

ELEMENT STEWARDSHIP ABSTRACT

for

Linaria genistifolia (L.) P. Miller ssp. *dalmatica* (L.) Maire & Petitmengin
(Synonym: *Linaria dalmatica* (L.) P. Miller)

AND

Linaria vulgaris P. Miller

Dalmatian toadflax, Broad-leaved toadflax

AND

Yellow toadflax, Butter and eggs, Wild snapdragon, Common toadflax

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SPECIES CODES

PDSCR110F1 (*Linaria genistifolia* ssp *dalmatica*)

AND

PDSCR110E0 (*Linaria vulgaris*)

SCIENTIFIC NAMES

Linaria genistifolia (L.) P. Miller ssp. *dalmatica* (L.) Maire & Petitmengin

Synonym: *Linaria dalmatica* (L.) P. Miller

AND

Linaria vulgaris P. Miller

COMMON NAMES

Dalmatian toadflax, Broad-leaved toadflax

AND

Yellow toadflax, Butter and eggs, Wild snapdragon, Common toadflax

The genus name *Linaria* is derived from the Latin word *linon* or *linum* which means flax. The specific name *genistifolia* refers to the leaves which resemble those in the genus *Genista* in the Fabaceae (legume family), and the specific name *dalmatica* refers to Dalmatia in eastern Europe where the plant is a native. The specific epithet name *vulgaris* means ordinary or common place.

DESCRIPTION AND DIAGNOSTIC CHARACTERISTICS

Linaria genistifolia ssp. *dalmatica* and *Linaria vulgaris* are perennial herbs of the figwort family (Scrophulariaceae). Both species are classified as weeds in Europe, Russia, Canada, and the United States, and are common throughout North America. The name “toadflax” will be used when referring to both species in this ESA.

A toadflax plant contains from 1-25 vertical, floral stems. These floral stems have thick-walled, woody xylem and supporting fibers. Flowers are bright yellow and resemble snapdragons. The tap root may penetrate one meter into the soil. Horizontal roots may grow to be several meters long, and can develop adventitious buds that may form independent plants.

Linaria genistifolia* ssp. *dalmatica

Linaria genistifolia ssp. *dalmatica* is most common in the western United States and has a tolerance to low temperatures and coarse soils. The worst-infested states are California, Idaho, Montana, Oregon, Washington, and Wyoming. Dalmatian toadflax is listed as a noxious weed in Colorado, Arizona, and New Mexico.

Mature dalmatian toadflax plants grow to be between 0.8 to 1.5 m tall. Leaves are broad, 2-5 cm long, ovate to ovate-lanceolate, 1-2.5 cm long and are alternate, generally clasping but crowded.

Flowers are born in loose, elongate, terminal racemes. The pedicels are 2-4 mm long when the flowers are mature and releasing pollen. The calyx is 5-7.5 mm long, the segments subequal, broadly lanceolate to ovate, sharply acute, and rigid. The corolla is strongly two-lipped and 14-24 mm long, excluding the 9-17 mm spur. The upper lip is 10-15 mm long. The lower lip is 5-11 mm long with a well-developed palate closing off the throat. The palate is densely white to orange bearded. Flowers are bright yellow. *Linaria genistifolia* ssp. *dalmatica* typically flowers from May to August.

Linaria genistifolia ssp. *dalmatica* produces egg-shaped to nearly round capsulate fruits 4-10 mm long by 4-8 mm wide. Seeds are sharply angular, slightly winged, and 1-2 mm long. A mature plant can produce up to 500,000 seeds annually, and they can remain dormant for up to ten years. Dalmatian toadflax produces seed from July to October.

Linaria vulgaris

Linaria vulgaris is common in eastern North America but can be found in many areas of the west. The worst-infested western states are Idaho, Montana, Oregon, and Washington. *Linaria vulgaris* is listed as a noxious weed in Arizona and New Mexico.

Yellow toadflax is smaller than dalmatian toadflax and grows to be 0.2 to 0.8 meters tall. Yellow toadflax leaves are soft, linear or linear lanceolate, sessile, and pale green. They are generally 2.5 cm long by 2-4 mm wide (Morishita 1991).

The flowers of *Linaria vulgaris* are similar to those of *Linaria genistifolia* ssp. *dalmatica*. Yellow toadflax flowers from May to August.

Yellow toadflax seeds are flattened, winged and 1-2 mm long. A mature plant can produce up to 30,000 seeds annually. A single stem has been reported to contain over 5,000 seeds (Saner *et al.* 1995). *Linaria vulgaris* produces seed from July to October.

STEWARDSHIP SUMMARY

Both *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* rapidly colonize open sites. They are most commonly found along roadsides, fences, range lands, croplands, clear cuts, and pastures. Disturbed or cultivated ground is a prime candidate for colonization. Toadflax can significantly reduce crop yields and stress native communities. In one study, toadflax-free plots produced 2.5 times more grass than plots where toadflax was present (Robocker 1974). In Alberta, yellow toadflax densities of over 180 stems/m² reduced the seed yields of some forage crops by 33% (Saner *et al.* 1995).

The seedlings of toadflax are considered ineffective competitors for soil moisture with established perennials and winter annuals (Morishita 1991). However, once established both species of toadflax suppress other vegetation mainly by intense competition for limited soil water. Mature plants are particularly competitive with winter annuals and shallow-rooted perennials (Robocker 1974).

Successful control can be obtained by pulling, or killing the plants with herbicide, before toadflax seed production begins. Since the plant also spreads through vegetative propagation, and the seeds can remain dormant for up to ten years, this process must be repeated every year for at least ten years to completely remove a stand. Competitive perennial grasses and forbs should be planted to utilize water and nutrients that would otherwise be readily available to toadflax.

IMPACTS (THREATS POSED BY THIS SPECIES)

Both species are persistent, aggressive invaders and capable of forming colonies through adventitious buds from creeping root systems. These colonies can push out native grasses and other perennials, thereby altering the species composition of natural communities. In North America, both species of toadflax are considered strong competitors. They are quick to colonize open sites, and are capable of adapting growth to a wide range of environmental conditions (4)¹. *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* are listed as weeds in North America, and are on noxious weed lists of several states and Canadian provinces.

Low-till cultivation practices have contributed to the resurgence of toadflax populations on agricultural lands (McClay 1992). By not tilling the soil, and subsequently damaging the root system of toadflax plants, toadflax colonies have been able to flourish. Intensive clean cultivation techniques are recommended for successful toadflax control on agricultural land. This requires at least two years with 8-10 cultivations in the first year and 4-5 cultivations in the second year (Morishita 1991).

GLOBAL RANGE

Linaria genistifolia* ssp. *dalmatica

Dalmatian toadflax is a native of the Mediterranean region from the coast of Croatia northeastward to Transylvania and Moldavia in northern Romania, southward and eastward around the Black Sea in the countries of Bulgaria, Albania, Greece, Crete, Turkey, Syria, Iran, and Iraq (Alex 1962). It generally grows in open, sunny places, from sea level up to 2,800 meters (roughly 9,200 feet). *Linaria genistifolia* ssp. *dalmatica* was first reported in North America in 1894 by T. D. Hatfield. He was a gardener in Massachusetts who was growing it as a perennial herbaceous ornamental (Alex 1962).

Linaria vulgaris

Yellow toadflax is a native of southeastern Europe and southwestern Asia. The present world distribution includes most of Europe and Asia, and it has been introduced to Japan, Australia, New Zealand, South Africa, Jamaica, Chile and North America. In North America, yellow toadflax is found throughout the continental United States and in every Canadian province and territory (Saner *et al.* 1995).

¹ Internet references that don't list the authors are numbered and can be located under the section titled INTERNET REFERENCES (UNKNOWN AUTHORS) at the end of this document.

Linaria vulgaris is recorded as first being introduced to America from Wales as a garden ornamental by a Welsh Quaker who came to Delaware with William Penn. It flourished and was cultivated at other colonial gardens where it spread into the wild (Mitich 1993).

HABITAT

In North America, *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* primarily occur on sandy or gravelly soil on roadsides, railroads, pastures, cultivated fields, range lands, and clear cuts (Saner *et al.* 1995). Both species of toadflax can adapt their growth to fit a range of habitats, and have a tolerance for low temperatures and coarse textured soils. They have a northern limit of 55° to 65° latitude.

Linaria genistifolia ssp. *dalmatica* is most common in the western United States while *Linaria vulgaris* is common throughout eastern North America, but is also found in areas of the west. In northeastern Washington, *Linaria genistifolia* ssp. *dalmatica* is spread throughout open, low-elevation, coniferous forests and adjacent shrub-steppe. In the province of Alberta, a 1987 survey estimated an infestation of *Linaria vulgaris* of 28,000 hectares (Saner *et al.* 1995). In Colorado, *Linaria genistifolia* ssp. *dalmatica* is commonly found between 1,524 to 1,981 meters (5,000 to 6,500 feet) in oak, aspen, sagebrush, mountain brush, and riparian communities. *Linaria vulgaris* is typically found from 1,829 to 2,591 meters (6,000 to 8,500 feet) on the western slope, but can also be found on the eastern slope of the state (4). In New England, *Linaria vulgaris* is occasionally a serious weed problem that leads to the premature abandonment of fields (Saner *et al.* 1995).

BIOLOGY-ECOLOGY

Both *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* are considered strong competitors in North America. Both species reproduce by seed and vegetative propagation. Once established, high seed production and the ability for vegetative reproduction allow for rapid spread and high persistence (Saner *et al.* 1995).

Both *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* are self-incompatible, and rely upon insects for pollination. The two most important pollinators are bumble bees and halictid bees (Zimmerman 1996). Spring emergence occurs about mid-April and depends primarily on temperature. The stems of seedling plants seldom exceed 40 cm. First leaves are 1 cm long. Prostrate stems emerge in September and produce leaves that are ovate, 3.8 cm by 2.2 cm in size. Prostrate stems are tolerant to freezing and are associated with floral stem production the following year (Robocker 1974).

The strong upright floral stems that characterize mature toadflax plants develop after a winter's dormancy, and emerge about the same time as new seedlings in mid-April. A single plant will produce from 1-25 floral stems. The ultimate survival of the stand, and probability of re-establishment, depends heavily on the number of floral stems and their seed production (Robocker 1974). Flowering occurs from May-August and seeds mature from July-September. A mature dalmatian toadflax can produce up to 500,000 seeds annually

(Morishita 1991). A large yellow toadflax can produce up to 30,000 seeds annually (Saner *et al.* 1995).

Both species can reproduce vegetatively. Stems develop from adventitious buds on primary and lateral roots. Vegetative reproduction from root buds can occur as early as 2-3 weeks after germination, and is possible from root fragments as short as 1 cm in length (Zimmerman 1996). These buds can grow their own root and shoot systems, and become independent plants the next year. Vegetative propagation can allow a stand of toadflax to spread rapidly. In one study, a stand of *L. vulgaris* increased by 418% in a single season, and a patch that was originally one acre in size expanded to cover 85 acres in a five-year period (Zimmerman 1996).

In addition to promoting growth, the large, deep, root systems of *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* exploit water efficiently. The tap root may penetrate 1 meter into the soil and lateral roots may be several meters long. The deep root system prevents grazing and shallow cultivation methods from dislodging or destroying plants (Saner *et al.* 1995).

Yellow toadflax contains a poisonous glucoside that is reported to be mildly poisonous to livestock (Morishita 1991). However, both species are considered unpalatable and reports of livestock poisonings are rare.

Linaria genistifolia ssp. *dalmatica* and *Linaria vulgaris* have relatively short lifespans. Individual plants live up to five years with an average lifespan of 3.8 years (Robocker 1974). The life span of toadflax stands is dependent on environmental conditions and the reproductive success of individual plants. The relatively short lifespan of toadflax plants bodes well for controlling these species.

RECOVERY POTENTIAL

The recovery potential of areas that have been cleared of toadflax is very high. The Magnusson Butte Preserve in Washington experienced increases in native and non-native annual grasses, forbs, and residual native perennial forbs following the removal of toadflax stands (Cornelius 1995). Communities that are in good condition may recover without replanting of desirable species as long as follow-up control visits are conducted annually. However, replanting competitive native grasses and forbs can help accelerate recovery of the area.

MONITORING REQUIREMENTS AND PROCEDURES

Monitoring should be conducted in early June when toadflax plants have formed buds and are beginning to flower. Any management program should also be conducted during the month of June. This is when root carbohydrate reserves are at their lowest, which makes it more difficult for the root system to recover. Follow-up work in late June or early July is recommended to locate and remove any late-flowering plants.

MANAGEMENT PROGRAMS

The key to managing *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* is to: 1) eliminate or greatly reduce seed production from established individuals (by cutting or pulling seed stalks prior to seed set, or by using insects to destroy flowers, seeds, or damage plants sufficiently so that no or few seeds are produced); and 2) destroy toadflax seedlings that arise from the soil seed bank before these plants become established (as above, plus herbicide).

Several insect species have been introduced as biological control agents for both toadflax species but none of them completely eliminate infestations. Also, the diverse geographic range of toadflax throughout North America makes it unlikely any one species of insect will be effective everywhere. Herbicide treatment, if applied at the right time, can significantly reduce toadflax seed production. Cutting, mowing, and discing of toadflax plants can be effective on agricultural lands if repeated annually.

A decade-long hand pulling experiment at the Magnusson Butte Preserve, in Washington, demonstrated how effective pulling could be. The experiment was first conducted in a 5 by 5 meter test plot, but was soon expanded over the whole 28 acre preserve. During the first week of June, a team of about 30 volunteers walked the preserve pulling all toadflax plants they found. The first week of June was an ideal time as the flowers were just beginning to appear, making the plants easier to locate. Also, the soil was still damp, which allowed for easy pulling without significant soil disturbance. At first, the stems were removed in bags to avoid a mulching effect on desirable native plants, but in later years when there were fewer plants they were simply dropped in place with no ill effect. A follow-up visit was conducted during the last week in June to remove any late-flowering plants that might have been missed. Teams were able to reduce the number of flowering stems each year by an estimated 90-95% preserve-wide. In the third year, it was noticed that flowering stems were not only reduced in number, but were significantly smaller in size and lower in vigor. The test plot also experienced an increase in native and non-native grasses and perennial forbs (Cornelius 1995).

This experiment in non-chemical control had some unforeseen benefits. The pulling program turned into a great community outreach program in that area. It allowed for new volunteers to become familiar with, and take an interest in, the Magnusson Butte Preserve.

BIOLOGICAL CONTROL

Five insects species have been approved by the USDA-APHIS-PPQ for release as biological control agents for *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris*. Anecdotal evidence to date suggests these insects have not been highly effective in controlling toadflax. A permit must be obtained from the USDA, Animal and Plant Health Inspection Service (APHIS) before you can transport these agents between states. Information on how to obtain a permit can be found at the bottom of this section under *Obtaining permits for field*

releases. Additionally, authorities that can be contacted for more information about each species are listed at the end of each section.

Brachyterolus pulicarius

Brachyterolus pulicarius is a shoot and flower-feeding beetle that was accidentally introduced from Europe. *B. pulicarius* is considered a biological agent for both *Linaria vulgaris* and *Linaria genistifolia* ssp. *dalmatica*. Adults emerge in May and feed on young toadflax stems and shoot tips. They mate in early June and the females lay eggs in the flower buds. The young larvae feed primarily on the anthers and ovaries in the buds and flowers, and the older larvae feed on maturing seeds (Harris 1961). An experiment using *B. pulicarius* indicated the beetle has no effect on root or shoot biomass of attacked plants. However, it delayed the onset of flowering of *Linaria vulgaris* for 27 days. The most significant effect was that total seed production was reduced by 74% on attacked plants (McClay 1992). *B. pulicarius* is currently found in most toadflax stands in Alberta and southern Saskatchewan. It contributed to a decline in the spread of *Linaria vulgaris* in Canada in the 1960's (McClay 1992).

Authorities for *B. pulicarius*

Eric M. Coombs, Oregon Department of Agriculture, 635 Capitol St. NE, Salem, OR 97310

Robert M. Nowierski, Department of Entomology, 413 Leon Johnson Hall, Montana State University, Bozeman, MT 59717

Gary L. Piper, Department of Entomology, Washington State University, Pullman, WA 99164-6382

Calophasia lunula

Calophasia lunula is a defoliating moth that is native of Eurasia and was introduced into the United States in 1968 to control both species of toadflax. In Canada, the moth defoliated up to 20% of the toadflax stems where it was established. Multiple releases of *C. lunula* were made in Colorado, Arizona, Montana, Oregon, Washington, and Wyoming, but no establishment of the moth was recorded on either toadflax species until 1989 (McDermott 1990). In 1989, *C. lunula* larvae were found on dalmatian toadflax plants just outside of Missoula, Montana. Since 1989, *C. lunula* has been established in three other sites in Montana, two sites in Idaho, and has become widely distributed throughout northeastern Washington (Rees *et al.* 1996). Studies show *C. lunula* is adversely affected by cold-temperatures, and this might be linked to its failure to establish in other states, and at higher altitudes (McClay and Hughes 1995). However, recent establishment success has renewed hopes that *Calophasia lunula* may become a significant biological control of toadflax in the United States.

Authorities for *C. lunula*

Robert M. Nowierski, Department of Entomology, 413 Leon Johnson Hall, Montana State University, Bozeman, MT 59717

Gary L. Piper, Department of Entomology, Washington State University, Pullman, WA
99164-6382

Jim S. Story, Western Agricultural Research Center, 580 NE Quest Lane, Corvallis, MT
59828

Eteobalea serratella* and *Eteobalea intermediella

E. serratella and *E. intermediella* are small root-boring moths native to the Mediterranean region and central Europe. Eggs are deposited in the leaf axils, or at the base of the stem. Larval mining occurs in the root crown area and causes substantial damage to the root system (Rees *et al.* 1996). Attacked plants had a shorter flowering season and produced seeds of lower weight. However, reduced seed weight of *Linaria vulgaris* has not been correlated with lower germination rates and root mining had no effect on plant survival (Saner and Muller-Scharer 1994). Continued root mining in the winter resulted in a doubling of stem production the following spring, but the total plant biomass remained the same (Saner and Muller-Scharer 1994).

Authority for *E. serratella* and *E. intermediella*

Robert M. Nowierski, Department of Entomology, 413 Leon Johnson Hall, Montana State University, Bozeman, MT 59717

Gymnaetron antirrhini

Gymnaetron antirrhini is a seed-eating weevil native to Eurasia. It was accidentally introduced into the United States and is now established in Idaho, Montana, Oregon, Washington, and Wyoming. *G. antirrhini* attacks yellow toadflax and one strain has adapted to dalmatian toadflax (Rees *et al.* 1996). Adults emerge in May to feed on young toadflax stems. They mate in June and the females lay eggs in the ovaries of the flowers. The larvae feed on immature seeds in the seed capsules. The mature larvae construct oval cells within the seed capsules where pupation occurs. *G. antirrhini* can reduce seed production in yellow toadflax by 85-90% (Rees *et al.* 1996).

Authorities for *G. antirrhini*

Eric M. Coombs, Oregon Department of Agriculture, 635 Capitol St. NE, Salem, OR 97310

Robert M. Nowierski, Department of Entomology, 413 Leon Johnson Hall, Montana State University, Bozeman, MT 59717

Gary L. Piper, Department of Entomology, Washington State University, Pullman, WA
99164-6382

Obtaining permits for field releases

To introduce one of the biological control agents described above into your state, you must first obtain a permit from the USDA-APHIS-PPQ. To obtain a permit you must complete a form PPQ-526, "Application and Permit to Move Live Plant Pests or Noxious Weeds", and

send the application to the Department of Agriculture in the state where the release is to be made. The form must be signed and sent for processing to the USDA-APHIS-PPQ office, Biological Assessment and Taxonomic Support (BATS), 4700 River Road, Unit 113, Riverdale, MD 20737. When this is signed by PPQ, a copy will be returned to the applicant as an approval record.

To find the phone number and address of the APHIS-PPQ State Plant Health Office in your state check on-line at: (<http://www.aphis.usda.gov/oa/ppqoffice.html>). For more information about the permit process, to download forms, check the status of your permit, or to search the Code of Federal Regulations, you can browse the APHIS-PPQ home page at: (<http://www.aphis.usda.gov/ppq/bats/permits/>). Finally, an expedite list of all insects, mites, and nematodes that require APHIS permits can be found on-line at: (<http://www.aphis.usda.gov/ppq/bats/weedagen.htm>).

TNC policy as of Spring 1998 requires that you receive prior authorization from the Home Office Director of Conservation Science for intentional release of any non-native biological control agents on a TNC preserve (see TNC Policies and Procedures manuals for details).

BURNING

Burning is not a recommended control method for *Linaria genistifolia* ssp. *dalmatica* and *Linaria vulgaris* (Saner *et al.* 1995). The large, deep, root systems of both species protect them from burning. In fact, areas that have been recently disturbed by fire are susceptible to increased toadflax infestation.

CHEMICAL

Permanent, long-term control cannot be achieved with herbicide treatment alone (Saner *et al.* 1995). Herbicides should be applied during flowering when carbohydrate reserves in the root of the plants are at their lowest. At the latest, herbicide treatment should be applied before seed dispersal, if it is to be effective.

The herbicides glyphosate, dicamba and picloram are considered effective for controlling toadflax. A six-year study found that phenoxypropionic herbicides such as diclorprop were more effective at controlling toadflax than phenoxyacetic herbicides such as 2,4-D (Robocker 1968). 2,4-D, MCPA, MCPB, and mecoprop do not control toadflax.

Picloram

Trade name(s): Tordon

Picloram applied at the rate of 2.25 kg/ha was considered an effective control of toadflax during a two-year test (Morishita 1991). Bending and twisting of leaves and stems is evident almost immediately after application.

Picloram is an auxin-type herbicide that causes disorganized plant growth when applied. Auxin-type herbicides are used for control of annual, perennial, and creeping perennial broad-leaved plants. All auxin-type herbicides are organic acids which take on a negative charge after ionization of acids and salts (Ross and Childs 1998). Picloram does not bind to soil and may leach to groundwater. Its average half-life in soil is 90 days, with a range of 20 - 330 days (Ahrens 1994). Its half-life in water is 2.3 - 41.3 days (6). Dissipation is relatively slow under the cool, dry conditions prevalent in much of the northwestern U. S. Picloram is not expected to bio-concentrate in aquatic organisms.

In humans, the EPA found that acute exposures to picloram could cause weakness, diarrhea, weight loss, and central nervous system damage. Long-term exposure above safe drinking water levels has the potential to cause liver damage (6).

Although picloram is effective at managing toadflax, it is a relatively non-selective compound, and has been observed to have a residual effect on other perennial broad-leaved plants. Damage to non-target vegetation is a major problem associated with all auxin-type herbicides (Ross and Childs 1998).

Dicamba

Trade name(s): Banvel, Clarity, Vanquish, Veteran

Dicamba applied at concentrations of 2.25 kg/ha was considered effective at controlling toadflax (Morishita 1991). Dicamba controls annual and perennial broad-leaved weeds in grain crops, grasslands, pastures, and range land.

Like picloram, dicamba is also an auxin-type herbicide, and has the same side effects. It is a relatively non-selective compound and can have a residual effect on non-target broad-leaved plants.

Dicamba does not bind to soil and may leach into groundwater. Its half-life in soil can vary from 4-555 days (2). Its potential to persist for long periods limits its use in natural areas. In water, dicamba does not bio-concentrate in organisms, and is broken down mainly by microbial degradation. When used according to instructions, dicamba poses little threat to wildlife (2). Dicamba is considered only slightly toxic to birds, and is of low toxicity to fish and aquatic organisms. Dicamba is not toxic to bees.

In humans, acute exposure to dicamba is moderately toxic by ingestion and slightly toxic by inhalation or dermal exposure. Symptoms of poisoning with dicamba include loss of appetite, vomiting, muscle weakness, slowed heart rate, shortness of breath, central nervous system effects, and exhaustion following repeated muscle spasms (2).

Glyphosate

Trade name(s): Roundup, Rodeo, Accord

Glyphosate has been used in Canada to control toadflax in crops, and is also recommended for spot treatments. Glyphosate applied at early bloom at 1, 2, and 4 kg per hectare provided 40, 70, and 90% control that season (Saner *et al.* 1995). However, abundant regrowth from the root systems occurred the following year.

Glyphosate inhibits production of the aromatic acids tryptophan, tyrosine and phenylalanine which are all needed for protein synthesis and other biosynthetic pathways. It is a relatively non-selective compound used to control broad-leaved weeds and grasses. Glyphosate will kill or damage non-target plants but this can be minimized by applying it directly to the leaves of toadflax or other targeted plants. Uses are limited to foliar applications since it is rapidly inactivated in the soil (Ross and Childs 1998).

Glyphosate biodegrades in soil and has a half-life of 47 days, according to Ahrens (1994). It has been stated that because glyphosate strongly adsorbs to clay particles, crops can be planted immediately after it has been applied. Greenhouse studies by Ahearn-Myerson *et al.* (1997), however, showed glyphosate may persist in an active form in soils for as long as 79 days. This contrasts with technical information on glyphosate which indicates it degrades rapidly due to normal soil microbial activity, and that it is not active once it contacts the soil or muddy water because it complexes with clay particles. Ahearn-Myerson *et al.* have not yet duplicated their study in the field but based on their greenhouse studies, they recommend that restorationists and others who use glyphosate should not re-plant treated areas until several weeks past the interval suggested by the manufacturer. Glyphosate's half-life in water is a few days, and it is not expected to bio-concentrate in aquatic organisms (5).

In humans, acute exposure to glyphosate can cause lung congestion and an increased breathing rate. Long-term exposure to glyphosate above safe levels has the potential to cause kidney damage, and effects on the reproductive system (5).

Additional information on herbicides

More information on chemical control of toadflax can be obtained from the Weed Management Library at 1-800 554-WEED, or from your State Weed Specialist.

- Arizona:** Everett Hall, Arizona Department of Agriculture, (602) 542-3309
California: Nate Dechoretz or Ross O'Connell, California Department of Agriculture Integrative Pest Management, (916) 654-0768
Colorado: Dr. George Beck, Colorado State University, (970) 491-7568
Idaho: Dr. Bob Callahan, University of Idaho, (208) 885-6617
Montana: Roger Sheley, Montana Department of Agriculture Extension Services, (406) 994-5686
New Mexico: Dr. Richard Lee, New Mexico State University, (505) 646-2888
Oregon: Tim Butler, Oregon Department of Agriculture Noxious Weed Control Program, (503) 986-4625
Utah: Dr. Steve Dewey, Utah State University, (801) 750-2256
Washington: Greg Haubrich, Washington Department of Agriculture, (509) 576-3039
Wyoming: Dr. Tom Whitson, University of Wyoming, (307) 766-3113

CUTTING, MOWING and DISCING

Cutting or removal of the above ground portion of toadflax plants reduces the current year growth, but it will not kill them. Cutting toadflax stands in spring or early summer is an effective way to eliminate plant reproduction through seed production and dispersal. However, the long dormancy of toadflax seeds requires that the process be repeated annually for up to ten years.

Mowing might be even less effective on toadflax compared to cutting since it cuts the plants several cm above the soil surface which may allow them to resprout more rapidly. For example bull thistle plants (*Cirsium vulgare*) cut at the soil surface did not recover but a high percentage of plants cut 5-10 cm above the soil surface resprouted (Randall pers. comm.). In addition, damage to surrounding plants and species should be evaluated before mowing is used.

Discing can be an effective method of toadflax control on agricultural lands. Successful control can be obtained by using intensive clean cultivation. This method requires at least two years with eight to ten cultivations in the first year, and four to five cultivations the second year (Morishita 1991).

GRAZING

Grazing does not control either species of toadflax. Toadflax is considered unpalatable, and yellow toadflax contains a glucoside that is mildly poisonous to livestock. Additionally, ground disturbance created by intensive grazing actually creates ideal habitat for toadflax infestation. Effective grazing management is necessary to reduce toadflax in pastures and range lands.

MANIPULATION OF WATER LEVEL AND SALINITY

No studies were found indicating that manipulating water levels or soil salinity to control toadflax have been tested.

PULLING

Hand pulling toadflax before seed set each year can be an effective control method. The hand pulling experiment on the Magnusson Butte Preserve in Washington showed that toadflax can be significantly reduced by pulling once a year as long as new seed is eliminated. Once again, this method must be repeated annually for up to ten years to completely remove a stand.

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EDITION:

March 25, 1998 (25 03 98)

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EDITED BY:

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