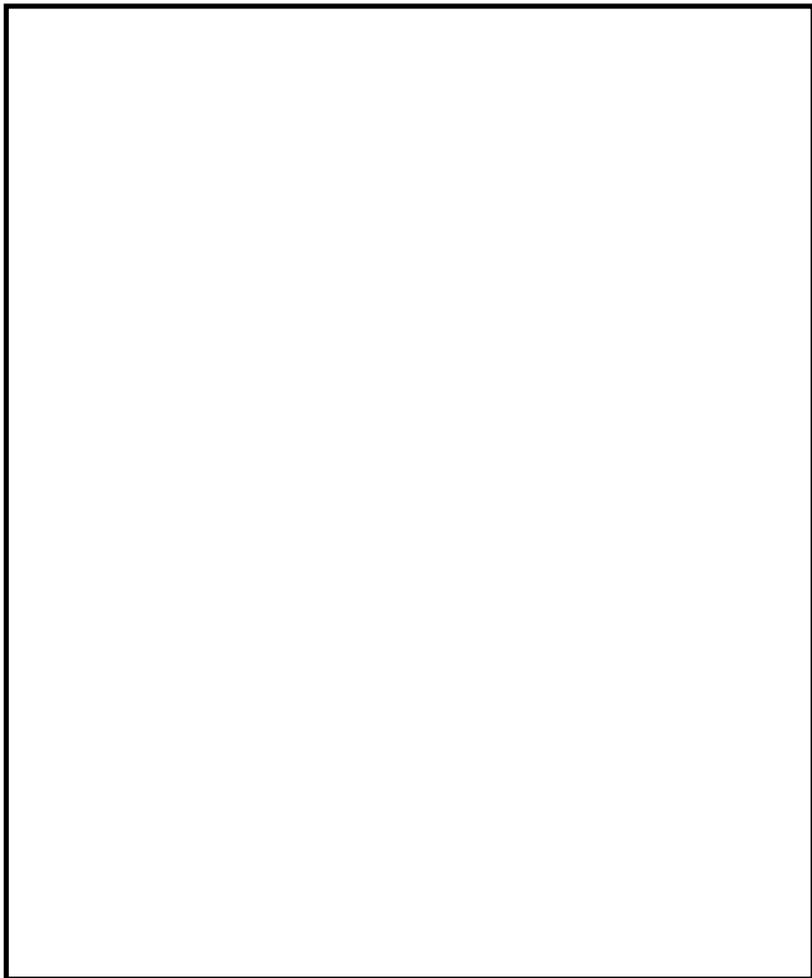

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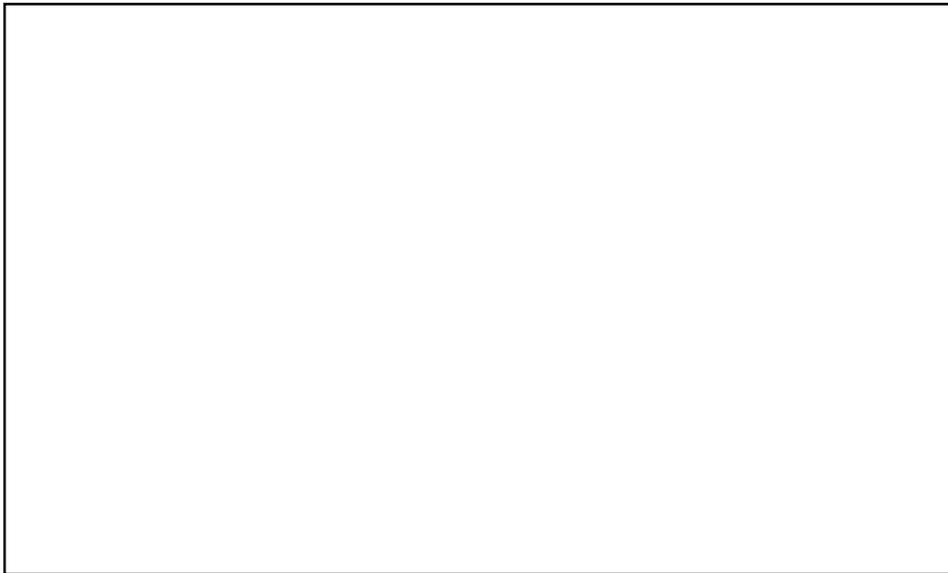
KNAPWEED 

ON MONTANA RANGELAND



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Don't get caught "knapping" with spotted knapweed on your range.

Controlling Knapweed on Montana Rangeland

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Spotted knapweed (*Centaurea maculosa*) threatens the long-term productivity of Montana rangelands. More than 4.5 million acres are infested.¹ If the present rate of invasion of susceptible sites is allowed to continue, the potential annual loss to Montana's range livestock industry will reach \$155 million dollars.²

Spotted knapweed has a detrimental impact on wildlife. In western Montana, use by elk (*Cervus canadensis*) estimated by pellet groups per acre varied from 35 on spotted knapweed to 1575 on bunchgrass sites. This indicates a drastic reduction of use on spotted knapweed-infested sites.³ A Forest Service assessment of spotted knapweed infestation on winter range in the Lolo National Forest forecast a loss of 220 elk annually by 1998.⁴ These losses were expected to adversely impact hunting, tourism, and recreational industries.

Spotted knapweed invasion onto bunchgrass rangelands is detrimental to the protection of soil and water resources.⁵ Runoff and sediment yield under simulated rainfall conditions were 56 percent and 192 percent higher on the spotted knapweed-dominated sites than on the bunchgrass-dominated sites.

This bulletin discusses the ecological characteristics of three common knapweeds. It also proposes management strategies to slow their rate of spread and describes methods to control the knapweeds.

Identifying Spotted Knapweed

Spotted knapweed is a short-lived perennial forb. Seedlings usually over-winter in the rosette stage and resume growth in early April. They are easy to recognize because the leaf margins are indented or divided about half way to the mid-rib. The stems make most of their growth in June. Stem height varies from two feet on upland sites to four feet on irrigated or high-moisture sites. The slender stems are many-branched and bear single, pinkish-purple flowers at the tips. Each flower head has bracts that are marked with fine vertical streaks and tipped with a dark comb-like fringe.

Spotted knapweed's bloom-period occurs from July through August. Individual flower heads bloom for two to six days before the bracts close. The bracts reopen after about 20 days, when seeds are dispersed.

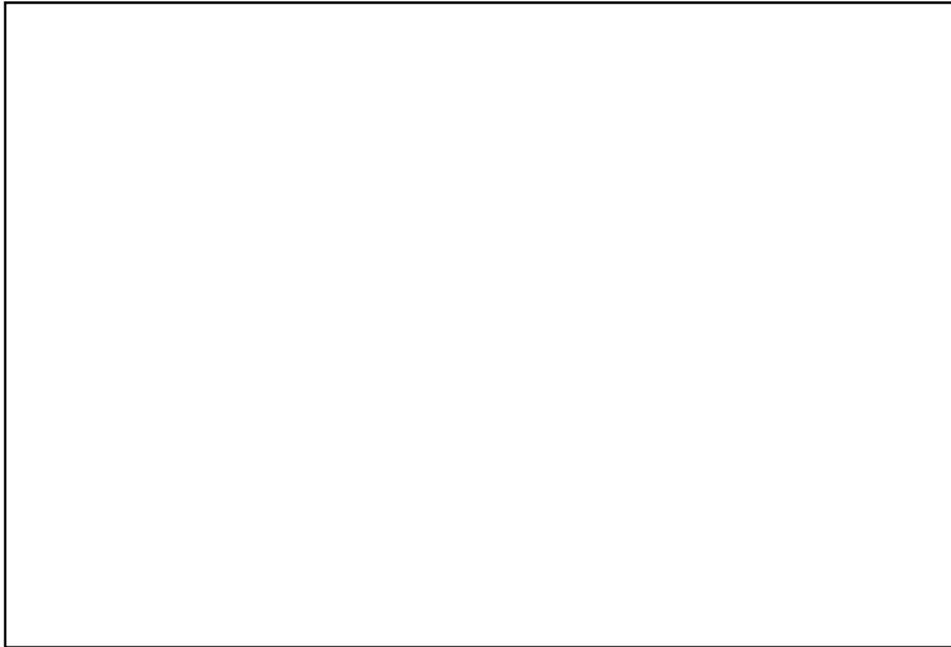
Identifying Diffuse and Russian Knapweed

Two other knapweeds also are serious problems on rangeland. Ecologically, they differ from spotted knapweed.

Diffuse knapweed (*Centaurea diffusa*) is a biennial, or short-lived perennial forb. The plants usually produce a single main stem. The thin stems are about two feet tall and many-branched. A single white flower is located on each branch tip. The seedhead bracts do not have the dark spots found on spotted knapweed. Diffuse knapweed bracts bear a rigid terminal spine about one-third of an inch long with four to five pairs of shorter, lateral spines. Because of the spines on diffuse knapweed, the recreational potential of invaded sites is impaired.

Russian knapweed (*Centaurea repens*) is a deep-rooted, rhizomatous, perennial forb that grows about two feet tall. Its stems are thin, stiff and covered with soft, short hairs. The rosette leaves are narrow at the base and widen toward the tip. Stem leaves are grayish-white and have irregular shaped lobes that are divided about one-half of the way to the mid-rib. The flowers are pink to purple.

Three important characteristics distinguish Russian knapweed from spotted or diffuse knapweed. First, the flower head bracts of Russian knapweed have light, thin hairs, a papery tip, and are green at the base. Second, Russian knapweed grows in patches and can spread



Spotted knapweed poses a long-term threat to productivity of Montana's rangeland.

by deep, scaly, creeping rhizomes. The dark colored roots can grow to depths of eight feet the first year and to 23 feet during the second season. Third, Russian knapweed is not a prolific seed producer.

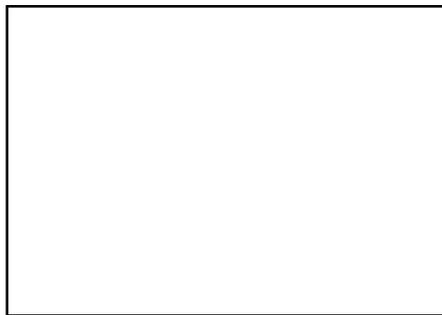
Understanding the Spread of Knapweed

Spotted knapweed was probably introduced to North America as a contaminant of hay or alfalfa seed from Eastern Europe or Asia in the early 1900s. Herbarium records at Montana State University indicate that spotted knapweed was first collected in Gallatin County in the mid-1920s. It spread to additional counties by 1940, and now can be found in all 56 Montana counties.

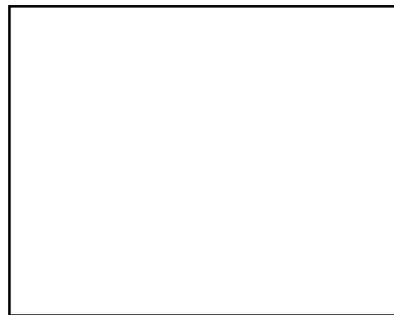
Spotted knapweed has the potential to continue spreading in Montana.⁶ On the basis of soil type, elevation, annual precipitation, evapo-transpiration, frost-free season and maximum July temperature, about 50 percent of Montana (46.5 million acres) will support spotted knapweed infestations. When cultivated lands are subtracted from this total, nearly 34 million acres of range and grazeable woodland are vulnerable. The threat is greatest in range dominated by bluebunch wheatgrass, needleandthread or Idaho fescue, and in woodland dominated by Ponderosa pine or Douglas fir.

The reproductive characteristics of spotted knapweed justifies the concern. While an average spotted knapweed plant produces about 1,000 seeds annually, up to 18,000 seeds can be produced. This means that as few as 100 plants per acre can produce more than one million seeds. Seeds may remain near the parent plant, or be transported to another site. Some seeds are transported by water, wind or animals, but people and their motorized vehicles are the main cause of knapweed spread in Montana.

Knapweed plants often are caught in the undercarriage of recreational vehicles, ranch machinery, trains and logging equipment. Vehicles driven several feet through a knapweed



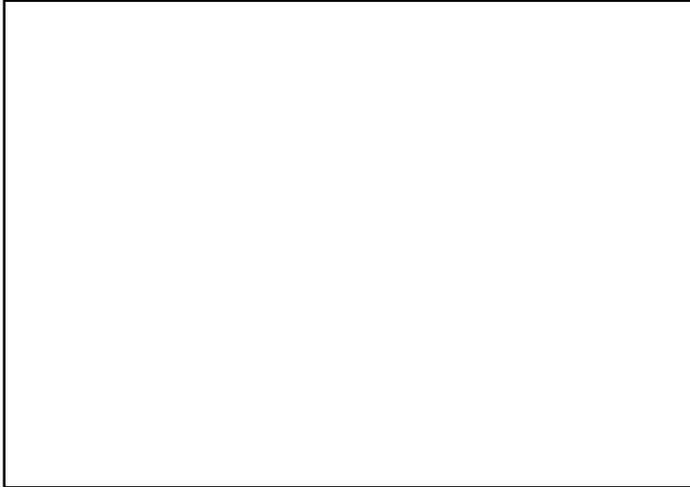
Spotted knapweed overwinters as a rosette. Early spring growth (shown here) gives it a competitive edge over native plants. The stems elongate in June.



The pink or purple flowers of spotted knapweed are similar to Russian knapweed or Canada thistle. However, the black-tipped bracts of the flower head distinguish spotted knapweed from other plants.



Diffuse knapweed is distinguished from spotted knapweed by white flowers and spiny bracts on the flower head.



The pink-purple flower of Russian knapweed is similar to spotted knapweed, but Russian knapweed has pale, egg-shaped flower head bracts.

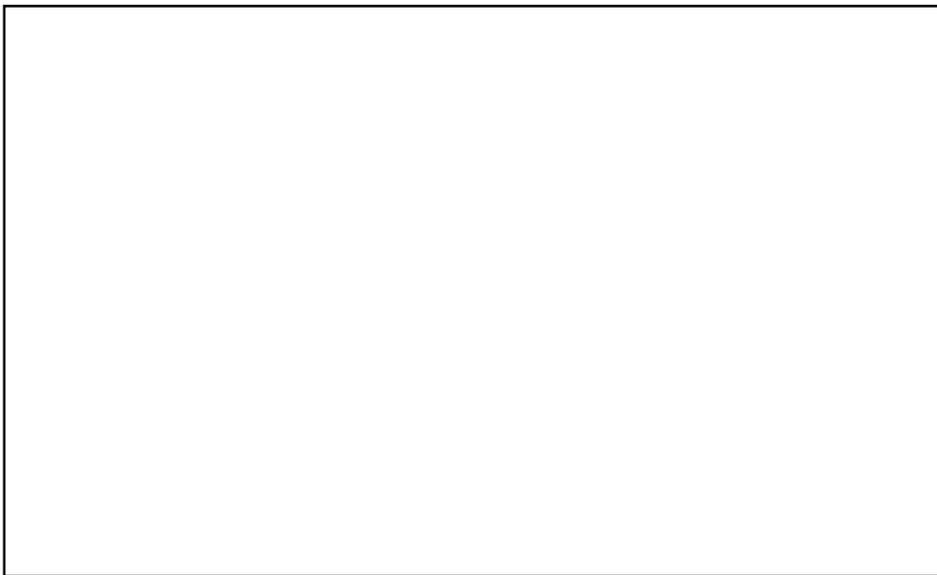
site can pick up nearly two thousand seeds, 10 percent of which may still be attached to the vehicle after 10 miles of driving.⁷ Thus, seed can be spread rapidly over hundreds of miles. Off-road vehicles also damage existing vegetation and disturb the soil surface, making it easier for knapweed to invade.

Hikers spread the weed when they pick knapweed flowers and then discard the wilted plants along trails and access sites to fishing, boating, or other recreation areas. Weeds are transported into the back country by horsemen and hunters hauling weed-contaminated hay, straw, and feed for their horses. Policies urging the use of certified weed-free hay and regulations requiring the use of pelleted feed are justified.

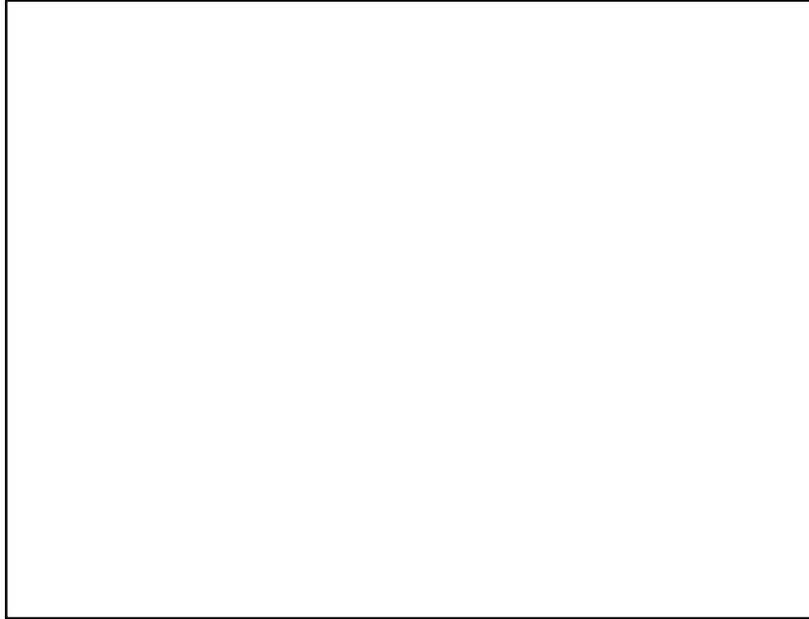
Spotted knapweed is adapted to a wide range of environmental conditions in Montana. Plants have been observed from 1,900 to more than 10,000 feet in elevation, and in precipitation zones ranging from eight to more than 80 inches annually. The largest infestations may occur on shallow or gravel range sites in the 10- to 14-inch precipitation zone. Spotted knapweed does not thrive on sub-irrigated or wet meadow sites. The establishment of spotted knapweed is enhanced more by soil disturbance than by soil property.

Seeds germinate throughout the growing season and subsequent seedling growth is vigorous if there is adequate moisture. Knapweeds are strong competitors for water and soil nutrients. Spotted knapweed may suppress seed germination and subsequent root growth of grasses and trees by releasing the chemical cnicin into the soil.⁸

Diffuse knapweed was introduced into the Pacific Northwest at about the turn of the century. MSU records show that diffuse knapweed was first collected in Mineral County in 1951. The largest infestations now are observed near Helena, Big Timber and Ennis.



Spotted knapweed can invade excellent condition rangeland dominated by rough fescue.



Spotted knapweed was first reported in the western part of Montana in the 1920s. Since then it has spread to every county.



Areas of Montana where there is high probability that spotted knapweed will grow, based upon the conditions found in 116 knapweed infestations.

Diffuse knapweed is a pioneer species. It quickly takes hold and thrives on disturbed, dry sites. New populations arise as mature plants die, break off at the rootstalk and shed seeds as they are blown or carried away.

MSU records show that Russian knapweed was first collected in Fergus County in 1934. Because it is not a prolific seed producer, the introduction of weed-infested hay or the movement of farm machinery are the mechanisms by which it spreads to new areas. Although Russian knapweed does not spread as fast as diffuse or spotted knapweed, an extensive root system makes it nearly impossible to eradicate.

Methods of Control

The most cost-effective method of controlling spotted knapweed is determined by the size and location of the infested areas. Small patches of spotted knapweed can be permanently eliminated with a persistent herbicide or cultural control program. However, an integrated weed management approach that uses cultural and biological methods, in conjunction with herbicides, is necessary to control large infestations and to slow the rapid spread of this weed. To be successful, management programs must continue annually over a period of years.

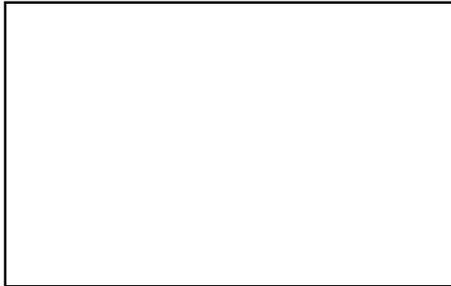
Long-term control of spotted knapweed is difficult because seeds remain viable in the soil for at least seven years.⁹ After seed production was stopped for three years, the seed reserve in natural populations declined from about four million to 174,000 seeds per acre (a 95 percent decrease). Seed number did not decline appreciably during the remainder of the study. Therefore, long-term control or eradication of spotted knapweed is not possible with a single treatment. Treatment programs must be continued until seed reserves in the soil are exhausted.

Chemical Control

The key to stopping the spread of spotted knapweed is early detection and treatment of invading plants. Picloram (Tordon[®]), clopyralid (Stinger[®]), 2,4-D and dicamba (Banvel[®]) will control spotted and diffuse knapweed on rangeland. These herbicides are selective for broadleaf weeds and generally do not harm grasses when applied at recommended rates.

Tordon[®] is the most effective herbicide for controlling spotted and diffuse knapweed (Table 1). Picloram at one-fourth pound of active ingredient per acre (one pint of Tordon[®] 22K) applied in early June will give 100 percent control of spotted knapweed for two to five years, depending upon the site conditions.¹⁰ The period of control tends to be shorter in areas with gravel soils or higher precipitation. Precautions on the label must be followed, because Tordon[®] is a restricted-use herbicide and can damage other broadleaf plants, including trees.

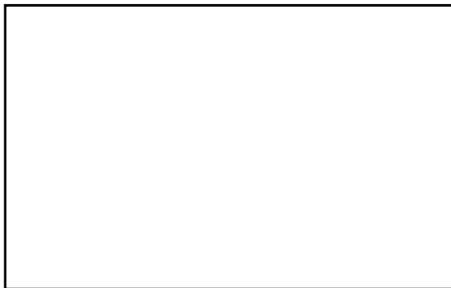
Spotted and diffuse knapweed can be controlled in the rosette stage by spraying with one-fourth pound per acre of clopyralid ($\frac{2}{3}$ pint of Stinger[®]), two pounds per acre of 2,4-D (two quarts of oil or water soluble amine or low volatile ester formulated with four pounds of active ingredient per gallon), or with one pound per acre of dicamba (one quart of Banvel[®]). Control is inconsistent and short term with 2,4-D and Banvel[®] (Table 1). For long-



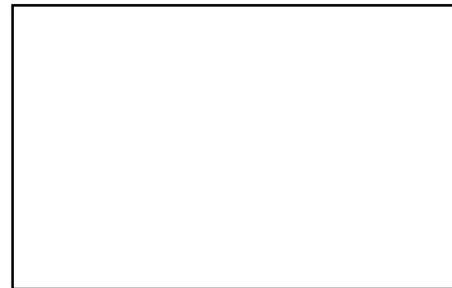
Spotted knapweed is easily transported by vehicles.



Spotted knapweed seed often is transported in the movement of gravel and other fill material.



Spotted knapweed seed also is transported in hay to infest new areas.



Once spotted knapweed is established along roadsides, it invades adjacent rangeland.

term control, 2,4-D treatments must be applied annually until no viable seed remains in the soil. Depending on environmental conditions, Stinger[®] and Banvel[®] may have to be applied every 2nd, 3rd, or 4th year.

The cost of treatment also is a consideration in the choice of herbicides. Assuming the cost of 2,4-D to be \$10.00 per gallon (four pounds active ingredient per gallon), and Tordon[®] to be \$85 per gallon (two pounds active ingredient per gallon), and with an aerial application cost of five dollars per acre, it costs more than twice as much to use 2,4-D to control spotted knapweed for a four year period (Table 2).

Herbicides should be applied to spotted and diffuse knapweed at the proper growth stage for optimum control. MSU research has shown that 2,4-D, Banvel[®], Stinger[®], and Tordon[®] were most effective when applied in late May to early June, when most of the plants are sending up a seedstalk. Herbicide effectiveness declines rapidly after flowering. Although

Table 1: Effect of a Single Herbicide Application on Spotted Knapweed Control in Montana

Herbicide	Formulation lb/gal	Pints per acre	Lbs a.i. per acre	Approx. cost ¹ \$/ac	Year						
					1	2	3	4	5	6	7
					Percent Control						
Tordon [®]	2	1.00	0.25	10.62	100	100	100	100	100	95	87
Banvel [®]	4	2.00	1.00	12.80	100	89	65	54	38	26	25
2,4-D	4	4.00	2.00	5.00	90	41	44	17	5	3	3
Stinger [®]	3	0.66	0.25	32.00	100	98	63	—	—	—	—

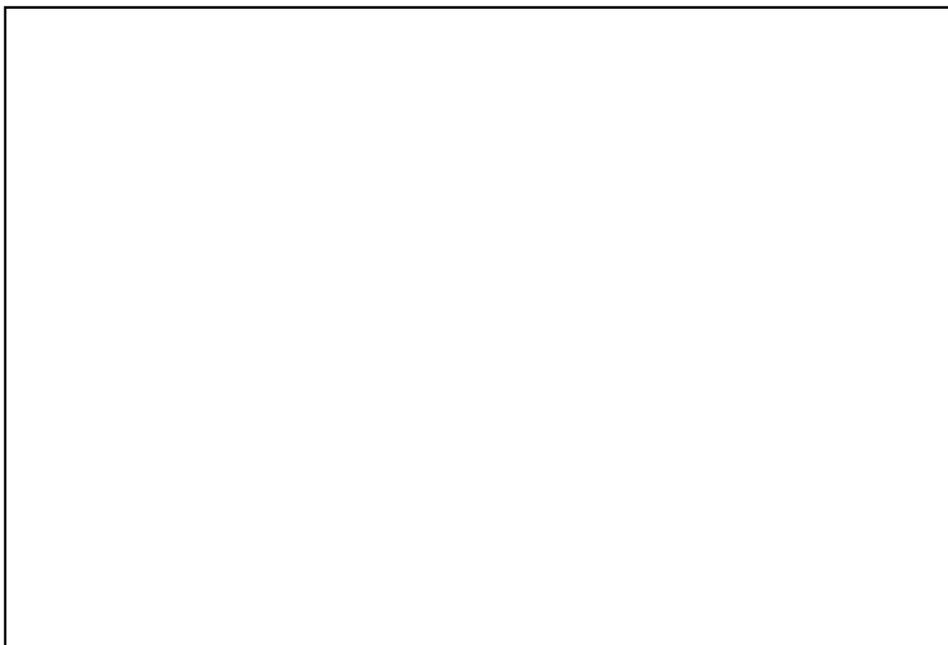
¹ Cost does not include cost of application.

Table 2: Per-acre Cost of Controlling Spotted Knapweed with Herbicide

Type of Herbicide	Cost	
	Cash Expense ¹	Interest
2,4-D at 2 lb.		
Year 1	\$10.00	\$4.64
Year 2	10.00	3.31
Year 3	10.00	2.10
Year 4	<u>10.00</u>	<u>1.00</u>
Subtotal	\$40.00	\$11.05
	Total 4-Year Cost	\$51.05
Tordon [®] at 1/4 lb.		
Year 1	\$15.62	\$1.82
Year 2	.00	1.81
Year 3	.00	1.81
Year 4	<u>.00</u>	<u>1.81</u>
Subtotal	\$15.62	\$7.25
	Total 4-Year Cost	\$22.87

¹ Expense includes cost of herbicide and application. Treatment with 2,4-D is applied annually for four years; the Tordon[®] treatment is applied in the first year only.

² Interest foregone on investment calculated at 10 percent per year, compounded annually.



Picloram (Tordon®) was used to control spotted knapweed on the Rafter D Ranch (right side of fence). No herbicide had been applied on the adjoining ranch.

the residual activity of Tordon® provides long-term control, Tordon® breaks down in sunlight. Tordon® is more effective if it is applied during a period in which rainfall is most likely to transport it into the soil.

Russian knapweed can be controlled on pasture and rangeland with Tordon® at the rate of two quarts (one pound active ingredient) per acre. Fair results occur with Stinger® at the rate of one to one and one-third pints (three-eighths to one-half pound active ingredient) per acre. Banvel® will control Russian knapweed at the rate of two to four quarts (two to four pounds active ingredient) per acre. Tordon® should be applied from the rosette to prebud stage or to fall regrowth. Banvel® should be applied during early bud stage for best results. Stinger® should be applied in the late bolt (flush of growth) to early bud stage.

Biological Control

Biological weed control is the deliberate use of natural enemies (parasites, predators or pathogens) to reduce weed densities to acceptable levels. Biological control is attractive because it is environmentally safe, self-perpetuating, selective, and very economical. Eight natural enemies, all native to Eurasia, have been introduced into Montana for control of spotted and diffuse knapweed.

Two flies (*Urophora affinis* and *U. quadrifasciata*) attack seed heads and were introduced into western Montana in 1973 and 1980, respectively. They are well established on both spotted and diffuse knapweed throughout most of the western half of the state.¹¹ Both fly species lay their eggs inside the knapweed flower buds in June. The larvae induce galls in the flower heads which reduce seed production. *U. quadrifasciata* is spreading much faster but *U. affinis* appears to be the more persistent colonizer. Seed reductions in excess of 50 percent are being recorded in areas where the two fly species coexist.¹²

A seedhead-attacking moth (*Metzneria paucipunctella*), released in Montana in 1980, is established in small numbers at two sites in western Montana. The larvae feed on the florets and seeds of spotted knapweed. Each larva destroys about eight seeds per seedhead.¹³

A root moth (*Agapeta zoegana*) and a root weevil (*Cyphocleonus achates*), released in 1984 and 1988, respectively, are both established in small numbers on spotted knapweed in western Montana. The larvae of both insects cause considerable damage, often killing small knapweed plants. Both insects are being mass-reared at the Western Agricultural Research Center at Corvallis to speed up their distribution throughout the knapweed-infested areas of the state.

A root beetle (*Sphenoptera jugoslavica*), released on diffuse knapweed in 1983, is established in small numbers. Additional releases of the beetle will be made in cooperation with USDA's Animal and Plant Health Inspection Service.

Introductions of two root moths (*Pelochrista medullana* and *Pterolonche inspersa*) have been unsuccessful to date. Further attempts to establish these two promising insects are planned.

The two seedhead flies are the only insects currently available for distribution by the public. Both insects can be easily collected from designated areas in western Montana. The two root insects, *A. zoegana* and *C. achates*, are currently being distributed throughout the state in limited numbers by MSU researchers. Procedures are being investigated to facilitate their distribution of by the public.

Three new insect species are to be introduced during the next three years. Following the addition of these three insects, a total of 11 species will have been introduced against the two knapweed species. This should allow the establishment of the assorted natural enemy combinations necessary to reduce knapweed density in many locations.

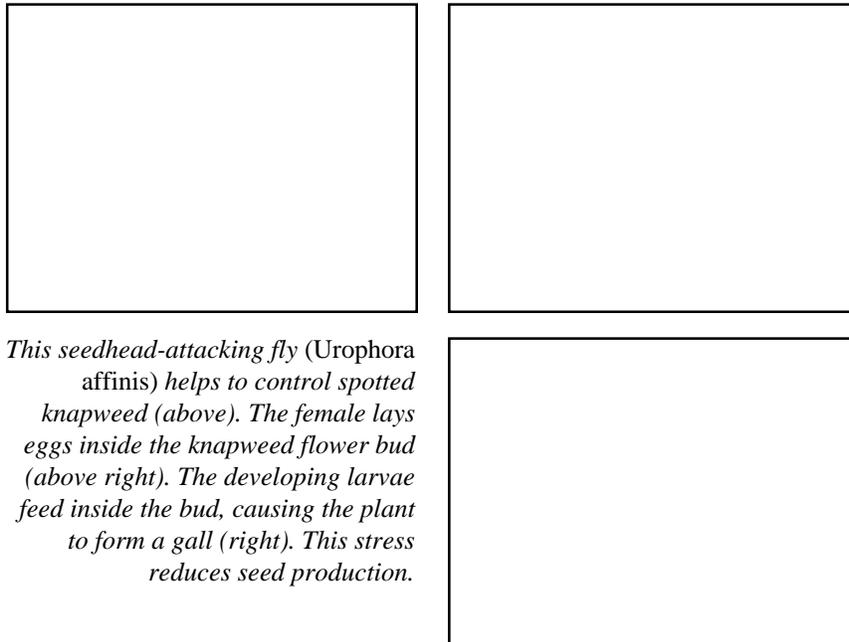
Cultural Control

Diligent hand-pulling will control very small infestations of knapweed. Since new plants can emerge from viable seeds in the soil, plants must be pulled every year until there are no more viable seeds. The entire plant must be pulled since regrowth can occur from the crown or root. For best results, plants should be pulled when the soil is wet and before seeds are formed. Plants with seeds should be disposed of by deep burial, or by burning in a very hot fire. Care should be taken not to disperse seed during transport for disposal. As with other methods, the presence of a vigorous stand of competing vegetation enhances the possibility of successfully controlling knapweed by pulling.

Greenhouse studies and field observations indicate that spotted knapweed grows better in full sunlight than shade.¹⁴ Because it does not grow well in shade, the invasion of spotted knapweed along roads in western Montana can be reduced by not harvesting the timber that provides shade.¹⁵ The problem of spotted knapweed invading and thriving on small acreages and homesites can be minimized by designing a “shady” landscape. Spotted knapweed plants will be gradually replaced as the tree and shrub canopy closes.

Mowing will reduce but not prevent spotted knapweed seed production.¹⁶ Number of plants producing seed in August was reduced from 79-99 percent by single mowings when plants were in the bud to early flower stage.¹⁶ However, knapweed rosettes escape mowing and the total number of plants may not be affected. Furthermore, the response of plants to mowing will vary with environmental conditions. Under greenhouse conditions, some spotted knapweed plants flowered even though they were clipped monthly from June through September.¹⁴

Fire has little potential for spotted knapweed control. Small islands are left unburned and the fires usually are not hot enough to eliminate all of the viable seed in the soil or to



prevent crowns from re-sprouting. A more realistic use of fire may be to remove standing and fallen litter and stimulate new growth, which enhances post-fire herbicide treatment.

As a cultural approach to knapweed control, nitrogen fertilizer, by itself, may be impractical.¹⁸ Knapweed exploits the additional nutrients at the expense of the competing vegetation. However, the potential of using nitrogen in combination with a herbicide (i.e., to increase grass competition after the knapweed is controlled) should not be overlooked.

On productive sites, spotted knapweed can be controlled by implementing an intensive management program that utilizes cultivation, irrigation and either annual crops or a seeded perennial forage. Control is much more difficult on less productive sites, where intensive management is not feasible. Mechanical treatments that disturb the soil are not recommended because they create an ideal seed bed for knapweeds.

Forage value of spotted knapweed for cattle, horses and most wildlife is less than the value of the native grasses which are displaced. However, livestock and big game animals do utilize knapweed. Use is greatest when the plants are green and actively growing. Prior to flowering, neutral detergent fiber varies from 24 to 53 percent, ether extract from 3.1 to 9.0 percent, crude protein from 6.2 to 18.2 percent, and in vitro dry matter digestibility from 53.2 to 61.8 percent.¹⁹ As plants matured during summer they became more fibrous and lower in protein. Grazing animals make little use of mature plants if other forage is available.

Some ranchers recommend that pastures infested with spotted knapweed be grazed early in the season and then rested to allow desirable forage to regain vigor. If the rest period is followed with another period of grazing in the fall, livestock has an opportunity to utilize the basal leaves of rosettes at least twice during the year. It was thought this treatment might reduce the competitive ability of the knapweed plants. However, greenhouse studies indicated that spotted knapweed was tolerant of clipping while bluebunch wheatgrass was easily harmed.¹⁴ Therefore, it is unlikely that spotted knapweed can be controlled by livestock grazing.

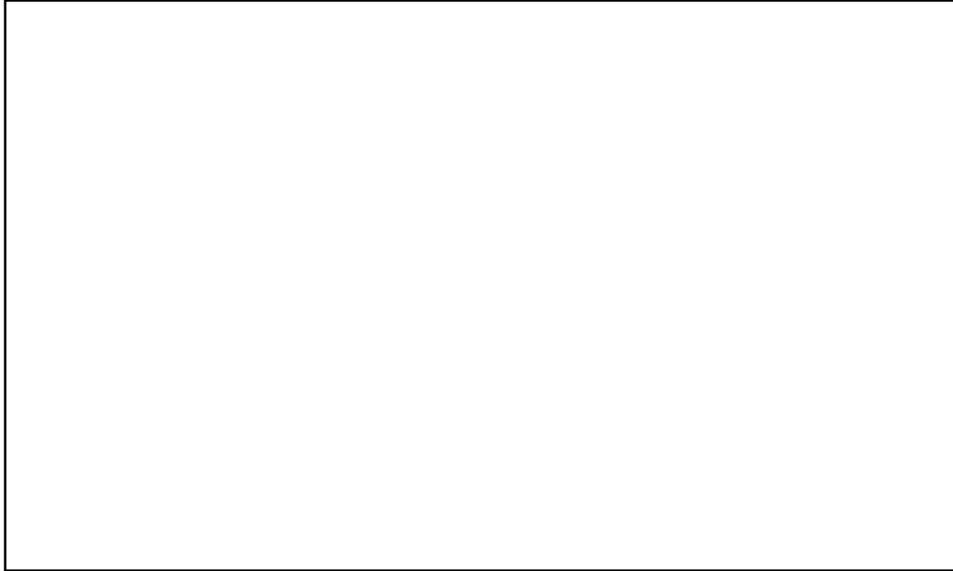
Strategies to Slow Knapweed Spread

Any knapweed control project must address the spread of spotted knapweed by people. Elimination or control of public access through infested areas would reduce the rate of spread.

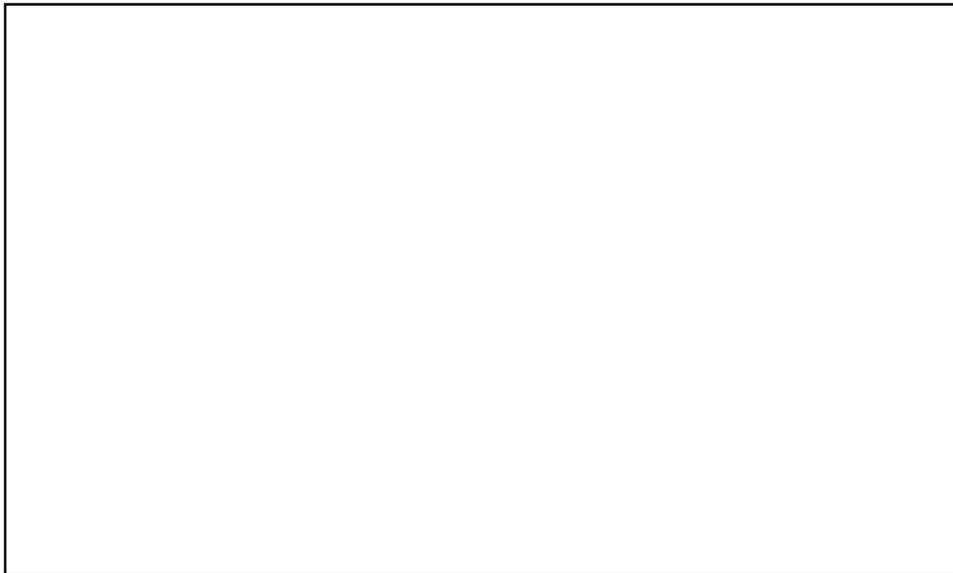
Knapweed also has been introduced to new areas by the movement of contaminated grain seed and hay. These problems were exacerbated by the large shipment of hay from western to eastern Montana during the drought in 1984 and 1985. Certified weed-free hay is now grown by some ranchers. Many National Forests now require all hunters and outfitters to use only weed-free hay or pelleted feed.

Subdividing rural areas has created serious knapweed problems. Subdivision activity disturbs soil, creating an ideal seedbed conducive to weed invasion. The problem is compounded by owners of small tracts who do not recognize the need for weed control.

Good grazing management often is the first defense to the rapid spread of spotted knapweed on rangeland. While knapweed can invade excellent condition range, its rate of spread



Sheep and other livestock will utilize spotted knapweed.



Spotted knapweed is more resistant to grazing than are the desirable forage plants.

is slower than on poor condition range. Although it is not known how much of the recent spread of knapweed can be attributed to poor range management, the invasion is accelerated by any form of soil disturbance.²⁰

Grazing systems — alternating periods of grazing use in a pasture with periods of rest to allow desirable plants to regain vigor — are an important tool for keeping rangeland in good condition. The rest rotation system, which allows one pasture to be rested from livestock use for a full year, has proved highly useful on Montana ranges. However, several Montana ranchers have observed that rest rotation is not effective on knapweed-infested range. They report that a year-long rest permits knapweed to produce seed, and they suspect that seeds are planted during the subsequent grazing period. Thus a rotation system that allows repeated periods of grazing and non-grazing during each growing season may be appropriate on knapweed-infested range. A herbicide program should be implemented in conjunction with a grazing system because competition by native forage species alone will not lower knapweed density.

Summary

Successful control of knapweed in Montana requires cooperation between private landowners, public land users and government agencies. To minimize the future spread of knapweed, each of us must do our part:

- Avoid driving motorized vehicles through knapweed infestations.
- Do not purchase or transport hay contaminated with knapweed.
- Minimize soil disturbance on range and other non-crop land.
- Use herbicides to eliminate small patches of knapweed.
- Seed desirable perennial grass species immediately on all areas that have been disturbed by construction, mining or other activities.
- Obey the weed laws and support local weed control programs.

Spotted knapweed cannot be controlled with a single treatment or in a single year. Regardless of initial control efforts, follow-up treatments will be needed in subsequent years. Future success requires a long-term commitment.

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