

Ecology and Management of yellow toadflax [*Linaria vulgaris* (L.) Mill.]

by

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Figure 1. A yellow toadflax infestation on an upland site.

Abstract

Yellow toadflax is a short-lived perennial herb native to the steppes of southeastern Europe and southwestern Asia (Eurasia). This species spreads by both seeds and vegetative buds on its roots and creeping rhizomes (see Figure 1). Yellow toadflax was intentionally introduced in North America but has escaped cultivation as an ornamental, a source of fabric dye, and as a folk remedy to become an opportunistic invader associated with natural and anthropogenic disturbances throughout the continental United States, in all Canadian provinces and territories, and in parts of Mexico. In Montana, yellow toadflax was first reported in Flathead County in 1899 and by 2006 was reported from 32 Montana counties, mostly west of the continental divide (<http://invader.dbs.umt.edu>). Yellow toadflax is typically found on sites with higher moisture resources than those supporting Dalmatian toadflax infestations. Despite being designated a

Montana noxious weed, it is still sold as an ornamental by nurseries and seed companies under the common name “butter-and-eggs.”

Herbicidal control of this weed requires high application rates and repeated treatments. Picloram (1 qt./ac.), metsulfuron (1.5 oz./ac.), chlorsulfuron (1.5 oz./ac.), or imazapic (12 oz./ac.) applied at bloom in May or June or to fall re-growth have resulted in a short term, local reduction of yellow toadflax populations. The longevity of control depends on site conditions, the degree of competition exerted by other plant species, and grazing management. Six insect species have been approved for release in the United States as biological control agents for yellow toadflax, however their effect on yellow toadflax growth and spread have been negligible or not quantified. Little information exists regarding the efficacy of sheep or goat grazing management of yellow toadflax. Cultural controls (tilling, mowing, and burning) when applied alone are ineffective in controlling yellow toadflax, but may improve the effectiveness of chemical, biological, and grazing controls when used in an integrated management program.

Biology and Identification

Yellow toadflax is known by a variety of common names, including: common toadflax, butter and eggs, common linaria, eggs and bacon, wild snapdragon, flaxweed, impudent lawyer, and Jacob’s ladder. The common and scientific names both refer to the plant’s vegetative resemblance to flax; the name toadflax is derived from the Old English “tode flax” or wild flax. The genus *Linaria* was therefore derived by Linnaeus from *linum*, Latin for flax, and *vulgaris* similarly reflects the Latin root for ‘common’. Hybrids occurring between *L. vulgaris* and *Linaria repens* are common in nature; because hybrids between *L. vulgaris* and *Linaria dalmatica* can be artificially produced under laboratory conditions, similar crosses potentially occur in the wild.

Stems. Yellow toadflax stems reach a height of less than one to three (rarely more) feet tall (0.3-0.9 m). The surface of the lower stem is generally smooth and without hairs or glands (glabrous), but may have glandular hairs on the upper stem and inflorescence. The stem is woody and red-hued at the base, becoming increasingly succulent and green at the apex. Although highly variable, active stem growth begins when soil temperatures reach 41 to 50°F (5-10 °C). The onset of stem ramification (branching) in early June when stem height reaches 15 to 25 inches (4-6 dm) in height is a reliable indicator that flowering is imminent. Stems die at freezing but may remain upright, facilitating wind dispersal of seeds throughout fall and winter.

Leaves. Yellow toadflax leaves are pale to silvery-green, narrow, linear, approximately two inches (5.5 cm) long, pointed at both ends, and with entire margins. A single vein may be apparent on the underside of mature leaves. Although alternately arranged along the stem, the leaves are generally numerous and may therefore appear to be opposite or whorled in arrangement because of crowding (see Figure 2).



Figure 2. Yellow toadflax stems showing the hairless, linear-shaped leaves pointed at both ends with smooth margins.

Flowers. Yellow toadflax has densely clustered, light butter-yellow colored, snapdragon-like flowers which have a distinctive bright-orange bearded ‘throat’. The flowers are arranged in compact spike-like racemes at the growing tip of the stems. The corolla consists of five united petals, with a two-lobed (bilabiate), light-yellow upper lip, and a three-lobed (trilabiate) light-yellow lower lip rising into an orange palate with a distinct, conical spur at the base (see Figure 3). The calyx has five distinct green sepals arranged in a crown-shape at the base of the flower. Flowering is determinate. Yellow toadflax is self-incompatible, with pollination thought to be accomplished predominantly by bumblebees and halictid bees. Depending on environmental conditions, flower buds form at the end of June, flowering begins in mid-July, and peak flowering occurs at the end of July. Flowering may continue through September. Staggered flowering reduces the chances of total seed failure from predation or resource limitation. Predation by biological control insects has been observed to induce changes in the timing of flower development.

Seeds. Yellow toadflax flowers develop into cylindrical, two-chambered capsules with numerous seeds discharged through two or three pores or slits at the apex. Fruit capsules become mature and open to disperse seeds in September. Yellow toadflax seeds are small (0.06 in or 0.02 mm), grey- to black-colored flattened discs with a notched, papery wing. Seed production is highly variable, depending on the number of stems produced per plant and the number of capsules produced per stem. A commonly cited average number of capsules per stem

are 30, with each containing the equivalent of 250 seeds, producing 7,500 seeds per stem and an average of 15,000-20,000 seeds per large, mature plant. The production of 5,584 seeds per stem was reported from plants in Saskatchewan, and one study found over 200,000 seeds produced per square meter. Seeds produced per capsule ranged from an average of 165 and 824 per capsule in the presence and absence of seed predators, respectively, and when under extreme competition with wheat. The viability of fresh seeds from Alberta was reported to be 40 to 50 percent. Immediate germination of seeds is possible but most seeds are dormant and may require wet stratification to germinate. Chilling followed by alternating warm and cool temperatures was reportedly found to break dormancy. Viable seeds can remain dormant for as long as eight years. Low field establishment of seedlings has been reported.

Roots. Yellow toadflax produces both a tap root and creeping lateral roots that are capable of developing vegetative buds. This facilitates the formation of dense, persistent colonies competitive with more desirable plant species for soil water and nutrients. Seedlings 2-3 weeks old are able to form vegetative root buds. The tap root can penetrate more than three feet into the soil and survives freezing temperatures to 5° F (-15° C). Individual tap roots are reported to have a life span of at least four years. Horizontal roots may be ten feet or more (several meters) long. Root fragments as short as 0.4 inches (1 cm) can produce 'daughter' stems; fragments eight inches (20 cm) long generated from 75 to 694 'daughter' stems in barley and fallow, respectively. Radial expansion of patches of yellow toadflax via root sprouts was four feet (1.2 m) per year in Canada. Vegetative stems develop from horizontal roots one to two inches (2-5 cm) below the soil surface. Underground sections of stems are also capable of producing buds. This species enhanced root competition and poor wintering survival are both attributed to having a root system that is close to the soil surface. Studies of root carbohydrate levels report little starch reserve accumulation during vegetative reproduction and little variation in the content of carbohydrates throughout the growing season.



Figure 3. Flowers of yellow toadflax showing the prominent spur at the base, light-yellow, two-lobed upper lip, and the orange three-lobed lower lip that forms a palate.

Habitat. Phenotypic variability in the growth form of yellow toadflax gives it the ability to colonize a wide range of habitats from sea level up to 8,000 feet (2,500 m) and north to about 55 to 65° latitude in North America. It is limited by wet and shaded conditions. Yellow toadflax is commonly found on gravelly or sandy soil along railroads, roads, in yards, gardens, dry fields and rangeland, pastures, cultivated fields, and grain fields. It is associated with a wide variety of plant communities.

Economic importance. Fresh plants of yellow toadflax are reported to be distasteful and avoided by cattle due to secondary compounds in the foliage. Secondary compounds serving a primarily defensive function in yellow toadflax include the alkaloids peganin (linarin) and choline, and the iridoid glycosides antirrhinoside and glycosylaucubin found in the foliage and stems; flavonoids are produced in the flowers and the seeds contain saponins. Yellow toadflax is not considered to be poisonous to livestock or wildlife; cattle will reportedly eat it dried, and it has been used as a treatment for cattle that cannot ruminate. Although yellow toadflax displaces forage plants via its clonal occupation of sites in pastures and rangeland, it is not considered allelopathic to other plant species. Infestations of 12 stems/m² can reduce yields of canola by 20 percent and similar reductions through competitive displacement in wheat yield have been reported where infestations reach 74 stems/m².

Beneficial aspects. Yellow toadflax is used in folk and homeopathic medicine. It has been used as an insecticide in animal bedding, as a yellow dye, and is regarded as a plant imbued with culturally significant properties.

Spread. The majority of seeds (80 percent) produced by yellow toadflax fall within 2 feet (0.5 m) of the parent plant. Long-distance transport of seeds may be facilitated by wind, water, ants, birds, rodents and other animals. The position of the capsule at the stem tip and the winged seed suggest that this species is adaptable for wind dispersal: seeds have been observed to redistribute efficiently by blowing across the snow surface in the winter. The oily seeds can float in water for extended periods and migration of populations along waterways is obvious. Seeds have been found in the crops of birds and it is likely that other animals that consume yellow toadflax capsules will pass viable seeds through their digestive tracts. Root and rhizome fragments are very effectively spread by farm implements on cultivated land. Horticultural plantings are a common means of yellow toadflax spread.

Management Alternatives

Herbicide.^{1/} Variable results from herbicide trials indicate that picloram and chlorsulfuron are the most effective herbicides for control of yellow toadflax on rangelands. Sequential treatments (up to three years) will be needed because yellow toadflax readily recovers from a single application.

In Colorado, picloram applied at 0.5 lb./acre (2 qt./ac. Tordon 22K®) at the flowering stage of development resulted in 100, 69, and 35 percent control at three separate sites. Chlorsulfuron applied at (1.25 oz./ac. Telar®) at flowering or in the fall resulted in 84 percent control one year later. The flowering and fall re-growth stages are believed to be the most susceptible for herbicide application. Applications made in the spring or pre-bloom are useful for reducing seed production. Yellow toadflax is reportedly not damaged, or only slightly damaged by 2,4-D, MCPA, 2,4-DB or MPCB.

Plants are tolerant of specific herbicides in many ways, including: preventing chemical penetration of the leaf surface; binding the chemical once it penetrates into the cytoplasm;

^{1/}Disclaimer:

Any mention of products in this publication does not constitute a recommendation by the NRCS. It is a violation of Federal law to use herbicides in a manner inconsistent with their labeling.

breaking down the chemical through metabolic processes; and exuding the chemical from the plant. The mechanism of yellow toadflax tolerance to herbicidal control is not fully understood. However, herbicide spray solution may bounce or run off the linear-shaped leaves, and specialized cells in the leaves and elsewhere containing crystalloid bodies may have a role in storing or breaking down herbicides and other chemicals that accumulate in the leaves.

On cropland, per-plant application of glyphosate at 5 lb./ac. (0.9 kg/ha) when yellow toadflax stems were three inches (8 cm) tall suppressed yellow toadflax and increased yields of barley. Applications of glyphosate at early bloom can provide 40 to 90 percent control during the season of application but expect abundant re-growth the following spring. Two years of 90 percent control has been reported after two to three cultivations (until mid-July) were followed by a mid-August application of glyphosate at 5 lb./ac. (0.9 kg/ha).

Forest Service land managers in Colorado began evaluating a number of tank mixes in 2005 in an effort to improve upon previous single formula applications with metsulfuron (Escort) which when applied at 2 oz./ac. resulted in a trend where the yellow toadflax became more dense while grasses thinned out significantly. Their best results came through the application of a tank mix consisting of: 1 qt. of Tordon®, 1 oz. of Telar®, 4 oz. of Overdrive® per acre, with LI-700® (a surfactant) added at a rate of 1 quart per 100 gallons of total mix. They found no significant difference in control attained spraying this tank mix in spring, fall or during summer, and while some desirable forbs and most grasses survived the treatment, vetch was found to be particularly susceptible to the mix. One downside was that most treated plots were dominated by bare ground cover in the year following the application, probably due to the low level of non-toadflax vegetation prior to treatment, on the plots. However, the possibility of chemical carryover cannot be ruled out.

Table 1. Chemical and product name, recommended application rate, soil residual half life, and eco-toxicity of herbicides commonly used to control yellow toadflax.

Chemical name	Product name	Rate/acre	Half life-days	Ecotoxicity (LC ₅₀ /EC ₅₀)
Imazapic	Plateau	12 oz	31-233	>100 mg/L
Metsulfuron	Escort/Cimarron	1.5 oz	14-180	>150 mg/L
Picloram	Tordon	1-2 qt	90	10-100 mg/L

Grazing and Mowing. Cattle generally avoid grazing on yellow toadflax. A review of the literature found no studies reporting sheep or goat grazing to control yellow toadflax, however, it is believed sheep or goats can be trained to graze yellow toadflax. Mowing will not reduce infestations of yellow toadflax, but it may reduce seed production if timed to prevent flowering.

Biological Control. Although the introduction of the toadflax flower-feeding beetle *Brachyterolus pulicarius* (Coleoptera: Kateridae) is thought to have been accidental, it has become ubiquitous on most North American infestations of yellow toadflax. Adult beetles feed on the growing shoot tips, axillary buds at the base of leaves, and to a lesser extent on the pollen, floral anthers and ovaries, causing significant stooing, flower destruction and seed reduction in attacked plants. Larval damage is concentrated entirely on the reproductive structures of the plant, where pollen, anthers, ovaries and immature seeds are consumed. Researchers have reported an 80-90 percent reduction in available seed from plants under simultaneous attack by *B. pulicarius* and *Rhinusa antirrhini*. The toadflax seed feeding weevils *R. antirrhini* (Paykull)

and *R. neta* (Germar), (formerly *Gymnetron antirrhini* and *G. netum*) were similarly unintentionally introduced to North America, with the former more widely distributed on yellow toadflax patches throughout the adopted range. *Rhinusa antirrhini* secretions deposited into seed capsules by either the ovipositing female or from her eggs stimulates the development of a spur at the oviposition site; this in turn causes the production of a gall that physiologically alters the 8-12 seeds surrounding the egg. The developing larva feeds on these deformed seeds and nearby unaffected seeds as it matures. Larvae of *R. neta* also feed on encapsulated yellow toadflax seeds, but no gall is produced in association with this agent. Field observations suggest that an antagonistic (negative) interaction will occur if the development (phenology) of the flower-feeding larvae is locally more advanced than that of the two larval seed-feeding species, which results in the predation of *Rhinusa* spp. eggs by *B. pulicarius*. Although the seed-feeding larvae of these three agents consume a significant proportion of the seed produced, their efforts commonly result in negligible impact on patch persistence due to both the low viability of yellow toadflax seeds and the vast number of seeds produced per plant.

The larvae or caterpillars of the toadflax defoliating moth, *Calophasia lunula* (Lepidoptera: Noctuidae) feed on the lower leaves and stems of yellow toadflax. Seedlings and young plants are particularly intolerant of the comprehensive defoliation that typifies *C. lunula*'s feeding habits, and localized mortality of individual seedlings can be fairly high. Pathogens introduced with this agent generally constrain it from building to the large, persistent populations necessary to effect a significant reduction in yellow toadflax populations. Both the toadflax and yellow toadflax root-boring moths, *Eteobalea intermediella* Riedl and *E. serratella* Treitschke (Lepidoptera: Cosmopterigidae), respectively, showed great promise for controlling yellow toadflax during European host specificity evaluations but have failed to become widely or obviously established and distributed in North America. The toadflax stem-mining weevil, *Mecinus janthinus* Germar (Coleoptera: Curculionidae) was initially collected from yellow toadflax in its native range, and all European host specificity tests evaluating the degree of attack on potential non-target hosts used yellow toadflax as the target (control) host in choice tests. The ensuing rarity of *M. janthinus* establishment on yellow toadflax in western North America is therefore very puzzling. Researchers are currently evaluating a related species, *M. heydeni*, for host specificity and increased control efficacy on yellow toadflax. Although the ideal yellow toadflax biological control agent has yet to be identified, all the approved agents discussed above can contribute to the overall erosion of the weed's fitness, and therefore merit consideration when an integrated weed management approach is adopted against this species.

Table 2. Biological control insects for management of yellow toadflax, the site of attack on the plant, insect life stage and plant life stage for collection, and the collection method for redistribution.

Insect	Type	Site of Attack	Collection	Collection Method
<i>Brachyterolus pulicarius</i>	beetle	flower	Adult	sweep net
<i>Calophasia lunula</i>	moth	foliage	larval	stems
<i>Eteobalia spp.</i>	moth	roots	pupal/adult	NA
<i>Gymnetron antirrhini</i>	weevil	seeds	adult	Sweep net
<i>Gymnetron linariae</i>	weevil	Root	adult	Sweep net
<i>Mecinus janthinus</i>	weevil	stem	adults	Sweep net

Fertilization. One study in bermudagrass showed six years of spring fertilization with 1,830 or 3,660 lbs./ac. (336 or 672 kg/ha) of potassium reduced yellow toadflax density from 32 to 9 plants/m². Conversely, nitrogen fertilization with 1,830 lbs./ac. (336 kg/ha) increased yellow toadflax from 8 to 44 plants/m². However, these rates of fertilization may also be detrimental to most desirable plants.

Burning. Prescribed burning will not control yellow toadflax and may increase the potential for its spread. Herbicide application on areas managed with prescribed fire is therefore recommended.

Tilling. On cultivated land, observations in Canada suggest that yellow toadflax increases when infrequent or minimum tillage techniques are used on cropland. For tillage to be effective, it should begin on summer fallow in June and be repeated every three to four weeks, or after seven to ten days of green re-growth. In post-seeding cultivation, shallow tillage is recommended to prevent establishment of spreading root fragments. Fall tillage should begin soon after crop harvest and be repeated every three to four weeks until frost kills top growth. Alternate fallow and cropping in 250-foot (80 m) strips has been suggested to reduce wind erosion and yellow toadflax stands. Studies indicate that tillage increases the susceptibility of yellow toadflax to glyphosate.

Re-vegetation. Plant competition has been reported to effectively prevent seed production of yellow toadflax. However, there is little information on re-vegetation of infestations with grasses or other species. Establishing competitive perennial grasses on disturbed land, followed by prescribed grazing management to maintain grass vigor will suppress yellow toadflax and prevent spread by seed. Refer to [Montana Plant Materials Technical Note 46](#), 'Seeding Rates and Recommended Cultivars,' and Extension Bulletin EB19 'Dryland Pasture Species for Montana and Wyoming' for seeding rate guidance and re-vegetation species selection. State and Area Resource Specialists can help determine the most appropriate, site-specific species mix, timing of seeding, and seeding methods. Where herbicides have been applied, chemical carryover should be assessed prior to planting permanent vegetation.

Integrated Pest Management

An integrated yellow toadflax weed management program should include prevention, early detection and small-scale eradication, containment, and large-scale population reduction. Prevention is guided by understanding and responding appropriately to how yellow toadflax spreads and its requirements for establishment, and includes maintaining competitive plant communities and preventing seed imports by horticultural plantings, using weed-free feed and seed, cleaning cultivation equipment before application on weed-free areas, and containing grazing animals that have fed in yellow toadflax infested areas for five days before moving them to weed-free areas. Early detection and small-scale eradication is achieved through persistent survey and aggressive herbicide application. Yellow toadflax populations are contained by herbicidal maintenance of patch borders on extensive infestations and vigilant detection and control of satellite populations, control actions that reduce seed production such biological control insect releases, and cultivation of competitive plants. Large-scale population reduction is achieved over the long-term by applying management alternatives such as prescribed grazing to maintain healthy, competitive perennial grasses, and biological control insects that simultaneously compromise yellow toadflax population fitness.

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