WRITTEN FINDINGS OF THE
WASHINGTON STATE NOXIOUS WEED CONTROL BOARD
Updated 2015

Scientific Name: *Linaria vulgaris* Mill.

Common Name: yellow toadflax, common toadflax, butter-and-eggs, wild snapdragon, toadflax, common linaria, toadflax

Family: Schrophulariaceae (also placed in Plantaginaceae)

Legal Status: Class C Noxious Weed in 1988

Images: left, *Linaria vulgaris* infestation; right, inflorescence with seed capsules forming at the base, flowers blooming in the middle and flower buds as the tip, both images by Michael Shephard, USDA Forest Service, Bugwood.org.

Description and Variation:
Overall habit:
Linaria vulgaris is an ill-smelling, herbaceous perennial that can grow 1 to 3.3 feet or sometimes taller. Plants are primarily hairless, slightly glaucous, and have narrow, alternate leaves. Racemes of yellow, snap-dragon like flowers bloom at stem tips and develop capsules that contain many small disk-shaped seeds. Plants growth can be highly variable depending on habitat conditions.

Roots:
Plants have an extensive root system of vertical and lateral roots (DiTomaso and Healy 2007). Plants have a taproot that can grow more than 3.3 feet (1 meter) deep in the soil (Saner et al. 1995). Lateral roots grow 2 to 7.9 inches (5 to 20 cm) below the soil surface, and spread 11.5 feet (3.5 meters) on average (DiTomaso and Healy 2007). Roots have adventitious buds that can form new stems (Saner et al. 1995). The roots of *L. vulgaris* can associate with vesicular-arbuscular mycorrhizae (DiTomaso and Healy 2007).

Stems:
Linaria vulgaris stems are erect and upright and can be branched near the tips (Hong et al. 1998). The stems are hairless or may have glandular hairs near the tips and in the inflorescence (DiTomaso and Healy 2007). Stems can develop a woody base (DiTomaso et al. 2013).

Images: left, young *Linaria vulgaris* plants with lateral roots, new vertical roots, and young stems image by Steve Dewey, Utah State University, Bugwood.org; right, looking down on vegetative stem with linear leaves radiating outward, image by John Cardina, The Ohio State University, Bugwood.org.

Leaves:
Plant have numerous leaves that are primarily alternately arranged, crowded on the stem, giving the appearance of being whorled or opposite (DiTomaso and Healy 2007). The leaves are soft, spreading outward to drooping, and nearly sessile to sessile with a tapering petiolate base (DiTomaso and Healy 2007). Leaf blades are linear to narrowly lanceolate with smooth edges and pointed tips (Hong et al. 1998, Saner et al. 1995). The leaves are 0.8 to 3.9 inches (2 to 10 cm) long by 0.04 to 0.2 inches (1 to 5 mm) wide and hairless or sparsely covered with hairs (DiTomaso and Healy 2007, Hitchcock et al. 1959).

Flowers:
The inflorescence is a terminal, erect raceme of crowded flowers (DiTomaso and Healy 2007, Hong et al. 1998). Flowers have a bad odor that has been described as cheesy or as an un-aired dairy, though the smell has also been described as a faint, sweet fragrance (Durant 1976 in Mitich 1993). The axis and flower stem (pedicels) are hairless to having short glandular hairs. Flower pedicels are 0.08 to 0.3 inches (2 to 8 mm long) (Hong et al. 1998). Bracts are linear to narrow lanceolate and longer than the pedicel. Flowers bloom from the base and progress upwards.

Flower calyx (sepals collectively) lobes are lanceolate to ovate-lanceolate (Hong et al. 1998). Flowers have five petals fused at the base and have bilateral symmetry– being 2-lipped, with a 2-lobed upper lip and a 3-lobed lower lip (DiTomaso and Healy 2007). Flowers have a downward-pointing spur near the base of the corolla tube that is straight to slightly curved, 0.4 to 0.6 inches (1 to 1.5 cm) long, and collects nectar (DiTomaso and Healy 2007, Hong et al. 1998). The corolla (petals collectively) is bright yellow to occasionally whitish, 0.6 to 1.4 inches (1.5 to 3.5 cm) long, including the spur (DiTomaso and Healy 2007). The corolla throat and lower lip have an orange, hairy palate (DiTomaso and Healy 2007). Flowers have 4 stamens that are arranged in 2 pairs and are not exserted (included in the corolla) (DiTomaso and Healy 2007).

Flowers have been found to have frequent abnormalities including peloric flowers, a mutation resulting in bilateral symmetrical flowers having radial symmetry (Saner et al. 1995).

Images: left, top of blooming flowers showing orange hairy palate in each flower, image by Mary Ellen (Mel) Harte, Bugwood.org; center, blooming raceme showing downward pointing spurs, image by Bob Nowierski, Montana State University, Bugwood.org; right, *Linaria vulgaris* seed capsules, image by John M. Randall, The Nature Conservancy, Bugwood.org.

Fruit:

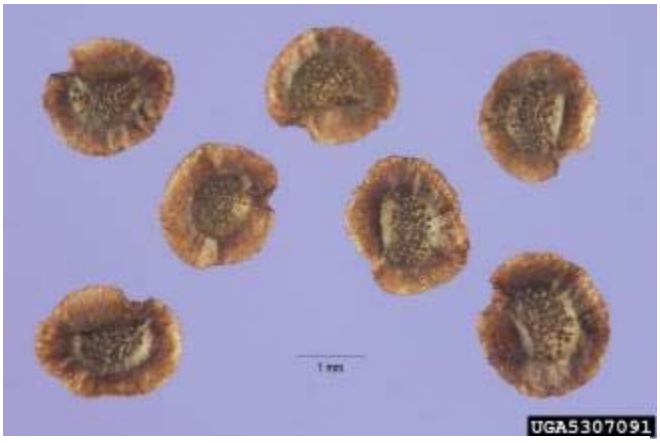


Image: left, mature *Linaria vulgaris* seeds, image by Steve Hurst, USDA NRCS PLANTS Database, Bugwood.org

The inflorescence axis elongates in fruit (Hong et al. 1998). The fruits are capsules, 0.4 to 0.5 inches (9 to 12 mm) long, nearly rounded in shape (ovoid-globose), containing two chambers (DiTomaso and Healy 2007). Capsules release seeds through two or three pores or slits at the top (Saner et al. 1995). The dark brown to black seeds are flat and circular, 1.5 to 2 mm in diameter and have a notched papery winged margin (DiTomaso and Healy 2007, Hong et al. 1998).

Similar Species:

Dalmatian toadflax, *Linaria dalmatica* ssp. *dalmatica*: *L. dalmatica* ssp. *dalmatica* is another species in the genus *Linaria* that is listed as a noxious weed in Washington. This species of *Linaria* can be easily

distinguished from *Linaria vulgaris* by leaf shape.—*Linaria dalmatica* ssp. *dalmatica*'s leaves are heart-shaped, not linear like *L. vulgaris*.

Images: left, *Linaria dalmatica* ssp. *dalmatica* in bloom, image by Bob Nowierski, Montana State University, Bugwood.org; center, stems and leaves of *L. dalmatica* ssp. *dalmatica*, image by Joseph M. DiTomaso, University of California - Davis, Bugwood.org; right, close up of *L. dalmatica* ssp. *dalmatica* leaves, image by WSNWCB.

Hybridization:

Linaria dalmatica ssp. *dalmatica*, Dalmatian toadflax, and *Linaria vulgaris* are able to spontaneously hybridize. Ward et al. (2009) studied hybridized plants in Montana and through genetic testing proved that hybrids had DNA from both species. They also found that the hybrid progeny are fertile and can produce viable seed. The hybrids were found to have traits of the parent plants including being an obligate outcrosser, a perennial, and being able to vegetatively reproduce. Ward et al. (2009) also found that hybrid progeny readily backcrossed with parent species. Jennifer Andreas, WSU Integrated Weed Control Project, sent plant samples to Dr. Sarah Ward of Colorado State University, for DNA testing that confirmed the presence of *Linaria vulgaris* and *L. dalmatica* spp. *dalmatica* hybrids in King County Washington (J. Andreas pers. comm.). These plants were found in the Greenwater Watershed in King County, close to the county line with Kittitas County, and are currently the only confirmed hybrids in Washington State (J. Andreas pers. comm.). There appears to be an increase chance of hybridization of these two species when they are growing within a few meters of each other at a site (Ward pers. comm. to J. Andreas per. comm.).

Images of hybrid plants (*Linaria vulgaris* x *L. dalmatica* ssp. *dalmatica*) found and tested in King County Washington, images by Jennifer Andreas, WSU Integrated Weed Control Project.

Habitat:

Linaria vulgaris grows in open, disturbed habitats in a wide range of soils and climate conditions (DiTomaso and Healy 2007). It can invade elevations from sea level to over 3000 meters and up to 60 degrees N latitude (Panchard et al. 2003). Plants prefer moist, gravelly soils and can grow in a variety of typically disturbed habitats including fields, rangeland, pastures, prairies, rocky hillsides, forest clearings, sagebrush communities, roadsides, burned sites, cultivated fields, railroad yards, waste places and gardens (DiTomaso and Healy 2007, Saner et al. 1995). *Linaria vulgaris* can also invade perennial forage crops, annual crops and summer fallow fields (Saner et al. 1995). It invades after both human and natural disturbances.

Beside disturbed habitats, plants can also grow in undisturbed habitats such as prairies and riparian areas (DiTomaso and Healy 2007). *Linaria vulgaris* can even tolerate subarctic conditions (DiTomaso and Healy 2007). It has also recently become a problem in pristine natural areas in the Rocky Mountains (Panchard et al. 2003).

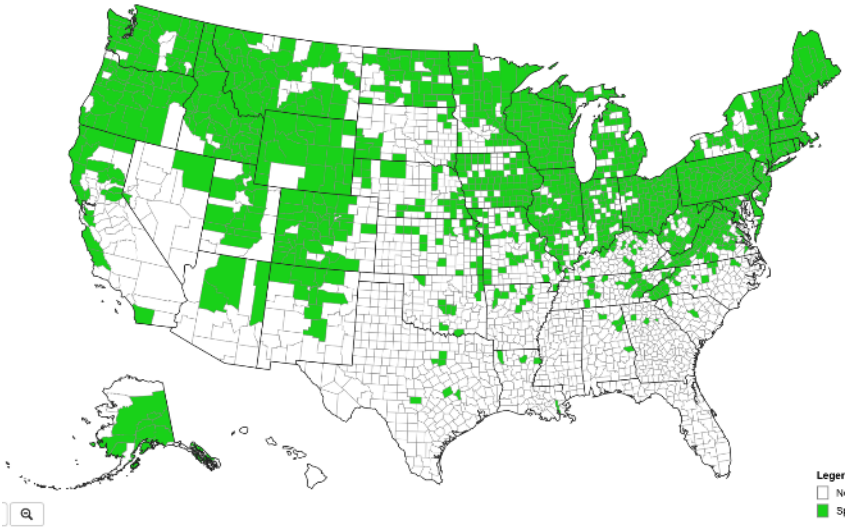
Geographical Distribution:

Linaria vulgaris is native to parts of Europe and Asia. The USDA GRIN database (USDA ARS 2015) specifically lists *L. vulgaris* native to:

- Asia: Turkey, Russian Federation, and China
- Europe: Denmark, Finland, Ireland, Norway, Sweden, United Kingdom, Austria, Belgium, Czech Republic, Germany, Hungary, Netherlands, Poland, Slovakia, Switzerland, Belarus, Latvia, Lithuania, Moldova, Ukraine, Albania, Bulgaria, Croatia, Greece, Italy, Romania, Serbia, Slovenia, France, and Spain

USDA GRIN database (USDA ARS 2015) lists *Linaria vulgaris* naturalized in temperate regions.

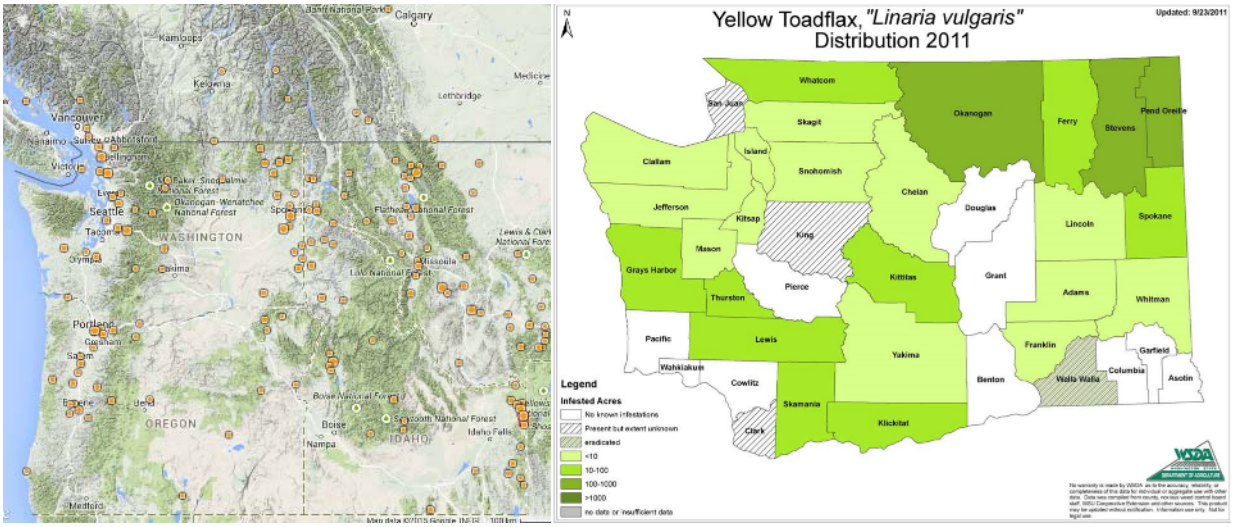
In the 1600's, *Linaria vulgaris* was brought to North America as an ornamental and has since escaped and naturalized (DiTomaso et al. 2013). In the United States, *L. vulgaris* is documented in every state except Hawaii (EDDMapS 2015).



Maps: County level distribution of *Linaria vulgaris* in the United States (EDDMapS 2015).

<u>Washington:</u>

The earliest herbarium records of *Linaria vulgaris* in Washington are from the 1920s. Specific records include a garden collection from Skamania County in 1923 (WTU 119913), a collection from Stevens County in 1923 from an open meadow (WTU 174565), a collection from Spokane County in 1923 (WTU 174564), a collection from 1925 near North Bend (WTU 15537), and a collection in Whatcom County from a field (WTU 22562). Herbarium records document *L. vulgaris* in both eastern and western Washington. The Washington State Department of Agriculture (WSDA) created a county level distribution map of *L. vulgaris* in 2011 which documents plants all over the state, with the highest abundance in northeast Washington (WSDA 2011).



Maps: left, herbarium species of *Linaria vulgaris* in the Pacific Northwest including Washington, Idaho, Oregon, western Montana, southern British Columbia and southern Alberta, map by Consortium of

Pacific Northwest Herbaria; right, Washington State Department of Agriculture county level distribution map of *L. vulgaris* in 2011 (WSDA 2011).

Listings:

Linaria vulgaris is listed as a noxious weed and/or as a regulated plant in Idaho, Colorado, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Washington, and Wyoming (National Plant Board 2015, USDA NRCS 2015).

Growth and Development:

Seeds on soil surface or buried up to 0.8 inches (2 cm) deep can germinate in the spring and the fall (DiTomaso and Healy 2007). Once seedlings have established, growth is rapid when competitive stress is absent (Nadeau, unpublished data in Nadeau and King 1991). The first leaves, cotyledons, are lanceolate, up to 0.5 inches (12 mm) long, pale green, lightly glaucous and hairless (DiTomaso and Healy 2007). Once seedlings lose their cotyledons, they look similar to new shoots that have grown from existing roots (DiTomaso and Healy 2007).

Plants grow rapidly, with first year plants able to develop up to 100 secondary shoots from roots and second year plants developing 200 to 250 shoots (DiTomaso and Healy 2007). Root fragments also have a high growth rate. Nadeau and King (1991) found that a planted 3.9 inches (10 cm) long piece of root with a 3.9 inches (10 cm) high stem produced an infestation 6.6 feet (2 meters) in diameter in one growing season (Nadeau et al. 1991 in Nadeau et al. 1992).

Plants have a highly variable phenology that depends on environmental conditions (Saner et al. 1995). Generally, flowers bloom May to September (DiTomaso and Healy 2007). Seed capsules develop from the base of the inflorescence, moving upward, forming while plants are still blooming. In Canada, capsules generally start to open at the beginning of September, and by the end of September most capsules are open (Saner et al. 1995). Plants die back in the fall, typically with freezing temperatures. Dead stems can remain upright and have seed-containing capsules still attached through the winter and sometimes longer, until wind knocks the seeds out or stems fall over (DiTomaso and Healy 2007, Saner et al. 1995).

Reproduction:

Plants reproduce by seed, and vegetatively by spreading roots and root fragments that can develop new plants (DiTomaso and Healy 2007). Plants can spread quickly by lateral roots sending up new stems from adventitious buds (DiTomaso and Healy 2007). Vegetative reproduction from root buds can begin as early as 2 to 3 weeks after germination (Zike 1954, Nadeau et al. 1992 both in Saner et al. 1992). Root fragments as small as 0.4 inches (1 cm) long are able to survive and grow (Nadeau et al. 1991 in Saner et al. 1995). Vegetative reproduction allows *Linaria vulgaris* to survive in harsh environments such as subarctic conditions, and in pastures and orchards with frequent burning or herbicide applications (Saniforth and Scott 1991, Saner pers. obs. both in Saner et al. 1995).

Linaria vulgaris is an obligate outcrosser, meaning that flowers cannot self-pollinate to enable seed production (Docherty 1982); however a small portion of seeds may be produced without cross pollination (Saner et al. 1995). Flowers are pollinated by insects that use the bright orange palates as nectar guides (Saner et al. 1995). Major pollinators of *L. vulgaris* include bumblebees and halictid bees (Arnold 1982, Newman and Thomson 2005, Saner et al. 1995). In a Colorado study, seven bee species, ants, unidentified lepidoptera and diptera visited *L. vulgaris* (Newman and Thomson 2005). When pollinators push through the flowering opening, *L. vulgaris*'s sticky pollen is effectively picked up

(Newman and Thomson 2005). Besides extracting nectar through the flower opening, bees can also illegitimately extract nectar by biting or reusing holes in the flower spur (Newman and Thomson 2005). Studies on the female fitness after nectar robbing have found no reduction in seed set, as there are usually enough legitimate flower visits to enable pollination (Stout et al. 2000, Nepi et al. 2002, Irwin and Maloof 2002 all in Newman and Thomson 2005).

Ants have been frequently observed on plants that had nectar robbed by the spur being pierced from the outside, and there may be some indirect benefit of ants reducing the impacts of other herbivores (Newman and Thomson 2005).

Seed production is highly variable, with ranges of seed produced per capsule being reported as 10 to 110 seeds, 10 to 40 seeds and 70 to 110 seeds per capsule (DiTomaso and Healy 2007, Arnold 1982 and Clements and Cavers 1990 in Saner et al. 1995). Seed production can be impacted by predation and competition from other plants. Overall seed production for a plant has been reported as 1,500 to 30,000 seeds, though defining what constitutes an individual plant can be difficult due to the clonal growth of L. vulgaris (DiTomaso and Healy 2007, Saner et al. 1995).

Seeds can be viable for 8 or more years (DiTomaso and Healy 2007). At maturity, seeds are primarily dormant and need a cool, moist period to break dormancy and germinate (DiTomaso and Healy 2007). When mature, most seeds are deposited near the parent plant. Nadeau and King (1991) recorded 87 to 96% of seeds were deposited within 50 cm of the parent plants in their study in Alberta. Of the seeds in their study, seed viability was 40 +/- 6% for an August collection and 51 +/- 4% for a September collection and 43 +/- 9% for an October collection.

Nadeau and King (1991) also found that *Linaria vulgaris* growing in competition with other plants may not produce seed capsules. They found that *L. vulgaris* growing with seeded barley plants may or may not flower, and those that did flower did not produce any seed capsules.

Though seeds are primarily deposited near the parent plant, they can also be dispersed by the wind (short distance), and by water, soil movement, humans and potentially by sticking to animals (DiTomaso and Healy 2007). Seeds can be dispersed by ants and have been found in the crops of birds (Ridley 1930 in Saner et al. 1995). Water dispersal is possible as seeds are oily and are able to float for a period of time (Lewis 1954 in Saner et al. 1995). Seeds can also be blown across the surface of snow (D. Maurice pers. comm. in Saner et al. 1995).

Linaria vulgaris has also been introduced as a crop contaminant. *Linaria vulgaris* was likely introduced into new areas in alfalfa seed (Harris and Carder 1971 in Saner et al. 1995). Seed-bearing plants have also been transported to new areas in baled hay (Mitich 1993).

Economic Importance:

Detrimental:

Linaria vulgaris is a nonnative, invasive perennial that can be difficult to control once it establishes. It can spread by seed and vegetatively by spreading roots and root fragments. Every stem has the ability to flower and produce seed its first year. Plants can form dense stands of growth and can crowd out native and desirable forage plants, reducing range carrying capacity. *Linaria vulgaris* can invade a wide range of habitats including high elevation, protected areas in the Rocky Mountains (Panchard et al. 2003).

Cattle avoid *Linaria vulgaris* in pastures, putting higher grazing pressure on other plants (Crockett 1977, McClay pers. comm. both in Saner et al. 1995). *Linaria vulgaris* has been a problem in forage crops like red fescue, where high densities of *L. vulgaris* have been found to reduce seed yields (Darwent et al. 1974). Saner et al. (1995) notes that in Canada, *L. vulgaris* may become more of a weed in annual crops as a result of reduced-tillage farming methods (McClay 1992). There is also concern of *L. vulgaris* in canola and cereals, as yields were reduced by 20% when crops were infested (O'Donovan and McClay 1987; O'Donovan and Newman 1989 in Saner et al. 1995).

Linaria vulgaris's root system can provide an overwintering site and harbor cucumber mosaic virus and broad bean wilt virus (Rist and Lorbeer 1989 in Saner et al. 1995).

Linaria vulgaris contains quinazoline alkaloids and also contains flavonoid glycosides of unknown toxicologic importance (Pethes et al. 1974, Bartik and Piskae 1981 in Burrows and Tyrl 2013). The alkaloids include vasicine (peganine), vasicinone, and deoxyvasicinone (Openshaw 1953, Groeger and Johne 1965, Johne 1986 all in Burrows and Tyrl 2013). Problems from intoxication have not been reported though vasicine is known to cause bronchodilation, hypotension, and uterine stimulation (Johne 1986 in Burrows and Tyrl 2013).

Beneficial:

Linaria vulgaris has a long history of use as an ornamental, medicinal use, as a dye, and historically as an insecticide (DiTomaso and Healy 2007, Saner et al. 1995).

There has been a wide range of medicinal uses for *Linaria vulgaris* over time. The plant is said to be antiphlogistic, astringent, cathartic, detergent, depurative, diuretic, hepatic, ophthalmic, and purgative, especially valued for its laxative and diuretic qualities (Plants for a Future n.d.). Internally it has been used in treatments for jaundice, liver diseases, gall bladder problems and skin problems (Plants for a Future n.d.). Plants are noted as being slightly toxic so dosage is critical (Plants for a Future n.d.).

In Europe, *L. vulgaris* has been used for centuries as a yellow dye (Plants for a Future n.d.). Saner et al. (1995) also reports of *Linaria vulgaris*'s use as a plant to reclaim areas despoiled by mining and on abandoned gravel pit slopes (Long 1974 and Heagy and Cavers 1980).

Control methods:

Linaria vulgaris is a difficult plant to control once it establishes at a site as plants can spread quickly through spreading roots and stems. Panchard et al. (2003) note that management of *L. vulgaris* should focus on new populations and dispersal corridors, making sure to monitor nearby disturbed environments. Monitor areas of disturbance near infestations such as overgrazed land, soil disturbance and clearing of perennial vegetation, as these practices encourage seedling survival (DiTomaso and Healy 2007).

Mechanical methods:

Young plants can be hand dug or pulled, but it is critical to remove all the roots as fragments left in the soil can resprout and develop new stems.

When controlling *Linaria vulgaris*, make sure to prevent seed production and starve the roots. Mowing can prevent plants from going to seed and stress plants, but it will not kill the roots and may in fact stimulate vegetative growth from the roots and stems (DiTomaso et al. 2013, Saner et al. 1995).

Cultivation can be used to control plants in appropriate areas, such as cropland. Cultivation can spread root fragments that can resprout, so take this into account when developing a management plan and moving equipment (DiTomaso and Healy 2007). Two or more years of repeat cultivation will be needed to control plants, starting in early June and repeating so there is never more than 7 to 10 days of green plant growth (Parker and Peabody 1983). Typically, this method will require 8 to 10 cultivations the first year and 4 to 5 cultivations the second year (Parker and Peabody 1983). To reduce the number of cultivations and reduce possible soil erosion, a combination of tillage and herbicide treatment can also be used (Saner et al. 1995). Seedlings that are less than 2 to 3 weeks old are particularly susceptible to cultivation and should be controlled before they age and begin to spread (Nadeau et al. 1992, Saner et al. 1995).

Cultural Methods:
Seedlings do not compete well for moisture with established vegetation, and competition appears to lower seed production (DiTomaso and Healy 2007). Prevent overgrazing of vegetation that can provide competition to *L. vulgaris*. Limit spring grazing to leave enough vegetation for competition in infested sites, and minimize soil disturbance to discourage seed germination (Saner et al. 1995). Planting non-invasive and/or native perennials and annuals will provide competition and reduce the survival and spread of *L. vulgaris*. Grasses can compete successfully with *L. vulgaris* (Carder 1963, Alberta Agriculture 1988, Nadeau et al. 1991 all in Saner et al. 1995).

Burning before flower production can prevent seed production for that year but, like mowing, burning will not kill seeds in the seedbank or roots, which can germinate and resprout (DiTomaso and Healy 2007). If plants are burned, further management of the site will be needed to prevent *L. vulgaris* and/or other weeds from invading burned areas, so for that reason burning is generally not recommended for *L. vulgaris* control (DiTomaso et al. 2013).

Biological Control: (information from the WSU Integrated Weed Control Project)
There are approved biological control agents for *Linaria vulgaris* available in Washington. Make sure use of other *L. vulgaris* management methods does not interfere with the effectiveness of biological control agents on sites. The toadflax flower-feeding beetle, *Brachypterolus pulcarius*, attacks both yellow toadflax and Dalmatian toadflax (*Linaria dalmatica* ssp. *dalmatica*). Larvae and adults damage plants by feeding on reproductive structures and young stems, respectively.

The yellow toadflax stem weevil, *Mecinus janthinus*, larvae and adults feed on *L. vulgaris*, though its establishment in Washington is unknown. This weevil's larvae feed (or mine) the stems, damaging the plant's ability to transport nutrients, while the adults feed on leaves and stems and can suppress flower development. There is also the toadflax seed capsule weevil, *Rhinus antirrhini* (formerly *Gymnetron*), a weevil that is typically already common where *Linaria vulgaris* occurs. Larvae of *Rhinus antirrhini* feed on immature seeds, and adults may impact growth of plants by feeding on flowers and young shoots.

Response to Herbicides:
Please refer to The Pacific Northwest Weed Management Handbook for a thorough list and information on timing, herbicides and herbicide rates to use for *Linaria vulgaris* control http://pnwhandbooks.org/weed/other-items/control-problem-weeds/toadflax-dalmatian-linaria-dalmatica-and-yellow-l-vulgaris. Spot and broadcast treatment using glyphosate, a non-selective herbicide, can also be used on rapidly growing plants in early spring to provide control (DiTomaso et al. 2013). Repeated applications of glyphosate may be needed to control *L. vulgaris* (DiTomaso et al. 2013).

In general, use herbicide control in combination with other control methods to reduce usage when possible. If using a foliar spray, treat plants when pollinators are not present or are the least active.

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