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Ecology and Management of Leafy Spurge (*Euphorbia esula* L.)

Abstract

Leafy spurge is a long-lived, deep rooted perennial forb adapted to many habitat types from riparian to dry hillsides. It has invaded over 2.5 million acres of land in the western United States and Canada. Vegetative re-growth from buds on spreading roots and rhizomes enable leafy spurge to form dense colonies that reduce forage production and native plant abundance and diversity. The milky latex in the sap of all parts of leafy spurge is a skin irritant, can cause blistering, and is poisonous to some animals. Leafy spurge is one of four state-listed noxious weeds reported from every county in Montana (see Figure 1). Direct and indirect annual economic losses attributed to leafy spurge in Montana, North Dakota, South Dakota and Wyoming combined were estimated to be greater than $130 million.

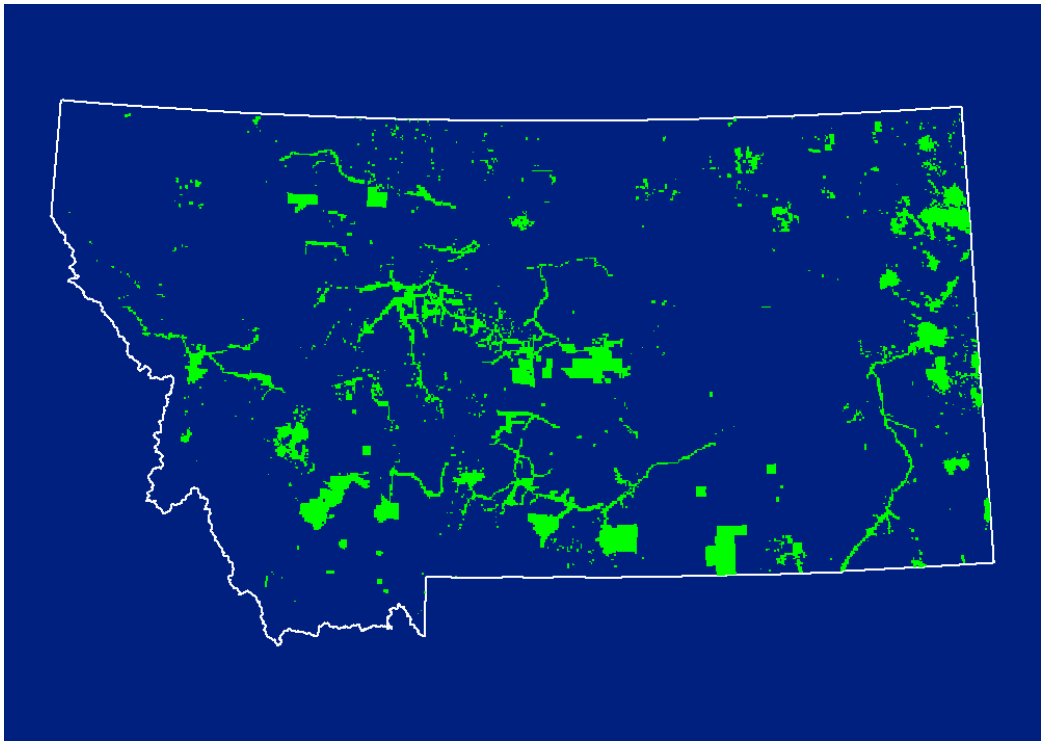

Figure 1. Leafy spurge infestation (green) reported in Montana in 2001. Each green dot on the map represents one section reporting leafy spurge. Permission to use this map was granted from Diana Cooksey, Adjunct Instructor, MSU-LRES and Coordinator of Montana Agricultural Potential System (MAPS). Additional information about section based maps can be found at: http://www.montana.edu/places/mtweeds/databasedev.html.

The extensive reproductive root system of leafy spurge enables it to regenerate after all control applications. Deep roots not attacked by biological control insects can send up new shoots. Twelve insect species have been approved for release in the United States as biological control agents for leafy spurge. Of these, six species of the *Aphthona* flea beetle feed in the roots

(larvae) and leaves (adults) and have been observed to reduce population densities in some areas. Other species include root, stem, leaf, and flower feeding insects. Sheep and goats will select leafy spurge over other forages once they are trained to eat it and have been used to reduce infestation density and prevent spread. Herbicides are not trans-located in the roots much beyond the top 20 inches in the soil leaving the remainder of the root system unaffected. Therefore, herbicidal control requires high application rates and repeated applications. Studies have shown that picloram (one quart/acre) combined in solution with 2,4-D (one quart/acre) applied at bloom or in the fall, or imazapic (8 to 12 ounces/acre) applied in the fall reduced leafy spurge by up to 90 percent after two consecutive years of treatment. The longevity of control will depend on site conditions, competitive plants, and grazing management. Cultural controls (tilling, mowing, and burning) when applied alone are ineffective in controlling leafy spurge, but may improve the effectiveness of herbicidal, biological, and grazing control when used in an integrated management program.

Plant Biology and Identification

Leafy spurge is a long-lived perennial that reproduces both by seed and underground adventitious buds on the root and root crown. Each flowering stem can produce between 30 and 130 seeds, and seed production per acre ranges from 25 to 4,000 pounds depending on density and site productivity. Seeds can remain viable in the soil for eight years or more, however most germinate in the first two years after production. Seed dormancy can be broken at any time and germination can occur in a wide range of temperatures. Seeds normally emerge from the top two inches of soil but can emerge when buried four inches deep. Peak seedling emergence is in late May and early June. Most seedlings do not produce flowers during their first year of growth; however shortly after emerging, seedlings can produce roots with vegetative buds capable of regenerating shoots rapidly if the seedling is injured.

Perennial propagation of leafy spurge is through the growth of buds on roots that can be found from the root crown to ten feet below the soil surface. Shoots that propagate from buried buds usually emerge in late April. Dormancy of buds can be broken at any time during the growing season if shoots are damaged or separated from the roots, and in the fall. Roots are dark brown, have a thick corky bark and the buds are pink (see Figure 2).

Figure 2. Leafy spurge root crown, tap root and rhizomes with reproductive buds.

Leafy spurge produces vegetative and flowering stems that grow to three feet tall. Both are hairless with pale green or blue-green leaves that are long (up to four inches), narrow, linear in shape, without serrations, and arranged alternately along the stem (see Figure 3). The stems and leaves exude a white, thick, milky latex when damaged.

Figure 3. Leafy spurge vegetative stem showing the linear-shaped leaves and milky sap where stem tip was broken off.

The flowers are clustered above yellow to yellow green bracts. The true flowers are green and inconspicuous with one seed-, and three pollen flowers per involucre. The flowers have no petals or sepals but have bracts below the flowers giving leafy spurge its showy yellow color (see Figure 4). The bracts develop in May or early June and the flowers develop two weeks later, usually in mid-June. This is an important consideration for timing of herbicide application. Flowering is completed (seed-set) by mid-July and seeds develop in capsules 20 to 30 days later. When dry, the capsules shatter dispersing the seeds away from the parent plant.

Figure 4. Leafy spurge flowering stem with showy bracts below inconspicuous flowers.

In late summer when soil moisture is depleted, leafy spurge becomes dormant and the stems dry to light brown or tan "canes." Vegetative stem growth resumes in the fall and continues until a hard frost kills the stems.

MANAGEMENT ALTERNATIVES

Biological

Biological control insects can provide sustained leafy spurge suppression where they establish in large numbers. However, insects do not establish in numbers that affect leafy spurge in all locations. Establishment can be affected by soil texture, moisture regime, plant productivity, the nutrient content in leafy spurge roots, and the timing of insect release.

Of the 12 insect species listed in Table 1, the *Aphthona* flea beetles have the most widespread establishment and reduction of leafy spurge in Montana. Flea beetle adults feed on leafy spurge leaves and can strip stems of leaves reducing photosynthetic sugar production used for root reserves and seed production. The larvae feed on the young roots and root hairs reducing the

uptake of nutrients and water, and providing entry points for soil-inhabiting pathogens. Where flea beetles establish in large numbers, reductions in leafy spurge density and production, and increases in the abundance and production of desirable grasses and forbs can be expected in three to five years. Of the six species, only *Aphthona abdominalis* is currently not established in Montana and is not available in the United States.

The different species of flea beetles have different optimum environmental conditions; however they all survive very cold, sub-freezing winter temperatures. *Aphthona nigriscutis* (see Figure 5) is best suited to dry sites with maximum solar exposure, flowering spurge stems less than 30 inches (70 cm) tall, fewer than 60 stems/yd^2, and well-drained soils with less than 3 percent organic matter. *Aphthona czwalinae* does not establish well in clay or acidic soils or in deeply shaded areas. Research in Canada indicates that ideal conditions for establishment of *A. cyparissiae* are where flowering stems are taller than 20 inches (51 cm), between 50 and 121 stems/yd^2, soils are between 40 to 60 percent sand, and that green needle grass (*Nasella viridula*) can be used as an indicator of suitable habitat. *Aphthona lacertosa* does well on both wet and dry sites, but appears to do best on open, sunny, mesic to moderately-dry sites. *Aphthona cyparissiae* and *A. flava* are brown and difficult to distinguish from each other, whereas *A. czwalinae and A. lacertosa* are black and similar in appearance. *Aphthona nigriscutis* adults are yellowish-brown with a black dot on the back behind the thorax at the leading edge of the wings.

Figure 4. An adult *Aphthona nirgriscutis* flea beetle.

The larvae of flea beetles develop in the soil, and cool soils may retard development and establishment of flea beetles. Reducing the leafy spurge canopy in dense infestations using herbicides, grazing, or mowing has been observed to improve flea beetle establishment. Ants are predators on flea beetles and releases should be made in areas free of ant mounds.

Aphthona flea beetles attack many species in the genus *Euphorbia* and they will attack species other than leafy spurge in the United States. *Aphthona nigriscutis* has been observed to feed on the native Rocky Mountain spurge (*Euphorbia robusta*) but no impacts have been determined. No non-target effects have been reported for the other *Aphthona* species.

Oberea erythrocephala is the red-headed leafy spurge stem borer. When adults lay eggs they girdle and often kill leafy spurge stems. The larvae also kill stems when feeding and reduce the plants ability to build root reserves and produce seeds. This insect only attacks specific biotypes

which affects its establishment. Riparian areas and mesic sites with trees are believed to be the best habitat for *Oberea*.

Hyles euphorbiae is commonly called the leafy spurge hawk moth. The destructive stage of this insect is the larvae that have five growth stages lasting two to three weeks, each with their own distinctive and conspicuous color pattern. The caterpillar-like larvae consume the leaves; however it does kill the plant and it may be most effective when released in combination with other insects. Hawk moths do well in dense leafy spurge stands in open areas near trees. Birds, ground squirrels, and other small mammals feed on hawk moth pupae, but the larval skin contains toxins that deter predators.

Spurgia esulae (also called *Bayeria capitigena*) is the leafy spurge tip gall midge. This insect forms a gall at the tip of the leafy spurge stem where the larvae concentrate and where pupation occurs. Feeding by each generation of the insect at the stem growing tip prevents the plant from producing seeds. It does well in dense stands of leafy spurge growing on slopes with southern aspects in cool climates. Currently, there is limited availability of this insect in Montana. Predation by native fly species may reduce *Spurgia* establishment. Once established this species may re-distribute long distances by wind.

Table 1. Biological control insects for management of leafy spurge, 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
Aphthona abdominalis	Flea beetle	Root/foliage	Adult	NA
Aphthona cyparissiae	Flea beetle	Root/foliage	Adults/July	Sweep net
Aphthona czwalinae	Flea beetle	Root/foliage	Adults/mid June-July	Sweep net
Aphthona flava	Flea beetle	Root/foliage	Adults/late June-mid August	Sweep net
Aphthona lacertosa	Flea beetle	Root/foliage	Adults/Summer	Sweep net
Aphthona nigriscutis	Flea beetle	Root/foliage	Adults/July	Sweep net
Chamaesphecia crassicornis	Moth	Root/stem	Eggs	NA
Chamaesphecia hungarica	Moth	Root	Adult/May-June	Roots/Sweep net
Dasineura sp.	fly	flower	Larvae-pupae/collect galls	NA
Hyles euphorbiae	Moth	Leaves/bracts	Larvae/July/September	Hand pick
Oberea erythrocephala	Beetle	Stem/root crown	Adults/June	Sweep net
Spurgia esulae	Fly	Shoot tips	Larvae-pupae/galls	Clipped stem bouquets

Aphthona abdominalis, Chamaesphecia hungarica and *Chamaesphecia crassicornis* were released in Montana in 1993, 1993, and 1994, respectively, but did not establish. *Dasineura* was permitted for release in the United States in 1991 but adults have not been reared in quarantine in the United State because of high rates of parasitism, thus have not been released, and are not currently available for distribution.

Grazing

Sheep and goats will readily graze leafy spurge once they have been trained to eat it. Grazing will stress leafy spurge, reduce root reserves and seed production, and improve the effectiveness of herbicide and biological control. When applied annually, it may reduce leafy spurge stand density and prevent spread. Grazing can be used in areas that are difficult to access and environmentally sensitive areas such as riparian areas where herbicide options are limited. Areas where biological control insect establishment is limited including areas with high water table, flooding, and soils consisting of 80% or more sand may be grazed by sheep or goats to reduce leafy spurge.

When combined with cattle grazing, grazing sheep or goats improves range use efficiency and may result in the ability to increase cattle numbers. Research has shown that cattle grazed with sheep gained 21 percent more weight than cattle grazing alone and sheep gained 12 to 36 percent more than when they grazed alone.

Grazing can begin in the spring when leafy spurge plants are two to six inches tall and can be continued through fall as long as plants are green. Grazing can be continuous during the growing season, or animals can be rotated through pastures. Stocking rates will vary depending on the productivity of the pasture, but generally four sheep or 12 goats per acre can graze a leafy spurge infested cow/calf pasture for one month. Divide the stocking rate by the number of months the sheep or goats are on the pasture if they are left for more than one month (e.g. one sheep and three goats per acre for four months). Pastures should be carefully monitored to prevent over-utilization of beneficial grasses. Sheep or goats that may have consumed seeds while grazing leafy spurge should be contained and fed weed-seed free forage for seven days before being moved to weed-free areas to prevent spread of leafy spurge seed through their feces.

Herbicide Control[1/]

Because of its extensive reproductive root system, herbicidal control of leafy spurge requires careful timing of application and repeated applications. Herbicides used for leafy spurge control include 2,4-D, glyphosate, dicamba, imazapic, and picloram (see Table 2). Herbicidal control of leafy spurge is most economically practical as an eradication strategy on newly established and small infestations.

Picloram applied at one pound per acre (two quarts, the highest rate allowed) during full bloom (two weeks after yellow bracts appear) or in the fall before a killing frost (mid-September) provides 75 percent or greater control of leafy spurge the first year after treatment. Application of this treatment every other year will be needed to maintain this level of control. A tank mix of

[1/] 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.

picloram at 0.25 pound (one pint) plus 2,4-D at one pound (one quart of a four gallon concentrate) per acre applied in June during flowering annually for four years provided 85 percent control of leafy spurge and was the most cost effective herbicide application in North Dakota. A fall application of picloram at 0.5 pounds plus 2,4-D at one pound per acre in the first year, followed by the 0.25 pound per acre rate of picloram plus one pound 2,4-D in June in subsequent years has been used by some managers. Picloram is a restricted use herbicide and cannot be used on porous soils with a groundwater table of ten feet or less, or near streams, ponds or irrigation ditches. On cultivated land, picloram cannot be applied at rates used to control leafy spurge.

Imazapic at 0.125 to 0.188 pounds (8 to 12 ounces) plus one quart methylated seed oil (MSO) per acre applied in mid-September provided 80 to 90 percent control of leafy spurge one year after treatment on test plots. Grass production may be reduced by imazapic but recovery can be expected. June application of imazapic increases grass injury and provides lower control of leafy spurge than the fall application.

Dicamba applied at six to eight pounds (1.5 to 2 gallons) per acre will give good control of leafy spurge one year after treatment. Control decreases rapidly the second year after treatment. A follow-up spring application of 2,4-D at one pound (one quart of a four gallon concentrate) may help reduce re-infestation. On test plots, dicamba at two pounds (two quarts) per acre applied annually in mid-June or early September provided 95 percent control of leafy spurge after three applications. Some herbicide products have a combination of dicamba and 2,4-D that have been effective in short-term management of leafy spurge. The product labels list the active ingredient in the herbicide. Always read the label to determine what is in the product.

Glyphosate plus 2,4-D at 0.4 plus 0.6 pounds per acre (3.38 pints of Campaign® or Landmaster BW®) applied at seed set (late June to mid-July) can provide season-long control of leafy spurge at 75 percent or greater with zero to ten percent grass injury. This application in the same area for two consecutive years may cause severe grass injury, and applied in the fall may result in 30 percent grass injury. A mid-June application of 2,4-D amine or ester at one pound per acre (one quart of a four gallon concentrate) will provide top-growth control of leafy spurge but no control the following year. Forage production is increased with a June, but not September application of 2,4-D. Glyphosate and 2,4-D can be applied in areas of high water table and near waterways and ponds.

There are risks associated with herbicidal control of leafy spurge that should be balanced against the resulting benefits, and the risks of alternative management actions, including the no action alternative, when making weed management decisions. Potential risks include human and environmental health, and economic.

The risks to human and environmental health can be minimized by strict adherence to application requirements defined on the herbicide label. The relative risks of chemicals can be compared by their eco-toxicity evaluations (see Table 1). Generally, the chemicals listed pose a low risk to human and environmental health. However, the degree of risk is dependent on dose and frequency of exposure. Frequency of exposure can be minimized by integrating biological and cultural control with proper forage utilization management to slow the growth and spread of leafy spurge and thereby reduce the number of herbicide re-applications.

The greatest environmental risk of herbicidal control of leafy spurge is injury to plants other than leafy spurge. High rates of imazapic and glyphosate will injure grasses. While careful calibration of spray equipment is always advised, it is particularly important with imazapic because over application can cause long-term injury to desirable forage plants.

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

Chemical name	Product name	Rate/acre	Half life-days	Eco-toxicity (LC_{50}/EC_{50})
2,4-D	Many names	1-2 qts	7	1-10 mg/L
Dicamba	Banvel Clarity	1-3 pts	10	>100 mg/L
Glyphosate	Many	0.6 lbs (with 2,4-D)	61 (not active)	5-8 mg/L
Imazapic	Plateau	8-12 oz	31-233	>100 mg/L
Picloram	Tordon	1-2 qt	90	10-100 mg/L

Cultural

Cultural control methods applied by themselves including tilling, mowing, burning, hand pulling and grubbing are not effective for reducing leafy spurge populations because of the regeneration from the extensive reproductive root system. Irrigation and fertilization may increase the competitiveness of leafy spurge with grasses. Seedlings a few weeks old have roots with vegetative buds capable of regenerating the plant after a physical treatment. Cultural methods that increase the competitiveness of desirable plants with leafy spurge will improve the effectiveness of other control practices.

Burning. Prescribed burning has been used prior to an herbicide application to improve the visibility of the weed and spray coverage by eliminating old stems and ground litter. However, burning does not increase herbicidal control of leafy spurge. Increased coverage of leafy spurge by herbicides has been found to be greatest if applied after leafy spurge has re-grown for five weeks after a burn. Fall or spring prescribed burning before insect release has been used to improve *A. nigriscutis* establishment by 50 percent.

Tilling. In cropland, intensive season-long cultivation and fall cultivation have been used to manage leafy spurge. Fall cultivation applied one or two times when leafy spurge is three to six inches tall allows growing crops, litter management, and reduces erosion compared to season-long cultivation. Herbicides applied at crop label rates should be applied seven days before the first fall cultivation. Season-long intensive cultivation requires using duck-foot cultivators tilling four inches (10 cm) deep beginning in the spring two to four weeks after leafy spurge has emerged and repeated every three weeks until the soil freezes for one or two growing seasons. This cultivation routine should not be interrupted because of quick recovery from root stocks as little as one-half inch long and one-tenth inch in diameter.

Re-vegetation. On leafy spurge infested rangeland and pasture sites, forage grasses will often recover naturally after biological, grazing, or herbicidal leafy spurge control. However, on degraded or abandon cropland sites, re-vegetation of perennial grasses is highly recommended to restore forage production and provide competitive suppression of leafy spurge. Grasses found to be competitive with leafy spurge include Russian wild rye, pubescent wheatgrass, western

wheatgrass, little bluestem, orchardgrass, bluebunch wheatgrass, and thickspike wheatgrass. 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.

The establishment of grass species can be improved with herbicidal control of leafy spurge. In the Bitterroot Valley, picloram (one quart/acre) or imazapic (ten ounces/acre) applied in mid-September before a fall-dormant seeding provided suppression of leafy spurge during establishment in the following spring without grass seedling injury. Sustained suppression using *Aphthona* flea beetles, sheep or goat grazing, and proper grazing management following grass establishment will be needed to maintain grass vigor where cattle graze.

Integrated Pest Management

Studies have shown that herbicide and *Aphthona* flea beetle management are compatible. Fall-applied picloram plus 2,4-D had little to no effect on the *A. nigriscutis* population numbers and no effect on over-wintering fitness. Leafy spurge root carbohydrate and protein content were not reduced by the herbicide treatment and larval feeding did not change the absorption or translocation of picloram and 2,4-D in leafy spurge. *Aphthona* flea beetle numbers increased after a fall picloram plus 2,4-D application in infestations where beetles were slow to establish. Also, leafy spurge stem density was observed to decrease three years faster where herbicides were combined with flea beetles than where insects were established without herbicides.

Leafy spurge infestations can be sprayed with picloram or 2,4-D without reducing the density of *Hyles euphorbiae* provided larvae have reached the fourth or fifth instar. Likewise, picloram, or 2,4-D does not affect *S.esulae* population density as long as 15 to 25 percent of the leafy spurge infestation remained untreated.

Grazing leafy spurge with sheep or goats is also compatible with *Aphthona* flea beetles. Grazing with sheep for ten days where *Aphthona* flea beetles had been released was shown to decrease leafy spurge density below densities where either treatment was applied alone.

An integrated leafy spurge weed management program will include prevention, early detection and small-scale eradication, containment, and large-scale population reduction. Prevention is guided by how leafy spurge spreads and its requirements for establishment and includes maintaining competitive plant communities and preventing seed imports by using weed-free feed and seed, cleaning equipment before application on weed-free areas, and containing grazing animals for seven days after they have fed in leafy spurge infestations and before moving them to weed-free areas. Early detection and small-scale eradication is achieved through persistent survey and herbicide application. Leafy spurge populations are contained by herbicidal control of population boarders and satellite populations, control actions that reduced seed production such as sheep or goat grazing and 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 sheep or goat grazing and biological control insects that reduce the leafy spurge population fitness and increase the fitness of desirable, competitive plant populations.

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