Forest Health Technology Enterprise Team

Technology Transfer
Biological Control

Biology and Biological Control of Common St. Johnswort

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Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Cover Photo: John M. Randall

Biology and Biological Control of Common St. Johnswort

2nd Edition

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Chapter 1: Introduction

Overview

Common St. Johnswort (*Hypericum perforatum* L.) is an exotic, perennial weed native to Europe, northern Africa, and Asia. It has a long history of use in herbal remedies for mild to moderate depression, chronic fatigue syndrome, wound healing, and as an antiviral agent. As such, it was introduced to the United States on multiple occasions by European settlers interested in the plant's medicinal properties. Common St. Johnswort escaped cultivation and quickly became a nuisance weed (Figure 1a). It was first reported escaped in Lancaster, Pennsylvania in 1793, in some portions of the Midwest in the mid-1800s, in Oregon between 1840 and 1850, and by the early 1900s it was established in Montana, California, Washington, and Idaho. Though currently present in 45 states and 8 Canadian provinces (Figure 1b), common St. Johnswort has primarily been a problematic weed in the West. At its peak abundance, it could be found on over 3.5 million acres (1.4 million ha) in California, Idaho, Oregon, and Washington.

Figure 1 Common St. Johnswort a. Infestation (Marianna Szucs, University of Idaho); b. North American distribution (USDA PLANTS Database)

Common St. Johnswort grows under a variety of conditions but is most commonly found in pastures, open grasslands, abandoned fields, sparse forests, roadsides, and disturbed places. Cropland habitat, especially under frequent cultivation, is not ideal for common St. Johnswort growth. This likely explains why populations have never been overly problematic in farming regions of the central U.S. This species is most often found growing from sea level to 5,000 ft (1,500 m) in elevation in North America and is present on all slopes and aspects, though it prefers southern exposure. Extreme temperatures in winter limit its range, as does annual precipitation less than 12 inches (30 cm). Though it is found in a variety of soils, common St. Johnswort grows most aggressively in well-drained, coarse-textured soil with neutral to acidic pH.

Most livestock will avoid common St. Johnswort, but poor feeding conditions and/or choices may make this weed seem more desirable to grazing animals. Glands on the weed's foliage produce hypericin, an oil and phototoxin. Upon ingestion, the feeding animals become sensitive to sunlight. This often leads to dermatitis, inflammation of the mucus membranes, itching, swelling, blisters, and open sores. Animals with lighter pigmentation, a thinner fur or wool covering, and softer skin (young) are affected most, as are nursing animals whose mothers are exposed to hypericin. If consumed in large quantities, starvation, dehydration, and even death may occur. Humans may also experience the same reactions when using herbal remedies containing hypericin.

Common St. Johnswort is a vigorous competitor in pastures, rangelands, and natural areas, displacing native and/or more desirable forage species throughout the West. At its peak densities in the mid-20th century, it was considered the leading cause of economic loss to California agriculture, attributed both to stock fatalities and to the loss of pasture and rangeland. After attempts to control the weed with herbicides were unsuccessful, a vigorous biological control program was initiated.

Classical Biological Control of Weeds

Most invasive plants in North America 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 non-native 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. Biological control agents may feed on a weed's flowers, seeds, roots, foliage, and/or stems. This damage 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.

Natural enemies used in classical biological control of weeds include a variety of organisms, such as insects, mites, nematodes, and fungi. In the U.S., most weed biological control agents are plant-feeding insects. Beetles, flies, and moths are among the most commonly used insects. To be considered for release in the United States, biological control agents must feed and develop only on the target weed and, in some cases, on a few closely related plant species. A potential biological control agent's life cycle should be closely matched, or synchronized, with the development of the target weed. If properly synchronized, foliage-feeding insects would be in the feeding stage when the weeds are actively growing, and seed-feeding insects would be in the feeding stage when the plant is actively developing seeds.

The most effective biological control agents tend to be those that damage the most vulnerable or most problematic and persistent parts of the host plant. Root- and stem-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. Some of these are listed in Table 1.

Host specificity is a crucial point of consideration for a natural enemy to be released as a biological control agent. Host specificity is the extent to which a biological control agent can survive only on the target weed. Potential biological control agents often undergo more than five years of rigorous testing to ensure that host specificity requirements are met. These tests are necessary in order to ensure that the biological control agents are effective and that they will damage only the target weed.

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

Advantages	Disadvantages
Target specificity	Protracted time until impact is likely
Continuous action	Unpredictable level of control
Long-term cost-effective	Uncertain "non-target" effects in the ecosystem
Gradual in effect	Irreversible
Generally environmentally benign	Not all exotic weeds are appropriate targets
Self dispersing, even into difficult terrain	Will not work on every weed in every setting

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 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, and 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 United States and makes recommendations to USDA-APHIS-PPQ about the safety and potential impact of prospective biological control agents. 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. The Canadian counterpart to TAG is the Biological Control Review Committee (BCRC).

In addition, each state in the United States has its own approval process to permit field release of weed biological control agents.

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 reduce the potential for negative impacts from biological control of noxious weed activities. In following the Code, practitioners reduce the potential for causing environmental damage through the use of biological control by voluntarily restricting biological control activities to those most likely to result in success.

Although weed biological control is an effective and important weed management tool, it does not work in all cases and is not 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.

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

Biological Control of Common St. Johnswort

One of the key characteristics of a successful biological control agent is host specificity. There are over 50 species and subspecies of closely related native *Hypericum* species in North America that may potentially be impacted by common St. Johnswort biological control agents. In order for a 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 native *Hypericum* species. Seed-feeding insects are often chosen for biological control programs because, as a group, they often have relatively high levels of host specificity. Unfortunately, common St. Johnswort is a prolific seed producer and is also capable of spreading via rhizomatous roots (see Chapter 2). Consequently, it is not particularly vulnerable to seed-feeding biological control agents. Following a series of lengthy and involved host specificity testing, researchers have identified biological control agents from other feeding guilds, including leaf-feeding and root-feeding organisms.

The first approved biological control agents released against common St. Johnswort in the U.S. were the klamathweed beetles *Chrysolina hyperici* (Figure 2) and *C. quadrigemina* in 1945 and 1946, respectively. The introductions of these insects led to a marked decrease of common St. Johnswort throughout much of its invaded range, though some infestations continued to expand even with *Chrysolina* present. Common St. Johnswort reductions have been permanent at most sites, though populations often fluctuate markedly, as do populations of *Chrysolina.* The common St. Johnswort biological control program has since expanded to include additional agents for control of this weed in years and sites seemingly unaffected by *Chrysolina*. As of 2010, five insects have been approved for release in the U.S. as classical biological control agents of common St. Johnswort. The biology of these agents is presented in Chapter 3.

Figure 2 Adult *Chrysolina hyperici* (Laura Parsons, University of Idaho)

Integrated Weed Management

The successful management of noxious weeds usually incorporates several control methods and activities over a number of years in order to reach the land manager's weed management objectives. The use of multiple weed control methods is called Integrated Weed Management. A successful weed management program relies on realistic management objectives, accurate weed identification and mapping, and post-treatment monitoring to answer the question: "Are current weed management activities enabling me to meet my weed management objectives?" Most successful weed management programs incorporate the following weed control methods: chemical (herbicides), mechanical, cultural treatments, and biological control.

Land managers choose weed control methods that will enable them to achieve their goal in the most cost-effective manner. The control method(s) employed in a weed management strategy 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 common St. Johnswort may be eliminated with a persistent herbicide program, but large areas will often require that managers employ additional control methods. No single control method will enable managers to meet their common St. Johnswort management objectives in all environments. 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 management objectives for common St. Johnswort, especially when it infests large acreages.

Is Biological Control of Common St. Johnswort Right For You?

When biological control is successful, biological control agents behave like a pest species of the target weed: they increase in abundance until they suppress the target weed. As local weed populations are reduced, biological control agent populations decline with them due to starvation and/or dispersal.

Some factors to be aware of before starting biological control activities include the following:

- The efficacy of biological control agents cannot be guaranteed
- Biological control will not work every time in every situation
- Biological control will not eradicate the weed
- Biological control may not, by itself, provide the desired level of control
- It might take years before you can see biological control impacts

For these reasons, 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:

What are my weed management goals: to eradicate the weed or reduce weed abundance?

Biological control does not eradicate target weeds, so it is not a good fit with an eradication goal. 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. If your goal is to reduce weed abundance, then biological control may help you achieve it.

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 immediate 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. Biological control may not be your best choice if you are looking for results within one to two seasons. In some weed infestations, more than five 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 a small weed problem (small infested area), weed control methods such as herbicides or hand pulling, followed by annual monitoring for re-growth, may be most effective in terms of reaching weed management goals with the lowest cover over time. 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.

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 enable you to successfully deal with your weed problems.

The ideal biological control program:

1. is based upon an understanding of weed, habitat, and land use conditions,
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, and
4. has realistic goals and timetables and includes adequate monitoring.

About This Manual

This manual provides information on common St. Johnswort and each of its biological control agents. It also presents guidelines to establish and manage biological control agents as part of a common St. Johnswort management program.

Chapter 1: Introduction provides introductory information on common St. Johnswort and biological control.

Chapter 2: Getting to Know Common St. Johnswort provides detailed descriptions of taxonomy, growth characteristics and features, habitat, and occurrence in the United States of common St. Johnswort. It also presents a list of related native and exotic *Hypericum* species present in the U.S.

Chapter 3: Biology of Common St. Johnswort Biological Control Agents describes the biological control agents of common St. Johnswort, including information on each agent's native range, original source of North American releases, part of plant 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 Common St. Johnswort Biological Control Program includes detailed information and guidelines on how to plan, implement, monitor, and evaluate an effective common St. Johnswort biological control program. Included are guidelines and methods for:

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

Chapter 5: An Integrated Common St. Johnswort Management Program discusses the role of common St. Johnswort biological control in the context of an integrated Common St. Johnswort management plan.

The **Glossary** defines technical terms frequently used by those involved in common St. Johnswort biological control.

Literature Cited lists the publications cited directly in this manual.

The **Appendices** are:

I. Troubleshooting Guide: When Things Go Wrong
II. PPQ Form 526: Interstate Transport Permit
III. Sample Biological Control Agent Release Form
IV. Common St. Johnswort Standardized Impact Monitoring Protocol (SIMP) Instructions and Monitoring Form
V. General Biological Control Agent Monitoring Form
VI. Common St. Johnswort Qualitative Monitoring Form
VII. Common St. Johnswort Biological Control-Associated Vegetation Monitoring

Chapter 2: Getting to Know Common St. Johnswort

Taxonomy

Common St. Johnswort is a member of the genus *Hypericum*, one of 40+ genera belonging to the Clusiaceae family. There are approximately 460 species in *Hypericum*. Members of this genus range from short-lived perennial forbs to shrubs and trees. The majority of *Hypericum* species generally have opposite, oval, and smooth-margined leaves frequently containing several translucent to black-colored glands producing resin (Figure 3). Flowers usually contain five yellow petals with numerous stamens. Flowers are bisexual and occur in short cymes (flower clusters in which the main axis and each branch end in a flower that opens before the flowers below or to the side of it).

Some floral classification systems recognize several varieties and hybrids of *Hypericum perforatum* in Europe. However, many others suggest that varying characteristics in common St. Johnswort simply represent a variable species, and that classification at the varietal level is not recommended. No hybrids are known to occur in North America.

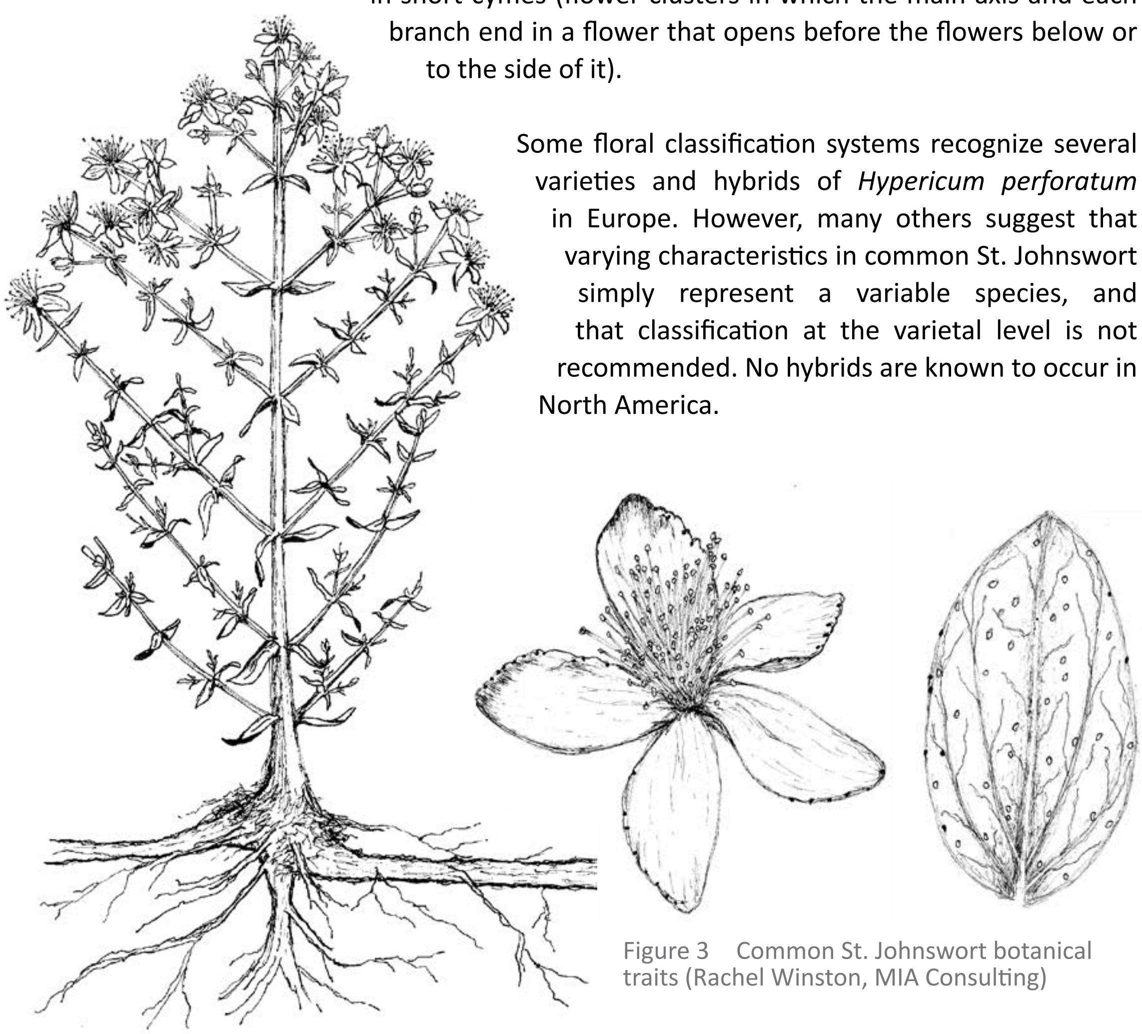


Figure 3 Common St. Johnswort botanical traits (Rachel Winston, MIA Consulting)

Native North American *Hypericum*

There are over 50 species and subspecies of *Hypericum* considered native to the U.S. and Canada, including tinker's penny (*H. anagalloides*), lesser Canadian St. Johnswort (*H. canadense*), and Scouler's St. Johnswort (*H. scouleri*) (Figure 4). Fifty-one native *Hypericum* species are listed with greater detail in Table 2.

Figure 4 Native *Hypericum*. a. Tinker's penny (William and Wilma Follette); b. Lesser Canadian St. Johnswort (Robert Mohlenbrock); c. Scouler's St. Johnswort (Sheri Hagwood, all USDA-PLANTS).

Table 2 Native *Hypericum* in the U.S. and Canada (USDA-PLANTS)

Scientific Name	Common Name	Duration	Habit	Distribution
H. adpressum	Creeping St. Johnswort	Perennial	Forb	CT, DE, GA, IL, IN, KY, MA, MD, MO, NC, NJ, NY, PA, RI, SC, TN, VA
H. anagalloides	Tinker's penny	Annual Perennial	Forb	AZ, CA, ID, MT, NV, OR, UT, WA; BC
H. ascyron	Great St. Johnswort	Perennial	Forb	CT, IA, IL, IN, KS, MA, MD, ME, MI, MN, MO, NE, NH, NJ, NY, OH, PA, VT, WI, WV; ON, QC
H. boreale	Northern St. Johnswort	Perennial	Forb	CT, DE, IA, IL, IN, MA, ME, MI, MN, NC, NH, NJ, NY, OH, OR, PA, RI, VA, VT, WA, WI, WV; BC, MB, NB, NF, NS, ON, PE, QC; SPM
H. brachyphyllum	Coastal plain St. Johnswort	Perennial	Forb Shrub	AL, FL, GA, LA, MS, SC
H. buckleii	Buckley's St. Johnswort	Perennial	Shrub	GA, NC, SC
H. canadense	Lesser Canadian St. Johnswort	Annual	Forb	AL, CT, DC, DE, FL, GA, IA, IL, IN, KY, MA, MD, ME, MI, MN, MS, NC, NH, NJ, NY, OH, OR, PA, RI, SC, TN, VA, VT, WA, WI, WV; NB, NF, NS, ON, PE, QC; SPM
H. chapmanii	Apalachicola St. Johnswort	Perrenial	Shrub Tree	FL
H. cistifolium	Roundpod St. Johnswort	Perennial	Forb Shrub	AL, FL, GA, LA, MS, NC, SC, TX
H. concinnum	Goldwire	Perennial	Forb Shrub	CA

Scientific Name	Common Name	Duration	Habit	Distribution
H. crux-andreae	St. Peterswort	Perennial	Shrub	AL, AR, DC, DE, FL, GA, KY, LA, MD, MS, NC, NJ, NY, OK, PA, SC, TN, TX, VA
H. cumulicola	Highlands scrub St. Johnswort	Biennial Perennial	Forb	FL
H. densiflorum	Bushy St. Johnswort	Perennial	Shrub	AL, DC, DE, GA, LA, MA, MD, NC, NJ, NY, OK, PA, SC, TN, TX, VA, WV
H. denticulatum	Coppery St. Johnswort	Perennial	Forb	AL, DE, GA, MD, NC, NJ, NY, PA, SC, TN, VA
H. dissimulatum	Disguised St. Johnswort	Annual	Forb	CT, MA, MD, ME, NC, NH, NJ, NY, PA, RI, VA, VT, WI, WV; NB, NF, NS, ON, QC
H. dolabriforme	Straggling St. Johnswort	Perennial	Forb	AL, GA, IN, KY, TN
H. drummondii	Nits and Lice	Annual	Forb	AL, AR, DE, FL, GA, IA, IL, IN, KS, KY, LA, MD, MO, MS, NC, OH, OK, PA, SC, TN, TX, VA, WV
H. edisonianum	Arcadian St. Johnswort	Perennial	Shrub	FL
H. ellipticum	Pale St. Johnswort	Perennial	Forb	CT, DE, IA, IL, IN, MA, MD, ME, MI, MN, NC, ND, NH, NJ, NY, OH, PA, RI, TN, VA, VT, WA, WI, WV; MB, NB, NF, NS, ON, QC; SPM
H. exile	Florida Sands St. Johnswort	Perennial	Shrub	FL
H. fasciculatum	Peelbark St. Johnswort	Perennial	Shrub	AL, FL, GA, LA, MS, NC, SC
H. frondosum	Cedarglad St. Johnswort	Perennial	Shrub	AL, CT, FL, GA, IN, KY, LA, MA, MS, NC, NY, SC, TN, TX, VA
H. galioides	Bedstraw St. Johnswort	Perennial	Shrub	AL, FL, GA, LA, MS, NC, SC, TX
H. gentianoides	Orangegrass	Annual	Forb	AL, AR, CT, DC, DE, FL, GA, IA, IL, IN, KY, LA, MA, MD, ME, MI, MN, MO, MS, NC, NH, NJ, NY, OH, OK, PA, RI, SC, TN, TX, VA, VT, WI, WV; NS, ON
H. graveolens	Mountain St. Johnswort	Perennial	Forb	NC, TN
H. gymnanthum	Claspingleaf St. Johnswort	Perennial	Forb	AL, AR, DE, FL, GA, IL, IN, KS, LA, MD, MO, MS, NC, NJ, NY, OH, PA, SC, TN, TX, VA, WV
H. harperi	Sharplobe St. Johnswort	Perennial	Forb	AL, FL, GA, SC
H. hypericoides	St. Andrew's cross	Perennial	Shrub	AL, AR, DC, DE, FL, GA, IL, IN, KS, KY, LA, MA, MD, MO, MS, NC, NJ, NY, OH, OK, PA, SC, TN, TX, VA, WV
H. kalmianum	Kalm's St. Johnswort	Perennial	Shrub	DC, IL, IN, MI, NY, OH, WI), CAN (ON, QC
H. lissophloeus	Smoothbark St. Johnswort	Perennial	Shrub	FL
H. lloydii	Sandhill St. Johnswort	Perennial	Shrub	AL, GA, NC, SC, VA
H. lobocarpum	Fivelobe St. Johnswort	Perennial	Shrub	AR, IL, KY, LA, MO, MS, OK, TN, TX

Scientific Name	Common Name	Duration	Habit	Distribution
H. maculatum	Large St. Johnswort	Annual	Forb	CO, CT, DE, IA, ID, IL, IN, KS, MA, ME, MI, MN, MO, MT, ND, NE, NH, NJ, NY, OH, OK, OR, PA, RI, SD, VT, WA, WI; AB, BC, MB, NB, NS, ON, PE, QC, SK
H. microsepalum	Flatwoods St. Johnswort	Perennial	Shrub	FL, GA
H. mitchellianum	Blue Ridge St. Johnswort	Perennial	Forb	NC, TN, VA, WV
H. x moserianum		Perennial	Shrub	OR, TN
H. mutilum	Dwarf St. Johnswort	Annual Perennial	Forb	AL, AR, CA, CT, DC, DE, FL, GA, HI, IA, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, NC, NE, NH, NJ, NY, OH, OK, PA, RI, SC, TN, TX, VA, VT, WA, WI, WV; BC, NB, NS, ON, QC, SK
H. myrtifolium	Myrtleleaf St. Johnswort	Perennial	Shrub	AL, FL, GA, MS, SC
H. nitidum	Carolina St. Johnswort	Perennial	Shrub	AL, FL, GA, NC, SC
H. nudiflorum	Early St. Johnswort	Perennial	Shrub	AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA
H. pauciflorum	Fewflower St. Johnswort	Perennial	Forb Shrub	TX
H. prolificum	Shrubby St. Johnswort	Perennial	Shrub	AL, AR, CT, DC, DE, FL, GA, IA, IL, IN, KY, LA, MA, MD, ME, MI, MN, MO, MS, NC, NH, NJ, NY, OH, OK, PA, RI, SC, TN, TX, VA, VT, WI, WV; ON
H. pseudomaculatum	False spotted St. Johnswort	Perennial	Forb	AL, AR, FL, GA, IL, KY, LA, MO, MS, OK, SC, TN, TX
H. punctatum	Spotted St. Johnswort	Perennial	Forb	AL, AR, CT, DC, DE, FL, GA, IA, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MO, MS, NC, NE, NH, NJ, NY, OH, OK, PA, RI, SC, TN, TX, VA, VT, WI, WV; NS, ON, QC
H. reductum	Atlantic St. Johnswort	Perennial	Forb Shrub	AL, FL, GA, NC, SC
H. scouleri	Scouler's St. Johnswort	Perennial	Forb	AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY; AB, BC
H. setosum	Hairy St. Johnswort	Perennial	Forb	AL, FL, GA, LA, MS, NC, SC, TX, VA
H. sphaerocarpum	Roundseed St. Johnswort	Perennial	Forb Shrub	AL, AR, GA, IA, IL, IN, KS, KY, LA, MI, MO, MS, NE, OH, OK, PA, TN, TX, WI; ON
H. suffruticosum	Pineland St. Johnswort	Perennial	Shrub	AL, FL, GA, LA, MS, NC, SC
H. tetrapetalum	Fourpetal St. Johnswort	Perennial	Shrub	FL, GA
H. virgatum	Sharpleaf St. Johnswort	Perennial	Forb	AL, AR, FL, GA, IL, IN, KY, LA, MD, MS, NC, OH, SC, TN, VA, WV

Non-Native North American Hypericum

In addition to the invasive common St. Johnswort, there are nine other exotic *Hypericum* species established in the U.S. and Canada (Figure 5 & Table 3). Though some of these species were introduced accidentally, the majority are escaped ornamentals. These nine species are now benignly naturalized throughout North America; none are widely problematic, nor are any listed as noxious in the U.S. or Canada. Consequently, the common St. Johnswort biological control program targets only common St. Johnswort. Exotic *Hypericum* species are listed with greater detail in Table 3.

Figure 5 Non-native *Hypericum*. a. Sweet-amber (Nova); b. Aaron's beard (Richard Webb, www.bugwood.org); c. Canary Island St. Johnswort (Forest & Kim Starr, USGS, www.bugwood.org)

Table 3 Non-native *Hypericum* in the U.S. and Canada (USDA-PLANTS)

Scientific Name	Common Name	Duration	Habit	Distribution
H. androsaemum	Sweet-amber	Perennial	Shrub	CA, OR, WA; BC
H. calycinum	Aaron's beard	Perennial	Shrub	CA, OR, TN, WA
H. canariense	Canary Island St. Johnswort	Perennial	Shrub Tree	CA, HI
H. gramineum	Grassy St. Johnswort	Annual Perennial	Forb	HI
H. hookerianum	Hooker's St. Johnswort	Perennial	Shrub	CA
H. humifusum	Trailing St. Johnswort	Perennial	Forb	NY
H. maculatum	Spotted St. Johnswort	Perennial	Forb	BC
H. parvulum	Sierra Madre St. Johnswort	Perennial	Forb	HI
H. pulchrum		Perennial	Forb	NF; SPM

Common St. Johnswort

Scientific Name

Hypericum perforatum L.

Synonyms

Common St. Johnswort, klamathweed, goatweed

Classification

Kingdom	Plantae	Plants
Subkingdom	Tracheobionta	Vascular plants
Superdivision	Spermatophyta	Seed plants
Division	Magnoliophyta	Flowering plants
Class	Magnoliopsida	Dicotyledons
Subclass	Dilleniidae	
Order	Theales	
Family	Clusiaceae	Mangosteen
Genus	*Hypericum* L.	St. Johnswort
Species	*Hypericum perforatum* L.	Common St. Johnswort

Description

At a Glance

Perennial forb (Figure 6) typically growing 1–3 feet (0.3 m–1 m) tall with numerous, rust-colored stems somewhat woody at their base. Roots produce short runners. Leaves are opposite, without stems or lobes, and are up to 1 inch (2.5 cm) long. Leaves have numerous transparent dots as well as tiny black glands along their margins. Flowers are numerous, bright yellow, ¾ inch (1.9 cm) in diameter, have many stamens, and have petals with additional black glands along margins. Flowering occurs from late spring through autumn. Seed pods are sticky, 3-celled, ¼ inch (⅔0.5 cm) long, and filled with numerous seeds.

Figure 6 Common St. Johnswort (Richard Old, XID Services, Inc., www.bugwood.org)

Roots

Common St. Johnswort plants consist of 1 to many aerial crowns attached to a system of vertical and lateral roots (Figure 7a). Vertical taproots often extend between 2–5 feet (0.6 m–1.5 m), depending upon the soil characteristics and moisture content. Lateral root (rhizome) growth may be extensive and occurs ½–3 inches (1.3–7.5 cm) below the soil surface. All common St. Johnswort roots are frequently protected by a tissue of suberized cells called polyderm.

In springtime, or following plant injury, lateral roots produce buds from which new crowns develop. This growth can also occur in autumn if there is sufficient precipitation. Lateral connecting roots often decay, leaving new crowns as independent plants. Roots of common St. Johnswort are frequently inoculated with arbuscular mycorrhizal fungi which, likely among other traits, help seedlings tolerate harsh environmental conditions.

Leaves

Leaves are hairless, oblong, and bright green in color. They have smooth or weakly-wavy

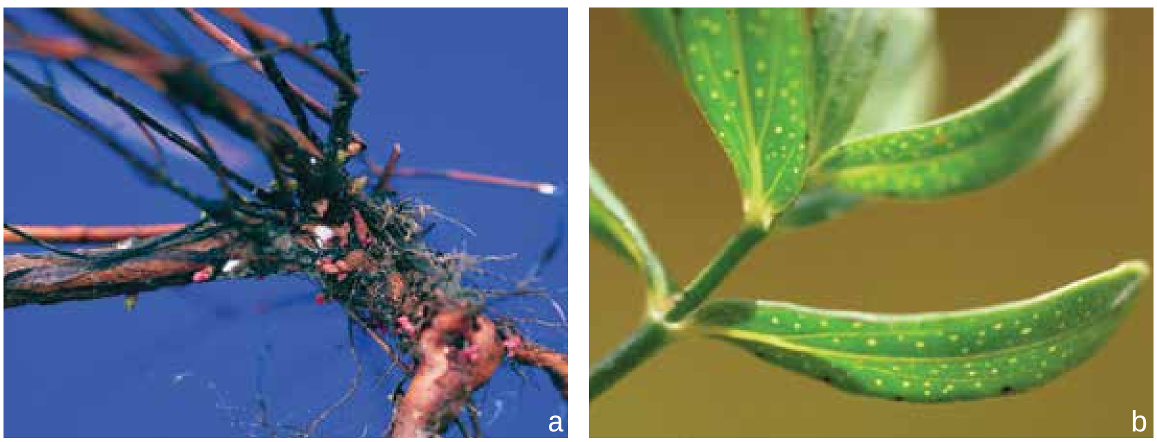


Figure 7 a. Roots; b. Leaves (Steve Dewey, Utah State University, www.bugwood.org)

margins. They are oppositely arranged on the stem, and attach directly to the stem without a petiole. The plant gets its species name (*H. perforatum*) from tiny transparent glands scattered throughout the leaves, apparent as leaves are held up to light. In addition, small and black oil-producing glands are scattered throughout, especially along leaf margins (Figure 7b).

Stems

Typical plants grow 1-3 feet (⅓0.3–1m) tall and can produce numerous stems somewhat woody at their bases. Each stem can have many upward-facing branches. Stems are hairless, 2-sided, have black glands along the ridges and distinct dark rings at lower nodes (Figure 8a). A reddish hue appears with maturity, and the entire plant eventually turns a deep rust color as stems die back prior to winter (Figure 8b).

Flowers

Flowers of common St. Johnswort occur in small clusters (cymes) at the tips of branches and

Figure 8 Common St. Johnswort a. Stems (Rachel Winston, MIA Consulting); b. Mature plant (Norman Rees, USDA ARS, www.bugwood.org)

stems (Figure 9a). Typical of cyme inflorescences, the endmost flower opens and matures before the flowers below or to the side. Each showy flower is ¾ inch (1.9 cm) in diameter and has five yellow petals with many yellow stamens. The black dots often visible along the petal margins are glands containing hypericin (Figure 9b). Flowers usually appear from late spring through autumn.

Fruits and Seeds

The fruit is a sticky, 3-celled capsule (Figure 10a). It is less than ½ inch (1.3 cm) long, rounded at the end, and rust-brown in color at maturity. Each capsule contains numerous

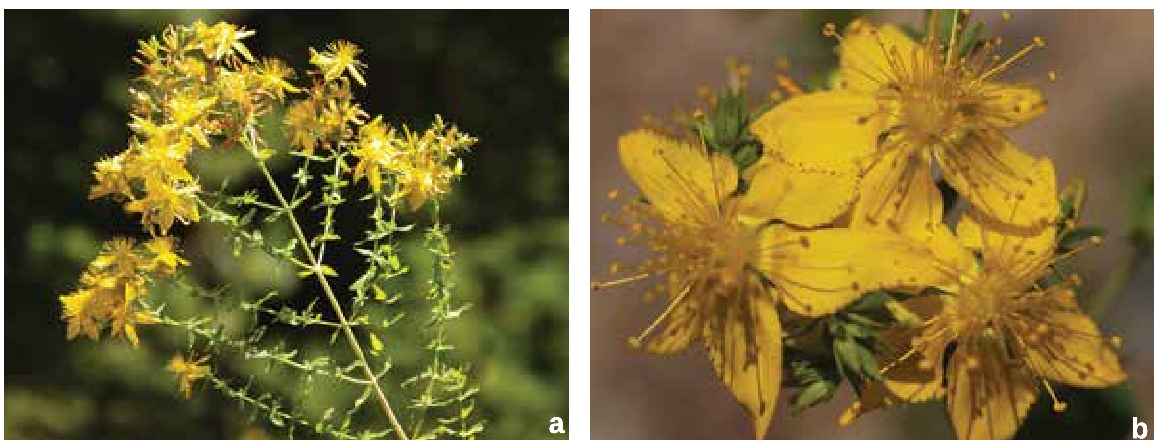


Figure 9 Inflorescences (a) and individual flowers (b) of common St. Johnswort. (Marianna Szucs, University of Idaho)

dark brown cylindrical seeds (Figure 10b). Seeds are less than 1 mm long (Figure 10c). Estimates of seed production vary tremendously but one plant is capable of producing an average of 15,000 to 34,000 seeds. Common St. Johnswort is a facultative apomict, meaning it can produce seeds with or without fertilization.

Biology and Ecology

Common St. Johnswort seed can be dispersed short distances by wind, and longer distances by humans, other animals, and water. The sticky capsule containing seeds is believed to be transported by adhering to fur, feathers, clothing, and machinery. The capsule exudes a

Figure 10 Common St. Johnswort a. Fruit (Jamie Nielsen, University of Alaska Fairbanks Extension); b. Fruit and seeds (Ken Chamberlain, Ohio State University); c. Seeds (Steve Hurst, USDA ARS) (all www.bugwood.org)

germination inhibitor. Consequently, seeds transported by water or washed with heavy rains have much higher germination rates.

Seeds germinate throughout spring and summer or following autumn rains. Though seeds of common St. Johnswort can germinate within days following dissemination, germination rates increase markedly with an after-ripening period of 4–6 or more months. Seeds may remain viable in the soil for several years, especially if buried more than 1 inch (2.5 cm) deep. Seeds germinate best in bare soil with plenty of moisture.

Seedlings (Figure 11) are susceptible to competition for light, nutrients, space, and moisture from mature common St. Johnswort plants and other species. As such, seedling mortality is extremely high. Those that survive the critical first year usually have extensive root systems, giving them a competitive advantage against other species. First year plants do not produce flowers or seeds, and it may take two to several years to reach maturity. Flowering plants bloom from late spring through early autumn.

Vegetative reproduction is responsible for much of the growth in a common St. Johnswort population. New stems originate at intervals along underground roots that may extend 3 feet (90 cm) or more from the parent plant. Grazing, fire, light defoliation, and poor site conditions (including shallow or very rocky soils) stimulate lateral root growth. Shortly after new stems establish, connecting roots often decay. It is therefore difficult to distinguish crowns developed by vegetative means from those arising from seed.

Figure 11 Seedling (Joseph DiTomaso, UC Davis, www.bugwood.org)

Distribution

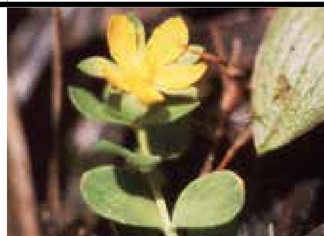
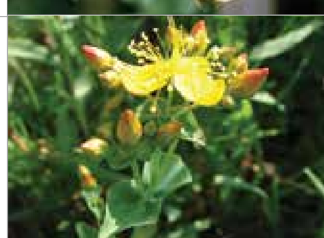
Common St. Johnswort is currently present in 45 states and 8 Canadian provinces (Figure 1b, repeated here in Figure 12a), though it is most problematic is California, Idaho, Montana, Oregon, and Washington. It is listed as noxious in seven states and two Canadian provinces and is a regulated non-native plant species in South Dakota (Figure 12b).

Commonly Confused Species

There are numerous species in North America that have similar leaves and/or flowers to those in the St. Johnswort family. However, the combination of opposite leaf arrangement, yellow flowers with five petals and numerous stamens, and the presence of tiny glands throughout leaves and petals help differentiate this family from potential look alikes. There are 59 other species of *Hypericum* present in the U.S. and Canada (see Tables 2 & 3). Twenty-six of these are shrubs or trees, and so should not be confused with the herbaceous common St. Johnswort. Of the remaining 27, only six natives and one exotic species occur in the West, where common St. Johnswort is such a problem. These species are described in Table 4 in order to aid in accurate differentiation.

Figure 12 States and provinces where common St. Johnswort is a. Established (USDA PLANTS) and b. declared noxious or regulated (INVADERS)

Table 4 Look-alike *Hypericum* in the U.S. and Canada (Credits from top to bottom: William and Wilma Follett, USDA PLANTS; kgNaturePhotography.com; Robert Mohlenbrock, USDA PLANTS; © 2010 Keir Morse; WVU Herbarium, courtesy Smithsonian Institution; Sheri Hagwood, USDA PLANTS; James K. Lindsey)

Species	Image	Features different from *H. perforatum*
Tinker's penny *H. anagalloides* Native		Found only in moist environments growing prostrate or low to the ground in carpet-like mats. Leaves are more round and stamens are fewer than *H. perforatum*.
Northern St. Johnswort *H. boreale* Native to eastern North America		Found only in wetlands or very moist areas, sometimes growing partly submerged. Delicate plant of short stature and with leaves and flowers much smaller than *H. perforatum*.
Lesser Canadian St. Johnswort *H. canadense* Native		Found only in moist soil. Has much smaller flowers with sepals obvious between petals. Leaves are long and narrow compared to *H. perforatum*.
Goldwire *H. concinnum* Native		Petals have more obvious venation and more scalloped margins than *H. perforatum* and are bent backwards away from the center of the flower. Leaves are more narrow and gray-green.
Pale St. Johnswort *H. ellipticum* Native to eastern North America		Grows in moist soil along shores of lakes, streams, and marshes. Leaves are more elliptic in shape and thinner than *H. perforatum*. Main stems are unbranched until flowered tips.
Scouler's St. Johnswort *H. scouleri* Native		Grows in more moist conditions than *H. perforatum*. Leaves are thicker and broader at their base than *H. perforatum* leaves.
Spotted St. Johnswort *H. maculatum* Introduced		Stems are hollow and have four ridges. Flowers and sepals are more spotted than *H. perforatum*.

Chapter 3: Biology of Common St. Johnswort Biological Control Agents

History

The biological control of common St. Johnswort was the first classical biological control program in the United States and Canada. It began in 1945 and 1946 with the approval and release of the klamathweed beetles *Chrysolina hyperici* and *C. quadrigemina*, respectively, in California. These beetles were so effective at reducing infestations of common St. Johnswort, this program became one of the most famous examples of a classical biological control success story. Grateful landowners in California erected a monument in honor of the beetles that saved their rangeland (Figure 13), and the journal *Scientific American* published an article in 1957 chronicling the common St. Johnswort biological control program and its achievements (Figure 14).

In some regions, the weed was completely removed from the landscape. In other areas, the weed population would rebound periodically, followed by a subsequent rebound in *Chrysolina* populations constantly keeping common St. Johnswort infestations around 3% of those levels observed at the weed's peak in the 1940's. In still other regions, common St. Johnswort appeared unaffected by *Chrysolina*, and populations continued to expand. Consequently, the biological control program was continued and resulted in the release of additional agents researchers hoped would complement the impacts of *Chrysolina*. To date, a total of five insect species are approved for release in the U.S. as classical biological control agents of common St. Johnswort. These include three beetles, one fly, and one moth.

Figure 13 Common St. Johnswort infestation in California a. before *Chrysolina* introductions; b. after *Chrysolina* introductions; c. monument in honor of *Chrysolina* (all USDA ARS European Biological Control Laboratory, www.bugwood.org)

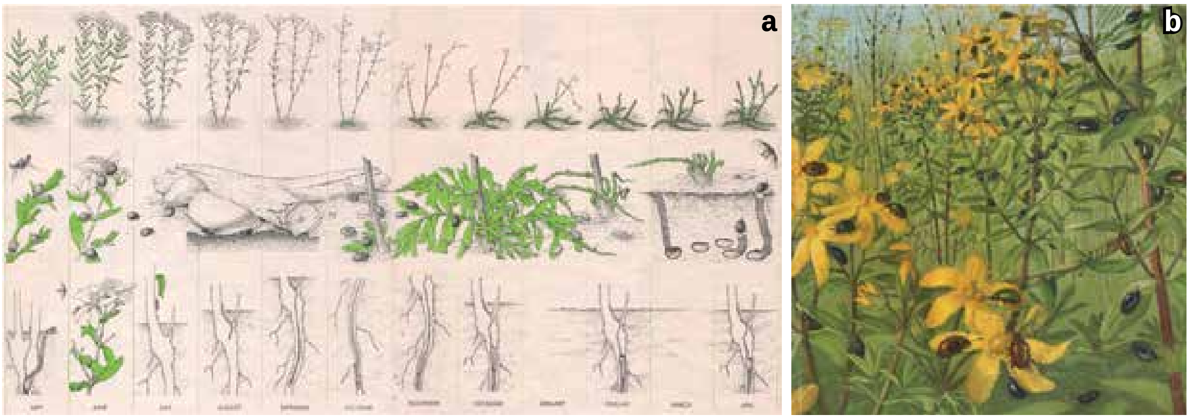


Figure 14 Illustrations from 1957 *Scientific American* article depicting the *Chrysolina* success story in California. a. Life cycles of common St. Johnswort (top), *Chrysolina* (middle), *Agrilus hyperici* (bottom) by month. b. *Chrysolina* spp. on common St. Johnswort.

Basic Insect Biology

Insects are the largest and 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 common St. Johnswort. 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 15 top). 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 15 left). The head of the adult insect has one pair each of compound eyes and antennae.

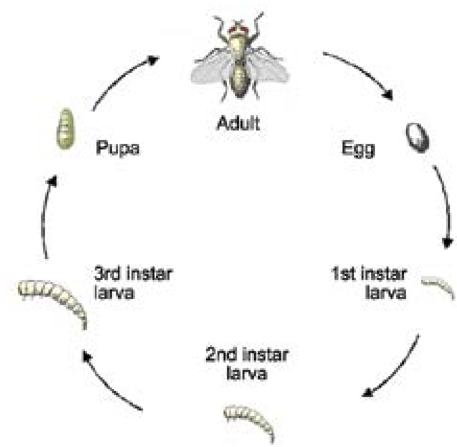
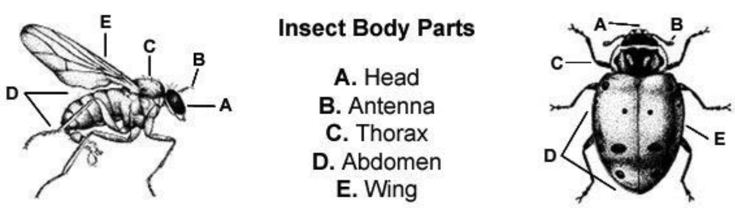


Figure 15 (top) Complete metamorphosis of an insect; (left) Body parts of adult insects (both www.bugwood.org)



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, the insect changes from a larva to an adult. Insects do not feed during the pupal stage.

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 than the elytra 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)

Many insects have the word "fly" in their common 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 common name (e.g., butterfly in the order Lepidoptera and mayfly in the order Ephemeroptera). Adult true flies are easily distinguished from other groups of insects by their single pair of membranous wings and typically soft bodies. Larvae of most true flies are legless and wormlike and are called maggots.

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 additional prolegs. The pupal stage is known as a chrysalis or cocoon.

Approved Common St. Johnswort Biological Control Agents

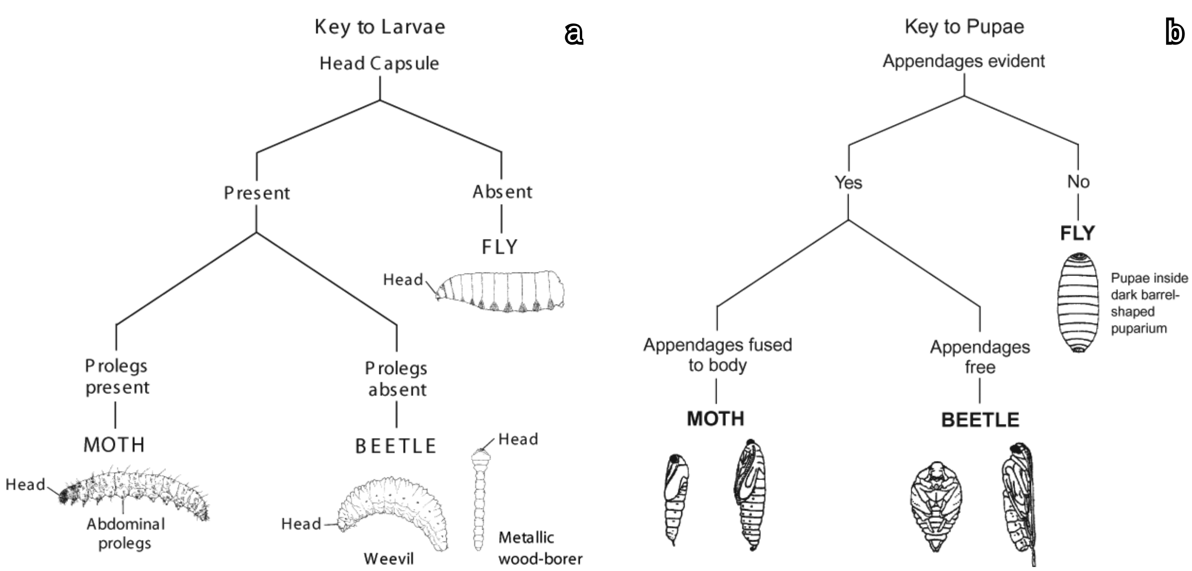


Figure 16 Identification key for a. insect larvae; b. insect pupae (both www.bugwood.org)

Five common St. Johnswort biological control species (three beetles, one fly, and one moth) are permitted for release in the U.S. These insects attack three distinct parts of common St. Johnswort plants: three of the biological control agents are leaf and flower defoliators, one is a leaf galler, and one is a stem/root miner (Figure 17).

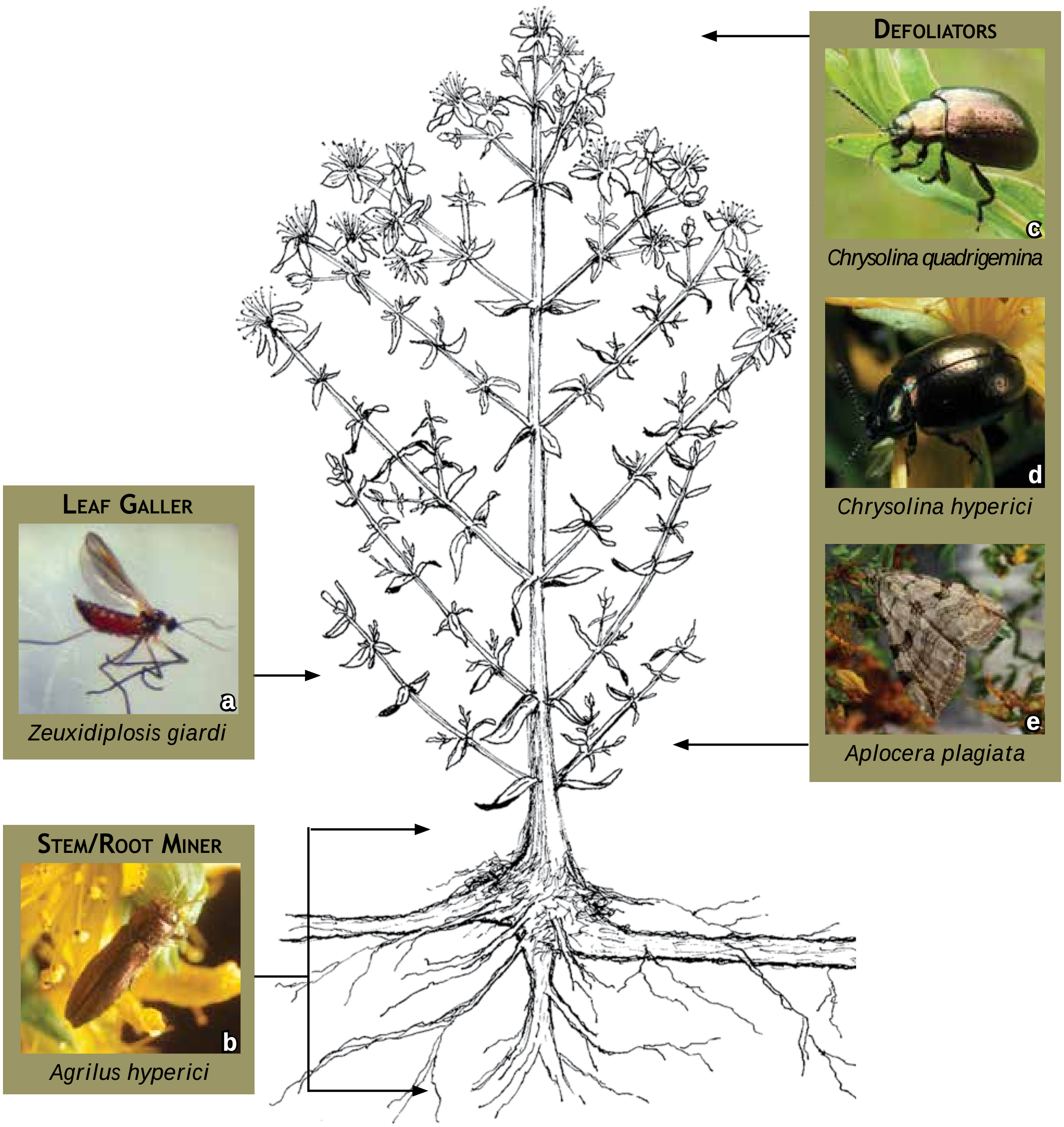


Figure 17 General location of attack for common St. Johnswort biological control. Plant: Rachel Winston, MIA Consulting; a. Norman Rees, USDA ARS, www.bugwood.org; b and d. Laura Parsons, University of Idaho; c. Cheryl Moorehead, www.bugwood.org; e. Eric Coombs, Oregon Department of Agriculture

Agrilus hyperici

Common St. Johnswort Root Borer

Order	Coleoptera
Family	Buprestidae
Native Distribution	Europe
Original Source	France
First U.S. Release	1950 California
Nontarget Effects	*H. concinnum*
Establishment	CA, ID, MT, OR, WA

Figure 18 Adult *A. hyperici* (Laura Parsons, University of Idaho)

Description

Larvae are white with brown mouthparts and are up to 2/5 inch (11 mm) in length. They complete four instars. Adults are a metallic brown color; females are all one color while males' heads are slighter greener than the rest of their bodies. Adults are flattened and tapered toward the rear and can be up to 1/5 inch (5 mm) long.

Life Cycle

Larvae overwinter within roots, feeding again within the roots the following spring as the plants bolt. Pupation occurs in the roots, with adults emerging through early summer as common St. Johnswort flowers. Adults are most active in the heat of the day. Following a 6-week oviposition period taking place near the base of common St. Johnswort plants in late summer, newly emerging larvae burrow into the roots to feed and then overwinter. There is one generation per year.

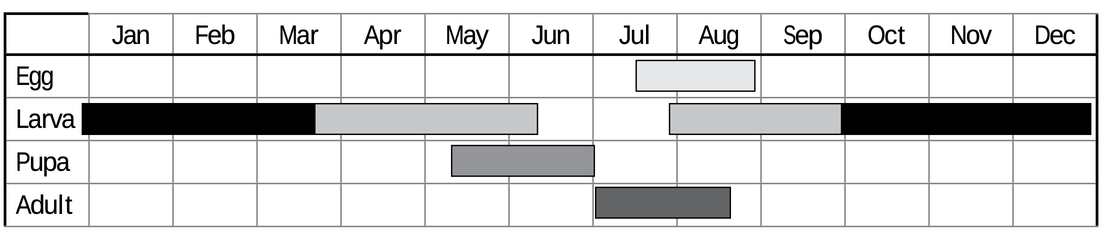


Figure 19 Life cycle of *A. hyperici*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Habitat Preference

This species is found mostly in mountainous regions in North America and drier, more southern portions of Europe. Damp sites are less suitable as larvae are often susceptible to fungal attack. This beetle prefers large plants with multiple stems. It will attack plants in shade, unlike some other common St. Johnswort biological control agents.

Impact

When larvae feed within roots of common St. Johnswort, root tissue can be completely consumed. Stems arising from attacked roots and root crowns are stunted and produce fewer flowers, with the attacked plant dying outright in some instances.

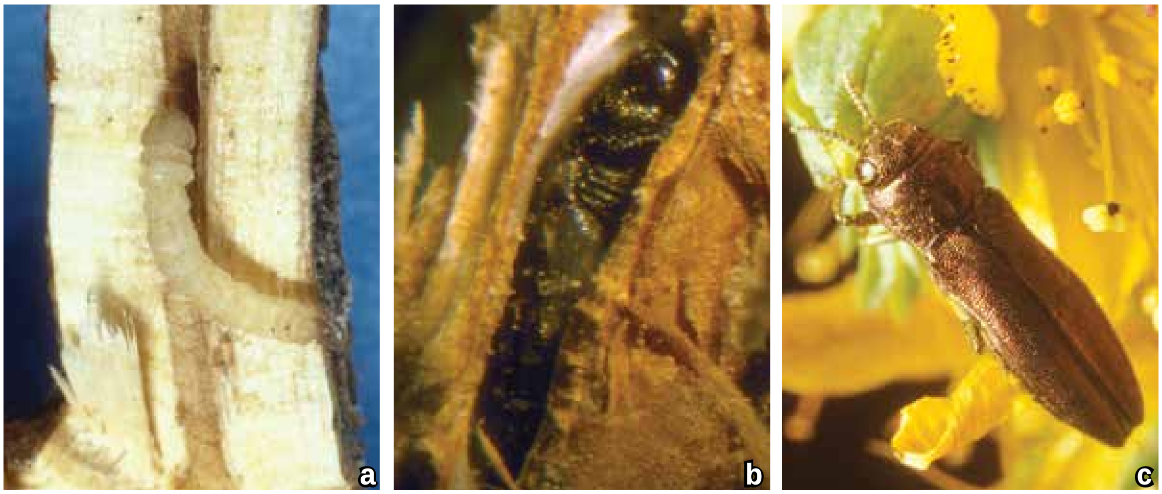


Figure 20 Stages of *Agrilus hyperici*. a. Larva (Norman Rees, USDA ARS, www.bugwood.org); b. Pupa (Norman Rees, USDA ARS, www.bugwood.org); c. Adult (Laura Parsons, University of Idaho)

Availability

This beetle is established throughout the western U.S. However, populations are small, and only limited numbers are available for collection. It is most widespread in northern Idaho, where it has contributed to common St. Johnswort control.

Comments

Both *Chrysolina* species may impact *A. hyperici* populations, though studies addressing this had varying results. In Australia, *A. hyperici* populations decreased significantly following strong competition with *Chrysolina*. *Chrysolina* populations multiply more rapidly than the slower-building *A. hyperici*. Greater numbers of *Chrysolina* are compounded by *Chrysolina* feeding on common St. Johnswort foliage earlier in the growing season. Complete defoliation of stems results in no food for the later-occurring *A. hyperici* adults, and the starving individuals fail to reproduce and quickly die. A separate study found that the densities of *Chrysolina* observed in Idaho were sufficiently low that negative interactions between *Chrysolina* and *A. hyperici* were unlikely. Regardless, new *A. hyperici* releases are best made in common St. Johnswort populations with low *Chrysolina* densities.

Agrilus hyperici has been observed attacking *H. concinnum*, a *Hypericum* forb/small shrub endemic to California. Long-term impacts of *A. hyperici* on this species have not been recorded.

Aplocera plagiata

Common St. Johnswort Inchworm

Order	Lepidoptera
Family	Geometridae
Native Distribution	Northern Europe
Original Source	Europe
First U.S. Release	1989 Montana
Nontarget Effects	None reported
Establishment	ID, MT, OR, WA

Figure 21 Adult *A. plagiata* (Eric Coombs, Oregon Department of Agriculture)

Description

Eggs are small, pearly-white ovals. Larvae resemble twigs and are reddish brown with weak gray stripes. They are up to 1 inch (2.5 cm) long and complete four instars. Pupae are greenish-golden and slender. Adults are triangular in shape and have gray wings with dark gray bands. Wingspans reach 1½ inches (3.8 cm).

Life Cycle

Overwintering larvae emerge in early spring and feed on common St. Johnswort foliage (typically at night) when the plant is bolting. Pupation occurs in the soil. Adults emerge in late spring and early summer and lay eggs on foliage. Larvae of the first new generation emerge in midsummer as common St. Johnswort flowers, repeating the life cycle. Second generation larvae hatch in late summer, coinciding with the late flowering stage of common St. Johnswort, and feed on foliage and flowers. This generation overwinters in the larval stage within the soil. There are up to two generations per year, depending on winter temperatures.

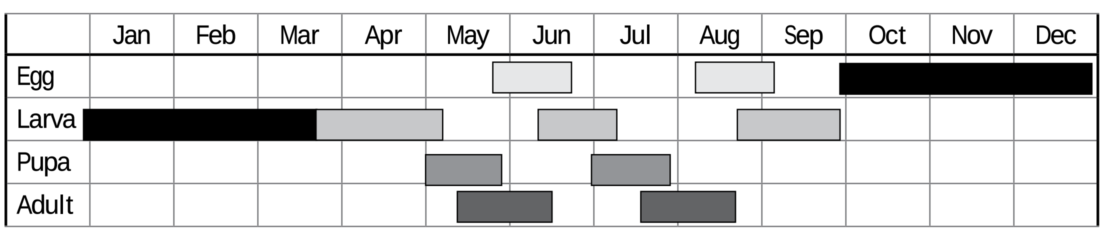


Figure 22 Life cycle of *A. plagiata*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Habitat Preference

This species prefers dry areas to those with high rainfall. It does well on rocky ground, open sandy places, and in limestone regions.

Impact

Larval defoliation only weakens common St. Johnswort plants. Attack by large populations of this biological control agent can lead to a reduction of flower and seed formation.

Figure 23 Common St. Johnswort defoliated by *A. plagiata* (Norman Rees, USDA ARS, www.bugwood.org)

Availability

Though populations are still at low densities throughout the West, this moth can be readily collected from northern Idaho, eastern Oregon, and eastern Washington.

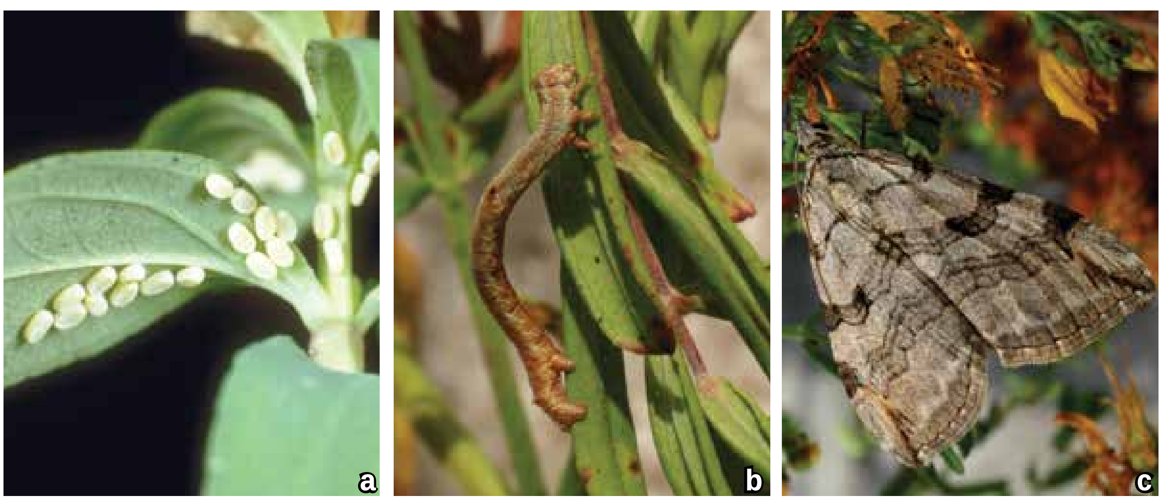


Figure 24 Stages of *Aplocera plagiata*. a. Eggs (Norman Rees, USDA ARS, www.bugwood.org); b. Larva (Eric Coombs, Oregon Department of Agriculture); c. Adult (Eric Coombs, Oregon Department of Agriculture)

Comments

Adults are usually fewer in number the first generation compared to second generation. Warm, dry, and long summers are needed to complete both generations. When cold temperatures arrive too soon, second generation larvae do not survive winter.

Chrysolina hyperici and *C. quadrigemina*

Klamathweed Beetles

Order	Coleoptera
Family	Chrysomelidae
Native Distribution	Europe and Asia
Original Source	England via Australia
First U.S. Release	1945, 1946 California
Nontarget Effects	*H. calycinum*, *H. concinnum*
Establishment	Throughout U.S.

Figure 25 Adult *C. hyperici* (Laura Parsons, University of Idaho)

Description

There are two species of klamathweed beetles established in North America, and they are morphologically very similar. *C. quadrigemina* is slightly larger and prefers more maritime conditions than *C. hyperici,* which is more cold and moisture tolerant. Larvae are initially orange and later gray. They complete four instars and are up to ¼ inch (6 mm) in length. Adults are oval-shaped, robust, and are up to 6 mm long. They are shiny metallic with green, bronze, or blue undertones.

Life Cycle

Larvae emerge in early spring and feed on young foliage when the plant is bolting. Ingesting common St. Johnswort makes larvae photosensitive, so most feeding occurs before sunrise. Pupation occurs in the soil in late spring. Adults emerge in early summer as common St. Johnswort begins flowering. They feed and then often rest in the soil over summer. If fall rains are sufficient, adults return to plants and resume feeding on foliage in the fall and laying eggs on leaves as common St. Johnswort is senescing. Both species primarily overwinter as eggs. When fall rains are not significant, adults overwinter and lay eggs in spring. In mild climates, fall-hatched larvae can survive the winter. There is one generation per year.

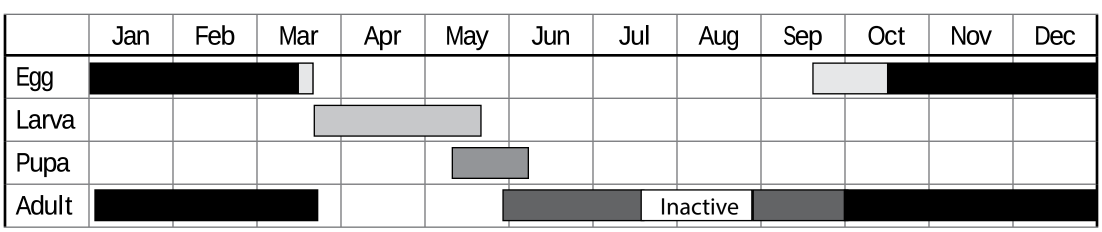


Figure 26 Life cycle of *Chrysolina* spp. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period. This figure illustrates the two most common overwintering scenarios. When fall rains are sufficient, adults resume activity in fall and lay eggs which overwinter. When fall rains are insufficient, adults overwinter and lay eggs in spring.

Habitat Preference

Both species do poorly in shaded, barren, or rocky areas. They prefer warm and sunny regions with wet winters. *C. hyperici* tolerates more moisture and colder winter temperatures than *C. quadrigemina*.

Impact

Larval feeding can decimate populations of common St. Johnswort. Summer defoliation by adults is also striking, but not quite as effective as larval feeding.

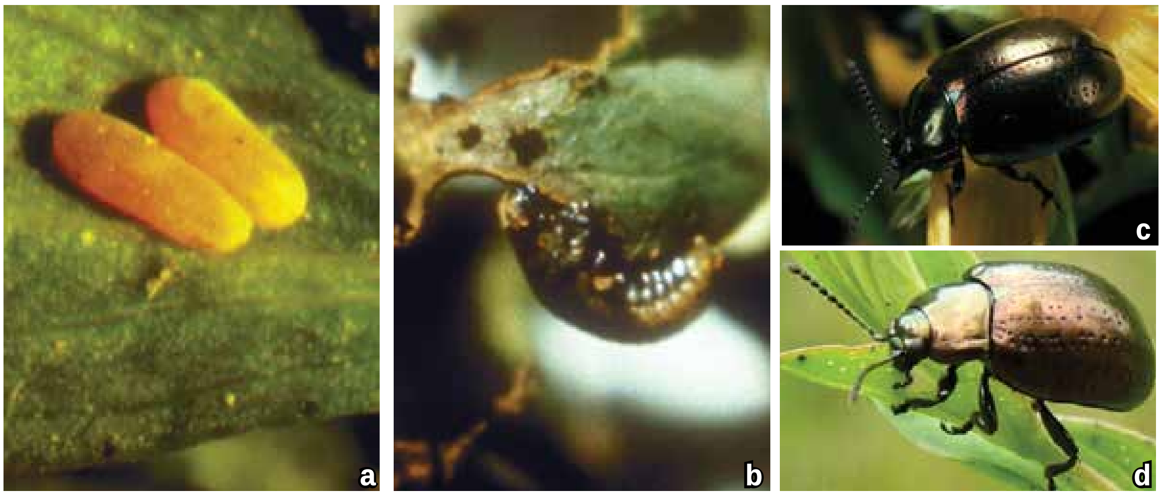


Figure 27 Stages of *Chrysolina* spp. a. Eggs; b. Larva (a,b Norman Rees, USDA ARS, www.bugwood.org); c. Adult *C. hyperici* (Laura Parsons, University of Idaho); d. Adult *C. quadrigemina* (Cheryl Moorehead, www.bugwood.org)

Availability

Both species are readily available.

Comments

Both species may have negative impacts on the common St. Johnswort root borer (*A. hyperici*), though data is inconclusive.

C. quadrigemina has been documented feeding on the exotic *H. calycinum* and the native *H. concinnum*, a forb/small shrub endemic to California. Long-term impacts on the native species have not been recorded. It is possible that *C. hyperici* also feeds on these two *Hypericum* species, though this has not been documented.

Figure 28 Attack by *C. quadrigemina* (Mark Schwarzländer, University of Idaho)

Zeuxidiplosis giardi

Common St. Johnswort Gall Midge

Order	Diptera
Family	Cecidomyiidae
Native Distribution	Europe
Original Source	France
First U.S. Release	1951 California
Nontarget Effects	*H. concinnum*
Establishment	CA, HI

Figure 29 Adult *Z. giardi* (Norman Rees, USDA ARS, www.bugwood.org)

Description

Eggs are elongated and pale red in color. Larvae are orange and can reach up to 1/12 inch (2mm) in length, completing three instars. Pupae are a yellowish-red, becoming darker red as they mature. Adults are very small (⅛ inch or 3 mm long) and have dark red bodies with gray heads, wings, and legs.

Life Cycle

Larvae emerge in early spring and feed on leaf buds, causing leaves to grow into a spherical gall that is green with reddish markings. Larvae feed inside at the base of the gall; several larvae are often found within one gall. Pupation also occurs inside. Adults are sexually mature upon emergence and live for up to five days. There may be up to seven generations per year, though there are usually fewer than five. Larvae and pupae overwinter inside galls.

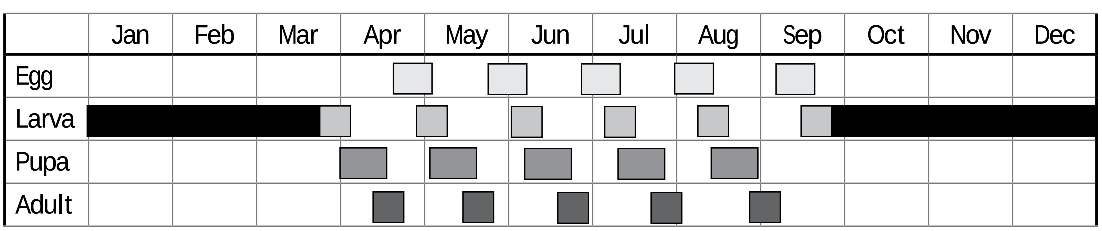


Figure 30 Life cycle of *Z. giardi*. Bars indicate the approximate length of activity for each of the life stages. Black bars represent the overwintering period.

Habitat Preference

This species does best with moderate to high humidity, thriving in damp locations and at high elevations. It does poorly in areas with dry summers and constant wind. Nor does it do well with heavy livestock grazing.

Impact

Most western U.S. infestations of common St. Johnswort occur in habitats unsuitable for *Z. giardi.* Consequently, it is not widespread or effective in most western states. It can be found in parts of California and is widely distributed in Hawaii, where it is responsible for a marked reduction of common St. Johnswort. In suitable habitats, this insect can cause a loss of vigor and reduction of both root and foliage development. Heavily attacked plants are unable to obtain moisture and frequently die during drier seasons.

Figure 31 a. Adult *Zeuxidiplosis giardi*; b. Damage (galls) caused by *Z. giardi* feeding (both Norman Rees, USDA ARS, www.bugwood.org)

Availability

This insect is not established in the majority of the northwestern U.S. due to the lack of suitable habitat. It can be found in small populations in California, and is readily available in Hawaii. Care should be taken if attempting to distribute this biological control agent throughout the Northwest, ensuring that recipient common St. Johnswort populations are in suitable climatic conditions.

Comments

The common St. Johnswort gall midge is capable of forming galls on *H. concinnum*, a forb/small shrub endemic to California. However, damage to this plant is insignificant.

Chapter 4: Elements of a Common St. Johnswort Biological Control Program

The results of using biological control to treat common St. Johnswort may vary greatly from site to site due to differing conditions. Land managers need to develop biological control programs that address management conditions and objectives unique to their area. The following steps can help in this endeavor.

Defining Your Goals and Objectives

Defining your weed management goals and objectives is the first and most important step in developing a 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 first define what will constitute a successful common St. Johnswort management program. For example, the goal of "a noticeable reduction in common St. Johnswort density over the next 10 years" might be achievable, but it is objective and also open to observer bias. Alternatively, the goal of "a 50 percent reduction in common St. Johnswort stems over the next three years" is more precise and measurable.

If your goal is to reduce the abundance of common St. Johnswort, biological control may be an appropriate weed management tool. However, by itself, biological control will not completely remove common St. Johnswort 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).

Taking Stock: Your Infestation and Your Options

Before embarking on common St. Johnswort management activities, you must first understand the scope of your problem, identify areas of special concern, and review and understand all weed management tools available to you in your situation.

Your first step should be to develop a distribution map of your common St. Johnswort infestation(s) at a scale that will allow you to address your weed problem in a manner consistent with your land-management objectives and your weed management resources. For example, in large management areas with significant common St. Johnswort infestations and limited resources, aerial mapping of large patches of common St. Johnswort may be sufficient to identify priority areas for additional survey and weed management activities

(Figure 32a). In other management areas with small, discrete common St. Johnswort infestations or where an infestation affects your ability to meet management objectives, intensive mapping and characterization of common St. Johnswort infestations (e.g. location, size, density, and cover) may be necessary to develop an appropriate weed management strategy (Figure 32b).

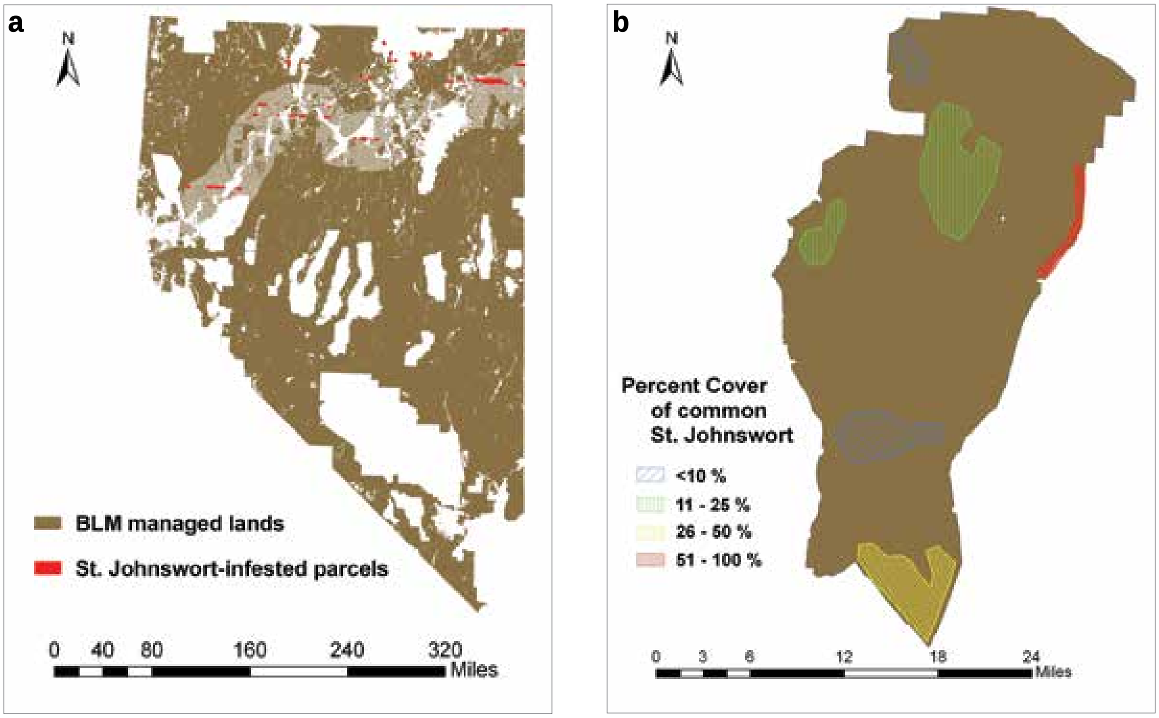


Figure 32 Hypothetical common St. Johnswort infestations for a. all Nevada land managed by the Bureau of Land Management (BLM) and b. Black Rock Desert, one of the numerous parcels of BLM-managed land in northwestern Nevada

Once you determine the scope of your common St. Johnswort infestations, review the management tools available—including use of 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. These management tools are described in detail in Chapter 5. Consult your agency or university biological control expert, cooperative weed management area, or county weed coordinator/supervisor to learn about other common St. Johnswort management activities underway or planned for your area, and the level of control that might be achieved by each.

Identify the resources that will be available for weed management activities, and determine if these resources will be consistently available until you meet your weed management program objectives. If resources are not available, identify what will happen at the treatment site if the activities are not implemented.

With a map of common St. Johnswort infestations in your management area, an understanding of your land management objectives, and a list of the weed management tools 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 Biological Control Program

When biological control is deemed suitable for treating your common St. Johnswort infestations, there are several important factors to consider while planning your approach. These include selecting appropriate release sites, obtaining and releasing insects, and monitoring the success of the program. These items are discussed below. If problems are encountered following the initiation of a biological control program, refer to the troubleshooting guide in Appendix I for potential responses.

Before you begin

There is a fair amount of preliminary work to do before you can implement a biological control release program. Some factors to address include:

- Many biological control programs do not result in visible weed reduction for a number of years (typically 3-5, or more). Make sure that you can make a long-term commitment to the program.
- Decide how long you can let biological control activities continue if weed control goals are not being met.
- Discuss your biological control program plans with neighboring landowners and land managers. Ask local weed managers about their experiences with biological control. Determine which agents they have used, alone or in combination with other weed control tools, and what level of control they achieved. Would their level of control be acceptable for your management area? Talk to neighboring managers about any activities, such as herbicide use, grazing, or mowing programs they have planned on their land. These measures could have a direct impact on your proposed biological control activities.
- Set short- and long-term goals. For example, a short-term goal might be to release and determine establishment of biological control agents; a long-term goal might be to reduce common St. Johnswort density by 50 percent within 10 years.
- Determine* what resources will be consistently available for 5 to 10 years for implementing, monitoring, and assessing your biological control program. These include:
  - Committing resources for field equipment and supplies,
  - Recruiting and training personnel, and
  - Identifying sources of biological control agents.

Selecting Biological Control Agent Release Sites

Establish goals for your release site

The overall management goals for a given site must be considered when evaluating its suitability for the release of biological control agents. Additional factors must be evaluated even after deciding that biological control is appropriate for a given site. Suitability factors will differ, depending on whether the release is to be:

- A general release, where agents are simply released for common St. Johnswort

management,
- A field insectary (nursery) release, primarily employed for production of biological control agents for distribution to other sites, or
- A 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

Biological control agents available for common St. Johnswort vary in their habitat and climatic preferences. If certain insects will be targeted for your biological control program, consider their preferred site characteristics when determining the location of your biological control efforts. In addition, if your biological control program goals involve establishing permanent monitoring sites which require regular visitation, consider site location, ease of accessibility, terrain, and slope.

For practical purposes, a common St. Johnswort infestation cannot be too large for

Figure 33 Common St. Johnswort infestation too small to be recommended for biological control efforts (John Randall, The Nature Conservancy, www.bugwood.org)

biological control releases; however, it might not be large enough (Figure 33). Small, isolated patches may not allow biological control agent populations to build up and persist and may be better suited for other weed control tactics, such as herbicide applications. An area with at least 1 acre (0.40 hectares) of common St. Johnswort might be considered as a minimum release site size, but a larger area of infestation is more desirable, especially for field insectaries. Infestations should be contiguous; relatively uniform weed populations are preferable to scattered patches over a given area. Most common St. Johnswort biological control agents do best in a moderately dense area of infestation.

Note land use and disturbance factors

Preferred release sites are those that experience little to no human (or other) disturbances. Fallow sites and natural areas are good choices for biological control agent releases. If a site must be disturbed (e.g., mowed or grazed), the activities should not take place during the spring and summer months when most biological control agents are active above ground. Sites where insecticide use is routine should not be used 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 receive regular insecticide sprays. Avoid sites prone to seasonal flooding. 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 practices occur regularly.

Figure 34 If the river in the background is subjected to seasonal flooding, this riparian infestation of common St. Johnswort is not recommended for biological control efforts (Carol DiSalvo, National Park Service, www.bugwood.org)

Survey for presence of biological control agents

Examine your prospective release sites to determine if common St. Johnswort 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 common St. Johnswort populations require less-frequent and short-term access; you may need to visit such a site only once or twice after initial release. If you are releasing insects on private land, it may be a good idea to obtain the following:

- Written permission from the landowner or land manager allowing use of the area as a release site
- Written agreement by 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)
- Permission to put a permanent location marker at the site

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 or plants. The simplest solution would be to select locations that are not visible

Figure 35 Gated access. (Chris Schnepf, University of Idaho, www.bugwood.org)

to, or accessible by, the general public. Being 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 public land manager. This will involve such things as posting trespassing restrictions, installing locks on gates, etc.

Another consideration is the 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 selecting biological control for release at a site, including agent efficacy, availability, and site preferences (Table 5).

Agent efficacy

Efficacy refers to the ability of the agent to directly or indirectly reduce the population of the target weed below acceptable damage thresholds or cause weed mortality resulting in control. Most of the available data on efficacy is anecdotal, observational, or based on limited experimental data.

It is preferable to release only the most effective biological control agents rather 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 five of the approved common St. Johnswort biological control agents described in this manual are established in the continental U.S. However, availability varies greatly between species. The *Chrysolina* beetles are readily available throughout the U.S. and have several collectable populations in all states with significant common St. Johnswort infestations. These insects should be easy to obtain from intrastate and local sources. *Aplocera plagiata* is less widespread but still available for collection in northern Idaho, eastern Oregon, and eastern Washington. *Agrilus hyperici* is even less common. Collection-sized populations can only be found in northern Idaho. *Zeuxidiplosis giardi* is the least abundant of common St. Johnswort biological control agents. It is readily available in Hawaii, but only small populations exist in the continental U.S. in California. Federal agencies and commercial biological control suppliers may be able to assist you in acquiring agents that are not available in your state (see Obtaining and Releasing Common St. Johnswort Biological Control Agents, below). County weed managers, extension agents, or federal and university weed or biological control specialists should be able to recommend in-state sources for various common St. Johnswort biological control agents.

Release site characteristics

General physical and biological site preferences for each agent have been developed from anecdotal observations and experimental data. These are listed in Table 5 to help land managers ensure that insects are released in sites with suitable conditions.

Table 5 Summary of general characteristics and site preferences of common St. Johnswort biological control agents released in the United States (through 2010)

Agent Characteristics				Site Characteristics	
Species	**Part Attacked**	**Efficacy**	**Availability**	**Favorable Conditions**	**Unfavorable Conditions**
Agrilus hyperici St. Johnswort root borer	Roots	High when populations large enough	Widespread in West but only dense in northern ID	Mountainous, dry regions with large, multi-stemmed plants; shade is tolerated	Damp sites make this insect susceptible to fungal attack
Aplocera plagiata St. Johnswort inchworm	Leaves and flowers	Low to Moderate	Widespread in West; only readily collected from N ID, E OR, E WA	Dry areas with rocky ground; open sandy places; limestone regions	High rainfall regions
Chrysolina hyperici and *quadrigemina* Klamathweed beetles	Leaves and flowers	High	Widespread and readily available	Warm and sunny with wet winters; *C. hyperici* tolerates more moisture and colder winter temperatures than *C. quadrigemina*	Shaded, barren, or rocky areas
Zeuxidiplosis giardi St. Johnswort gall midge	Leaves	High where conditions are suitable	Only in HI and small populations in CA	Moderate to high humidity in damp locations and high elevations	Dry summers and constant wind; does poorly in grazed areas

Obtaining and Releasing Common St. Johnswort Biological Control Agents

You can obtain common St. Johnswort 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 Common St. Johnswort 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 types of 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 after released. 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 Common St. Johnswort Biological Control Agents on page 47). Get your permits early to avoid delays.

- Some states, counties, and universities have "field days" at productive insectary sites (Figure 36). On these days, land managers and landowners are invited to collect or receive freshly collected common St. Johnswort biological control agents for quick release at their 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 common St. Johnswort and plant communities.

Figure 36 Field day in northern Idaho (Chris Schnepf, University of Idaho, www.bugwood.org)

Typically, field days are conducted at several sites in a state and on several dates during the summer. Although designed primarily for intrastate collection and distribution, 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 state and/or adjacent states.

Collecting Common St. Johnswort Biological Control Agents

Planning and timing of collection is critical. 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 common St. Johnswort biological control agents are listed in Table 6. For all species, collect only on a day with good weather; insects are usually not active in rainy and very windy conditions.

Table 6 Recommended timetable and methods for collecting common St. Johnswort biological control agents in the U.S.

Type	Scientific Name	Life Stage	Plant Growth Stage	Timing	Method
Beetle	*Agrilus hyperici*	Adult	Flowering	Summer (Jun-Aug)	Net and aspirator
	Chrysolina spp.	Adult	Flowering	Summer (Jun-Sep)	Net and aspirator
Fly	*Zeuxidiplosis giardi*	Larvae or pupae in galls	Growing season	All season (Mar-Nov)	Hand transfer galls
Moth	*Aplocera plagiata*	Larvae	Flowering	Midsummer to fall (Jul-Sep)	Sweep net

Beetles

Beetles are best collected in the adult stage. Adult *Agrilus hyperici* and *Chrysolina* spp. can be collected with a sweep net (with or without an aspirator) during summer when plants are in flower. Keep in mind that *Chrysolina* adults often rest in the soil during late summer (July and August).

Flies

Sweeping adult flies is possible, though this is not always the best stage for collection. Adult flies are fragile and can be damaged during collection. This is especially true for the tiny common St. Johnswort gall midge. Consequently, *Zeuxidiplosis giardi* is best transferred by placing plants infested with galls into uninfested patches throughout the growing season. Alternatively, galls infested with larvae may be hand-picked and transferred to uninfested patches of common St. Johnswort. When transferring galls, it is important to keep the galls moist to prevent dessication. Transferring infested galls may also transfer unwanted parasitoids or other seed head insects. To avoid this, seed heads can be collected in fall and stored at 39–46°F (4–8°C). Two-three weeks prior to their normal emergence time, bring them to room temperature in rearing cages or breathable, clear containers. Once they emerge, flies can be transferred to new common St. Johnswort infestations.

Moths

The common St. Johnswort inchworm, *Aplocera plagiata*, is best collected in the larval stage using sweep nets. First generation larvae are available in midsummer as common St. Johnswort flowers. Second generation larvae hatch in late summer or early fall, coinciding with the late flowering stage of common St. Johnswort. Adults may be collected and transferred as well, though this stage is fragile and sweep netting often results in injury to the moths.

Sweep net

A sweep net is made of cotton or muslin on a hoop 10–15 inches (25–38 cm) in diameter attached to a handle 3 feet (0.9 m) long (Figure 37). They can be purchased from entomological, forestry, and biological supply companies, or you can construct them yourself. As their name implies, they are used to "sweep" insects off common St. Johnswort.

Figure 37 Sweep net (Laura Parsons, University of Idaho, www.bugwood.org)

A sweep is made by swinging the net through the plant canopy. 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. This reduces the potential harm that could result from knocking biological control agents around with debris or from damage inflicted by other insects inside the net.

Sweep netting is a relatively easy and efficient manner for collecting insects from the above-ground portion of plants, and is the ideal method for collecting adult beetles. The best time for sweeping common St. Johnswort insects 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 common St. Johnswort moths and midges (*A. plagiata* and *Z. giardi,* respectively) 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 biological control species.

Aspirator

Use an aspirator (Figure 38) to suck the insects directly from common St. Johnswort or the sweep net. This provides selective sorting (no unwanted or unknown material is inadvertently collected). Aspirating can be done in the field or indoors. When aspirating indoors, cool the insects to make them less active and easier to collect. 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.

Figure 38 Aspirator (Laura Parsons, University of Idaho, www.bugwood.org)

Hand-picking

Simply pick the insects from the common St. Johnswort plants by hand or tap them into a net or plastic tray using a tool such as a badminton racquet. Forceps or tweezers may be helpful. Hand-picking works best for stationary or slow-moving insects, such as the larvae of *A. plagiata*. Use clippers if collecting galls.

Containers For Common St. Johnswort Biological Control Agents

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

Figure 39 Cardboard containers (Martin Moses, University of Idaho, Bugwood.org)

After collection, biological control agents 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 (Figure 39) are ideal for all common St. Johnswort biological control agents. They are rigid, permeable to air and water vapor, and are available in many sizes. Unfortunately, most manufacturers have stopped producing them, and they are becoming increasingly difficult to find.

As an alternative, you can use either light-colored, lined or waxed-paper containers (e.g., ice cream cartons are particularly suitable) 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. Untreated paper bags (lunch bags) work well for transporting agents across short distances. However, they are fragile and offer little physical protection for the agents within, you must seal them 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 paper towels to provide a substrate for insects to rest and hide and to help regulate humidity. Include fresh sprigs of the common St. Johnswort foliage (as food) before adding the agents. Common St. Johnswort sprigs should be free of seeds, flowers, and any other insects. Do not place sprigs in water-filled containers; if the water leaks, it will likely drown your 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 Common St. Johnswort Biological Control Agents

Keeping the containers cool

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 containers. Always keep coolers out of the direct sun, and only open them again when you are ready to remove the 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 40°F or 4.4°C) until you transport or ship them.

Transporting short distances

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

Shipping long distances

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 before sealing the shipping container. For additional security and protection, you may place the sealed shipping containers or coolers inside cardboard boxes.

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

Common Packaging Mistakes

Excess heat. Do not expose biological control agents to direct sunlight or temperatures above 80°F.

Excess moisture. Remove spilled or excess water in the container.

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

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, Saturday, or Sunday, delaying release of the agents for several days.
- Clearly label the contents of your 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 X-ray or otherwise 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, verify that someone will be there to accept the shipment, and instruct them not to open or X-ray the container.

Purchasing Common St. Johnswort Biological Control Agents

A number of commercial suppliers provide common St. Johnswort biological control agents. County weed managers, extension agents, or university weed or biological control specialists maybe able to recommend one or more suppliers. Make sure that a prospective supplier can provide the species you want and can deliver it to your area at a time appropriate for field release. (You may want to know where and when the agents were collected.) Interstate shipments of common St. Johnswort biological control agents by commercial suppliers also require a USDA permit (see the box above and Appendix II). Determine in advance whether you or the shipper is responsible for obtaining the permit. Do not purchase or release unapproved, non-permitted biological control organisms.

Regulations Pertaining to Common St. Johnswort Biological Control Agents

U.S., intrastate. Generally, there are few if any restrictions governing collection and shipment of biological control 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.

U.S., interstate. The interstate transportation of biological control agents is regulated by the U.S. Department of Agriculture (USDA), and an approved 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—ideally, at least six months before actual delivery date of your biological control agent. You can check the current status of regulations governing intrastate 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 common St. Johnswort 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 boundaries.

Releasing Common St. Johnswort Biological Control Agents

Establish permanent location marker

Place a steel fence post or plastic or fiberglass pole at least 4 feet (1.2 m) tall as a marker at the release point (Figure 41). 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. If tall, conspicuous posts are not practical or suitable at your release site because of too much human or large animal traffic or a high risk of vandalism, etc., mark your release sites with short, colorful plastic tent or surveyor's stakes or steel plates that can be etched or tagged with release information and located later with a metal detector and GPS.

Figure 41 Permanent marker for biological control agent release site (Rachel Winston MIA Consulting).

Record geographical coordinates at release point from GPS

This should be done as a complement to, rather than a replacement for, a physical marker and will help locate release points if markers are damaged or removed. With the coordinates, be sure to record what coordinate system you are using (e.g., latitude/longitude or UTM).

Prepare map describing access to release site, including roads, trails, relevant landmarks

The map should be a complement to, not a replacement for, a physical marker and latitude and longitude or UTM coordinates. It will be especially useful for a long-lived project 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 that are difficult to access.

Complete relevant paperwork at site before or just after releasing biological control agents

Your agency may have release forms for you to fill out. Typically, the information you would provide would include a description of the site's physical location, including GPS-derived latitude, longitude, and elevation coordinates; a summary of its biological and physical characteristics and use; the names of the biological control agent(s) released; date and time of the release; weather conditions during the release; and the names of the person(s) who released the agents. (See Biological Control Agent Release Form in Appendix III). The best time to record this information is while you are at the field site; don't wait until you are back in the office to do it. Once back in the office, submit the information to your county extension agent, university, or state department of agriculture. Keep a copy for your own records.

Set up a photo point

A photo point is used to visually document changes in common St. Johnswort 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). Pre- and post-release photographs should be taken from roughly the same place and at the same time of year. Make sure each photograph includes your release point marker (Figure 42).

Release as many agents as possible

For practical purposes, there is probably no maximum number of biological control agents that could be released. In other words, you can never release too may insects. As a general rule of thumb, it is better to release as many individuals of an agent as you can at one site than to spread those individuals thinly over two or more sites. 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. Guidelines for a minimum release size are uncertain for most agents, but releases of 200 individuals or more are encouraged.

Figure 42 Photo point for common St. Johnswort infestation a. before and b. after *Chrysolina* introductions (USDA ARS European Biological Control Laboratory, www.bugwood.org)

Adults of common St. Johnswort biological control agents should be released in a group at the marked release point. This is preferred to scattering released biological control agents throughout the common St. Johnswort infestation. Releases 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.

When larvae or pupae are collected in galls and stems of infested common St. Johnswort tissue, it is best to broadcast the infested plant material into the litter from previous years' growth. Emerging biological control agents can utilize nearby soil and litter for pupation or shelter or crawl up new host common St. Johnswort plants to complete their life cycles. If there are a number of ant mounds or ground dwelling animals in the area, a better option may be to tie a bouquet of infested material to a nearby fencepost.

Documenting, Monitoring, and Evaluating a Biological Control Program

Weed biological control success is measured by how well the biological control agents reduce the targeted weed densities near or below a pre-determined threshold. Measurement of the weed population in relation to this threshold will determine if your efforts have been successful. The effects of biological control agents usually take much longer to appear than those of herbicide and mechanical control strategies and at least several years to have full impact on the weed.

The need for documentation

Documenting the 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. Documenting initial conditions, coupled with data from periodic evaluations of the biological control agent's establishment and impact, can indicate whether or not the biological control program is working as desired or if additional releases of the same or different biological control agents are needed. Similarly, it can provide critical information for other land managers and help them predict where and when biological control might be successful.

The value of monitoring and evaluation efforts will be greatly enhanced if the information you collect is recorded and accessible by other land managers and researchers. Institutional memory is short if based on personal recollection, and documentation of initial conditions, release locations, successes, and failures will provide critical information to those who will follow you. Documenting successes and failures can help prioritize future research and collection efforts. At the very least, it should help others avoid releasing biological control agents that do not work and concentrate on those that do. Publicly accessible information on release locations, sizes, and outcomes can be extremely useful information for biological control researchers and policy makers. Finally, other land managers need to know the location of your releases so that they can avoid engaging in activities—such as cultivating, mowing, and applying herbicides or insecticides—that would harm your biological control agent populations.

Figure 43 Monitoring biological control in common St. Johnswort patch at the close of the growing season (Rachel Winston, MIA Consulting)

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 III).

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) (http://ceris.purdue.edu/napis/). Biological control 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 that can store information on biological control agent releases on federal and non-federal lands. As of the writing of this document, BC releases made on FS lands should be entered into the FACTs database. Other agencies may maintain their own databases for this information. Many of the databases maintained by state and federal agencies have some safeguards in place to prevent undesirable uses of the information they contain.

Information collection

For any weed biological control program, pre- and post-release monitoring is critical to determine if management goals have been achieved. Information on both biological control agent populations and the status of common St. Johnswort are collected during monitoring.

Status of common St. Johnswort and other plants

- What is the distribution and density of the target common St. Johnswort?
- Are the biological control agents causing damage to the target common St. Johnswort plants and/or nontarget vegetation? What percentage of the plants are attacked?
- Has there been a change in the common St. Johnswort population and distribution since introducing the biological control agents?
- Has there been a change in desirable vegetation at the release site?
- Is there a change in undesirable plants, such as other noxious invasive weeds, at the release site?

Populations of biological control agents

- Are biological control agents established at the release site?
- Are biological control agent populations increasing in size?
- How far beyond the initial release point(s) at a given site have biological control agents spread?
- Are surplus biological control agents collectable at the site?

To address these questions, monitoring activities must be focused on biological control agents, their impacts (damage) on individual common St. Johnswort plants, the common St. Johnswort population, and the rest of the plant community in the vicinity of the release.

Assessing the status of common St. Johnswort and other plants

The ultimate goal of a biological control program is to reduce the abundance of the target weed and enable the recovery of more desirable vegetation on the site. To determine the efficacy of biological control efforts, there must be monitoring of plant community attributes, such as target weed distribution and density. Ideally, monitoring occurs before biological control efforts are started (pre-release) and at regular intervals after release.

The methods used in pre-release vegetation monitoring should enable land managers to determine later if they are achieving the objectives of the weed biological control program. Often, land managers use reductions in common St. Johnswort patch size or density to gauge the success of weed management efforts. Pre-release estimates of common St. Johnswort stem density, flowering and vegetative stems, patch size, and patch perimeter at the release sites are frequently measured to enable pre- and post-treatment comparisons.

Land managers may have a goal of changing the structure and composition of the plant community through biological control. Pre-release sampling techniques, which allow managers to describe pre-treatment vegetation, are integral to assessing progress towards this goal.

Pre-release monitoring should include the establishment of control plots where no insects will be released. These plots should be as similar as possible in habitat type (the same soil type, aspect, and exposure) to the release plots. Control sites should be far enough away from release sites so that it is unlikely they will be colonized by biological control agents at least during the monitoring period of the program. For consistency, the same data collection protocols should be used at control and release sites.

In order to measure biological control agent impact accurately, methods for assessing plant densities after biological control agents are released must be the same as the pre-release methods. Post-release assessments should be planned annually for at least three to five years after the initial agent release.

There are many ways to qualitatively (descriptively) or quantitatively (numerically) assess common St. Johnswort populations and other plant community attributes at release sites.

Qualitative (descriptive) vegetation monitoring

Qualitative monitoring uses descriptive elements of common St. Johnswort at the management site. Examples include listing plant species occurring at the site, estimates of density, age and distribution classes, visual infestation mapping, and location of the photo points. Qualitative monitoring provides insight into the status or change of common St. Johnswort populations. However, its descriptive nature does not generally allow for detailed statistical analyses. Data obtained in qualitative monitoring may trigger more intensive monitoring later on.

Quantitative vegetation monitoring

The purpose of quantitative monitoring is to measure changes in the common St. Johnswort population before and after biological control agent release. It may be as simple as counting flowering common St. Johnswort plants in an area or as complex as measuring plant height, flower and production, biomass, or species diversity. If designed properly, quantitative data can be statistically analyzed and give precise information on population or community changes.

The Standardized Impact Moni-toring Protocol (SIMP) used by the state of Idaho for weed and vegetation monitoring is described in Appendix IV. It is a combination of qualitative and quantitative elements and can be easily modified to meet your personal or agency needs. For additional vegetation monitoring protocols, see Appendices VI and VII.

Figure 44 Quantitative vegetation monitoring (Mark Schwarzländer, University of Idaho)

Assessing impacts on non-target plants

Sampling of vegetation other than common St. Johnswort should be included in a vegetation monitoring program in order to assess potential non-target impacts of the biological control program. Specific methods will depend on the species targeted for sampling in particular areas.

Changes in abundance of other desirable or undesirable vegetation

Biological control agent releases, among other land management strategies, can affect the presence and relative abundance of many other plant species even though the agents do not directly utilize them. If biological control works to remove common St. Johnswort at a site, it will create an empty niche to be filled by alternative—hopefully desirable—vegetation. These indirect effects are the result of changes in common St. Johnswort abundance. As this weed becomes less abundant, the utilization of site resources is altered; some plants become more abundant, while others become less so. Within the overall management plan for your site, it may be important to document the changes in other vegetation after you release your biological control agents.

Depending on your program goals, you may need to document quantitative and/or qualitative changes for groups of plants, such as native forbs or exotic perennial grasses, or on individual species, such as a rare plant or a food plant for a native butterfly.
Plant species may be considered beneficial (e.g., native and introduced forage plants) or deleterious (e.g., other invasive weeds). One important management goal should be to avoid invasion of a site by another exotic weed after successful biological control of common St. Johnswort; in other words, you do not want to replace one invasive weed with another. For this reason, we strongly recommend that you monitor populations of other exotic weeds that are known to be problematic in your area.

You will need to clearly define site management goals and become familiar with the plant communities at your release location and nearby sites. You can easily modify the vegetation sampling procedures described above to monitor changes in density and/

or cover for common St. Johnswort as well as other plant species, both before and after you release your biological control agents.

Direct impacts of biological control on nontarget plants

The host ranges of the currently approved common St. Johnswort biological control agents are for the most part restricted to *Hypericum perforatum* (see Chapter 3). There are 59 other species of *Hypericum* present in the U.S. and Canada (see Tables 2 & 3 in Chapter 2). Twenty-six of these are shrubs or trees, and are unlikely to be fed upon by approved common St. Johnswort biological control agents. Of the 27 *Hypericum* that are forbs, only six natives and one exotic species occur in the West, where common St. Johnswort is such a problem as to warrant biological control efforts. The majority of these overlapping species only occur in very wet environments and are unlikely to occur with or near populations of *H. perforatum*. One native species, *H. concinnum* (Figure 45), is a forb that can co-occur with common St. Johnswort, and there have been a few documented instances where approved agents fed up upon this native species. Though evidence of this feeding is either anecdotal or insignificant, care should be taken in the management of your common St. Johnswort biological control program to ensure that *H. concinnum* and any other native St. Johnswort species are identified and monitored along with common St. Johnswort.

The first step in addressing possible non-target attacks on native St. Johnswort species is to become familiar with the plant communities present at and around your release sites. A visual, pre-release survey may locate native St. Johnswort species that are present. You may have to consult with a local botanist, if available, for advice on areas where these plants might be growing, what specific habitats they typically utilize, and how you can identify them. Herbarium records at a university or other research institution may provide guidance about the local or statewide distribution of native St. Johnswort species.

Figure 45 Native *Hypericum concinnum* (© 2010 Keir Morse)

If you do find one or more native St. Johnswort at a potential biological control release site, you should not immediately cancel plans to release biological control agents; generally, native St. Johnswort species are not attacked or may experience limited exploratory feeding by approved common St. Johnswort biological control agents. The vegetation sampling procedures described above can be easily modified to monitor changes in density and/or cover of specific, known native St. Johnswort species, before and after biological control agents are released. Concurrently, you may wish to collect additional data, such as the number of agents observed on nontarget St. Johnswort, the amount of foliar feeding observed, or the presence of galls.

If you observe approved biological control agents feeding on and/or developing on native St. Johnswort, 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 St. Johnwort to any specific insect and thus bias its identification.

Assessing common St. Johnswort 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 are peaking, 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 their opinion.

General biological control agent surveys

If you wish to determine whether or not a common St. Johnswort biological control agent has established after initial release, you may simply need to find the biological control agents themselves and/or evidence (that is, plant damage) of their presence. The easiest way to confirm biological control agent establishment in the years following release is to find one or more of the insect's life stages at the release site (Table 7). Begin looking for biological control agents where they were first released. If you do not find any, continue to explore the area around the release site. Sometimes, biological control agents do not like the area where they were released and move to patches of common St. Johnswort nearby. Damage characteristic of individual biological control agents can also indicate successful establishment. Typical damage traits are listed in Table 7.

Additional monitoring methods

To determine the density of insects at the release site or how far the biological control agents have spread from the release point, a more systematic monitoring method is needed. Numerous approaches can be taken in setting up a monitoring program; these will vary depending on the information you wish to obtain from monitoring efforts.

A simple method for monitoring the abundance of common St. Johnswort biological control agents used statewide in Idaho is described in Appendix IV. This approach was created by the Idaho Biocontrol Task Force (a group of state, federal and tribal land managers as well as university researchers). It was designed to be simple, efficient, and sufficiently versatile to allow for the collection of information from the same sites over multiple years. You can easily modify these protocols to meet your personal or agency needs. Alternative general biological control agent monitoring forms can be found in Appendix V.

Table 7 Life stages/damage to look for to determine establishment of common St. Johnswort biological control agents.

Scientific Name	Life Stage	Where to Look	When to Look	Damage
Agrilus hyperici	Adults	Foliage during the heat of the day	Spring/Summer (May-Jun)	Adults do not do any appreciable damage to host plants
	Larvae	Roots	Fall-Spring (Sep - Apr)	Plants appear stunted; dissection will reveal mined tissue and dark frass
Aplocera plagiata	Adult	Foliage	Spring/Summer (May-Jun)	Adults do not do any appreciable damage to host plants
	Larvae	Foliage, actively feed at night	Midsummer; Early Fall (Jun-Jul; Sep)	Plants appear stripped and wilty
Chrysolina spp.	Adults	Foliage, actively feeding during the heat of the day	Summer (Jun-Sep)	Plants appear stripped and wilty
	Larvae	Foliage, actively feeding before sunrise	Spring (Apr-May)	Plants appear stripped and wilty
Zeuxidiplosis giardi	Adult	Foliage; very small and hard to notice	Short-lived throughout growing season (May-Sep)	Adults do not do any appreciable damage to host plants
	Larvae	Galls in leaves	Growing season (May-Sep)	Form leaf galls that stunt growth of host plants; give malformed appearance

Chapter 5: An Integrated Common St. Johnswort Management Program

Introduction

Integrated weed management (IWM) is a systems approach to management of undesirable plants. IWM is described in the Federal Noxious Weed Act as a system for the planning and implementation of a program using an interdisciplinary approach to incorporate multiple methods for containing or controlling an undesirable plant species or group of species. Components include but are not limited to:

- Education and Outreach
- Prevention
- Monitoring
- Early Detection and Rapid Response (EDRR)
- Biological controls (insects, mites, or pathogens)
- Physical or mechanical treatments (tilling, mowing, etc.)
- Cultural practices (grazing, reseeding, etc.)
- Chemical treatment
- General long-term land management practices

An integrated, coordinated approach to weed management has two interdependent goals:

- The development of a long-term plan to manage all land in a designated area, with landowners and land managers working together towards effective management.
- The implementation of the most effective weed control methods for the target weed, regularly assessed and adjusted as needed.

A program that integrates multiple control methods—such as biological agents, chemical controls, and cultural practices—is far more likely to achieve long-term success against common St. Johnswort than any single control method used alone.

Integrating Biological Control

Classical biological control has been applied to many invasive weed species, and there are several examples in which both single- and multiple-agent introductions have successfully controlled the target weeds. The use of biological control agents alone to control weeds can be effective with some invasive plants, such as common St. Johnswort in some locations, but may take three to five years or more to reduce weed populations to manageable levels. The success rate for classical biological control may increase when multiple species of biological control agent are used so long as the different species attack different plant parts (leaves, roots, stems, etc.) of the target weed at different times during the growing season or are released over a larger range of infestation.

Though some agents have helped reduce common St. Johnswort densities in many regions, biological control agents have not established in all areas where common St. Johnswort occurs. Even when established, biological control agents do not eradicate the target weed. Where ideally suited, biological control can maintain common St. Johnswort densities below economically significant levels. Biological control agents are not going to work against this weed every time at every site; integration with other management tools or simply resorting to other tools may be required and is often encouraged in order to attain common St. Johnswort management objectives.
Land managers have learned successful, long-term common St. Johnswort control programs must be cost-effective. Because this weed occurs in a wide variety of environments across North America (Figure 46), no single control method can be successful in all infestations.

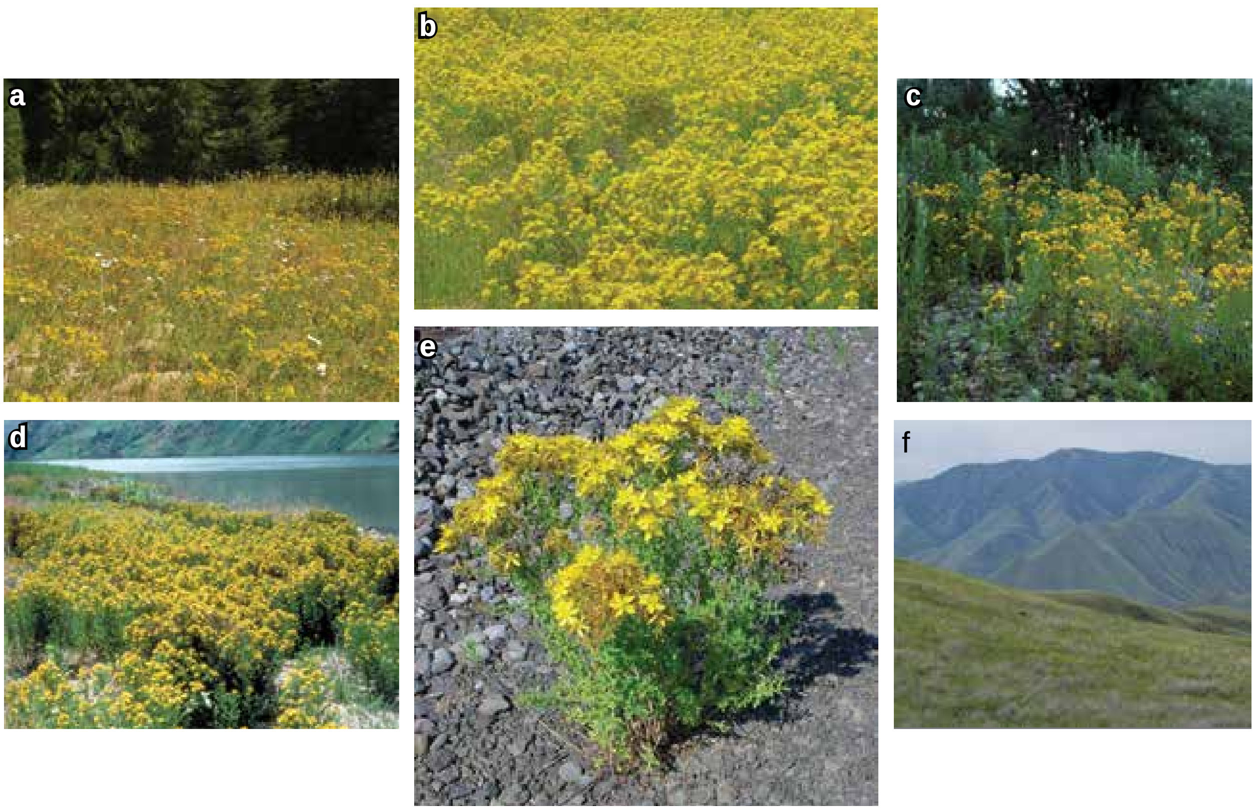


Figure 46 Various habitats where common St. Johnswort can thrive: a. high mountain meadow (Marianna Szucs, University of Idaho); b. deserted pasture (Richard Old, www.xidservices.com); c. shady forested hillside (John Randall, The Nature Conservancy, www.bugwood.org); d. riverbank (Carol DiSalvo, National Park Service, www.bugwood.org); e. barren wasteland (Richard Old, www.xidservices.com); f. grassland hillside (Mark Schwarzländer, University of Idaho)

Land managers have also recognized that they must operate under social constraints that will limit the weed management tools they can use in sensitive areas, such as wilderness, near waterways, and on public lands. A wide variety of successful weed management methods—including herbicide mixtures, selective grazing practices, reseeding, and biological control agent releases—have long been used. Each method was initially used alone, but long-term management is greatly improved when various control methods are used in combination according to infested habitat type, land use, ownership, and available resources.

Weed Control Methods Used to Manage Common St. Johnswort

The most commonly cited activities for the control of invasive plants are listed in the introduction to this chapter. These activities are described in detail below, with emphasis on how to integrate each with biological control methods (where applicable). Common St. Johnswort plants within a population may show considerable variation in growth form, extent of vegetative reproduction, response to stress, and flowering frequency. Therefore, management strategies must be site-specific.

Education and outreach

Education and outreach activities should aim to increase public awareness of noxious weeds, the problems they cause, their distribution, and ways to manage them (Figure 47). Education efforts should be a significant component of any IWM strategy and program, regardless of the other weed control methods employed.

Figure 47 Weed education billboard (Carl Crabtree, Idaho County Weed Control)

Prevention and exclusion

Prevention and exclusion activities are aimed at areas not currently infested by common St. Johnswort and intended to keep uninfested areas weed-free. Though this weed is already present throughout much of North America, there are many areas where it has not yet established and other areas where it remains at low densities. Preventing further introduction and spread to uninfested areas is much more environmentally desirable and cost-effective than is the subsequent treatment of large-scale infestations.

Common St. Johnswort is spread by the movement of seed-contaminated hay, wind, motorized equipment, wildlife, or water dispersion into uninfested areas. Where these factors can be controlled, preventing the spread of common St. Johnswort requires cooperation among all local landowners. 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.

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 before entering uninfested sites.

An early-detection and rapid-response (EDRR) program is a specific protocol for tracking and responding to infestation spread. It relies heavily on education and outreach activities to be effective. EDRR programs target areas into which a weed may spread and take a two-prong approach by: 1) educating the public to aid in detection of the weed and 2) initiation of rapid response eradication efforts at all verified locations of the weed.

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 natural enemies from the origin of the invasive weed. This method of common St. Johnswort management is most suitable for large scale populations. For new infestations, or satellite outbreaks of the weed, more rapid control methods should be utilized (chemical treatment with or without mechanical control). Refer to Chapter 3 for detailed descriptions of the biological control agents currently approved for use against common St. Johnswort.

Physical or mechanical treatment

Physical treatment utilizes hand pulling, hoeing, tilling, or mowing to disrupt and remove weeds and is the oldest method of weed control. Mulching can be used to control regrowth. Physical methods can be very effective in controlling common St. Johnswort, but are labor-intensive.

Hand pulling and Hoeing

Hand pulling and hoeing may be successful on small populations of common St. Johnswort if they are applied persistently. It is important to remove as much of the root as possible, while minimizing soil disturbance, and removing all common St. Johnswort plant parts from the area to prevent possible vegetative growth or seed dispersal.

Tilling

Common St. Johnswort 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 below the soil surface (Figure 48). 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 methods, this technique can result in the vegetative spread of the weed from root fragments. Tilling is generally not practical or desirable in wildlands and nature preserves.

Tilling is not usually compatible with biological control efforts. Tilling and disking frequently disrupt and destroy biological control agents overwintering in common St. Johnswort roots and galls or in soil litter.

Figure 48 Mechanical treatment. (John Byrd, Mississippi State University, www.bugwood.org)

Mowing

Cutting back the above-ground portion of a plant will remove top growth and can reduce common St. Johnswort seed production, especially if the plants are mowed frequently during the growing season. Mowing should be done as close to the ground surface as possible. If the mowing height is too high, the plant may subsequently produce flowers below the cutting height. Likewise, mowing conducted after plants have started producing seed may help distribute seed.

A single mowing treatment does not injure the root system, and long-term control is not possible unless done often enough so that root carbohydrates are depleted and roots die. Frequent mowing, however, might be too costly or infeasible for larger infestations. Mowing, if applied infrequently or if not well-timed, can increase the spread of this weed by encouraging new growth from underground rhizomes since sprouting may occur immediately after crown removal or defoliation.

Alternatively, mowing can be used to reduce non-target plant cover and litter prior to fall herbicide applications as this will improve coverage of the chemical on fall common St. Johnswort rosettes.

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 excess plant litter during late winter and very early spring when *Agrilus hyperici, Aplocera plagiata* and *Chrysolina* spp. are overwintering either in the soil litter or roots is compatible with biological control. However, mowing during this same time period or at any other time of year would destroy the galls of *Zeuxidiplosis giardi* and the larvae or pupae contained inside. Mowing during spring and early summer when most species are active in some stage in the above-ground portion of common St. Johnswort could kill large numbers of insects.

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 biological controls and chemical treatments.

Figure 49 Seed sower (Norbert Frank, University of West Hungary, www.bugwood.org)

Seeding competitive species

Common St. Johnswort is a strong competitor; however, it is itself sensitive to competition in its early stages or after it has been suppressed by cultivation, chemical control, or insects. If the weed is suppressed by one or more methods, but its ecological niche remains unfilled, reinvasion by common St. Johnswort or by other undesirable species will likely occur. Long-term management of this weed requires the establishment and maintenance of desirable competitive species.

Seeding can be used to help establish competitive native species, such as grasses and forbs, in a common St. Johnswort infestation. The choice of plant species to be seeded should reflect site conditions, management, and future use. In Australia, seeding subterranean clover (*Trifolium subterraneum*) and canarygrass (*Phalaris* spp.), helped control common St. Johnswort populations in pasture land. The most competitive grasses in northwestern North America include wheatgrass, wild rye, and smooth brome; however, the best type of grass to plant in competition with common St. Johnswort varies by region. Consult your local county extension agent or Natural Resource Conservation Services representative for the best alternatives. Control of common St. Johnswort prior to seeding grasses is important. Herbicides may help reduce common St. Johnswort vigor prior to a fall or early spring seeding of grasses; contact your local county extension agent or weed control authority for current chemical recommendations

Incorporating biological control 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. In order to establish a suitable site for re-seeding, either an area must be tilled to provide an acceptable seed bed and/or herbicides such as glyphosate must be applied to reduce competition from common St. Johnswort. Tilling can disrupt and destroy biological control agents overwintering in soil litter and plant roots, and heavy herbicide use will reduce the common St. Johnswort shoots on which some biological control agents feed, thus hindering establishment of biological control agent populations.

Seeding of competitive species using a no-till seeder would be less disruptive to an established common St. Johnswort biological control population than conventional seeding techniques. Unfortunately, no-till seeding has been successful only when the site was mowed or burned prior to seeding, and an herbicide was applied to control broadleaf and grass weeds. The thick thatch of dead common St. Johnswort stems often found in old stands can reduce seedling establishment and ultimately may result in undesirable species replacing the seeded species. Intensive management techniques often establish competitive species first, using biological control agents only after the seeded species have become established and the weed has begun to re-grow.

Prescribed fire

Although this method of cultural control is used against many domestic and exotic plants (Figure 50), the majority of studies addressing this method demonstrate that fire increases the frequency and density of common St. Johnswort. In some cases, fire has been documented to stimulate germination of common St. Johnswort seed. Furthermore, repeated burning may deplete the soil of organic material and thus favor this weed and other undesirable plants. Therefore, burning is not indicated as a potentially effective method for controlling common St. Johnswort. It can, however, be useful for burning off dead plant litter, thus allowing herbicide applications to be more effective.

Biological control agents must be able to survive controlled burns, and this often depends on the

Figure 50 Prescribed fire (David Cappaert, Michigan State University, www.bugwood.org)

timing of the burn. 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 can often escape the fire by flying off, readily re-establishing on recovering common St. Johnswort not killed during the fire event.

Grazing

As mentioned previously in this manual, most livestock will avoid common St. Johnswort. However, poor feeding conditions and/or choices may make this weed seem more desirable to grazing animals. Glands on the weed's foliage produce hypericin, an oil and phototoxin. Upon ingestion, the feeding animals become sensitive to sunlight. This often leads to dermatitis, inflammation of the mucus membranes, itching, swelling, blisters, and open sores. Animals with lighter pigmentation, a thinner fur or wool covering, and softer skin (young) are affected most, as are nursing animals whose mothers are exposed to hypericin. If consumed in large quantities, starvation, dehydration, and even death may occur. Consequently, grazing is not often pursued as the first choice for controlling common St. Johnswort infestations. However, in rugged or remote rangeland where chemical and mechanical control measures are expensive or difficult, a grazing management strategy may prove critical.

If managed properly, grazing will suppress growth, flower, and seed production of common St. Johnswort. Recent research has contributed to the development of guidelines that will minimize the harm to grazing stock and create the best chance for desirable species to re-establish and outcompete common St. Johnswort. These guidelines are listed in Table 8.

Please note that animals may respond differently to the effects common St. Johnswort, depending on both the animal's traits and site/plant characteristics. Should your livestock exhibit signs of toxicity, move them off the weed as soon as possible, taking careful measures they do not spread common St. Johnswort seeds or rhizome fragments wherever you move them. Toxicity symptoms include restlessness, head rubbing, pawing the ground, head shaking, intermittent hind limb weakness with knuckling over, panting, confusion, and sometimes depression. Some will lie down; some will develop diarrhea. Those with photosensitisation will develop inflammation and swelling around

Figure 51 Grazing sheep (Steve Dewey, Utah State University, www.bugwood.org)

Table 8 Guidelines for grazing common St. Johnswort to minimize harm to livestock and to improve pasture re-establishment and competitive ability (Guidelines developed by Dr. Chris Bourke, New South Wales Department of Primary Industries and modified slightly for North America)

Guideline	Recommendation
Guideline 1	Use dark fully pigmented, non-lactating, non-pregnant cattle (not calves) as a knock down option two months prior to commencing grazing with sheep or goats
Guideline 2	Use merino sheep, preferably from fine (less than 20 microns) or superfine (less than 17 microns) bloodlines. If using goats, follow the same principles choosing darker pigmented animals if possible.
Guideline 3	Make sure sheep have at least four months wool growth cover. Never use recently shorn animals.
Guideline 4	Utilize adult wethers or dry, non-pregnant ewes. Never graze pregnant ewes, lactating ewes, lambs or weaners on common St. Johnswort pastures.
Guideline 5	Use high stocking rates during the grazing period.
Guideline 6	Start grazing sheep on new common St. Johnswort growth in late autumn, winter, and early spring. During this time sheep will eat the soft, green, prostrate growing shoots which are low in hypericin, thus suppressing regrowth.
Guideline 7	In subsequent years, as less and less common St. Johnswort remains, grazing can gradually be increased by starting earlier in autumn and ceasing later in spring. However, once the new spring flower spikes reach a height of 5-10 cm, move the stock off to avoid poisoning.
Guideline 8	Repeat this process every year and try to replace diminishing common St. Johnswort infestations with more appropriate pasture species.
Guideline 9	If possible, fence off heavy common St. Johnswort infestations so that very heavy stocking rates can be used during safe grazing periods. Never overgraze as this favors common St. Johnswort re-infestation.
Guideline 10	Ideally stock should have access to good shade, even during winter months. This will increase their tolerance.
Guideline 11	Never graze common St. Johnswort infestations while they are flowering or forming seed capsules.

the eyes and forehead and can damage themselves by rubbing irritated areas of skin. Animals with abnormally high body temperatures (hyperthermia) become difficult to muster and handle.

Chemical control

Herbicides are important tools for controlling noxious weeds and are available for common St. Johnswort control in a variety of environments (Figure 52). Herbicide usage is most applicable for small infestations, including new populations and satellite infestations, and for use on the leading edge of large advancing populations. Herbicides are often too costly to be of practical value for treating extensive infestations of common St. Johnswort. Repeated applications are often required to keep this weed in check, and most studies indicate herbicides are rarely completely effective against common St. Johnswort alone. Small patches may be missed, the soil seed bank must be taken into account for several years, and potential damage to associated vegetation must also be considered, especially in natural areas. Because of this, herbicides are best used as part of a larger, integrated system (for example planting desirable competitive species, and utilizing grazing and biological control methods). Some studies suggest grazing prior to herbicide application will help remove nontarget plant growth that would otherwise intercept the spray.

Herbicide timing, application rates, and restrictions vary by state and location. Please consult your local weed officer or county agricultural extension agent to learn which herbicides work best and when to apply them in your situation. For additional specific recommendations, refer to the Pacific Northwest Weed Management Handbook, 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 include the following:

Figure 52 Backpack spraying, Region 8 Archive, USDA Forest Service www.bugwood.org)

- 2,4-D can be used on new growth from fall or spring emergence. If used for spot treatments in early spring, it will control plants germinating from seed and prevent them from flowering. It can be used in tank mixtures for broadcast applications to kill aboveground growth of common St. Johnswort.

- Glyphosate is best used on new growth during fall when plants are storing reserves in the roots for winter. This is a non-selective herbicide, and so should only be used 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 common St. Johnswort. It is best to use a nonionic or organosilicone surfactant with metsulfuron. Grazing restrictions apply to its use, as do restrictions for use on some grasses. This strong herbicide may result in stunting or death of some desirable species of plants in the pasture. Spot spraying only individual plants or patches of common St. Johnswort is preferable to a broadcast treatment. Metsulfuron is often mixed with 2,4-D for increased control.

- Use picloram on new growth from fall or spring emergence. This herbicide can be used throughout active growth stages, but is best pre-bloom. Picloram requires a high usage rate but has a long soil residual period, which will reduce regrowth from roots or seedlings. This herbicide cannot be used near water, and will kill desirable legume species.

Application timing is very important to ensure the most effective use of herbicides. It is good to treat common St. Johnswort with fall applications when plants are storing reserves in the root system for winter. Spring-emerged seedlings or rosettes are also often vulnerable and easier to control. Location, growth stage, stand density, environmental conditions (e.g., drought or cold temperatures), and land use all determine the best choice of product and application rate. Always refer to the label prior to applying herbicides to common St. Johnswort infestations. If land usage of treated areas includes grazing practices, it is important to remove animals from pastures sprayed with herbicides until after the common St. Johnswort plants are completely dead. Herbicide treatment often increases palatability which might increase unwanted consumption by livestock.

Little is known about the combined effects of biological control agents and herbicides. It is likely that herbicides in conjunction with leaf-feeding biological control agents (*A. plagiata, Chrysolina spp.,* and *Z. giardi*) is NOT an efficient use of resources. Successful herbicide applications will result in a lack of food for the biological control agents, decreasing their populations and ability to control recovering common St. Johnswort individuals. Likewise, plants partially or fully defoliated by leaf-feeding biological control agents will not absorb enough herbicide to kill them. The actions of herbicides and the root feeding insect *A. hyperici* appear to be more complementary, though hard evidence of this is lacking.

If it is the goal of the land management program to protect any established biological control agents, herbicide applications should occur at a time least disruptive to the agents-even if the timing is not ideal for the chemicals. In order to ensure that the insects maintain viable populations as the common St. Johnswort infestation is reduced, 25 percent of the area should remain untreated to serve as "refuges" for biological control agents.

General Long-Term Land Management Practices

Use Pesticides Safely!

- Read the pesticide label, even if you have used the pesticide before. Follow the all instructions on the label.
- Wear protective clothing and safety devices as recommended on the label.
- Bathe or shower after each pesticide application.
- Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.

Peter M. Rice

Common St. Johnswort has persistent growth characteristics, and seed can remain viable in the soil for several years. Therefore, you should implement long-term weed management programs. Long-term weed management includes re-treatment with herbicides or continued cultural, mechanical, or biological control practices to maintain low populations of this weed. Range improvements—such as grazing systems, cross-fencing, and water development—will help retard the invasion of many weed species, including common St. Johnswort. Sites with no desirable species should be reseeded with a competitive plant species as part of the total management program (Table 9).

Table 9 Comparison of common St. Johnswort management options.

Management Technique	Advantage	Disadvantage	Comments
Herbicides	Fast acting	Expensive for large areas	Best used on small patches when common St. Johnswort 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
	High success rate for reducing common St. Johnswort densities	May harm desirable vegetation, especially broadleaf species	
	Rapidly enhances grass production	Many natural areas are inaccessible to spray equipment	
		Public resistance to chemical controls	
		Regulations or policies may prohibit use in some areas	
Biological Control	Can be very selective	Some risk of undesirable effects on native plants	Most economical option for large infestations and will control common St. Johnswort in a variety of environments in which the weed occurs, especially if multiple agents are introduced
	Agents generally do not have to be reintroduced once established	Not successful in all situations	
	Public acceptance is generally higher than with other weed control methods	Permanent: cannot be undone	
		Measurable changes in weed densities may take many years	
Grazing	Allows use of the land even with heavy common St. Johnswort infestations	Cannot be used in many natural areas such as national parks and wilderness areas	Will remove top-growth only, and does not reduce the root mass. The same areas must be grazed annually or common St. Johnswort will rapidly reestablish
	Can be used in combination with biological or chemical control methods	Improper management can result in livestock poisoning	
		Non-selective	
		Expensive	
		Can exacerbate the problem	
Mechanical/Cultural Treatments	Very effective	Not appropriate for natural areas and wildlands	Not always compatible with biological control agents so is best used when an areas is being "reclaimed"
	Can be used to reseed native species	Expensive for larger infestations	

Glossary

abdomen	The last of the three insect body regions; usually containing the digestive and reproductive organs
annual	A plant that flowers and dies within a period of one year from germination
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
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

cyme	Flower cluster in which each stem ends in a flower that opens before the flowers below or to the side of it
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
facultative apomict	Able to produce seeds with or without fertilization
forb	Herbaceous plant (does not have solid woody stems)
gall	An abnormal growth on a plant, usually induced by an insect that lives within the gall
genera	A taxonomic category ranking below family and above species and consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species
glandular	Having glands (group of specialized cells which produce and secrete a specific substance)
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
hermaphroditic	Having both male and female reproductive parts
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
hypericin	An oil and phototoxin produced by St. Johnswort that is toxic and makes feeding animals sensitive to sunlight
inflorescence	The flowering part of a plant
instar	The phase of an insect's 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 of species using all available methods
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
metabolic sink	Site of a plant that receives photosynthate (food) produced by the plant, diverting the resource away from the plant's normal use
molting	Process of insect development that involves shedding its exoskeleton and producing another for the next instar
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
opposite	Leaf attachments emerge in pairs of two at each plant node, on opposite sides of the stem
oviposit	To lay or deposit eggs
perennial	A plant that lives more than two 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 larvae 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)
ramet	An individual part of a clone
rhizome	A rootlike subterranean stem, commonly horizontal in position, that produces roots below and sends up shoots progressively to the soil surface
rosette	A compact, circular, and normally basal cluster of leaves
senescence	Final stage in a plant's life cycle
sepals	Leaf-like structures (usually green) that lie beneath petals
species	A fundamental category of taxonomic classification, ranking below a genus or subgenus and consisting of related organisms capable of interbreeding
stamens	Male reproductive parts of flowers, located near flower centers and resembling capped threads
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

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