

# Field Guide for Managing Diffuse, Meadow, Spotted, and Squarrose Knapweeds in the Southwest



## Cover Photos

*Top left: Meadow knapweed, Cindy Roche, Bugwood.org*

*Top right: Squarrose knapweed, Steve Dewey, Utah State University, Bugwood.org*

*Bottom left: Diffuse knapweed, Norman E. Rees, USDA Agricultural Research Service, Bugwood.org*

*Bottom right: Spotted knapweed, Joseph M. DiTomaso, University of California, Davis, Bugwood.org*

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## Diffuse knapweed (*Centaurea diffusa* Lam.)

## Meadow knapweed (*C. pratensis* Thuill.)

## Spotted knapweed (*C. stoebe*)

## Squarrose knapweed (*C. virgata* Lam. ssp. *squarrose*)

Sunflower family (Asteraceae)

Diffuse, meadow, spotted, and squarrose knapweeds are invasive weeds common to western states. Diffuse and spotted knapweeds are listed as noxious weeds in Arizona and New Mexico. Squarrose knapweed has been listed as a noxious weed in Arizona. Although meadow knapweed is not currently found in Arizona or New Mexico, it is included in this guide to facilitate early identification and control.

This field guide serves as the U.S. Forest Service's recommendations for management of diffuse, meadow, spotted, and squarrose knapweeds in forests, woodlands, rangelands, and deserts associated with its Southwestern Region. The Southwestern Region covers Arizona and New Mexico, which together have 11 national forests. The Region also includes four national grasslands located in northeastern New Mexico, western Oklahoma, and the Texas panhandle.

## Description

Collectively, knapweeds are invasive plants that range from annual to biennial to perennial in growth form. At maturity, all knapweeds have deep taproots; basal rosettes; highly-branched flowering stems; and white, pink, or purple thistle-like disk flowers. Proper identification should always be made before managing knapweeds. Phyllaries (involueral bracts) and seed appearance are key distinguishing features by which species can be identified. The pappus or tuft of hairs on each seed is especially important. Table 1 provides important growth and plant features associated with *Centaurea* species addressed in this field guide.

**Table 1. Growth characteristics**

Species	Life Span	Growth and Root Habit	Vegetative/Flower Appearance	Phyllary Characteristics	Reproductive Method and Seed Appearance
Diffuse knapweed	Short-lived perennial, biennial, or sometimes an annual	Prostrate rosette base; stems 6 to 24 inches tall. Long, stout taproot.	Basal leaves 4 inches long, stems branched in the upper half; white or pink-purple flowers.	Crab or comb-like; 1/3 inch long terminal spine with 4 to 5 lateral spines.	Seed only. Seeds are dark brown, oblong, 1/8 inch long with a pappus of short, pale bristles.
Meadow knapweed	Perennial	Prostrate rosette base; stem 20 to 42 inches tall. Woody or fleshy taproot.	Deep green leaves; rose to purple flowers, sometimes white; central flowers shorter than outer.	Light to dark brown with a deeply fringed margin; metallic golden at time of flowering.	Seed and via root or crown fragments. Seeds are pale tan and plumeless; 1/8 inch long.
Spotted knapweed	Short-lived perennial or biennial	Prostrate rosette base; stem 24 to 48 inches tall.	Basal leaves, 8 inches long, deeply-lobed; resin-dotted stem leaves smaller, not lobed; alternate; pink or purple flowers.	Stiff, black-tipped with soft, spine-like fringe at the tip; shorter center spine. Black tips make flower head appear spotted.	Seed and via lateral roots. Seeds are black or brown with pale vertical lines; 0.1 inch long with bristly pappus half the length of the seed.
Squarrose knapweed	True perennial; long lived; woody base.	Prostrate rosette base; stem 18 to 36 inches tall.	Grey-green, deeply lobed basal leaves; upper leaves linear, entire. Purple or pink flowers.	Similar to diffuse (short-spiny), but central terminal bract bent backward; pale-green to straw colored or may be purplish.	Seed only. Pale to dark brown seed with pale vertical stripes; short white pappus; 1/8 inch long.

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## **Ecology**

### ***Impacts/threats***

Knapweeds are highly competitive, persistent plants; and dense, impenetrable stands of knapweed can displace desirable vegetation. They are often the first plants to establish on disturbed sites, roadsides, or areas cleared in preparation for development. Spotted and diffuse knapweeds are aggressive weeds that rapidly invade disturbed rangeland, pasture, and fallow cropland. While meadow and squarrose knapweeds have a more limited range, they can quickly out-compete desirable native plants. Knapweeds have high amounts of phytotoxins, and a high knapweed density at a site can make native plants appear to be sick and soils seem barren.

### ***Location***

Diffuse knapweed is wide ranging, although it prefers shrub-steppe and dry forest zones. Meadow knapweed prefers moister and cooler habitats such as forest openings or along rivers and streams. Spotted knapweed has the widest distribution of the four species and is present in all western states. It prefers grasslands and open forests. Squarrose knapweed has limited distribution and prefers dry, open rangeland with shallow soils. Diffuse and spotted knapweeds are found mainly in northern parts of New Mexico and Arizona. Meadow knapweed is currently found in California and may reach other states in the Southwest relatively soon.

### ***Spread***

Knapweed seed is easily dispersed by wind and water. Seed can also be spread in hay that is not certified to be weed free. Seed adhering to surfaces and undercarriages of vehicles (especially road maintenance equipment) can be carried for long distances. Seeds may be carried for shorter distances on animals and humans. Birds transport and disperse seed after eating them. Mature stems of diffuse and squarrose knapweed break off at the base and tumble over the landscape during winter, thereby dispersing seed.

## ***Invasive Features***

Knapweeds readily establish on disturbed sites, especially along roadsides, railways, waste and cleared areas, and overgrazed rangeland. Mechanical disturbance can favor growth of knapweeds over grass species. However, disturbance is not necessary for knapweed invasions to occur. Spotted knapweed develops a symbiotic association with a soil fungus that can divert carbon from grasses. This reduces the ability of grass species to compete and may shift vegetative composition toward a knapweed monoculture.

## **Management**

To manage knapweeds, the first priority should be to prevent knapweed from establishing in areas where they are not currently present. Next, treat small infestations upon otherwise healthy sites. Finally, eradicate large infestations. Always closely follow knapweed control efforts with monitoring and be prepared to spot treat surviving plants and seedlings until none can be found. Regardless of the control approach, knapweeds typically cannot be eliminated within a single year or by using only one method. In most cases, at least 3 or more consecutive years of treatment are necessary to deplete knapweed seed in the soil. The following actions should be considered when planning a management approach:

- Maintain healthy plant communities to prevent or limit knapweed infestations. This may involve using improved grazing management strategies to prevent plant spread.
- Check purchased hay for presence of weed seeds; use certified weed-free hay or pellets for horses used in back-country areas.
- Limit disturbance and/or promptly revegetate disturbed areas.
- Map and keep annual records of reported infestations.
- Survey and eradicate new populations of knapweed as early as possible.

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- Use a combination of mechanical, cultural, biological, and chemical methods for effective control.
  - Include monitoring and followup treatment plans for managing missed plants and seedlings.

Prior to treating an infested site, the plant community should be evaluated as to how it will respond once knapweed is removed. In many instances, native plants (if present) will reoccupy the site naturally, thereby precluding the need for reseeding. In areas where reseeding is needed, carefully evaluate soil conditions and select control methods that can enhance the seeding procedure. A complete restoration program may be required to control large knapweed populations.

Table 2 summarizes management options for controlling knapweed under various situations. Choice of method(s) to use for knapweed control depends on the degree and density of an infestation, current land use, and site conditions (accessibility, terrain, microclimate, other flora and fauna present, etc.). Other important considerations include treatment effectiveness, overall cost, and number of years needed to achieve complete control. More than one control method may be needed for a particular site.

## **Physical Control**

Physical methods to control knapweeds should focus on reducing seed production and preventing germination, which are mainly accomplished through removal of seed heads and the root system. These methods usually have to be repeated and must be timed properly to be effective.

### ***Manual Methods***

**Hand pulling, hoeing, or digging** – Hand removal can be effective for small knapweed infestations, but it usually must be repeated as much as 2 to 4 times per year for multiple years. Plants should be removed in early bolt before flowers have opened and gone to seed, and the taproot should be removed as much as possible. For spotted knapweed, it is important to remove the entire crown since it can regrow from root fragments. After hand removal,

knapweed populations may return from new or missed plants. It may be helpful to stake areas that have been pulled and then monitor closely for new seedlings.

Proper disposal of debris is essential in preventing knapweed spread. Mulching or incinerating are acceptable disposal methods, especially for plants removed before the flowering or seed set stages.

### ***Mechanical Methods***

**Tillage** – Tillage with a plow, disc, or other implement may favor further invasion, especially with diffuse and spotted knapweeds. This practice is usually not recommended; however, disc tillage may be used in certain agronomic situations as a component in a combined control and reseeding strategy. See “Control Strategies” section for more information.

**Mowing** – Mowing during the early vegetative and bolt stages is a commonly used practice to reduce flowering and seed production. Mowing mature plants that have already flowered is not recommended as this facilitates seed dispersal and spread. Some vegetation management experts do not recommend mowing at all. Mowed knapweed plants often produce side branches with greater numbers of flowers, even with repeated mowing and proper timing.

### ***Prescribed Fire***

Burning is likely to result in crown resprouts and increased seed germination, especially in spotted and diffuse knapweeds. Therefore, fire by itself is not an effective means to control knapweeds; but it can be a component of a combined strategy. See “Control Strategies” section for more information.

## **Cultural Control**

Proper identification of knapweed species is important for their management. Land managers, the local public, and road crews should be educated on knapweed identification and ecology so they can assist with the reporting of suspected infestations. Vehicles and livestock should be checked for knapweed seed after going through infested areas. If

**Table 2. Management options\***

<b>Site</b>	<b>Physical Methods</b>	<b>Cultural Methods</b>	<b>Biological Methods</b>	<b>Chemical Methods</b>
Roadsides, fence lines, or noncrop areas	Mow in the bud to early flower growth stage and repeat as necessary for plant suppression. Mowing mature plants with seed is not recommended. Consider using mowing as part of a combined approach.	Implement requirements for vehicle operations and educate road maintenance personnel to identify and report infestations along roads.	Consider using a classical biological control agent (gall-forming flies and weevils) in combination with another control method. Effectiveness of agents may be limited due to possible disturbances in agent life cycles from roadside operations.  Use of grazing animals may aid in plant suppression and support of other control methods.	Use truck or tractor spraying equipment. Wash underneath vehicle after application to prevent spread.
Rangeland, pasture, or riparian corridors	Mowing - Same as above.  On suitable sites, consider cultivation in combination with herbicide spraying and later reseeding. Include a cover crop when reseeding with desired species.  Tillage alone is usually not recommended for knapweed control.  Burning does little to control, but it may be used to prepare for herbicide application or to dispose of hand-pulled debris.	Use certified weed-free hay and seed.  After passing through infested areas, inspect and remove any seed from animals, clothing, and vehicles before entering treated or uninfested areas.  Use weed screens on irrigation water intakes.	Consider using a classical biological control agent (gall-forming flies and weevils) in combination with another control method. Effectiveness of classical biological control agents varies by specific location.  Closely manage grazing to prevent overuse. Avoid grazing in areas where knapweed seed has ripened inside seed head.	Use ground or aerial broadcast spraying. Backpack or ATV spraying may be more practical in areas difficult to access. Wash underneath vehicle after application to prevent spread.
Wilderness, other natural areas, and/or small infestations	Remove by pulling, hoeing, or digging 2 to 4 times per year. Diffuse and spotted knapweeds should be severed at least 2 inches below root crown to prevent resprouting. Squarrose knapweed should be severed at least 8 inches below soil surface.	Use certified weed-free hay.  After passing through infested areas, inspect and remove any seed from animals and clothing before entering treated or uninfested areas.  Post signs warning visitors to inspect for seeds and remove them from animals, clothing, and vehicles when leaving an infested area.	Same as above.	Use backpack or hand-held sprayers.  Broadcast spraying by aerial or ground methods may be used on thicker stands, if allowed. Wash underneath vehicle after application to prevent spread.

\* Choice of a particular management option must be in compliance with existing regulations for land resource.

possible, use weed screens on irrigation water intakes within infested areas to prevent seed from being transported by irrigation canals. In some cases, reseeding with native perennial grass may be useful after controlling knapweed.

## Biological Control

### Grazing

Diffuse, meadow, spotted, and squarrose knapweeds can be grazed by sheep, goats, and cattle, especially in spring during early growth stages. Intense short-term grazing in spring or when desirable grasses are dormant can reduce young knapweed plants. Meadow knapweed is more readily grazed than the other three knapweed species and is intolerant of continuous heavy grazing. Mature knapweed plants are usually avoided by grazing animals; however, knapweed seed can be inadvertently eaten and spread in manure. Therefore, care should be taken when moving livestock from infested to uninfested areas.

### Classical Biological Control

There have been several classical biological control agents introduced throughout the United States for knapweed control. Three of the insects listed in table 3 are known to affect all knapweed species covered in this guide. Biological control agents alone may reduce but will not eradicate

knapweed populations. However, these agents can be highly effective in combination with other control methods. For further information on biological control of knapweeds, see Wilson and Randall (2005) in the “Reference and Further Information” section of this field guide.

Agents used for biological control in southwestern states should be adaptable to arid environments and local conditions. Public, tribal, and private land managers may obtain biological control agents for release directly from local offices of the USDA Animal and Plant Health Inspection Service (APHIS) when the agents are available. Other sources for biocontrol agents include private companies or locally developed insectaries. A permit must be obtained from APHIS before biological control agents can be transported across state boundaries. Regulations and permit applications (PPQ 526 permit forms) pertaining to interstate shipment of biological control agents can be found at <http://www.aphis.usda.gov/ppq/permits/>. Although biological control agents may be collected and released within a given state without a permit from APHIS, the state’s Department of Agriculture or Agricultural Extension Service should be consulted for any regulations relating to movement of these agents inside the state.

**Table 3. Classical biological control agents**

Species	Type of Agent	Site of Attack/Impact	Use/Considerations for Release
<i>Urophora affinis</i>	gall-forming fly	Attacks early bud and seed head stages. Larvae destroy seeds within gall. Gall diverts energy from other areas of plant and causes reduced vegetative growth and fewer seed heads. Forms a woody gall.	Affects spotted, diffuse, and squarrose knapweeds. Not known to affect meadow knapweed.
<i>Urophora quadrifasciata</i>	gall-forming fly	Papery gall forms within seed head. Each larva destroys two seeds. Damaged florets are destroyed and adjacent florets abort.	Affects spotted, diffuse, squarrose, and meadow knapweeds. Up to 95 percent fewer seeds when combined with <i>U. affinis</i> .
<i>Larinus minutus</i>	beetle/weevil	Adult feeding defoliates plants; larvae feed on seeds. Adults can also destroy seedlings.	Affects spotted and diffuse knapweeds. Can establish on squarrose and meadow knapweeds. Very effective when combined with the two <i>Urophora</i> species listed in the table.
<i>Bangastemus fausti</i>	beetle/weevil	Adults feed on foliage in spring and on flowers in summer; larvae damage seeds.	Affects spotted, diffuse, squarrose, and meadow knapweeds. Often destroys flowers before they produce seeds. Prefers hot, dry sites.

## Chemical Control

A single herbicide spray application will reduce knapweed populations; however, it is important to anticipate the need for followup spot treatments for several years to ensure long-term control success. Knapweeds are best controlled with a selective, postemergent, broadleaf herbicide that has little or no effect on associated native grass species. Choice of herbicides listed in table 4 should be made after considering cost, availability, and effectiveness of individual products. Typically, native grasses respond favorably after knapweed control and will increase in cover within a year of spraying. When native grasses are sparse at the time of spraying, it may be necessary to reseed with competitive perennial species in the fall or spring after herbicide control.

Commonly used herbicides for knapweed control include picloram, dicamba, and clopyralid applied alone or in combination with 2,4-D. Two relatively new herbicides, aminopyralid and aminocyclopyrachlor, are labeled for knapweed control and are also effective. The main herbicide entry into the plant for all products listed in table 4 is through the leaves with only minor entry through the roots. These herbicides target emerged, broad-leaved plant species so caution should be taken if nontarget species need to be protected. This includes woody species that may also be impacted. Consult the label for specific information.

The most effective time to spray spotted or diffuse knapweeds is in the fall during the seedling to early rosette stage since lower rates of herbicide can be applied. In spring, higher rates should be used to spray plants during the late

**Table 4. Herbicide recommendations**

Common Chemical Name (active ingredient)	Product Example <sup>1</sup>	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example <sup>2</sup>	Time of Application	Remarks
Picloram <sup>3</sup>	Tordon 22K	1–2 pints	1–3%	Fall during rosette stage or in spring during bolt to bloom stage; use higher rate at bolting to bud stage.	Persistent, selective herbicide. May pose a risk to groundwater in permeable soils or in areas where the water table is near the surface.
Picloram <sup>3</sup> + 2,4-D <sup>4</sup>	Grazon P+D	2–3 quarts	1–3%	Same as above.	Adding 2,4-D in spring broadens spectrum of activity but may damage desirable forbs and shrubs.
Aminocyclopyrachlor + chlorsulfuron	Perspective	4.75–8 ounces Use a high quality adjuvant as recommended on the label.	Add 5–9 grams of dry flowable powder to 1 gallon of water.	Most effective in late fall after frost but before soil freeze.	Labeled for noncrop use (includes natural areas such as wildlife management areas, wildlife habitats, recreation areas, campgrounds, trailheads, and trails).  May also be used on public, private, and tribal lands as part of an early detection and rapid response (EDRR) in treating infestations of invasive weed species.  Persistent; selective; may cause temporary injury to some grass species.

**Table 4. Herbicide recommendations (continued)**

Common Chemical Name (active ingredient)	Product Example <sup>1</sup>	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example <sup>2</sup>	Time of Application	Remarks
Aminocyclopyrachlor + metsulfuron methyl	Streamline	4.75–8 ounces	Same as above.	Same as above.	Same as above.
Aminopyralid	Milestone	5–7 fluid ounces	3–5%	Fall during rosette stage or in spring during bolt to bloom stage; use higher rate at bolting to bud stage.	Labeled for use on sensitive areas, such as wildlife management areas and natural areas. May be applied up to water's edge. Limited grazing restrictions.
Clopyralid	Reclaim	1/3–1-1/3 pints	1–3%	Same as above.	More selective than 2,4-D or dicamba, but may injure legumes such as clover.  Persistent in soil; very soluble in water and mobile in soil; potential to leach into groundwater.
	Transline	2/3–1 pints	1–3%		
Clopyralid + 2,4-D <sup>4</sup>	Curtail	4 pints	1–3%	Same as above.	Same as above.
Clopyralid + triclopyr	Redeem	2 pints	1–3%	Same as above.	Same as above.
2,4-D <sup>3</sup>	Several manufacturers	1–2 quarts	5–10%	Early spring; apply when flower stem begins to elongate.	Less expensive, also less effective alone. Not persistent; need to apply annually to control new seed germination.
Dicamba	Banvel, Vanquish, Clarity	1–2 pints	1–3%	Fall or early spring; apply to rosettes before bolting.	Use higher rate for older or dense stands.
Dicamba + 2,4-D <sup>4</sup>	Weedmaster	2 pints to 1 quart	3–5%	Same as above.	Adding 2,4-D in spring broadens spectrum of activity but may damage desirable forbs and shrubs.
	Banvel, Vanquish, or Clarity with 2,4-D	Tank mix 1 pint dicamba with 2 pints 2,4-D	1–3%		

<sup>1</sup> Trade names for products are provided for example purposes only, and other products with the same active ingredient(s) may be available. Individual product labels should be examined for specific information and appropriate use with knapweeds.

<sup>2</sup> Herbicide/water ratio - As an example, a gallon of spray water with a 3 percent mixture is made by adding a sufficient volume of water to 4 ozs of liquid herbicide until a volume of 1 gallon is reached (4 oz ÷ 128 oz/gal = 0.03 or 3 percent). For dry formulations, particulates should be added to sufficient water as specified by the label until the required concentration or volume of spray water is reached.

<sup>3</sup> Restricted use pesticide - A certified applicator's license is required for purchase and use.

<sup>4</sup> 2,4-D is a restricted use pesticide in New Mexico only. A certified applicator's license is required for purchase and use.

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rosette or bolting stage; or before flowering when there are 4 to 6 inches of growth and good growing conditions. Effectiveness of herbicide spraying is lower when plants are drought stressed or leaf damaged; therefore, herbicide application is not recommended when plant growing conditions are severe. Consider rotating herbicides from year to year to prevent development of resistance.

Herbicides may be applied using various broadcast methods such as spraying with ATVs or UTVs, or by using conventional boom sprayers that are pulled or attached to a tractor or truck. For individual plant treatment (IPT), knapweed foliage should be wetted thoroughly with a hand-held single nozzle backpack sprayer. When using picloram or another postemergent herbicide, spray an extra 10 to 15 feet around the infested area to ensure control of root sprouts and seedlings. Label instructions and guidelines for mixing, application, and grazing restrictions following herbicide treatment should always be followed.

## Control Strategies

Knapweed species are difficult to control, and an integrated management strategy with a combination of control methods is typically necessary to manage infested sites. The following strategies should be considered when managing knapweeds:

- **Spray–grazing management strategy** – Treat infestation by broadcast spraying with a selective herbicide and practice improved grazing management. If native grasses do not respond naturally, then consider reseeding with perennial forage species. Periodically monitor for newly emerged seedlings and spot treat them.
- **Mow–spray strategy** – Mow during late bud to early bloom, or graze during bolt in spring. Repeat as necessary during the growing season, and spray regrowth in fall. Consider reseeding the next spring with a variety of desirable native perennial species. Periodically monitor for newly emerged seedlings and spot treat them.
- **Burn–spray strategy** – Use prescribed burning in summer, allow new shoots and seedlings to emerge, and follow with herbicide spraying in the fall. Consider reseeding with a variety of desirable native perennial species the next spring. Periodically monitor for newly emerged seedlings and spot treat them.
- **Strategy for small knapweed infestations** – Individual plants may be pulled, grubbed, or spot sprayed. The removed plants should be piled and destroyed by fire or mulching. Periodically monitor for newly emerged seedlings and spot treat them.
- **Strategy for heavy knapweed infestations** – When managing a large, heavily infested area where reseeding will be necessary, the area should be cultivated during the summer using a disc or plow. The knapweed should be allowed to regrow before a broadcast spray is applied in fall with a truck-mounted or boom sprayer. Reseed in late fall or the next spring with a variety of adaptable perennial native species. Periodically monitor for newly emerged knapweed seedlings and spot treat them. Since nitrogen is often limiting in these situations, evaluate the need for using a fertilizer, cover crop, or animal waste to boost the health of planted species. Conduct soil testing to confirm fertilizer needs.

Regardless of the initial strategy used, the key to successful knapweed control is long-term planning, integrated management, and monitoring of treatment areas on an annual basis. Always evaluate the need to reseed in order to encourage competition from desirable plants, especially perennial native grasses. Failure to perform followup treatments could result in recolonization of knapweed and a return to pretreatment levels of invasion.

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## Suggested Web Sites

Encycloweedia datasheets by California Department of Food and Agriculture:

Available at <http://www.cdffa.ca.gov/phpps/IPC/weedinfo/centaurea.htm>

For information about calibrating spray equipment:

NMSU Cooperative Extension Service Guide A-613 Sprayer Calibration. Available at [http://aces.nmsu.edu/pubs/\\_a/A-613.pdf](http://aces.nmsu.edu/pubs/_a/A-613.pdf)

Forestry images:

Available at [www.forestryimages.org](http://www.forestryimages.org)

Herbicide labels online:

Available at <http://www.cdms.net/LabelsMsds/LMDefault.aspx>

Invasive Plant Atlas of the United States:

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