents require the weed to be at specific growth stage for optimal oviposition; collect agents from sites with plants in similar stages.
Few biological control agents collected	Collection at wrong time	Refer to Table 7 for collection time and technique.
	Collection technique	Biological control agents can be killed/damaged during sweeping or aspirating so sweep lightly; avoid debris.
		Use motorized aspirator if manual aspirating is difficult.
	Conditions at time of collection wrong	Refer to Chapter 4 "Collecting Tansy Ragwort Biological Control Agents" for guidelines on desirable weather conditions.
	Population insufficient	Only collect from well established populations
Agents not found after release	Site is unsuitable or too small	Refer to Chapter 4 "Selecting Biological Control Agent Release Sites."
	Not enough agents released	Release as many agents as is feasible to ensure survival and reproduction
	Pesticide use/mowing in area	Select sites where management activities do not interfere with biological control agent life cycles.
	Released on wrong species	Ensure tansy ragwort and the correct biocontrol agent are used.
	Ants or other predators preyed upon biocontrol agents	Release only at sites with no obvious ant mounds or high insect predator populations (e.g. mice, voles).
Cannot locate release site	Location marker not obvious	Use bright-colored wooden, metal, or plastic stake.
	Site destroyed	Communicate with all direct and neighboring land users
	Map poorly/incorrectly drawn	Check map; redraw with more detail or add landmarks; GPS.

Appendix IV: PPQ Form 526 Interstate Transport Permit Application

The form below is a sample version of the Interstate Transport Permit Application, and is included herein to demonstrate information required. Permits are applied for electronically only. Please see http://www.aphis.usda.gov/permits/ppq_epermits.shtml to apply.

APHIS Animal and Plant Health Inspection Service

Plant Protection Quarantine

United States Department of Agriculture
Animal and Plant Health Inspection Service
4700 River Road
Riverdale, MD 20737

Permit to Move Live Plant Pests and Noxious Weeds

Importation

Regulated by 7 CFR 330

This permit was generated electronically via the ePermits system

PERMITTEE NAME: Dr. John Q. Public
ORGANIZATION: Biological Control Specialists
ADDRESS: Happyville, MD 00123-1234

PERMIT NUMBER: P526P-00-00000
APPLICATION NUMBER: P526-00000-000
FACILITY NUMBER: 1A

HAND CARRY: Yes
DATE ISSUED: 07/08/2000

PHONE: (123) 555-4722
FAX: (123) 555-5587

EXPIRES: 07/08/2003

DESTINATION: RAAB, Bldg. # 51, W. Main St., Roswell, NM, 88202

RELEASE: Roswell, NM

Under the conditions specified, this permit authorizes the following:

Article Category: Invertebrate Pests – Bugs

Regulated Article	Life Stage(s)	Intended Use	Shipment Origins	Originally Collected	Culture Designation
Longitarsus jacobaeae	Adult	Release - Biocontrol	MT	Originally Switzerland Collected from Outside North America	
Botanophila seneciella	Larvae/ Pupae	Release – Biocentrol	MT	Originally Europe	

Permit Number P526P-00-0000

THIS PERMIT HAS BEEN APPROVED ELECTRONICALLY BY THE FOLLOWING PPQ HEADQUARTER OFFICIAL VIA EPERMITS	DATE
I. M. Official PPQ Official	07/08/2000

WARNING: Any alteration, forgery or unauthorized use of this Federal Form is subject to civil penalties of up to $250,000 (7 U.S.C.s 7734(b)) or punishable by a fine of not more than $10,000, or imprisonment of not more than 5 years, or both (18 U.S.C.s 1001)

Appendix V: Sample Biological Control Agent Release Form

Exotic weed biological control: ***General Release Site Information***
USDA-APHIS-PPQ

				Site code:	
State:		**County:**		**Site name:**	
Lat.:		**Long.:**		**Elev.:**	

Landowner and/or contact person

Name		**Title (if appl.)**
Address		
City	**State**	**ZIP**
Phone	**e-mail**	

Extent of weed infestation: ☐ ≤5 ac (2 ha) ☐ 5 –100 ac (2 – 40 ha) ☐ 100 – 1000 ac (40 – 400 ha) ☐ > 1000 ac (400 ha)

Weed distribution: ☐ Largely or totally continuous ☐ Interrupted ('patches' separated by uninfested areas)

General site topography: ☐ Level ☐ Slight slope ☐ Moderate slope ☐ Steep slope ☐ Hilly

Aspect: ☐ North ☐ South ☐ East ☐ West ☐ Northwest ☐ Northeast ☐ Southwest ☐ Southeast

Soil type: ☐ Gravel/cobble ☐ Sand ☐ Sandy loam ☐ Loam ☐ Silt loam ☐ Clay loam ☐ Clay

Probability of flooding: ☐ Very low (rarely occurs) ☐ Low–moderate (occasional years) ☐ High (e.g. yearly)

Treatments at site in last year: ☐ Herbicide(s) [if so, chemical:___________] ☐ Grazing ☐ Burning ☐ Cutting ☐ Bulldozing/plowing ☐ Other:________________________

Native (pre-infestation) plant communities at site, if known:

____
____
____

Biocontrol agent(s) released:	
Date and time agent(s) released:	
Number of agent(s) released:	
Weather conditions at time of release:	
Released by (name and affiliation):	

Appendix VI: Tansy Ragwort Qualitative Monitoring Form

Name: ________________________________**Date:** _____________**Time:**____________ **am/pm**

Location:____ **Site #:**___________________________________

Biocontrol species:___________________________________ **Year of release:** ___________________________

Cover class estimate by plant category						
	0%	1-5%	6-20%	21-45%	46-70%	71-100%
Tansy Ragwort						
Annual Grasses						
Perennial Grasses						
Forbs						
Shrubs						
Trees						

Dominant plant species on site:
Other noxious weeds:

Estimate tansy ragwort density class (✓check one)			
Flowering plants/meter sq		Tansy ragwort distribution	
0		Isolated	
1-25		Scattered	
26-50		Scattered-Patchy	
50-75		Patchy	
>75		Continuous	

Tansy ragwort phenology class at time of monitoring	
Tansy ragwort stage	Estimated percent
Seedling	
Rosette	
Bolting	
Flowering	
Senescent	

Comments/Observations ____

____

____

____

Appendix VII: General Biocontrol Agent Monitoring Form

SITE: ______________________ STATE: ________ COUNTY______________________ DATE: _________ _________ _______
year month day

DATA COLLECTOR: ____ TIME: __________________________
First and last name

UTM DATUM:_______________ UTM YEAR:___________
LAT/LONG: N ______°__________' W _____°_________' UTM E: _________________ UTM N: _________________

ELEVATION: _____________ TEMPERATURE: _________ WEATHER: ____

INSECT COUNTS:

Species	Method	# insects (use Chart A)
Tansy ragwort flea beetle	Randomly select 25 plants, dissect root and leaf petiole tissue and count larvae	
Ragwort seed head fly	Randomly select 100 seed heads during first bloom sequence, visually count how many have evidence of larvae	
Cinnabar moth	In a 5 1-minute intervals, count the number of larvae you see on foliage	

Chart A: Insect abundance		
	1	1-10
	2	11-25
	3	26-100
	4	100-500
	5	>500

TANSY RAGWORT:

Chart B: Damage Class		
	0	<1%
	1	1-5%
	2	6-25%
	3	> 25%

Chart C: Cover Class		
	0	<1%
	1	1-5%
	2	6-25%
	3	26-50%
	4	51-75%
	5	76-95%
	6	>95%

Quad #	Tansy Ragwort				Stems					
	% damage (use Chart B)*			% cover (use Chart C)	# rosettes	# bolting stems	Height 4 tallest stems (cm)			
	CM	SF	FB							
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

* CM=Cinnabar moth, SF=Seed head fly, FB=Flea beetle

Notes:

Appendix VII (Instructions): General Biocontrol Agent Monitoring Form

Materials needed: 20 meter tape measure (65 ft), 0.2 x 0.5 m (0.2 x 0.55 yard) quadrat frame, stopwatch, sweep net, monitoring form, pencils, clipboard, camera, and GPS unit to relocate transects.

General: The purpose of this monitoring activity is to estimate the abundance of tansy ragwort and its biological control agents at the site, and to record measurements of a sample of tansy ragwort plants. Conduct the monitoring when the biological control agents are at their peak. Monitoring is easier with two people, one to make the observations and the other to record data.

To set up the transect, place the 20-meter tape randomly within the infestation. Mark the beginning of the transect with a post or stake. Place permanent markers every 2 meters (for a total of 10 markers) beginning at the 2-meter mark and ending at the 20-meter mark. Place the quadrat frame parallel to the tape with the permanent marker in the upper left corner starting at 2-meters. Repeat the frame placement at each of the next 2-meter intervals for a total of 10 measurements (one at each permanent marker).

1) Site information: Fill out the site information at the top of the form and take a photo of the site.

2) Insect counting: Use the chart for the method to count insects. Carefully approach the site and avoid disturbing the vegetation. Adult insects often jump or fly from the vegetation once you approach; moth larvae may drop from foliage when disturbed. Use Chart A to record the category of abundance (1-5).

3) Locate the transect: After you have completed the insect counts, locate the transect (if this is second year monitoring or later) using the GPS coordinates and the permanent markers. If this is the first monitoring, place the transect, record GPS coordinates at the 0-meter mark, and add permanent markers.

4) Position the quadrat: Position the quadrat along the transect, as close to the ground as possible, carefully positioning the quadrat along that transect line. Be sure not to damage the plants. The quadrat should be in the same location as the previous year's quadrat. Move stems in or out of the frame area so that all stems originating inside the quadrat are included.

5) Estimate feeding damage: Examine the tansy ragwort for any damage to the leaves, shoots, flower heads, etc., such as shot-hole feeding by the flea beetle or malformed flower heads due to fly larvae feeding on capitula and seeds. Standing over the frame, estimate the percent of damage over the entire quadrat, using Chart B to determine the category of damage.

6) Estimate percent cover: Standing over the frame, estimate how much of the quadrat is covered by tansy ragwort. Use cover estimates in Chart C to estimate percent cover class.

7) Count stems: Count the number of tansy ragwort plants within the quadrat. Count the number of rosettes and number of bolting plants.

8) Measure stems: Select the four tallest tansy ragwort stems in each quadrat (if there are fewer than 4 stems/quadrat, measure all that are present). Measure the stem height (to the closest cm).

9) Other observations: Record any general observations or useful information; disturbances, grazing, fire, etc., for the sample quadrat or the site in general.

Appendix VIII: Tansy Ragwort Quantitative Monitoring Form

SITE: ______________________ **STATE:** ________ **COUNTY**______________________ **DATE:** _________ _________ _______
year month day

DATA COLLECTOR: ____ **TIME:** __________________________
First and last name

UTM DATUM:_______________ **UTM YEAR:**___________

LAT/LONG: N ______°_________' **W** _____°_________' **UTM E:** _________________ **UTM N:** ________________

ELEVATION: _____________ **TEMPERATURE:** _________ **WEATHER:** ____

Chart A: Cover Class

0	<1%
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	>95%

Percent of Quadrat (Use Chart A; total for each column is 100%)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Vegetated										
Soil, litter										
Rock										

Vegetation Cover (Use Chart A; total for column may exceed 100% due to overlapping of vegetation)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Tansy ragwort										
All other vegetation:										
Forbs										
Grasses and Sedges										
Woody plants										

Individual Species (names) (Check if present or use Chart A to indicate percent cover)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10

Appendix VIII (Instructions): Tansy Ragwort Quantitative Monitoring Form

Materials needed: 20 meter tape measure (65 ft), 1.0 m^2 quadrat frame, data sheets, pencils, clipboard, camera, and GPS unit to relocate quadrats.

General: The purpose of this activity is to estimate the abundance of other vegetation in the community, and to record measurements of tansy ragwort plant attributes. Monitoring is easier with two people, one to make the observations and the other to record data.

To set up the transect, place the 20-meter tape randomly within the infestation. Mark the beginning of the transect with a post or stake. Place permanent markers every 2 meters (for a total of 10 markers) beginning at the 2-meter mark and ending at the 20-meter mark. Place the quadrat frame parallel to the tape with the permanent marker in the upper left corner starting at 2-meters. Repeat the frame placement at each of the next 2-meter intervals for a total of 10 measurements (one at each permanent marker).

1) Site information: Fill out the site information at the top of the form and take a photo of the site.

2) Locate the transect: After you have completed the insect counts, locate the transect (if this is second year monitoring or later) using the GPS coordinates and the permanent markers. If this is the first monitoring, place the transect, record GPS coordinates at the 0-meter mark, and add permanent markers.

3) Position the quadrat: Position the quadrat frame as close to the ground as possible, carefully positioning the quadrat along that transect line. Be sure not to damage the vegetation. The quadrat should be in the same location as the previous year's quadrat.

4) Estimate amount of vegetation: Standing over the frame, estimate how much of the quadrat is vegetated, and how much is not vegetated (bare ground, rock, etc). Use cover estimates in Chart A to estimate percent cover.

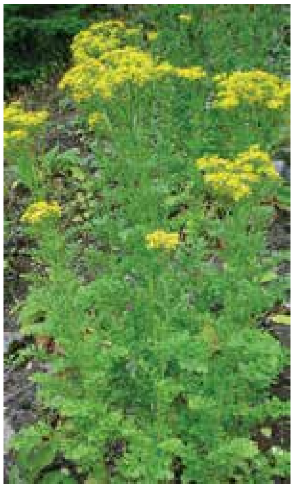
5) Estimate percent cover of vegetation: Standing over the frame, estimate how much of the quadrat is covered by tansy ragwort, how much is covered by other forbs, grasses, or shrubs. Use cover estimates in Chart A to estimate percent cover. Because vegetation can naturally overlap, it is possible to have a combined total percent cover to exceed 100%.

6) Estimate percent cover of individual species: Standing over the frame, estimate how much of the quadrat is covered by individual species, other than tansy ragwort. Use this section to track specific species, for example perennial grasses, native forbs, etc.

7) Other observations: Record any general observations or useful information, such as disturbances, grazing, fire, etc.

Appendix IX: Tansy Ragwort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form

Idaho's Statewide Monitoring Guidelines for the Tansy Ragwort Flea Beetle (*Longitarsus jacobaeae*) and Tansy Ragwort (*Jacobaea vulgaris*)



Overview:

A critical part of successful weed biological control programs is monitoring to measure populations of biological control agents and the impact that they are having on the target weed. Monitoring should be conducted on an annual basis for a number of years. The Idaho State Department of Agriculture, in conjunction with the University of Idaho, Nez Perce Biocontrol Center, and federal land management agencies has developed a Standardized Impact Monitoring Protocol (SIMP), outlined below, which enables land managers to take a more active role in monitoring populations of the tansy ragwort flea beetle (*Longitarsus jacobaeae*) and its ability to control tansy ragwort (*Jacobaea vulgaris*). This monitoring protocol was designed to be implemented by land managers in a timely manner (1 hr) while collecting data which will enable researchers to better quantify the impact of the tansy ragwort flea beetle on tansy ragwort.

Tansy Ragwort:

Tansy ragwort may be an herbaceous biennial, winter annual or short-lived perennial depending on the site. Plants typically grow 0.3-0.9 meters (1-3 ft) tall. The root system consists of soft, fleshy roots. Plants form rosettes (image at right) in spring originating from a root crown or a seedling. Then as a plant stem bolts, characteristic deeply lobed to pinnately toothed leaves alternate along the stem (image above). Stems arise singly or in clumps from the root crown and branch near the top to produce multiple flowers. Flowering may occur from June through October, depending on location. Flower heads consist of yellow ray (outer) and disc (center) florets. Ray florets (typically 13) grow 8-20 mm (1/3 to ¾ inch) long, and seeds produced by the center disc florets are topped by feathery, dandelion-like pappus hairs. Tansy ragwort seed can be dispersed short distances by wind and longer distances by animals and water. Tansy ragwort grows under a variety of conditions but is most commonly established in pastures, abandoned fields, sparse forests, rangelands, roadsides, and disturbed places. All parts of the tansy ragwort plants contain pyrrolizidine alkaloids, substances toxic to cattle, horses, goats, and deer.

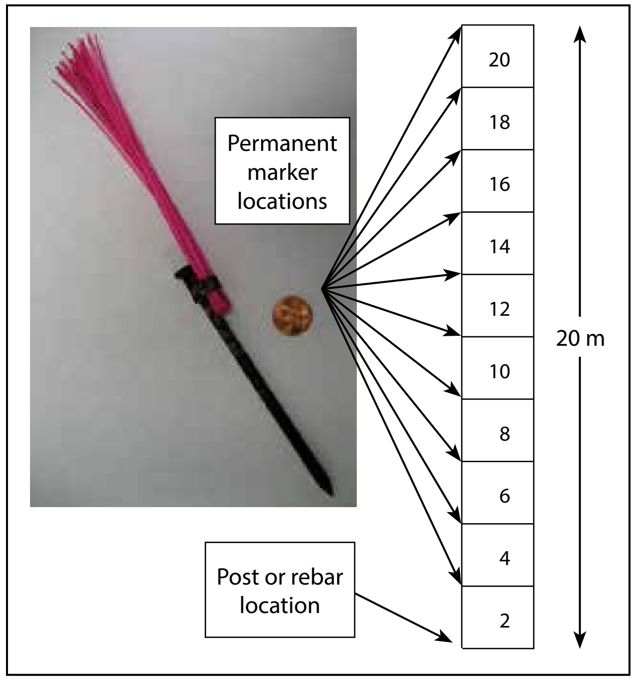
Tansy Ragwort Flea Beetle:

The tansy ragwort flea beetle (left) is considered the most effective of the three approved tansy ragwort biological control agents in the U.S. There are three strains of flea beetle, each with a unique life history, though all three strains have 1 generation per year. The Italian PNW strain overwinters as larvae, eggs, or adults, the Italian cold-adapted (CAD) strain overwinters as eggs or larvae, and the Swiss strain overwinters as eggs. Adult feeding results in characteristic shot holes in leaves, and larvae mine in the root crowns of tansy ragwort.

Appendix IX: Tansy Ragwort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form

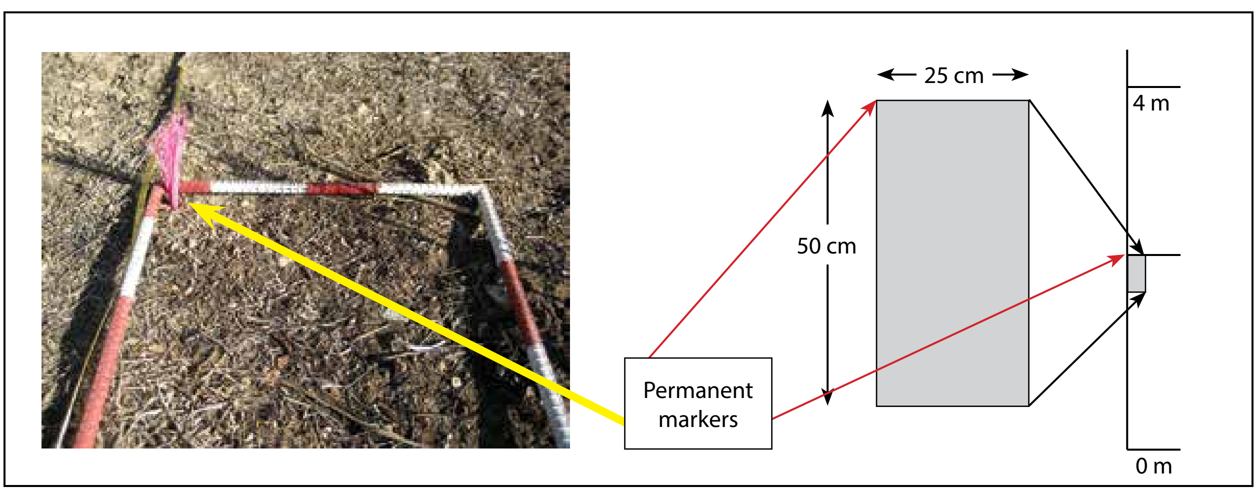
Monitoring:

SIMP is based upon a permanent 20 meter vegetation sampling transect randomly placed in a suitable (at least 0.4 hectares or 1 acre) infestation of tansy ragwort and sweep net samples of flea beetle adults. Annual vegetation sampling will allow researchers to characterize the plant community and the abundance and vigor of tansy ragwort. Sweep net samples of adult tansy ragwort flea beetle adults will provide researchers with an estimate of flea beetle population levels.



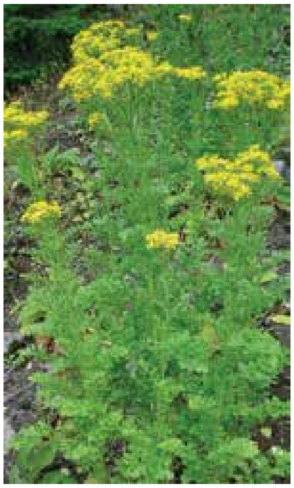
Permanent Site Set-up:

To set up the vegetation monitoring transect, you will need: 1) a 25 x 50 cm Daubenmire frame, 2) a 20 m tape measure for the transect and plant height, 3) 10 permanent markers (road whiskers and 16 penny nails), 4) a post (stake or piece of rebar) to monument the site (see pictures for examples of field equipment), and 5) 1 hour at the site during the last week of July. To set up the transect, place the 20 m tape within the infestation. Mark the beginning of the transect with a post. Place permanent markers every 2 m (for a total of 10 markers) beginning at the 2 m mark and ending with the 20 meter mark on the tape measure. Place the Daubenmire frame parallel to the tape on the 50 cm side with the permanent marker in the upper left corner starting at 2m (see pictures). See data sheet for how to conduct monitoring. Repeat the frame placement at 2 meter intervals for a total of 10 measurement (at permanent markers).



Appendix IX: Tansy Ragwort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form

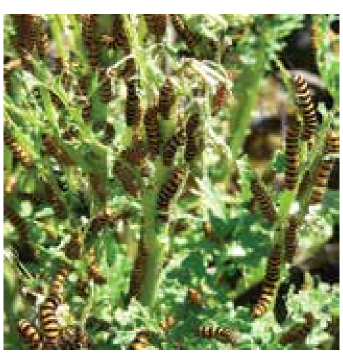
Idaho's Statewide Monitoring Guidelines for the Cinnabar Moth (*Tyria jacobaeae*) and Tansy Ragwort (*Jacobaea vulgaris*)



Overview:
A critical part of successful weed biological control programs is monitoring to measure populations of biological control agents and the impact that they are having on the target weed. Monitoring should be conducted on an annual basis for a number of years. The Idaho State Department of Agriculture, in conjunction with the University of Idaho, Nez Perce Biocontrol Center, and federal land management agencies has developed a Standardized Impact Monitoring Protocol (SIMP), outlined below, which enables land managers to take a more active role in monitoring populations of the cinnabar moth (*Tyria jacobaeae*) and its ability to control tansy ragwort (*Jacobaea vulgaris*). This monitoring protocol was designed to be implemented by land managers in a timely manner (1 hr) while collecting data which will enable researchers to better quantify the impact of the cinnabar moth on tansy ragwort.

Tansy Ragwort:

Tansy ragwort may be an herbaceous biennial, winter annual or short-lived perennial depending on the site. Plants typically grow 0.3-0.9 meters (1-3 ft) tall. The root system consists of soft, fleshy roots. Plants form rosettes (image at right) in spring originating from a root crown or a seedling. Then as a plant stem bolts, characteristic deeply lobed to pinnately toothed leaves alternate along the stem (image above). Stems arise singly or in clumps from the root crown and branch near the top to produce multiple flowers. Flowering may occur from June through October, depending on location. Flower heads consist of yellow ray (outer) and disc (center) florets. Ray florets (typically 13) grow 8-20 mm (1/3 to ¾ inch) long, and seeds produced by the center disc florets are topped by feathery, dandelion-like pappus hairs. Tansy ragwort seed can be dispersed short distances by wind and longer distances by animals and water. Tansy ragwort grows under a variety of conditions but is most commonly established in pastures, abandoned fields, sparse forests, rangelands, roadsides, and disturbed places. All parts of the tansy ragwort plants contain pyrrolizidine alkaloids, substances toxic to cattle, horses, goats, and deer.



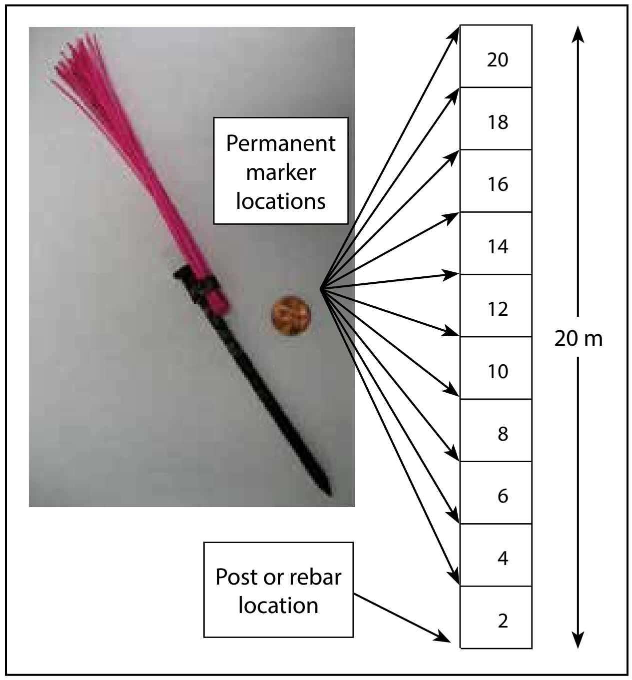
Cinnabar Moth:

The cinnabar moth has one generation per year and overwinters as a pupa in the soil. Adults emerge in late spring and lay eggs in clusters on the undersides of tansy ragwort rosette leaves. Hatching larvae feed on the undersides of rosette leaves, and older larvae feed on bolting stem leaves and developing buds- often in groups of 10-30 larvae (image at left). Larvae may completely defoliate tansy ragwort plants, leaving only bare stems behind. Larvae feed until ready to pupate, when they leave the plant for a pupation site in the soil.

Appendix IX: Tansy Ragwort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form

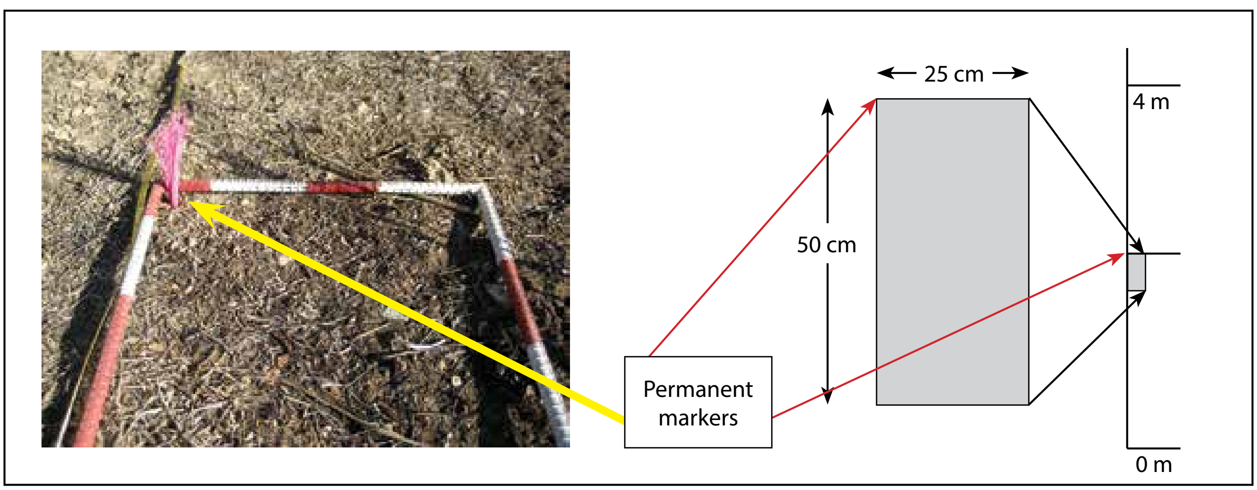
Monitoring:

SIMP is based upon a permanent 20 meter vegetation sampling transect randomly placed in a suitable (at least 0.4 hectares or 1 acre) infestation of tansy ragwort and a timed count of cinnabar moth larvae. Annual vegetation sampling will allow researchers to characterize the plant community and the abundance and vigor of tansy ragwort. Timed counts of late instar cinnabar moth larvae will provide researchers with an estimate of cinnabar moth population levels.



Permanent Site Set-up:

To set up the vegetation monitoring transect, you will need: 1) a 25 x 50 cm Daubenmire frame, 2) a 20 m tape measure for the transect and plant height, 3) 10 permanent markers (road whiskers and 16 penny nails), 4) a post (stake or piece of rebar) to monument the site (see pictures for examples of field equipment), and 5) 1 hour at the site during the last week of July. To set up the transect, place the 20 m tape within the infestation. Mark the beginning of the transect with a post. Place permanent markers every 2 m (for a total of 10 markers) beginning at the 2 m mark and ending with the 20 meter mark on the tape measure. Place the Daubenmire frame parallel to the tape on the 50 cm side with the permanent marker in the upper left corner starting at 2m (see pictures). See data sheet for how to conduct monitoring. Repeat the frame placement at 2 meter intervals for a total of 10 measurement (at permanent markers).



Appendix IX: Tansy Ragwort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form

Monitoring biological control agents is an essential component of a successful biological control program. Monitoring data can be used to accurately document the impact of this weed management practice. This monitoring form has been endorsed by the Nez Perce Biocontrol Center, University of Idaho, Forest Health Protection, Bureau of Land Management, and Idaho State Department of Agriculture. The monitoring information from this form will be used to document vegetation cover, target weed density, and biological control agent abundance. When conducted annually, this monitoring data will document changes that occur over time.

Standardized Impact Monitoring Protocol (SIMP) Biological Control Monitoring Form

General Information:

Observer(s):		Date:	Landowner:
Permanent site? Y N	Site name:		Weed:
Biological control agent:		Insect Stage:	
Lat/Long: N ° ‘	W ° ‘	UTM Datum:	UTM E:
		UTM Year :	UTM N:

Weed Infestation:

Size in acres:	Picture taken?	Yes No	If Y, picture direction:

Vegetation cover (all in %, rows add to 100%):

Frame	Target weed%	Other weed%	Forb/shrub%	Perennial Grass%	Bare ground%	Litter%	Moss%	Total%
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Target weed size/density:

Frame	Number of Stems	Height of tallest stem (cm)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Biological control agent:

10 sweeps repeated 6 times (for AP, GA, LA, LOJA, CYAC & OBER) **OR** a 3 min timed count repeated 6 times (for MEJA, TYJA, ACMA galls & URCA galls)

Count site	Insect (or gall) count
1	
2	
3	
4	
5	
6	

Notes:

Appendix IX: Tansy Ragwort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form

A step-by-step guide for completing the SIMP biological control monitoring form:

General Information:

- Observer(s) – Who are you?
- Date – Today's date.
- Landowner – Who is the landowner/land manager?
- Permanent? – Is this a permanent monitoring site?
- Site name – Which site are you monitoring? This could have a specific name if it is a permanent site.
- Weed – Which target weed are you are monitoring?
- Biological control agent – Which biological control agent you are monitoring?
- Insect Stage – What is the developmental stage of the agent are you monitoring (egg, larva, nymph, pupa adult)?
- Lat/Long OR UTM – What are the GPS coordinates of the site you are monitoring? If UTM (preferred), what datum and year is your coordinate system?

Annual grass – note stems which are typically solitary or in a few stemmed tufts.

Vegetation Cover (all in %, rows add up to 100%) – All percentages are to be estimated to the nearest 5%. If there is a trace of any of the vegetation you monitoring in the frame, round up to 5%.

- Frame – Which frame number are you working on (1= 2m, 2= 4m, …,10 = 20m)?
- Target weed % – What is % cover of the target weed to the nearest 5%?
- Other weeds % – What is the % cover of any other weeds in the frame to the nearest 5%? Count undesirable annual grasses as weeds.
- Forb/Shrub % – What is the % cover of native forbs/shrubs in the frame to the nearest 5%?
- Grass % – What is the % cover of perennial grass to the nearest 5%?
- Bare Ground/Litter % – What is the % cover of bare ground/litter to the nearest 5%?

Target Weed Size/Density

- Frame – Which frame number are you working on (1=2m, 2=4m,…,10=20m)?
- Number of stems – How many stems of the target weed are in the frame?
- Height of tallest stems (cm) – How tall is the tallest stem of the target weed in the frame (in cm)?

Perennial grass – note the multiple stem base with multiple year's growth.

Biological Control Agent

- Count location – Identify 6 sites at least 5 paces away from the vegetation transect but within the same weed infestation.
- \# of insects per 10 sweeps – How many insects are in your net after 10 sweeps of the surrounding vegetation? Take one step between each sweep. Repeat 5 more times (for a total of 6 sweep sites, 60 sweeps) moving at least 2 steps away from the last sweep location **(for AP, CYAC, GA, LA, LOJA & OBER)**.
- \# of biological control insects or galls per 3 min. count – How many biological control agents or galls do you see in a 3 minute period? Carefully approach the plants and be sure to count insects one time only. Please repeat 5 times (for a total of 6) moving at least 4 paces away from the first count location **(for MEJA, TYJA, ACMA galls & URCA galls)**.