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

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## 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)

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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 administers 4 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; and highly branched flowering stems with white, pink, or purple thistle-like disk flowers. Proper identification should always be made before managing knapweeds. Phyllaries (involucral bracts) and seed appearance are key distinguishing features by which species can be identified. The pappus (tuft of hairs) on each seed is especially important for identification. 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. |

## Ecology

### *Impacts/Threats*

Knapweeds are highly competitive, persistent plants; 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.

### *Site/Distribution*

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 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

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 actions should be considered when planning a management approach:

- Maintain healthy plant communities to prevent or limit knapweed infestations. This may involve improving grazing management practices to prevent plant spread.
- Limit disturbance and/or promptly revegetate disturbed areas.
- Check purchased hay for presence of weed seeds; feed certified weed-free hay or pellets to horses used in backcountry areas.
- Survey for new populations of knapweed and eradicate them as early as possible.
- Map and keep annual records on large infestations.
- Use a combination of mechanical, cultural, biological, and chemical methods for effective control.
- Include monitoring and follow-up treatment for managing missed plants and seedlings.

Table 2 above summarizes some management options for controlling knapweed under various situations. Further details on these management options are explained below. Choice of method(s) to use for knapweed control depends on the extent 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

## Table 2. Management options*

| Site | Physical Control | Cultural Control | Biological Control | Chemical Control |
|---|---|---|---|---|
| Roadsides, fence lines, or non-crop 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. | Use seed, mulch, and fill materials certified to be weed-free.<br><br>Implement requirements for vehicle operations and educate road maintenance personnel to identify and report infestations along roads. | Consider using a biocontrol 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.<br><br>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 spraying to prevent spread. |
| Rangeland, pasture, or riparian corridors | Mowing - Same as above.<br><br>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.<br><br>Burning does little to control, but it may be used to prepare for herbicide application or to dispose of hand-pulled debris. | Use seed and forage hay certified to be weed-free; use pellets for horses in backcountry areas.<br><br>After passing through infested areas, inspect and remove any seed from animals, clothing, and vehicles before entering treated or un-infested areas.<br><br>Use weed screens on irrigation water intakes. | Consider using a biocontrol agent (gall-forming flies and weevils) in combination with another control method. Effectiveness of classical biological control agents varies by specific location.<br><br>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 re-sprouting. Squarrose knapweed should be severed at least 8 inches below soil surface. | Use seed and forage hay certified to be weed-free; use pellets for horses in backcountry areas.<br><br>After passing through infested areas, inspect and remove any seed from animals and clothing before entering treated or un-infested areas.<br><br>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.<br><br>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 the land resource.

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. Physical control methods can be more effective when combined with other control methods (see the "Integrated Control Methods" segment at the end of this section).

### *Manual Methods*

**Hand pulling, hoeing, or digging** – Hand removal can be effective for small knapweed infestations, but it usually must be repeated as many 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*

*If using machinery to manage knapweed, the equipment should be cleaned after use to prevent movement of seed into un-infested areas.*

**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 part of a combined control and reseeding strategy.

**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. Consequently, mowing should be combined with another control method.

### *Prescribed Fire*

Burning is likely to result in crown re-sprouts 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 combined with other control methods.

## 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. Seed and materials used for mulch, forage, or fill should be certified to be weed-free; pellets may be used for horses in backcountry areas. Vehicles and livestock should be checked for knapweed seed after going through infested areas. If 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 un-infested areas.

**Table 3. Classical biocontrol agents approved for knapweeds**

| Species | Type of Agent | Knapweed Species Attacked | Site of Attack/Impact | Use/Considerations for Release |
|---|---|---|---|---|
| *Agapeta zoegana* | moth | Spotted (primarily) and diffuse | Larvae feed in roots. There can be multiple larvae in the roots. Larvae are mobile and can move a short distance to other plants. Larval feeding can kill young plants; larger plants often do not flower. | *A. zoegana* was first released in the United States in 1984 and is now established in most western states. |
| *Bangastemus fausti* | weevil | Spotted, diffuse, squarrose, and meadow | Adults feed on foliage and in the flower base, destroying the flowers and ovules before they produce seeds. Weevils can consume 95 to 100 percent of the seed. In the fall, attacked seed heads have a characteristic emergence hole similar to emergence holes of *Larinus* species. | Prefers hot, dry sites. |
| *Chaetorellia acrolophi* | fly | Spotted, squarrose, and diffuse | This fly feeds on flowers and seed heads; it does not cause plants to form galls. Larval feeding can significantly reduce seed production; a single larva can destroy all of the seeds in a single seed head. | *C. acrolophi* prefers plants in moist habitats and is generally associated with scattered plants rather than in dense stands of spotted knapweed. This fly is not widely distributed |
| *Cyphocleonus achates* | weevil | Spotted (primarily), diffuse, and squarrose | Larvae feed in roots. Small plants can be killed as a direct result of larval feeding. Most damage is done when multiple larvae occupy a root or when the attacked roots are small. Older larvae cause a gall to form in the root, which acts as a metabolic sink. Plants are stunted and some survive only one season after being infested with *C. achates*. Tunneling in the root also exposes the plant to bacterial and fungal infection that can cause additional secondary injury. | *C. achates* is not a strong flyer and consequently has been slow to establish and spread. In hot weather, adults can be seen on the tops of the plants. This is probably the best root-boring biocontrol agent available for knapweed today. |
| *Larinus minutus* | weevil | Diffuse, spotted, squarrose, and meadow | Adult feeding can severely defoliate plants. Larval feeding reduces seed production; a single larva can destroy the contents of an entire diffuse knapweed seed head. Emerging adults make characteristic emergence holes in the center of affected seed heads similar to the emergence holes created by *B. fausti* and *L. obtusus*. | Affects spotted and diffuse knapweeds. Can establish on squarrose and meadow knapweeds. Very effective when combined with other root knapweed biocontrol agents. |
| *Larinus obtusus* | weevil | Spotted (preferred) and diffuse | One or two larvae destroys most of the developing seeds in the head. Any seeds not eaten become part of the pupal chamber. Adult feeding on foliage can reduce photosynthesis and plant vigor. Emerging adults make characteristic holes in the center of affected seed heads, similar to the emergence holes created by *B. fausti* and *L. minutus.* | *L. obtusus* prefers moist sites in contrast to the other seed head weevils for knapweed, which prefer and thrive in drier sites. |

**Table 3. Classical biocontrol agents approved for knapweeds (cont.)**

| Species | Type of Agent | Knapweed Species Attacked | Site of Attack/Impact | Use/Considerations for Release |
|---|---|---|---|---|
| *Metzneria paucipunctella* | moth | Spotted (preferred), diffuse, and meadow | Larvae feed on developing seeds. Each larva can destroy an average of eight seeds and reduce the viability of others. Older larvae web seeds together preventing seeds from dispersing over long distances. | *M. paucipunctella* can suffer severe mortality during cold winters. Moth feeding complements the biological control caused by *Urophora* species. *M. paucipunctella* larvae are aggressive and will kill one another or other knapweed seed head-infesting larvae. White-footed deer mice are known to eat many of the larvae during the winter months. |
| *Pelochrista medullana* and *P. inspersa* | moths | Diffuse and spotted | Damage to the roots is similar to that caused by *A. zoegana*. Larvae cause considerable root damage and as a result, plants attacked by the larvae are stunted and produce fewer flowers. The infested root becomes spongy and easy to pull from the ground. Feeding damage reduces root storage. | *P. inspersa* is established in British Columbia and Idaho, *P. medullana* has not yet been found in the United States. |
| *Sphenoptera jugoslavica* | beetle | Diffuse (preferred), spotted, and squarrose | Larvae mining the roots can cause significant impact; adult feeding on the leaves is much less damaging. The larvae cause a gall-like swelling in the knapweed root near the crown. The depletion of root carbohydrates can kill the plant or retard rosette growth. Attacked plants are often stunted and produce fewer seeds the following season. | This beetle prefers hot, dry sites with shallow, stony soils typical of those infested with diffuse, spotted and squarrose knapweed. |
| *Terellia virens* | fly | Spotted (preferred) and diffuse | *T. virens* larvae cause considerable destruction of seeds; partial feeding damage on other seeds can reduce viability of the remaining seeds by up to 90 percent. | *T. virens* prefers plants on south-facing slopes and dry locations. |
| *Urophora affinis* | gall-forming fly | Spotted, diffuse, squarrose, and meadow | Attacks early bud and seed head stages causing the formation of a woody gall. Larvae directly destroy seeds within the gall. Galls drain nutrients from other parts of the plant resulting in fewer seed heads and reduced vegetative growth. | *U. affinis* does not disperse as well as *U. quadrifasciata* and other seed head-feeding agents. On sites with both *U. affinis* and *U. quadrifasciata* infesting knapweed, *U. affinis* tends to dominate. |
| *Urophora quadrifasciata* | gall-forming fly | Spotted, diffuse, squarrose, and meadow | Papery gall forms within seed head. Each larva destroys two seeds. Damaged florets are destroyed and adjacent florets abort. | There does not appear to be a decrease in the number of seed heads on plants attacked by *U. quadrifasciata.* The fly spreads rapidly, more so than *U. affinis*. |

### *Classical Biological Control*

Thirteen biocontrol agents (moths, flies, weevils, and a beetle) have been introduced throughout the U.S. for knapweed control (see table 3). Biocontrol agents may reduce but will not eradicate knapweed populations. However, these biocontrol agents can be highly effective when used in combination with other control methods such as herbicides, mechanical methods, or cultural practices. For further information on classical biocontrol of knapweeds, see Winston et al. (2011) in the "Reference and Further Information" section of this field guide.

Organisms (insects, pathogens, etc.) used as biocontrol agents in southwestern States should be adaptable to arid environments and local conditions. Public, tribal, and private land managers may obtain biocontrol agents for release directly from local offices of the USDA Animal and Plant Health Inspection Service (APHIS) when these agents are available. Other sources for biocontrol agents include locally developed insectaries or private companies.

A permit must be obtained from APHIS before biocontrol agents can be transported across State lines. Regulations and permit applications (PPQ 526 permit forms) pertaining to interstate shipment of biocontrol agents can be found at *https://www.aphis.usda.gov/aphis/ourfocus/planthealth/import-information/permits/regulated-organism-and-soil-permits/sa_apply/ct_plantpest_howtoapply*. Although biocontrol agents may be collected and released internally in a given State without an APHIS permit, the State's department of agriculture or agricultural extension service should be consulted for any regulations relating to movement of these agents within the State.

## Chemical Control

Knapweeds are best controlled with a selective, post-emergent, broadleaf herbicide that has little or no effect on associated native grass species (table 4). Commonly used herbicides for knapweed control include picloram, dicamba, and clopyralid applied alone or in combination with 2,4-D. Two new herbicides, aminopyralid and aminocylopyrachlor, are labeled for knapweed control and are also effective. Choice of herbicides should be based on cost, availability, and effectiveness of individual products.

The main herbicide point of 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 non-target species need to be protected. Consult the label for specific information.

### *Herbicide Application*

A single herbicide spray application will reduce knapweed populations; however, it is important to anticipate the need for follow-up spot treatments for several years to ensure long-term control success. 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.

The most effective time to spray spotted or diffuse knapweeds is in the fall during the seedling to early rosette stages since lower rates of herbicide can be applied. In spring, higher rates should be used to spray plants during the late 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 under severe growing conditions. Consider rotating herbicides from year to year to prevent development of resistance.

Any equipment used to spray herbicide should be calibrated. Herbicides may be applied using various types of broadcast equipment such as ATVs or UTVs, or 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 backpack or hand-held sprayer that has a single nozzle When using picloram or another post-emergent herbicide, spray an extra 10 to 15 feet around the infested area to ensure control of root sprouts and seedlings. Precautionary measures should be taken to protect desirable native plants (including woody species) during application. Label instructions and guidelines for mixing, application, and grazing restrictions following herbicide treatment should always be followed.

## Table 4. Herbicide recommendations

| Common Chemical Name (active ingredient) | Product Example[1] | Broadcast Treatment (rate per acre) | Spot Treatment (spray solution)[2] | Time of Application | Remarks |
|---|---|---|---|---|---|
| Picloram[3] | 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[3] + 2,4-D[4] | 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<br>Use a high quality adjuvant as recommended on the label. | Add 5–9 grams of dry flowable powder to1 gallon of water. | Most effective in late fall after frost but before soil freeze. | Labeled for non-crop use includes natural areas such as wildlife management areas, wildlife habitats, recreation areas, campgrounds, trailheads, and trails).<br>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.<br>Persistent; selective; may cause temporary injury to some grass species. |
| 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. |
| | Transline | 2/3–1 pints | 1–3% | | Persistent in soil; very soluble in water and mobile in soil; potential to leach into groundwater. |
| Clopyralid + 2,4-D[4] | 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[4] | Several manufacturers | 1–2 quarts | 5–10% | Early spring; apply when flower stems begins to elongate. | Less expensive, also less effective alone. Not persistent; need to apply annually to control new seed germination. |

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

| Common Chemical Name (active ingredient) | Product Example[1] | Broadcast Treatment (rate per acre) | Spot Treatment (spray solution)[2] | Time of Application | Remarks |
|---|---|---|---|---|---|
| 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[4] | 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% | | |

[1] 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.

[2] Spray solution is the herbicide/water ratio in a spray mix that may be used for spot treatment with backpack or hand-held sprayers. The amount of product applied during an annual growing season must not exceed the maximum application rate per acre as specified by the product label – refer to the product label for the site type and application.

[3] Restricted-use pesticide - A certified applicator's license is required for purchase and use.

[4] 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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## Integrated Control Methods

The following combinations of control methods should be considered for managing knapweed infestations that cover large areas:

- **Mow–herbicide** – 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.
- **Tillage–herbicide–reseed** – When managing a large, dense infestation on a tillable 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. 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.
- **Burn–herbicide** – 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 in the next spring. Periodically monitor for newly emerged seedlings and spot treat them.
- **Herbicide–grazing** – 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.

## Management Strategies

To manage knapweeds, the first priority should be to prevent knapweeds from establishing in areas where they are currently absent. Next, treat small infestations on otherwise healthy sites. Satellite and small, isolated populations should be eradicated by pulling, grubbing, or spot spraying individual plants. Removed plants should be piled and destroyed by fire or mulching. Large infested areas should be contained and gradually eradicated over time if possible, starting around the perimeter. Periodically monitor for newly emerged seedlings and spot treat them.

Always evaluate the need to reseed treated areas to encourage competition from desirable plants, especially perennial native grasses. A complete restoration program may be required to control large knapweed populations. 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, evaluate soil conditions and select control methods that can enhance the seeding process. Because nitrogen is often limiting, evaluate the need for using a fertilizer, cover crop, or animal waste to boost the health of planted species. Conduct soil testing for fertilizer needs.

The key to successful knapweed control is long-term planning, integrated management, and monitoring of treatment areas on an annual basis. Regardless of the management 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. Since it is ordinarily useless to treat an area only one time without retreatment, sufficient resources must be allocated for the area where control is attempted. After initial treatment, it is especially important that resources are also available to respray or retreat the treated area as necessary. Always closely follow knapweed control efforts with monitoring and be prepared to spot treat surviving plants and seedlings until none can be found. Failure to perform monitoring and follow-up treatments may result in recolonization of knapweed.

## References and Further Information


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## Suggested Web Sites

Encycloweedia datasheets by California Department of Food and Agriculture: Available at http://www.cdfa.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/A613

Forestry images: Available atwww.forestryimages.org

Herbicide labels online: Available at http://www.cdms.net/

Invasive Plant Atlas of the United States: Available at http://www.invasive.org/weedus/index.html

## For more information or other field guides, contact:

USDA Forest Service
Southwestern Region
Forest Health
333 Broadway Blvd., SE
Albuquerque, NM 87102

## Or visit the Southwestern Region's website for invasive species:

*http://www.fs.usda.gov/goto/r3/invasivespecies*