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YELLOW AND DALMATIAN TOADFLAX

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YELLOW AND DALMATIAN TOADFLAX

By

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Abstract

Yellow toadflax and Dalmatian toadflax are non-native plants that have become two of the most troublesome invasive weeds in North America. Infesting forests, range and grasslands, and other areas, these two weeds are very prevalent in the Pacific Northwest. This publication outlines the plants' characteristics, variations, growth and reproduction, distribution and economic impact, as well as management strategies.

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Yellow and Dalmatian Toadflax

Introduction

Dalmatian toadflax, *Linaria dalmatica* (L.) Mill. (Figure 1), and yellow toadflax, *Linaria vulgaris* Mill. (Figure 2), commonly referred to as “butter and eggs,” are two non-native plants that were introduced into North America as ornamentals from the Mediterranean region. Introduced by the 1800s, these two non-native plants have since escaped flower beds and have become two of the most troublesome invasive weeds infesting millions of acres across much of temperate North America. In the Pacific Northwest (defined here as Washington, Oregon, and Idaho) these plants can be found infesting forests, range and grassland, rights of way, lands put into conservation programs like the Conservation Reserve Program (CRP), and other disturbed areas (Sing et al. 2015). Surprisingly, these plants can still be found today occurring in flower beds (Figure 3).



Figure 1. Dalmatian toadflax plant. Photo by Eric Coombs, Oregon Department of Agriculture, Bugwood.org.



Figure 2. Yellow toadflax plant. Photo by L. Berry, Bugwood.org.



Figure 3. Dalmatian toadflax ornamental planting (2009). Photo by Dale Whaley, Washington State University.

Both of these plants can produce a significant amount of seed and can also propagate via an extensive root system either from vegetative shoots that are produced from lateral rhizomes (Dalmatian toadflax) or from buds (yellow toadflax) (Sing et al. 2015). These two attributes provide a distinct advantage and can displace native or desirable vegetation, thereby reducing forage for livestock and wildlife (Figure 4).

Identification

Dalmatian and yellow toadflax belong to the plantain (Plantaginaceae) family. New seedlings (Figure 5) rapidly grow to produce mature, upright stems (Figure 6). Both plants produce upright stems, 11 to 35 inches (Dalmatian toadflax) and 11 to 24 inches (yellow toadflax). Dalmatian toadflax is more robust than yellow toadflax with increased branching in the upper third of the plant.



Figure 4. Dalmatian toadflax infestation. Photo by Dale Whaley, Washington State University.



Figure 5. Dalmatian toadflax seedlings. Photo by Linda Wilson, University of Idaho, Bugwood.org.



Figure 6. Dalmatian toadflax mature stems. Photo by Dale Whaley, Washington State University.

Dalmatian toadflax has light blue-green, waxy, pointed, heart-shaped leaves that clasp the stem, while the leaves of yellow toadflax are pale green, long, narrow, and pointed at both ends. Flowers of Dalmatian toadflax occur in clusters with the separate flowers attached by short, equal stalks at equal distances along a central stem (Figure 7). They can range from 0.75 to 1.5 inches long, are bright yellow with a yellowish-orange bearded throat and have a long, straight, or somewhat curved spur. Flowers of Dalmatian toadflax are one inch or longer, bright yellow with an orange throat, and long spur. Yellow toadflax flowers, on the other hand, are also one inch or longer but are a more pale yellow and have a brighter orange bearded throat (Wilson et al. 2005). Flowers of both toadflax species appear as dense terminal clusters that gradually elongate, with new flowers forming above as the fruits mature below (Figure 8).

Seeds of both species are formed in a two-celled capsule, round for Dalmatian and oval for yellow toadflax. Dalmatian toadflax seeds are strongly angular and slightly winged. Yellow toadflax seeds are more flattened, less angular, and have papery margins (Coombs et al. 2004).

Variation

In the literature, Dalmatian toadflax is referred to by a number of scientific names, including *Linaria genistifolia* (L.) Mill., *Linaria genistifolia* (L.) Mill. ssp. *dalmatica* (L.) Maire & Petitm., and *Linaria dalmatica* (L.) Mill. Variations in leaf appearances have caused researchers to take a closer look at this species. These variations are classified as narrow-leaved (*L. dalmatica* ssp. *macedonica*) and broad-leaved toadflax (*L. dalmatica* ssp. *dalmatica*). It is unclear whether these two forms are distinct subspecies or if they are just a Dalmatian toadflax species that exhibit simple variations in leaf



Figure 7. Dalmatian toadflax flowers. Photo by Bob Nowierski, Montana State University, Bugwood.org.



Figure 8. Yellow toadflax flowers. Photo by Wendy VanDyk Evans, Bugwood.org.

appearance. It has been suggested that drought-stressed plants having experienced unfavorable environmental conditions may play a role in why plants may possess both broad and narrow leaves (Sing et al. 2015).

The species *Linaria genistifolia* (L.) Mill. and *L. dalmatica* (L.) are thought to be very closely related but can be distinguished by flower size. Flowers of *L. genistifolia* are significantly smaller (0.5–0.6 inches long) compared to flowers of Dalmatian toadflax (0.8–1.6 inches long). At the time of this publication, it is unclear how widespread *L. genistifolia* may be or if it is present at all in North America (Sing et al. 2015).

Hybridization is believed to play a role in species appearance and identification. In areas where both Dalmatian and yellow toadflax coexist, hybridization has occurred, leading to the creation of plants that have combined characteristics of the two parental species, which can make proper identification challenging (Figure 9). Leaves of these plants can be narrower than typical Dalmatian toadflax leaves yet wider than typical yellow toadflax. Although not yet confirmed by DNA analysis at the time of this publication, it is hypothesized that plants exhibiting broad leaves may in fact be a hybrid referred to as *L. dalmatica* ssp. *dalmatica* and those with more narrow leaves as *L. genistifolia*, commonly known as broomleaf toadflax (Sing et al. 2015). All of the control information presented in this publication applies to all forms of Dalmatian toadflax, regardless of the species or variation.

Growth and Reproduction

Flowering occurs from May to August for both species and seeds mature from July through September for Dalmatian toadflax and from July to October for yellow toadflax. These plants are heavy seed producers: 5,000 to 30,000 seeds for yellow toadflax and over 500,000 seeds Dalmatian toadflax plant (Coombs et al. 2004; Sing et al. 2015; and Wilson et al. 2005). Seeds of Dalmatian toadflax are spread and dispersed from fall through the winter, and late summer to winter for yellow toadflax. Seeds of both species can be spread by humans, animals, motorized vehicles, and sometimes water. Seeds ingested by animals such as deer, elk, cattle, and birds may remain viable as they pass through the digestive system, and this can be a primary mode of long- distance seed dispersal. Seeds also can be dispersed vast distances when caught on motorized equipment, within hay or other forages, in mud attached to shoes, or those caught in animal fur. A high percentage of Dalmatian toadflax seeds typically germinate within the first year, whereas others can remain dormant for up to 10 years in the soil. Yellow toadflax has a lower germination rate of around 50% and can remain viable in the soil up to 8 years (Sing et al. 2015, Wilson et al. 2005).



Figure 9. Hybrid toadflax plant (center) between yellow toadflax (left) and Dalmatian toadflax (right). Elizabeth Goulet, Cornell University, Bugwood.org.



Figure 10. Yellow toadflax root system. Photo by Steve Dewey, Utah State University, Forestry Images.

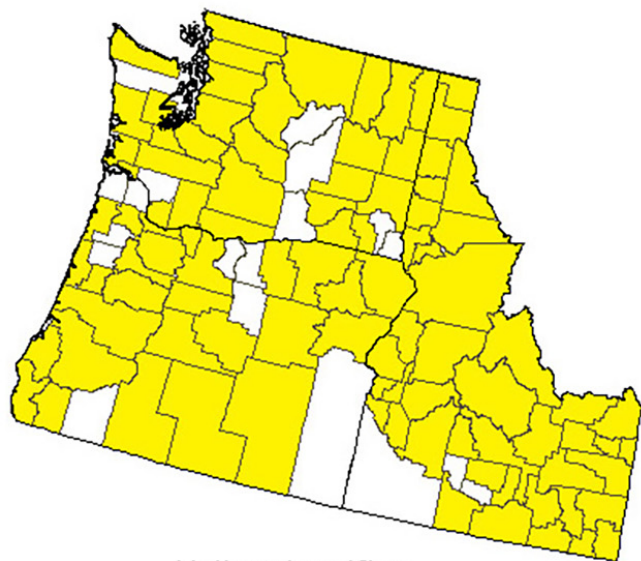
Furthermore, both of the species have an extensive root system that can contribute to their invasive capability (Figure 10; Vujnovic and Wein 1997). Yellow toadflax can produce taproots that can grow up to 3.3 feet deep (1 m), whereas Dalmatian toadflax taproots are large and can penetrate deep down to a distance of 4 to 10 feet (1.2 to 3 m) depending on soil types. Both plants can produce lateral roots or branches that extend out several feet to several yards from the parent plant. Vegetative buds formed along these roots can give rise to new plants the following spring. Dalmatian toadflax root fragments severed by tillage or via other factors as small as 0.4 inches long (1 cm) can give rise to new plants. In contrast, yellow toadflax root fragments need 4 inches or longer (10 cm) in order to develop into a new plant (Sing et al. 2015).

In addition to upright flowering stems, Dalmatian toadflax can also produce a number of prostrate, non-flowering stems (rosettes) that sprout in the late summer or early autumn. These rosettes remain green throughout the winter months, especially under the protection of snow cover. Unlike Dalmatian toadflax, yellow toadflax stems die back completely in winter and do not produce an overwintering rosette (Sing et al. 2015).

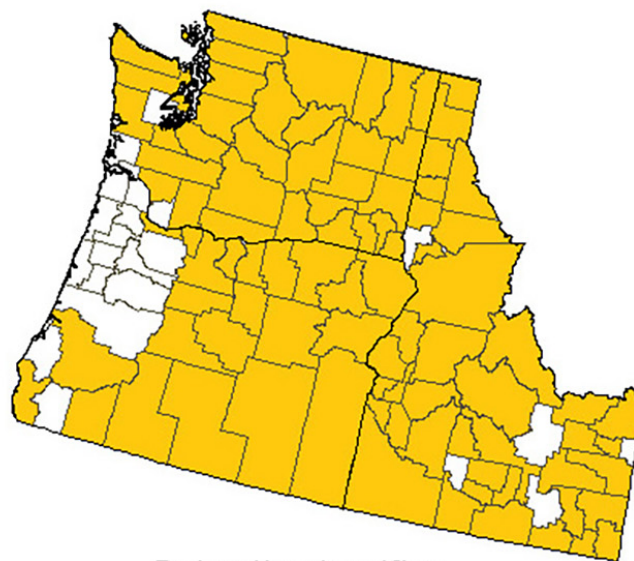
Distribution and Economic Impact

Both toadflax species typically grow in well-drained, rocky- or sandy-textured soils and in open, sparsely vegetated sites. Yellow toadflax is typically associated with sites that are more moist and fertile compared to Dalmatian toadflax (Sing et al. 2015). In western North America, these two plants are common inhabitants of disturbed, open habitats along roadsides, waste areas, gravel pits, and areas affected by fire. Soil disturbance can be an important contributing factor of seedling establishment for both toadflax species. Other forms of disturbance such as overgrazing, trampling, cultivation, logging, and burning can reduce the amount of native vegetation or competition and allow Dalmatian toadflax to take over a site. As a general rule of thumb, weeds are more likely to invade areas following some form of disturbance to the ecosystem. However, this is not necessarily the case for yellow toadflax, as it has been documented invading undisturbed, healthy sites such as those found in backcountry locations (Sing et al. 2015).

As a whole, yellow toadflax is considered more widespread than Dalmatian toadflax. Yellow toadflax can be found throughout much of the US (49 continental states) and Canada (ten provinces and two territories). Whereas, Dalmatian toadflax is considered to be less abundant in the US, occurring in 18 fewer states (31 as of this publication). In Canada, it too can also be found inhabiting ten provinces (Sing et al. 2015).



Yellow toadflax



Dalmatian toadflax

Figure 11. Distribution of yellow and Dalmatian toadflax in the Pacific Northwest states of Washington, Oregon, and Idaho in 2016. Maps courtesy of USDA-NRCS, National Plant Data Team, Greensboro, NC.



Figure 12. Conservation Reserve Program toadflax infestation. Photo by Dale Whaley, Washington State University.

Both toadflax species have become pervasive in the Pacific Northwest (Figure 11). Dalmatian toadflax has become particularly problematic in rangeland and land enrolled in CRP (Figure 12), thereby reducing the diversity and value of the land. The cost of control for severe infestations can quickly exceed the “annual rental payments” issued by the US Department of Agriculture. This program pays producers to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality.

Crops ranging from grains, oilseed, and berries and small fruits to oil mint can be negatively impacted and reach economic injury levels when yellow toadflax infestations become large enough (Sing et al. 2015).

Management Strategies

Once Dalmatian and yellow toadflax become well established, it can be a challenge to eradicate either species due to their prolific seed production, extensive root systems, and regenerative capabilities. Successful management of well-established populations requires a sustained and integrated approach of all possible control methods (Table 1).

Prevention, Early Detection, and Rapid Response

The first and most important consideration in any weed management program is prevention. As the name implies, the idea is to stop the introduction of new weeds, thus forestalling future weed infestations. Forage, mulches, weed-free gravel, truck or boat washing stations, and using clean or certified seed whenever possible are all forms of prevention. Re-seeding with native grasses or forbs or other competitive vegetation can also help diminish the likelihood of a weed invasion.

Unfortunately, even the best prevention efforts cannot always stop all invasive species. If toadflax plants are able to survive and flourish beyond preventative tactics, then a second line of defense known as Early Detection Rapid Response (EDRR) must be taken. The goal of EDRR is to detect new weed infestation through surveys and then respond quickly with controls. Stopping new weeds before they establish in the ecosystem can reduce the potential for further spread and reproduction. This, in turn, can save land managers both time and money that would have been spent on subsequent control measures had the weed gone undetected.

Table 1. Control options for Dalmatian and yellow toadflax infestations.

| Method | Technique/Timing | Advantages | Disadvantages |
|--------------|--|---|---|
| Hand pulling | Immediately on new infestations. | Inexpensive; can eliminate young plants quickly. | Time-consuming for large infestations; must get all the roots; requires repeated visits and monitoring for 10 years. |
| Cultivation | Best to begin cultivation early in June and repeat as needed so that there are never more than 7 to 10 days with green growth visible. Sweep-type cultivators provide the best result. Continue cultivation for at least 2 years, with 8 to 10 cultivations in the first year and 4 to 5 cultivations the second year. | Can impact populations. | Only works on flat ground; must repeatedly cultivate; has been known to make infestations worse from fragmented roots; disturbs soil. |
| Mowing | When plants are actively growing; prior to bud development. | Can help reduce seed production. | Requires multiple visits; will not likely have any adverse effect on the perennial root system. |
| Herbicides | Spray plants when actively growing; 6 to 8 inches tall or target fall re- growth. | Can significantly suppress or kill plants; provide residual control. | Expensive (when dealing with large infestations); timing is important; must use a surfactant to penetrate waxy cuticle. |
| Biocontrol | Release insects when the plants are actively growing and prior to egg laying. | Cost-effective; decrease vigor and reproduction; self- perpetuating; best for inaccessible areas. | Slow initial impact; insects are susceptible to fire; subject to predators; not recommended for small infestations. |

Cultural Control

Cultural control methods can be effectively used to weaken the competitive capacity of both toadflax species. Competition for light, water, nutrients, and space after seeding desirable vegetation can be a deterrent for establishment and expansion of toadflax populations. Landowners should contact their local Natural Resource Conservation Service (NRCS) or native seed dealers to learn more about re-seeding. Burning can remove competition and create a disturbance that actually favors expansion of toadflax and other weeds; therefore, it is not recommended. Depending on how intense the fire is, burning can actually be detrimental to certain overwintering biological control agents.

Livestock Grazing for Control

The utilization of animals such as cattle, horses, domestic sheep, and domestic goats can be an effective form of management for Dalmatian toadflax. As for yellow toadflax, grazing animals will generally tend to avoid this plant especially if other vegetation is available. To overcome this problem, cattle and sheep that have been continually exposed to yellow toadflax can develop a “preference” for this plant and will seek it out amongst other vegetation. At the time of this publication, it is unclear what effect grazing may have on hybrid toadflax (Sing et al. 2015).

Grazing, like other management tools, can have limitations. Grazing can be difficult and time-consuming to implement strategically, and may have negative long-term consequences for plant communities. Grazing can also be detrimental in several ways. The removal of plant material can actually make toadflax infestations worse by stimulating re-growth, similar to mowing. If seeds are not broken down during digestion and remain viable, they could be transported long distances or possibly even to new areas through feces. Therefore, animals that have grazed toadflax should be kept on site and fed weed-free forage for a minimum of 72 hours to allow seeds to pass through and be excreted before being moved to new areas (Sing et al. 2015).

It is also important that the animals do not overgraze a site. Animals that have been grazing too long in one area can adversely affect the native plant community, diminishing its ability to compete with either toadflax species. Whenever grazing is implemented, proper livestock management (i.e., controlled duration of grazing and stocking rates) needs to take place to allow grazed vegetation to recover). As a rule of thumb, sparse toadflax infestations should be grazed with low stocking rates and more dense infestations with high to heavy stocking rates. Remember that it is important to allow grazed vegetation to recover and thus not keep animals confined to one specific area for a long period of time. For additional

information on grazing, see Pasture and Grazing Management in the Pacific Northwest (PNW 614).

A final area of concern when implementing grazing is whether biological control agents such as *Brachypterolus pulicarius*, *Calophasia lunula*, *Mecinus* spp., or *Rhinusa antirrhini* are present. Grazing may cause harm to foraging or mating adults, larvae feeding on the leaves, or developing larvae and pupa within the seedpods and stems.

Physical and Mechanical Control

Successful management of Dalmatian and yellow toadflax, especially after they have established, can be labor intensive. Hand pulling generally only works for small, individual plants and only if continued for several years. Pulling large infestations of more mature plants can leave behind pieces of viable root fragments, which may develop into new plants. Plowing or tillage may also cause new shoots or regrowth to develop from severed root fragments. Mowing can help reduce seed production but will not likely adversely affect the perennial root system of these plants.

Chemical Control

There are several herbicide options to choose from that are effective at controlling both toadflax species (Table 2). However, timing and the ability to penetrate the plant’s waxy cuticle is a must to be effective. It is recommended to use a methylated seed oil (MSO) or silicone surfactant when chemically treating either plant species in order to penetrate the plant’s waxy cuticle.

Herbicide applications are most effective when plants are 6 to 8 inches tall (late spring/early summer). This level of growth allows for enough plant surfaces to absorb the herbicide.

Spraying toadflax during summer months is NOT recommended. Stress from hot, dry conditions can cause plants to develop a thicker wax layer on the leaf surface, which can act as a barrier to herbicide absorption into the plant. Herbicide movement within the plant will likely be reduced due to a slowed rate of translocation and metabolism, thereby leading to a reduction in overall efficacy.

Control of toadflax can also be achieved with a fall herbicide application by targeting the fall regrowth (generally first week of October into November). However, it is important to keep in mind that the plant will already have gone to seed by this time. The Pacific Northwest Weed Management Handbook (available from Extension offices in Idaho, Oregon, and Washington and online at <http://pnwhandbooks.org/weed/>) contains additional herbicide recommendations for managing Dalmatian and yellow toadflax. Herbicide labels should be consulted for grazing restrictions for different species of livestock.

Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing or applying herbicides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

Biological Control

Classical biological weed control (often referred to as biocontrol) is the intentional use of an invasive plant’s natural enemies to reduce its overall health and reproductive capabilities. The main objective of any biological control program is to shift the competitive balance away from the

Table 2. Herbicide recommendations.

| Common Chemical Name (active ingredient) | Product Example | Application Rates | Application Phenology |
|--|-----------------|--------------------------|---|
| Aminocyclopyrachlor + Clorsulfuron | Perspective* | 4.75 to 11 oz/ac | Plants 6 to 8 inches tall up until bud formation, or fall rosette |
| Picloram | Tordon | 1.5 to 2 pt/ac | Same as above |
| Picloram + Metsulfuron | Tordon + Escort | 1.5 to 2 pt/ac + 1 oz/ac | Same as above |
| Picloram + Chlorsulfuron | Tordon + Telar | 1.5 to 2 pt/ac + 1 oz/ac | Same as above |
| Chlorsulfuron + Metsulfuron | Telar + Escort | 1.33 oz/ac + 0.76 oz/ac | Same as above |
| Imazapic | Plateau | 0.188 lb/ac | Fall rosette, before hard frost |

Note: Rates listed below are for rangeland and rights of way. For a list of additional target areas and rates, refer to the label. Additional information is available in the PNW Weed Management Handbook.

*At the time this publication was written, PERSPECTIVE Herbicide is NOT labeled for Conservation Reserve Program (CRP) acreage application.

target weed back to desirable grasses and forbs and return those once weed-dominated lands to more diverse and productive plant communities. In order to locate biocontrol agents, research scientists must first identify the plant's native range and survey those areas for possible insects, mites, or pathogens. Potential agents then go through rigorous testing to determine their overall effectiveness, and their host specificity is assessed to ensure they will attack only the target weed and not attack native species or commercial crops. These tests are carried out by the US Department of Agriculture–Animal and Plant Health Inspection Service–Plant Protection and Quarantine (USDA-APHIS-PPQ).

Biocontrol agents are best suited for large, well-established weed infestations on sites where other control methods have failed or have become no longer feasible. A limitation when using biocontrol is that it often takes significant time to see impacts and therefore requires patience and perseverance on the part of the land manager. Results can sometimes be achieved in as little as four years, but generally takes longer as the biocontrol agent reaches sufficient population levels to impact the target weed. In some instances, it may take more than ten years before definitive impacts are observed. Therefore, this tool should be thought of as a long-term management strategy and not a quick or simple fix. Landowners should contact their local Extension educator that deals with biological weed control, their state department of agriculture, or their noxious weed control board for more information.

There are eight different biological control insects that attack different parts of the plant. They include: (1) the seed-feeding weevil, *Rhinusa antirrhini*, (2) a flower-feeding beetle, *Brachyterolus pulicarius*, (3) two stem-mining weevils, *Mecinus janthinus* and *M. janthiniformis*, (4) a root galling weevil, *Rhinusa linaria*, (5) a defoliating moth, *Calophasia lunula*, and (6) two root-boring moths *Eteobalea intermediella* and *E. serratella*. The root-galling weevil, *R. linaria*, as of this publication is only established in British Columbia at a handful of sites. Both root-boring moths have failed to establish and the seed-feeding weevil *R. neta* was an accidental introduction and is not approved for redistribution in the US. *R. antirrhini* was also accidentally introduced but has since been approved for redistribution because it is widespread and exhibits minimal impact to the toadflax (Sing et al. 2015). See Table 3 for the four most widely encountered biological control agents of Dalmatian and yellow toadflax.

Brachyterolus pulicarius

The toadflax flower-feeding beetle, *Brachyterolus pulicarius* L., was unintentionally introduced into North America in 1919 as a contaminant of imported toadflax plants. The beetle has since been approved and is now widespread throughout

North America on both toadflax species. The insect attacks both Dalmatian and yellow toadflax, exhibiting a distinct preference for the latter species (Sing et al. 2015).

Adults are dark brown to black, somewhat oval in shape, about 0.12 inches long and have shortened wings, thus exposing a portion of the abdomen (Figure 13). Adults emerge from the soil in late spring and start feeding on young shoot tips and axillary buds at the base of toadflax leaves. They also feed on pollen from other spring-flowering plants such as dandelion, clover, wild mustard, strawberry, apple, and dogwood, but this feeding has no detrimental effect on these plants. In early June, mated females begin laying eggs in unopened toadflax flower buds. After three to seven days, small, yellowish larvae emerge from the eggs, penetrate floral buds and feed on the anthers and ovaries within the buds. Older larvae will also consume developing seeds. After larvae have consumed the floral tissues and developing seeds in a flower, they will move to other flowers in search of food. After feeding for three to five weeks, larvae exit the damaged flowers and burrow into the soil where they pupate and subsequently overwinter. The beetle completes one generation annually (Wilson et al. 2005).

While this agent is widespread, its overall impact is less than desired. On Dalmatian toadflax in the US, adult feeding damage results in plant stunting and leads to increased secondary branch production. This overall damage is considered minimal at most sites. This insect prefers yellow toadflax and at times can reduce seed production by 80–90%. Any seeds produced by beetle-damaged flowers are typically smaller and less viable than seeds from non-infested flowers. However, even with the potential to destroy a large percentage of seed, the overall impact has been shown to be minimal, even on its preferred host (Sing et al. 2015).



Figure 13. Toadflax flower-eating beetle *Brachyterolus pulicarius*. Photo by Daniel K. MacKinnon, Colorado State University, Forestry Images.

Table 3. Dalmatian and yellow toadflax biological control agents approved for release in the Pacific Northwest.

| Name | Type of Agent | Size/Color | Impact | Availability |
|---|---------------|---|---|---|
| Toadflax flower-feeding beetle (<i>Brachyterolus pulicarius</i>) | Beetle | 2–3 mm long and somewhat oval-shaped; shiny, dark brown to black or sometimes black with brown mottling. | <ul style="list-style-type: none"> Adults feed on young, succulent shoot tips and some reproductive parts. Larvae feed on pollen, anthers, ovaries, and maturing seeds. Can reduce seed output >75% in attacked flowers; however, decreasing seed output does not kill existing plants. | Very limited availability. |
| Toadflax feeding moth (<i>Calophasia lunula</i>) | Moth | <p>Adults 1.0–1.5 cm long, mottled grey-brown with light and dark markings on the wings.</p> <p>Young larvae (caterpillars) are gray-black, and about 5 mm long.</p> <p>Older larvae are brightly colored with white spots and black and yellow parallel stripes.</p> | <ul style="list-style-type: none"> Defoliation of terminal stems, flowers, and older foliage. Level of impact is inconsistent from year to year. Population levels usually too low to achieve strong impacts. Seedlings and one-year-old plants can die from defoliation; larger plants can usually rebound from defoliation. | Very limited availability. |
| <p>Dalmatian toadflax stem-mining weevil (<i>Mecinus janthiniformis</i>)</p> <p>Yellow toadflax stem-mining weevil (<i>Mecinus janthinus</i>)</p> | Weevil | <p><i>M. janthinus</i> adults are smaller (2.4–3.4 mm vs. 3.2–6.0 mm) long for <i>M. janthiniformis</i>.</p> <p>Newly emerged adults of both species are bluish-black.</p> | <ul style="list-style-type: none"> Adults feed on leaves and stems, thereby weakening the plant, suppressing flowering and seed production, and severely stunting shoots. Larvae mine the stems causing premature wilting of shoots and suppressing flower formation. | <p><i>M. janthiniformis</i> Readily available.</p> <p><i>M. janthinus</i> Currently not widely available.</p> |
| Toadflax seed-galling weevil (<i>Rhinusa antirrhini</i>) | Weevil | <p>Adults reared from yellow toadflax are 2.5–3.0 mm long; those developing on Dalmatian toadflax are up to 5 mm.</p> <p>Gray to black and covered in dense short hairs. Snout long, distinctly curved, and pointed.</p> | <ul style="list-style-type: none"> Adult feeding insignificant. Female-inserted eggs triggers the development of a gall, which causes adjacent seeds to become swollen and non-viable. Developing larvae feed on both abnormal and normal seeds, thereby reducing seed output. | Limited availability. Well established on yellow toadflax throughout the US and Canada. |

Calophasia lunula

The toadflax feeding moth, *Calophasia lunula* (Hufnagel), was initially introduced from Europe into Canada in 1962 as the first biocontrol agent for Dalmatian and yellow toadflax. This noctuid moth was later released in the US in 1968, where it has since become widespread in several western states.

Adult moths are 0.4 to 0.6 inches long and are mottled grey-brown in color with light and dark markings on the wings (Figure 14). First generation adults emerge around mid-May and live anywhere from a few days to several weeks. During this period, they feed on the nectar of toadflaxes and other flowering plant species at night and are inactive during the day.

The eggs of *C. lunula* are laid singly, primarily on the foliage, and to a lesser degree on the flowers of both Dalmatian and yellow toadflax. Adult females produce an average of 100 eggs. In about 10 days, the eggs hatch and the grayish-black larvae start feeding on young, tender leaves. As the larvae grow over their four-week developmental period, they become much more colorful and recognizable by the longitudinal stripes of yellow, black, and gray, with black and white spots on their bodies (Figure 15; Sing et al. 2015; Wilson et al. 2005).

Larvae prefer to consume younger leaves and shoots but will move to and devour older leaves and stems as they continue to develop and as the plants become increasingly defoliated. Smaller plants can be completely stripped of flower buds and leaves, leaving behind naked stems (Figure 16). This type of defoliation can kill seedlings and one-year-old plants, diminish root sugar reserves, and eventually impact plant vigor and reduce seed production in more mature, established plants (Peterson et al. 2005).



Figure 14. *Calophasia lunula* adult. Photo by Bob Richard, USDA-APHIS-PPQ, Forestry Images.



Figure 15. *Calophasia lunula* larva. Photo by Bob Richard, USDA-APHIS-PPQ, Forestry Images.



Figure 16. *Calophasia lunula* larval feeding damage. Photo by Gary Piper, Washington State University, Forestry Images.

Mature larvae move down the stem and construct cocoons from silk, chewed leaves, and soil particles. Cocoons are generally found attached at the base of a toadflax stem or nearby in soil or leaf litter. Pupation occurs within the cocoon and lasts about one week. This insect may have 1 to 3 generations per year depending on climate and elevation. In warmer climates at lower elevations, this insect can have 1 to 3 generations, whereas, in colder climates and at higher elevations, 1 to 2 generations are more typical. This insect overwinters as a pupa inside the silken cocoon and will emerge the following spring when conditions become favorable (Sing et al. 2015; Wilson et al. 2005).

Larvae of this insect can be found consistently on both Dalmatian and yellow toadflax infestations throughout much of the US and southern parts of Canada. Larval feeding in high densities has been shown to significantly defoliate both toadflax species. Unfortunately, this level of damage is inconsistent from year to year, and older, more mature plants can overcome the defoliating effects of larval feeding and still produce a small amount of seed (Coombs et al. 2004, Sing et al. 2015). An additional concern with this insect is that it is not entirely host-specific to toadflaxes and has shown that caterpillars can feed and develop on plants in the genus *Antirrhinum*. One such native species is *Sairocarpus virga* (formerly *Antirrhinum virga*). Therefore, caution should be taken when redistributing this insect, especially if this species is present or nearby in the area (Sing et al. 2015).

Mecinus janthinus* and *M. janthiniformis

The stem-mining weevil, *Mecinus janthinus* Germar, native range includes Eurasia. In 1991, researchers collected this weevil from France and Germany and released it in Canada. In 1996, weevils collected from these same two countries would later be released in the US. The stem-mining weevil, *Mecinus janthiniformis* Toševski & Caldara, native range is southeastern Europe. This weevil was originally collected in Macedonia and released in Canada in 1992. At some point, prior to 1996, this weevil crossed the Canadian border and started attacking Dalmatian toadflax in the US. (Sing et al. 2015; Toševski et al. 2011).

Newly emerged adults are bluish-black, somewhat cylindrical in shape, about 0.2 inches in length, and have a long, curved snout (Figure 17). A number of site-specific factors such as elevation, latitude, and if any snow cover remains at the site can all influence adult spring emergence. Adults are generally active from late April to mid-August (Sing et al. 2015). They can often be found in large numbers on the upper third of the plant, feeding on the new succulent foliage and buds. Damage on the leaves, shoots, and stems caused by adult feeding resembles a shot hole pattern. Extensive feeding damage can result in the death of the terminal portions of the stems, thus



Figure 17. Stem-boring weevil *Mecinus janthiniformis* for Dalmatian toadflax. Photo by Bob Richard, USDA-APHIS-PPQ, Forestry Images.



Figure 18. *Mecinus janthiniformis* adult feeding damage. Photo by Dale Whaley, Washington State University.

inhibiting potential flower development and seed formation (Figure 18). Up to 100% of the plants in an area may experience injury from adult feeding once the insect has become well established (for Dalmatian toadflax only).

Depending on weather conditions and elevation, females start laying eggs in late April through early July. Eggs are deposited individually into holes chewed into the stems and then covered with masticated plant tissue to help protect the eggs from desiccation and predation (Figure 19). Multiple females often utilize the same stem for egg deposition. A female produces up to 45 eggs during her lifetime. As the plant develops, the oviposition holes resemble bumps or calluses on the stems (Sing et al. 2015).

The small, creamy-white larvae begin to feed on tissues inside the stems. Larvae feed and tunnel short distances (1 inch) within the stems over a period of four to five weeks. This type of feeding activity negatively impacts plant vigor by disrupting the flow of nutrients and water. This, coupled with adult feeding, can limit the number of flowers produced, and thereby reduces the amount of seed produced by the plant, affects the plant's overall health, and can even cause death (Figure 20; Sing et al. 2015).

Pupation occurs starting in mid-June through early September for both species in oval chambers formed within the mined stems (Figure 21). It takes an average of 50 to 63 days to go from egg to adult. Newly formed adults overwinter within the feeding chambers in the dead stems. During the following spring, adults will chew their way out of the old stem in search of new plant growth, leaving a small round hole. Therefore, it is important not to destroy or remove the old stems as this would be detrimental to either *Mecinus* spp. This weevil completes one generation per year. Toadflax stems that lack sufficient snow cover can expose adults to cold temperatures and humidity. Temperatures that reach -18.5°F (-28°C) can severely impact survivability with documented mortality rates of 75% to 100% (Sing et al. 2015).



Figure 19. *Mecinus janthiniformis* oviposition scar. Photo by Gary L. Piper, Washington State University, Bugwood.org.



Figure 20. Dalmatian toadflax upper shoot killed from adult feeding. Photo by Dale Whaley, Washington State University.



Figure 21. *Mecinus janthiniformis* larval feeding damage. Photo by Bob Richard, USDA-APHIS-PPQ, Forestry Images.

M. janthiniformis is highly effective and one of the most destructive and successful biocontrol agents released for Dalmatian toadflax in North America. This insect has been shown to be an excellent flier and can quickly move throughout toadflax-infested areas. It has been recorded traveling over two miles in just four years from release sites in Canada. Since its introduction into the US, *M. janthiniformis* has readily established itself, spread very rapidly from release locations, and has provided 100% control of Dalmatian toadflax at some sites within three to five years after release.

Survey results have shown that *M. janthinus* on Yellow toadflax is not currently as widespread as *M. janthiniformis* is on Dalmatian toadflax, but has proved to establish well when released in new areas. While it has yet to reach the dramatic impacts of reductions in populations seen with *M. janthiniformis* on Dalmatian toadflax, in some areas impacts have been reported to be high (Sing et al. 2015).

Rhinusa antirrhini

The toadflax seed-galling weevil, *Rhinusa antirrhini* Paykull, was unintentionally introduced in Massachusetts in 1909 on yellow toadflax (yellow toadflax biotype) and currently can usually be found inhabiting both yellow and Dalmatian toadflax infestations. A second strain (Dalmatian toadflax biotype) was collected from the former Yugoslavia and intentionally released in the United State in 1993 and again in 1996 (Sing et al. 2015). The beetle is more abundant on yellow toadflax than Dalmatian toadflax.

Adult weevils are gray to black and covered in dense, short hairs. They have a long, curved pointed snout with a pair of elbowed antennae arising near the base of the snout (Figure 22). The size of this weevil varies depending on which toadflax plant it has been utilizing. Adults that have developed on yellow toadflax are smaller in size, 2.5 to 3 mm long, while those utilizing Dalmatian toadflax as a host can be up to 5 mm long. (Sing et al 2015).



Figure 22. Toadflax seed-galling weevil *Rhinusa antirrhini*. Photo by Bob Richard, USDA-APHIS-PPQ, Forestry Images.

Overwintered adults emerge around mid-May to June and begin to feed on the developing young shoots of both toadflax species. Oval and flattened eggs are deposited within developing seed capsules. This egg deposition ultimately causes a gall to be produced, which, in turn, decreases seed viability. Those 8–17 seeds closest to the developing egg become swollen, enlarge to 10 times their normal size, and have a pale, watery appearance. Larvae will initially feed on the swollen seeds while mature larvae may also feed on normal seeds. These swollen seeds are no longer viable. While reports from Washington have shown a high reduction in seed output, upwards of 90%, more normal seed reduction rates of 30% to 40% have been experienced elsewhere, like Oregon, having had minimal impact on weed populations (Sing et al. 2015).

Maintenance

Once the Dalmatian or yellow toadflax infestation has been successfully managed using the control options outlined above, competitive vegetation must be established in order to restore the disturbed area and create a desirable plant community that can withstand weed invasion. In addition, existing land management practices may have to be adapted to promote and maintain a healthy plant community. In any event, the control site should be continually monitored in the spring or early summer for the potential of re-establishing toadflax populations and for any new invading weed species that may try and colonize the site.

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Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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