Watson Woods Riparian Preserve
High-Priority Noxious Weed List

Updated July 9, 2013

Species:

Spotted Knapweed	*Centaurea maculosa*
Russian Knapweed	*Acroptilon repens*
Scotch Thistle	*Onopordum acanthium*
Dalmatian Toadflax	*Linaria dalmatica*
Russian Olive	*Elaeagnus angustifolia*
Tamarisk	*Tamarix ramosissima*
Common Teasel	*Dipsacus fullonum*

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Forest Service

Southwestern Region

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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. biebersteinii*)
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 encompasses 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.

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.
- 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 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.

Table 2. Management options*

Site	Physical Methods	Cultural Methods	Biological Methods	Chemical Methods
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, 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.

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 on APHIS' Web site 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.

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

Table 3. Classical biological control agents

Species	Type of Agent	Site of Attack/Impact	Use/Considerations for Release
Urophora affinis	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.
Urophora quadrifasciata	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 *U. affinis*.
Larinus minutus	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 *Urophora* species listed in the table.
Bangastemus fausti	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.

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 aminocylopyrachlor, 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 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.

Table 4. Herbicide recommendations

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[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 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[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	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 and habitat management areas; 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[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[3]	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[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] 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.

[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.

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.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/A-613.pdf

Forestry images:

Available at www.forestryimages.org

Herbicide labels online:

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

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
Forestry and Forest Health
333 Broadway Blvd., SE
Albuquerque, NM 87102

Or visit:

http://www.fs.usda.gov/main/r3/forest-grasslandhealth

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Field Guide for Managing Russian Knapweed in the Southwest

Cover Photos

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Russian knapweed (*Rhaponticum repens* L., formerly *Acroptilon repens* L.)

Sunflower family (Asteraceae)

Russian knapweed is an invasive plant that has been listed as a noxious weed in Arizona and New Mexico. This field guide serves as the U.S. Forest Service's recommendations for management of Russian knapweed in forests, woodlands, and rangelands associated with its Southwestern Region. The Southwestern Region encompasses 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

Russian knapweed (synonyms: Turestan thistle, creeping knapweed, mountain bluet, Russian cornflower, hardheads) is an introduced, long lived, creeping perennial. This invasive weed is the most widely distributed of the various knapweed species. It is widespread in northern states including Colorado, Montana, and Wyoming and is currently becoming more common in New Mexico and Arizona. Russian knapweed can be distinguished from other knapweeds by its scaly, brown to black, spreading rhizomes and by its unique flowering bract features.

Growth Characteristics

- Long lived, creeping perennial; slow to establish but can spread rapidly once present; difficult to eradicate.
- Grayish-green rosette base; dense hairs; emerges in early spring.
- Erect branching stem, 18 to 36 inches tall, covered with cobwebby hairs.
- Brown to black, scaly rhizomes; long lived, deep vertical root system (grows to 20 feet deep or more).
- Flowers from June to September; pink to lavender, thistle-like, terminal flowers; urn-shaped flower heads, 0.25 to 0.5 inch in diameter; rounded bracts with papery tips.
- Reproduces mainly vegetatively via root buds near each scale on the rhizome; forms dense patches of cloned plants. Also produces seed (50 to 500 seeds per plant; viable for 2 to 3 years).
- Releases allelopathic chemicals that can inhibit growth of other plants; contains sesquiterpene lactones that are toxic to horses.
- Relatively shade intolerant.

Ecology

Impacts/threats – In dense stands, Russian knapweed develops into a near monoculture due to its ability to out-compete resident vegetation. Such monocultures can contribute to reduced wildlife presence and a decline in species diversity. This knapweed is toxic to livestock (especially horses), and its presence reduces forage availability.

Location – Russian knapweed adapts to a variety of soil types, including poorly drained and alkaline/saline soils. It prefers areas with moist but not excessively wet soils. It readily invades pastures, degraded croplands, alfalfa fields, rangeland, roadsides, riparian and runoff areas, river bottoms, drainages, and irrigated fields. Large populations are distributed extensively throughout northern New Mexico, and smaller populations are present in most central and southern counties of the State. In Arizona, Russian knapweed is a concern in northeastern and southeastern counties.

Spread – Although Russian knapweed produces seed, it spreads mainly through vegetative propagation that arises from adventitious buds along a creeping, perennial root system. Root fragments of 1 inch or more in length can produce new plants if the fragments are buried in soil to a depth no greater than 6 inches. Seed or root fragments may be introduced into new areas via waterways such as irrigation ditches, streams, or rivers. Russian knapweed may also spread through transported hay that is not certified to be weed free or through attachment of propagules that adhere to the undercarriages of off-road vehicles and road maintenance equipment.

Invasive Features – Russian knapweed's competitiveness is believed to be related to its ability to release harmful allelopathic chemicals that can inhibit growth of other plants. As a possible result of allelopathic effects, revegetation efforts following Russian knapweed control are often hampered unless measures are taken to mitigate soil condition. The weed can also cause as much as an eightfold increase in zinc concentration in nearby soil surface layers as compared to upper layers of soils without knapweed.

Management

Russian knapweed is quite difficult to control once established. Prevention, early detection, and eradication are the best management tools for controlling this noxious weed. Initial treatments to control Russian knapweed should attempt to remove as much of the knapweed population as possible, and secondary treatments should be anticipated to remove remaining plants. Small knapweed stands on otherwise healthy sites should be eradicated first. Large knapweed infestations should be controlled and then eradicated when possible. The perimeter of large infestations should generally be treated first to prevent the infestation from spreading. As with other creeping perennial weeds, treated knapweed plants should be stressed sufficiently by control methods to cause depletion of stored nutrients in root systems. The following actions should be considered when planning an overall management approach:

- Maintain healthy plant communities and the presence of ground litter to prevent or limit knapweed infestations. This may involve using improved grazing management to prevent excessive grazing, and reseeding areas with desirable grasses and forbs after disturbance.
- Detect, report, and map known infestations. Keep annual records of reported infestations.
- Eradicate new populations of Russian knapweed as early as possible.
- Combine mechanical, cultural, biological, and chemical methods for most effective knapweed control.
- Implement a monitoring and followup treatment plan for missed plants and seedlings.
- Use certified weed-free seed and hay; use pellets for horses used in back-country areas.

Table 1 summarizes management options for controlling Russian knapweed under various situations. Choice of individual control method(s) for Russian knapweed depends on the degree and density of 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 the number of years needed to achieve control. More than one control method may be needed for a particular site.

Physical Control

A number of mechanical control methods for Russian knapweed have been examined, but most have shown limited effectiveness. In general, mechanical control methods need to be combined with chemical spraying for long-term management of Russian knapweed.

Manual Methods

Hand pulling or digging – Hand pulling or hoeing can be effective for small, less established infestations of Russian knapweed if repeated annually over multiple years. Removal is generally easier and more effective in late spring when soil is moist and plants are beginning to bolt (but before seed set). It is very important to pull up all parts of the plant, especially the roots. Wear gloves and properly dispose of debris by burning or bagging and burying in a landfill to prevent spread.

Mechanical Methods

Tillage – Shallow cultivation or tillage without herbicide spraying as a followup treatment should be avoided since this practice often leads to an increase in knapweed dominance. Disking or plowing cuts roots into fragments

Table 1. Management options*

Site	Physical Methods	Cultural Methods	Biological Methods	Chemical Methods
Roadsides, fence lines, or noncrop areas	Mow at 2 to 3 week intervals during growing season but before seed set. Follow up with an herbicide application in the fall.	Avoid driving vehicles and equipment through infested areas; wash if travel through these areas is unavoidable. Educate road crews and others to identify and report infestations.	A gall-forming nematode (*Subanguina picridis*) may be available in some western states including New Mexico.	Use truck or tractor-mounted spraying equipment to broadcast treat. Wash underneath vehicle after application to prevent spread.
Rangeland, pasture, or riparian corridors	Deep cultivation (12 inches) repeated over 3 years can be effective. Shallow cultivation/tillage is not recommended as severed root fragments may regrow. Burning is ineffective and may contribute to further knapweed dominance.	Use certified weed-free seed and hay. Use pellets for horses in backcountry areas. Check animals, clothing, and vehicles for seeds. Always evaluate the need to reseed with native perennial grass when considering knapweed control.	Closely manage grazing to prevent overuse. Consider grazing heavily infested sites in late summer or early fall rather than spring. Maintain litter cover to reduce knapweed germination. A gall-forming nematode (*Subanguina picridis*) may be available in some western states including New Mexico.	In areas difficult to access, an ATV-mounted sprayer or backpack unit may be the most practical application methods. Wash underneath vehicle after application to prevent spread.
Wilderness, natural areas, and/or small infestations	Hand pulling, hoeing, or digging must remove all root stock to be effective; wear gloves for pulling; pull when soil is moist; most effective on newly established plants.	Use certified weed-free seed and hay. Use pellets for horses in backcountry areas. Check animals and clothing for seeds. Post signs warning visitors to remove seeds after passing through infested areas. Always evaluate the need to reseed with native perennial grass when considering knapweed control.	Same as above.	Use backpack or hand-held sprayers. Broadcast spraying with ground methods may be used on thicker stands if allowed. Remove seed from clothing to prevent spread.

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

that can survive desiccation and promote further spread. See the "Control Strategies" section for more information.

Mowing – If repeated continually throughout the growth season, mowing will suppress shoots and flowers; however, mowing will not reduce Russian knapweed populations.

Prescribed Fire

Burning as a single control method is not recommended. New plants from roots are quickly produced after fire which often leads to increased dominance by Russian knapweed. However, fire may be used as a secondary treatment in combination with other control methods, such as disposal of debris.

Cultural Control

Prevention, early detection, and plant removal are critical for preventing Russian knapweed establishment. Land managers, road crews, and the local public should be educated on identification of knapweed species so that they can help report all suspected infestations. Vehicles, humans, and livestock should be discouraged from traveling through infested areas. A program to check and remove seed from vehicles and livestock after travel through infested areas

should be implemented to help stop dispersal. To prevent seed from being transported by irrigation canals, use weed screens on irrigation water intakes inside infested areas if possible.

Reseeding with native perennial grass after disturbance should always be considered in controlling knapweed. Tillage should be used before reseeding to alleviate any remaining allelopathic effects from Russian knapweed on soil condition.

Biological Control

Grazing

Livestock (including cattle, sheep, and goats) normally will not graze Russian knapweed due to its bitter flavor; however, animals may graze the weed lightly during early growth. The weed is especially toxic to horses and should not be grazed by them. The time of grazing preferred for pastures infested with Russian knapweed should occur during late summer, early fall, or winter. Use grazing to encourage perennial grass growth and competition against Russian knapweed. Reduce grazing pressure in early spring when grasses are first starting to grow and allow grasses to tiller and produce seed. Utilization of knapweed by livestock should be carefully monitored, and heavy grazing should be avoided.

Classical Biological Control

Table 2 lists some potential biological control agents that can affect Russian knapweed. Although biological control agents may weaken Russian knapweed populations, they have not been shown to reduce them. A gall nematode (*Subanguina picridis)* has been released in northwestern New Mexico to help control Russian knapweed. It forms galls on stems, leaves, and root crowns. Several other biocontrol agents such as a gall-forming wasp (*Aulacida acroptilonica*) and a rust fungus (*Puccinia acroptili*) are currently being evaluated but have not yet been released.

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 on the APHIS Web site 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

Table 2. Classical biological agents

Species	Type of Agent	Site of Attack/ Impact	Use/Considerations for Release	Remarks
Subanguina picridis	gall-forming nematode	stems, leaves, and root crowns	Readily spreads for long distances without assistance.	Successfully established in Washington, Colorado, Montana, Oregon, Utah, and Wyoming.
Aulacidea acroptilonica	gall-forming wasp	stems	Currently being researched	
Puccinia acroptili	rust fungus	roots	Currently being researched	

Agricultural Extension Service should be consulted for any regulations relating to movement of these agents inside the state.

Chemical Control

Russian knapweed is best controlled with a selective, postemergent herbicide. Typically, the main herbicide entry into the plant is through the leaves and stems; but certain herbicides can enter through the roots. Control results can vary due to weather and plant growth stage. Herbicides generally provide significant reduction of a knapweed population with a single application; however, followup treatment should always be anticipated.

All herbicides recommended in table 3 will effectively control Russian knapweed when properly applied. Selective herbicides used for effective control of Russian knapweed include picloram, aminocyclopyrachlor, aminopyralid, and clopyralid. Picloram is a restricted-use pesticide and should not be used near waterways or whenever the water table is near the surface. Glyphosate or imazapyr can be used for followup spot treatment, but these treatments may create a bareground situation.

Precautions should be taken if nontarget plants (including woody species) need to be protected. This includes situations where spray drift, soil erosion, or water movement potentially could occur. Each herbicide product will have different requirements and restrictions according to the label. Read and understand prior to any application. To prevent development of resistance in Russian knapweed for repeated treatments, the label should be consulted for guidelines on rotating herbicide active ingredients. Consult the registrant if you have questions or need further detail.

The most effective period to spray Russian knapweed generally is in the fall (preferably after a frost) when rosettes begin to emerge or mature plants appear dormant (grey stems, no leaves). Spraying earlier may provide only short-term control. Herbicides may be applied by

Table 3. Herbicide recommendations

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Picloram[3]	Tordon 22K	1–2 quarts	1–3%	Most effective in late fall after frost. Apply 1 pt/acre if used in combination with cultivation and reseeding.	May be used in combination with 2,4-D.[4] Restricted use herbicide that is selective although persistent. Picloram may pose a risk to groundwater in permeable soils or in areas where the water table is near the surface. Wait 2 months to reseed perennial grasses.
Aminocyclopy-rachlor + chlorsulfuron	Perspective	4.75–8 ounces	Add 5–9 grams of dry flowable powder to 1 gallon water.	Most effective in late fall after frost.	A selective blend of active ingredients labeled for noncrop use (includes natural areas such as wildlife management areas, wildlife habitats, recreation areas, campgrounds, trailheads, and trails). Persistent; selective for broad-leaved plants; may cause temporary injury to some grass species. 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.

Table 3. Herbicide recommendations (continued)

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Aminocyclopyrachlor + metsulfuron methyl	Streamline	4.75–9.5 ounces	Same as above.	Same as above.	A selective blend of active ingredients labeled for noncrop use (includes natural areas such as wildlife management areas, wildlife habitats, recreation areas, campgrounds, trailheads, and trails). Persistent; selective for broad-leaved plants and certain brush species; may cause temporary injury to some grass species. Can be used in riparian areas. 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.
Aminopyralid	Milestone	4–6 fluid ounces	5–10%	Spring and summer at bud to flowering growth; or in late fall on dormant plants.	May be used in combination with 2,4-D. Use higher rate on older stands; late fall treatment of dormant plants can be very effective. Add 0.25–0.5 percent nonionic surfactant for mature plants or for adverse conditions. Labeled for use up to water's edge. No grazing restrictions.
Clopyralid	Curtail	1–2 quarts	1–3%	Bud to full bloom or in late fall after frost.	May be used in combination with 2,4-D. Can be used on rangeland, irrigated pasture, or meadows but not directly to water. Wait 30 days to reseed perennial grasses.
	Reclaim, Transline	1–1-1/3 pints	1–3%		
Glyphosate	RoundUp, many products	4–4.8 quarts	2%	Late bud to early flower; late summer or fall.	Use primarily as followup spot treatment. Direct spray or use a wipe method when desirable plants are present.
Imazapyr	Arsenal	2 pints	1%	Anytime plants are growing or in the fall after frost.	Use primarily as followup spot treatment. Direct spray or use a wipe method when desirable plants are present. In addition to overspray, nontarget plants may also be killed or injured by root transfer of imazapyr between intertwined root systems.

[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 Russian knapweed.

[2] 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 ounces 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.

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

[4] 2,4-D is a restricted use pesticide in New Mexico only.

backpack sprayers, ATV or UTV sprayers, or conventional boom sprayers that are pulled or attached to a tractor or truck. In situations where Russian knapweed is dense and widespread, aerial application by fixed wing or helicopter aircraft should be considered.

Control Strategies

The key to successful Russian knapweed control is long-term planning, integrated management, monitoring treated areas on an annual basis, and possibly reseeding in order to encourage competition from desirable plants, especially perennial native grasses. Planning and treatments to control Russian knapweed should be designed to meet specific site conditions. An integrated management strategy that combines control methods as necessary should be implemented to contain, reduce, or eradicate Russian knapweed populations. As discussed in the "Management" section of this guide, Russian knapweed populations growing in small isolated patches on otherwise healthy sites should have first priority for treatment. For heavily infested areas, plants at the perimeter should be treated first. The larger, denser cores of the infested area should be addressed in the final stage of treatment. Failure to perform followup monitoring and treatment may result in recolonization of Russian knapweed and a return to a pretreatment level of invasion.

The following strategies should be considered to contain and reduce populations of Russian knapweed:

- **Mechanical–herbicide strategy** – One example of a combined control strategy is to mow or disk at 2 to 3 week intervals during growing season, then apply herbicide to knapweed regrowth in the fall. Consider reseeding the area shortly thereafter with competitive perennial grasses. Perform followup monitoring and spot treat any new or regrowing plants. Grazing should be managed to favor establishment of desirable perennial grasses.
- **Individual plant treatment for sparse infestations or followup** – Use a backpack sprayer, wiper, or sponge applicator per the herbicide label to administer spot treatment in the fall. For individual plant treatment (IPT), the foliage should be wetted thoroughly (apply until it begins to run off). 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/or seedlings. A wiping or direct spray method using a 2 percent glyphosate solution may be used when plants are in bloom but before seed matures. This approach is most appropriate when other desirable broadleaved plants are present. Areas treated with glyphosate can be reseeded after 3 days.
- **Strategy for an infestation with an adequate grass understory present** – Spray selective herbicide in autumn to control Russian knapweed and allow native grasses to return naturally in the next growing season. Defer grazing on areas sprayed for one or more growing season to allow grasses to increase and gain a competitive advantage. Monitor sprayed areas carefully for 2 or 3 years and spot spray returning Russian knapweed plants.
- **Strategy for an infested site with little grass understory** – Consider planting with a mixture of native grass, shrub, and forb seed. Control Russian knapweed first by herbicide spraying in fall and later cultivate to bury allelopathic plant residue. Follow up with planting by late fall to allow seed to take advantage of any early spring moisture that may be available. To use less seed and ensure more successful establishment, consider seeding with a grain drill. A no-till, rangeland drill may be necessary on particularly rocky, steep, or hard sites. Select native perennial grass species according to individual site conditions and moisture availability. Periodically monitor the next growing season for newly emerged Russian knapweed seedlings and spot treat them.

Adaptive Management – A persistent commitment over many years is required for successful control of Russian knapweed. Therefore, realistic goals and objectives should be established to manage Russian knapweed infestations occurring extensively throughout a given landscape. To improve long-term success, consider using an adaptive management strategy with the overall goal of restoring desirable plant communities. The stepwise process for adaptive management involves:

1. Assessment of the overall weed problem,
2. Establishing management goals and objectives,
3. Implementation of control strategies,
4. Monitoring the effectiveness of management actions,
5. Evaluating actual outcomes in relation to expected results, and
6. Adjusting practices as necessary.

Steps of this process should be repeated in sequence as part of a continuous learning cycle that improves management planning and strategy by learning from the outcomes of previous management actions. In general, an adaptive management strategy may be considered to be successful if:

1. Stakeholders are actively involved and remain committed to the process,
2. Monitoring and assessment are used to adjust and improve management decisions, and
3. Management goals and/or objectives for the resource are being achieved.

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Suggested Web Sites

For information on invasive species:

http://www.invasivespeciesinfo.gov/

http://www.invasive.org/weedus/index.html

For information about calibrating spray equipment:

NMSU Cooperative Extension Service Guide A-613 Sprayer Calibration at http://aces.nmsu.edu/pubs/_a/A-613.pdf

Herbicide labels online:

http://www.cdms.net/LabelsMsds/LMDefault.aspx

For more information or other field guides, contact:

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

Or visit:

http://www.fs.usda.gov/main/r3/forest-grasslandhealth

USDA

United States Department of Agriculture

Forest Service

Southwestern Region

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Field Guide for Managing Annual and Biennial Invasive Thistles in the Southwest

Cover Photos

Top left: Bull thistle plant, Steve Dewey, Utah State University, Bugwood.org
Top right: Scotch thistle, Steve Dewey, Utah State University, Bugwood.org
Bottom left: Musk thistle, Ricky Layson, Ricky Layson Photography, Bugwood.org
Bottom right: Scotch thistle plant, Steve Dewey, Utah State University, Bugwood.org

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Bull thistle (*Cirsium vulgare* (Savi) Tenore)
Musk thistle (*Carduus nutans* L.)
Plumeless thistle (*Carduus acanthoides* L.)
Scotch thistle (*Onopordum acanthium* L.)
Sunflower family (Asteraceae)

Bull, musk, plumeless, and Scotch thistles are annual and biennial nonnative plants in the sunflower family that are considered invasive. Plumeless and Scotch thistles are listed as noxious weeds in both Arizona and New Mexico. Musk thistle and bull thistle have been listed as noxious weeds only in New Mexico.

This field guide serves as the U.S. Forest Service's recommendations for management of annual and biennial invasive thistles in forests, woodlands, and rangelands associated with its Southwestern Region. The Southwestern Region encompasses 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

All thistles addressed in this guide are annual to biennial in growth form. They reproduce solely by seed and are prolific seed producers. The seed remains viable in the soil for many years. At maturity, these spiny weeds have basal rosettes, purplish disk flowers, and flowering stems that are highly branched. Distinguishing features by which individual species can be identified include plant size, appearance of phyllaries (involucral bracts), and the hairiness and shape of the leaves. Growth characteristics useful for identifying these thistles are given in table 1.

Ecology

Impacts/threats – Thistles are highly competitive and persistent plants. Given suitable conditions, these weeds rapidly invade rangeland, pastures, abandoned fields, roadsides, and disturbed sites. A high density of thistles reduces availability of quality forage and the diversity of flora and fauna species. Additionally, most thistles have taproots that do not stabilize the soil as well as the fibrous roots of native grass species; therefore, high densities of thistles can contribute to soil erosion and stream sedimentation.

Location – Thistles establish readily on disturbed or neglected sites, especially along roadsides, railways, ditchbanks, and waste areas. Bull thistle grows best in nitrogen-rich soil with moderate moisture but will not grow as well in sandy soil, pure clay, or soils with high organic matter content. Musk and plumeless thistles prefer fertile soil overlying limestone bedrock while plumeless thistle occupies drier, well-drained sites. Scotch thistle prefers sites in dry climates with fertile soils and high moisture content.

Spread – Thistle seed is easily dispersed by wind, water, birds, and other animals. Seed can be carried long distances by adhering to surfaces and undercarriages of road vehicles and road maintenance equipment. Thistles may also be introduced to new areas via seed in hay that is not certified to be weed free.

Invasive Features – Excessive grazing favors thistle growth over grasses since livestock do not prefer to graze these weeds. In spring, thistles develop a large rosette base that shades the soil and reduces competition from other emerging plants. Additionally, some thistles have allelopathic properties that slow or prevent growth of desirable plant species, thereby allowing these thistles to thrive.

Management

Since all thistle species addressed in this guide are prolific seed producers, high priority for thistle management should be directed toward preventing establishment and eliminating new plants as soon as they are found. Small infestations occurring within otherwise healthy sites should be given special consideration for control treatment.

Table 1. Growth characteristics

Species	Life Span	Growth and Root Habit	Vegetative Appearance	Flower and Phyllary[1]	Seed
Bull thistle	Biennial or annual	Rosette up to 3 feet in diameter. Several primary roots each with many laterals.	Bushy appearance. Leathery, deeply lobed, green leaves; prickly hairs on upper side; underside wooly; yellowish pointed spines. Hairy stems with dark purple veins; broad, prickly wings line stem.	Purple disk flower. Phyllary urn-shaped; spiny.	Glossy light brown to pale yellow or white seed with narrow, dark brown stripes; 0.1 to 0.15 inch long.
Musk thistle	Biennial or winter annual	Rosette up to 2 feet or more in diameter. Single, fleshy taproot 15 to 16 inches long.	Waxy, pale green silver-margined leaves with yellow spine tips. Multibranched stems; stem wings do not extend completely up stem.	Showy purplish-red disk flowers that "nod" at a 90 degree angle. Phyllary with broad, overlapping, brown bracts; resembles a pine cone.	Straw-colored glossy seed with stripes, plume-like bristles, and a light apical rim; 0.15 to 0.2 inch long.
Plumeless thistle	Biennial or winter annual	Rosettes up to 2 feet or more in diameter. Stout, fleshy taproot.	Plant looks like a candelabrum. Deeply lobed leaves with white margins and 1 to 3 very stiff spines; hairy underside. Flower stems branched with spiny wings.	Red to purple disk flowers (smaller than musk thistle). Very narrow phyllary bracts with short, sharp spines.	Small, grey to light brown seed with slight curvature and distinct light apical collar; 0.07 to 0.11 inch long.
Scotch thistle	Biennial or short-lived perennial	Rosette up to 6 feet in diameter. Stout, fleshy taproot up to 12 inches or more.	Large, grey-green, coarsely lobed, spiny-edged leaves with wooly hairs. Stems have prominent spiny wings.	Purple disk flowers on globe-shaped heads with many spiny phyllaries in overlapping rows.	Mottled brown to blackish seed with wavy ridges and pinkish to red pappus bristles that fuse into a ring at the base; 0.16 to 0.2 inch long.

[1] A phyllary is an involucral bract subtending (located below) the flower head of a composite plant.

Larger infestations should be managed using an integrated management strategy. Regardless of the approach for treatment, do not anticipate that thistles will be effectively controlled in a single year or by using only one control method. Complete control will likely require several years of monitoring with repeated treatment. Strategies to contain and reduce thistle populations require long-term planning and integrated management. The following actions should be considered when planning a management approach:

- Maintain healthy plant communities to prevent or limit thistle infestations. This may involve using improved grazing management strategies to prevent overgrazing.
- Check hay and straw for presence of weed seed before using them in thistle-free areas. Certified weed-free hay and pellets should be fed to horses used in back-country areas.

- Limit disturbance and/or promptly revegetate disturbed areas with desirable perennial forage species, especially perennial grasses.
- Detect, report, record, and eradicate new populations of thistle as early as possible.
- Map known infestations. Keep annual records of reported infestations.
- Combine mechanical, cultural, biological, and chemical methods for most effective thistle control.
- Implement monitoring and a followup treatment plan for missed plants and seedlings.

Table 2 summarizes management options for controlling thistles under various situations. Choice of individual method(s) for thistle control depends on the degree and density of the 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 the period of time needed to achieve control. More than one control method may be needed for a particular site.

Special Considerations – There are at least 20 species of native thistles in the genus *Cirsium* in Arizona and New Mexico. These native thistles are noninvasive and are important constituents of their ecological communities. Since native thistles can be confused with nonnative thistles, accurate identification of thistle species should be an important first step in managing invasive, nonnative thistles.

The Sacramento Mountain range in southern New Mexico serves as habitat for the endangered Sacramento Mountains thistle (*Cirsium vinaceum*) which is protected under the Endangered Species Act of 1973. Portions of the mountain range within Otero County are also inhabited by local populations of Wright's marsh thistle (*C. wrightii*) which is a New Mexico listed endangered species and a Federal candidate for listing. Wright's marsh thistle is also found in Eddy, Chaves, Guadalupe, and Socorro Counties in New Mexico. Both thistle species occur in wetland habitats such as spring, seeps, and marshy edges of streams and ponds. To avoid harm to these species, information should be obtained from the U.S. Fish and Wildlife Service at (505) 346-2525 before implementing treatment of thistle in these types of habitats associated with the Sacramento Mountains and the aforementioned counties.

Physical Control

Physical methods can be used to control thistles by reducing seed production and preventing germination through the destruction of individual thistle plants and any maturing seed heads. Methods that sever or eliminate the entire top of a thistle or its root system usually have to be repeated and must be timed properly to be most effective.

Manual Methods

Hand pulling, hoeing, grubbing, or cutting may be done any time of year; but these methods are most effective if done before development of flower heads occurs. Thistle plants should be severed 2 to 4 inches below the soil surface to prevent resprouting from the root crown. For isolated thistles or small infestations, seed heads of individual plants may be clipped and placed in bags for disposal. This method can prevent further seed dispersal or seedling establishment from disturbance while allowing treated sites to be more easily relocated next year.

Proper disposal of debris is essential in preventing spread. If flowers or seed are not present, plants may be pulled and left onsite. If flowers or seed are present, debris should be bagged and removed from the site for safe disposal or else piled and burned onsite.

Mechanical Methods

Properly timed and repeated tillage with a plow or disc can provide effective control; however, ill-timed or nonrecurring tillage may favor further invasion. In areas with high densities of viable thistle seed, tillage may actually

Table 2. Management options*

Site	Physical Methods	Cultural Methods	Biological Methods	Chemical Methods
Roadsides	Repeat mowing very close to surface throughout the growth season (preferably in the bolt to early bud growth stage before seed matures and disperses). Consider mowing as part of a combined approach.	Educate road crews to identify and report infestations along roads; implement requirements for vehicle operations in infested areas.	Use biological control agents (gall-forming fruit flies, flies, beetles, or weevils) if release does not threaten rare or endangered native thistles (see table 3). Agents for thistle control may be used only if thistle infestations are large enough to sustain control agent populations. Effectiveness of agents may be limited due to possible disturbances in agent life cycles from roadside operations.	Apply herbicides in spring or fall at rosette stage. When using truck or tractor spraying equipment, wash thoroughly afterward to prevent seed spread.
Rangelands	For smaller infestations, hand pull; otherwise, cut plants 2 to 4 inches below the surface with a hoe, grubbing tool, or spade. Cut prior to flowering. For larger infestations, use well-timed mowing to reduce seed production (bolt to flower bud stage). Although prescribed burning is not recommended, individual plant treatment with a blow torch or similar device may be an option in localized situations.	Use certified weed-free hay. After passing through infested areas, inspect and remove any seed from animals, clothing, and vehicles before entering treated or uninfested areas. Use certified seed to reseed.	Use a prescribed grazing strategy to target young thistles. Closely manage grazing to prevent overuse. Use biological control agents (gall-forming fruit flies, flies, beetles, or weevils) if release does not threaten rare or endangered native thistles. Agents for thistle control may be used only if thistle infestations are large enough to sustain control agent populations.	Use individual plant treatment with a backpack sprayer on sparse populations. For extensive and dense infestations, use ground or aerial broadcast spraying.
Wilderness or natural areas	Same as above.	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.	Same as above.

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

increase establishment of thistle seedlings in succeeding seasons through disturbance of the soil surface. If tillage is used, thistle plants should be cultivated shortly after they emerge but before they reach a height of 3 inches. Shallow cultivation in hot, dry weather greatly stresses plants. Tillage will not eradicate seeds; therefore, tillage may be more effective as a component in a combined control strategy. See the "Control Strategies" section for more information.

Mowing reduces plant height of thistles but may not entirely eliminate flowering and seed production. Some vegetation management experts do not recommend mowing at all since plants often produce side branches that have more flowers, even with repeated mowing and proper timing. However, mowing may be useful as part of a combined strategy (see the "Control Strategies" section for more information). If mowing is used, cut soon after plants begin to bolt but before flowering; repeat mowing about every 21 days during active growth. For sites where plants have begun to flower, consider walking through the infested area before mowing and either pull plants or cut stems that have open flowers. Flower heads should be bagged and disposed offsite to prevent seed dispersal.

Prescribed Fire

Broadcast burning can eliminate existing plants, but this activity is likely to favor invasive thistles in future years. Thus, prescribed burning is not ordinarily recommended for thistle management. However, individual plant treatment (IPT) using a blowtorch or flamethrower has been used with some success on thistles in California.

Cultural Control

If invasive thistles are not currently present, steps should be taken toward preventing their introduction. Early detection and plant removal are critical for preventing establishment of thistle. Land managers, the local public, and road crews should be educated on how to identify invasive thistle species so they can help report suspected infestations.

Biological Control

Grazing

Livestock generally avoid entering dense stands of mature thistle; but they will graze young, immature thistles. Prescribed grazing, therefore, can be part of an effective control strategy if an intensive, short-term, grazing approach is used. Cattle, sheep, and goats can be used to graze bull thistle rosettes. Musk thistle is readily grazed by sheep and goats from rosette to bolting stage and by cattle before the bud stage is reached. Scotch thistle is grazed by goats and cattle in the seedling to vegetative stages. Use of grazing in combination with herbicide can increase effectiveness of both of these control methods. See the "Control Strategies" section at the end of this field guide for more information about combined approaches.

Classical Biological Control

Numerous classical biological control agents have been introduced throughout the United States for control of thistles, including those listed in table 3. Biological control methods for invasive thistles primarily involve using insect larvae to impact the root, stem, leaf, or flower. Control with biological agents may be most suitable for remote, otherwise inaccessible pastures and rangeland sites where mowing, cultivating, or treating with herbicide is impractical. Biological control agents for thistle control may be used only if thistle infestations are large enough to sustain control agent populations. Some agents have been found to be less effective when their life cycle is disturbed, either by the presence of livestock or by management actions involving the thistle. Treatments such as cutting or spraying may not allow the biological control agent to complete its life cycle. As a result, the needs of the biological control agent (if present) should be considered before other treatment methods are implemented. For further information on biological control of annual and biennial thistles, see Winston et al. (2008) in the "References and Further Information" section of this field guide.

Table 3. Classical biological control agents

Species	Type of Agent	Plant Impacted/ Site of Attack	Impact on Host	Use/Considerations for Release
Urophora stylata Fabricius	gall-forming fly	Bull thistle; seed.	Adult lays eggs in the closed flower buds. Each larva forms its own gall tissue and the gall forms around the immature seed. Mature larvae reside in the flower head through winter. Pupation is in May, and adults emerge in June.	Species is well established in the western U.S. with 60 to 90 percent of bull thistle seed heads infested in some areas.
Rhinocyllus conicus	beetle/ weevil	Musk thistle; seed head and upper stems.	The larvae burrow into the seed head. Since musk thistle reproduces entirely by seed, *R. conicus* can disrupt seed production.	Seems to establish best on sites heavily infested with musk thistle where life cycle will not be disturbed and cattle are absent. This particular weevil species should not be released as a biological control agent since it can feed on native thistles including the endangered Sacramento Mountains thistle.
Trichosirocalus horridus	beetle/ weevil	All thistles addressed in this guide; rosette shoot tip.	Larvae burrow down petiole into the growth point. Heavy feeding by mature larvae results in death of rosette. As larval infestation increases, stressed thistle becomes more susceptible to competition from perennial grasses.	Released in Oklahoma and Texas; recently appeared in the Sacramento Mountains of New Mexico. This particular weevil species should not be released as a biological control agent since it can feed on native thistles including the endangered Sacramento Mountains thistle.

An important consideration for release of a biological control agent is whether the agent will impact native thistles, especially rare or endangered species. For example, recent expansion of seed head weevil (*Rhinocyllus conicus*) from early release sites has enabled the weevil to attack the endangered Sacramento Mountains thistle in southern New Mexico. The rosette weevil (*Trichosirocalus horridus*) has also recently arrived in the Sacramento Mountains, and its presence could impact the Sacramento Mountains thistle along with local populations of the Wright's marsh thistle which is a New Mexico listed endangered species and a Federal candidate for listing. To help prevent such impacts, these particular weevil species should not be released as biological control agents. Land managers should contact the New Mexico Ecological Services Field Office of the U.S. Fish & Wildlife Service at (505) 346-2525 before releasing any biological control agents within the Sacramento Mountains or Eddy, Chaves, Guadalupe, and Socorro Counties in New Mexico that can impact these endangered thistles.

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 on the APHIS Web site 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.

Chemical Control

Thistles are best controlled with a postemergent broadleaf herbicide that is foliar applied. The most commonly used herbicides include dicamba, clopyralid, or picloram either alone or in combination with 2,4-D. Two relatively new herbicides—aminopyralid and aminocylopyrachlor—are labeled for thistle control and are also effective. Cost, availability, and effectiveness are important in the choice of product to use. Herbicides listed in table 4 are effective in reducing invasive thistles while allowing perennial native grasses to compete. These herbicides can impact other desirable broadleaf and woody species; therefore, caution should be taken if nontarget species need protection. Label instructions and guidelines for mixing, application, and grazing restrictions following treatment should always be followed.

For thistles covered in this guide (bull, musk, plumeless, and Scotch), the best time for application is usually during the fall when new plants have emerged and are actively

Table 4. Herbicide recommendations

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Aminopyralid	Milestone	bull, musk, and plumeless thistles: 3–5 fluid ounces Scotch thistle: 5 to 7 fluid ounces	3–5%	Lower rate for rosette; higher rate at bolting. Fall or spring.	Labeled for use on wildlife and habitat management areas, natural areas. May be applied up to water's edge. No grazing restrictions.
Aminopyralid + 2,4-D[3]	GrazonNext	bull, musk, and plumeless thistles: 1.5–2 pints Scotch thistle: 2–2.6 pints	3–5%	Full leaf through flowering. If using in combination, wait 9 to 12 months to spray after last mowing.	Most perennial grasses are tolerant of this herbicide, as long as they are established.
Aminocyclopyrachlor + chlorsulfuron	Perspective	3–8 ounces	Consult label for spot applications.	Apply to actively growing plants. Lower rate for rosette in fall; higher rate at bolting in spring.	Selective herbicide used on noncrop sites; may cause temporary injury to some grass species.
Aminocyclopyrachlor + metsulfuron methyl	Streamline	4.75–9.5 ounces	Same as above.	Same as above.	Same as above.
Clopyralid	Stinger Reclaim	0.33–1.3 pints	1–3%	During active growth at rosette stage.	Established perennial grasses are tolerant.

Table 4. Herbicide recommendations (continued)

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Clopyralid + 2,4-D[3]	Curtail	1–2 quarts	1–3%	Rosette in spring or fall.	Same as above.
Clopyralid + triclopyr	Redeem	1.5–2 pints	1–3%	Same as above.	Same as above.
Imazapic	Plateau	8–12 ounces	3–5%	Same as above.	May cause slight damage to cool season grasses.
Metsulfuron + 2,4-D[3] + dicamba	Cimarron Max	Rate II to III	Consult label	Same as above.	Established perennial grasses are tolerant.
Picloram[4]	Tordon 22K	0.5–2 pints	1–3%	Any growth stage; however, application is most effective in the fall when plants are in rosette stage.	May pose a risk to groundwater in permeable soils or in areas where the water table is near surface.
Picloram[4] + 2,4-D[3]	Grazon P+D	bull thistle: 1–2 pints other thistles: 2–4 pints	1–2%	Lower rate for rosette stage in spring or fall; higher rate for bolt to bud growth stage.	Established perennial grasses are tolerant.
Dicamba + diflufenzopyr	Overdrive	4–6 ounces	1–3%	Rosette in spring or fall.	Use higher rate for older or denser stands.
Dicamba + 2,4-D[3]	Weedmaster (premixed)	1.5–2 pints	1–2%	During active growth; lower rate for rosette in fall; higher rate in spring (not advisable to spray during bolt).	Same as above.

[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 thistle.

[2] Herbicide/water ratio. As an example, a 3 percent spray mixture is made by adding a sufficient volume of water to 4 ounces 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.

[3] 2,4-D is a restricted use pesticide in New Mexico only. A certified applicator's license is required for purchase and use.

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

growing during the seedling to rosette stage. Spraying in spring through the summer is also effective, but higher rates of application may be necessary. Consult label directions carefully. Herbicides may be applied by backpack sprayer, ATV or UTV sprayers, or a conventional boom sprayer that is pulled or attached to a tractor or truck. For individual plant treatment (IPT), wet the foliage and stem thoroughly with a single nozzle, hand-held sprayer.

Control Strategies

To meet the overall goal of restoring a native plant community, control methods discussed in this guide may be used in various combinations to reduce competition from a thistle population. Initial treatment should attempt to eliminate live thistle plants and disrupt seed production as much as possible. Treated areas should always be monitored closely and, if necessary, retreated for further thistle control.

The following strategies should be considered for management of annual and biennial thistles:

- **General control strategy for thistles** – Since annual and biennial thistles germinate nearly year-round, a range of plant sizes may be present at any one site. If thistle seedlings and young rosettes are mostly present in fall or early spring, consider applying a herbicide as the initial control treatment. Mowing or using a controlled, short term, intensive grazing approach may be a better option on an infested area if starting treatment in late spring or summer. When mowing, cut weeds very close to surface during the early bud stage before flowers begin to color or mature. Mowing will need to be repeated during the summer growing season. Herbicide spraying in the fall should be considered as a followup treatment after mowing. Monitor for return of perennial native vegetation and reseed with desirable perennial forage species if necessary, especially perennial grasses. Repeat for multiple years.
- **Strategy for small infestations of thistle** – Use hand pulling, grubbing, hoeing, cutting (stems or seed heads), or spot spraying to treat individual plants. Destroy debris via fire or mulching (or bag and remove plants and/or seed heads). If treated site is disturbed, reseed with desirable perennial grasses. Periodically monitor for emerged plants and spot treat or hand remove.

Regardless of the strategy used, the key to successful long-term thistle control is to continuously monitor treated sites and re-treat these areas when necessary. Failure to perform followup management may result in recolonization and a return of the population to pretreatment levels.

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Suggested Web Sites

2,4-D Safe Handling Guide:

http://www.cdms.net/LDat/ld02B005.pdf

Dow AgroSciences labels:

Clarity: http://www.cdms.net/LDat/ld797002.pdf

Curtail: http://www.cdms.net/LDat/ld02B005.pdf

Grazon P + D: http://www.cdms.net/LDat/ld0B1014.pdf

GrazonNext: http://www.cdms.net/LDat/ld8C6002.pdf

Milestone: http://www.cdms.net/LDat/ld77N006.pdf

Reclaim: http://www.cdms.net/LDat/ld1KP006.pdf

Redeem: http://www.cdms.net/LDat/ld4KE004.pdf

Stinger: http://www.cdms.net/LDat/ld02P012.pdf

Tordon22K: http://www.cdms.net/LDat/ld0AJ013.pdf

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http://aces.nmsu.edu/pubs/_circulars/CR_597.pdf

Encycloweedia Datasheets by California Department of Food and Agriculture:

http://www.cdfa.ca.gov/phpps/ipc/weedinfo/spinythistle-key.htm http://www.cdfa.ca.gov/phpps/ipc/weedinfo/onopordum.htm

Herbicide labels available at:

http://www.cdms.net/LabelsMsds/LMDefault.aspx

NuFarm Agricultural Products labels:

Weedmaster: http://www.cdms.net/LDat/ld8QL000.pdf

For more information or other field guides, contact:

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

Or visit:

http://www.fs.usda.gov/main/r3/forest-grasslandhealth

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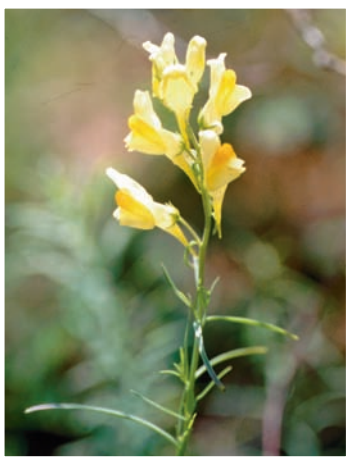
December 2012

Field Guide for Managing Dalmatian and Yellow Toadflaxes in the Southwest



Cover Photos

Top left: Dalmatian toadflax; Utah State University Archive, Utah State University, Bugwood.org
Top right: Dalmatian toadflax flower; Bob Nowierski, Montana State University, Bugwood.org
Bottom left: Yellow toadflax, David Powell, U.S. Forest Service, Bugwood.org
Bottom right: Yellow toadflax flower; Richard Old, XID Services, Inc., Bugwood.org

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Dalmatian toadflax (*Linaria dalmatica* (L.) Mill. ssp. *dalmatica*)
Yellow toadflax (*Linaria vulgaris* Mill.)
Figwort family (Scrophulariaceae)

Dalmatian toadflax and yellow toadflax are invasive plants that have been introduced into the southwestern United States. Both species are listed in New Mexico as noxious weeds; however, only Dalmatian toadflax is listed in Arizona.

This field guide serves as the U.S. Forest Service's recommendations for management of Dalmatian and yellow toadflaxes in forests, woodlands, and rangelands associated with its Southwestern Region. The Southwestern Region encompasses 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

Dalmatian toadflax (synonyms: broad-leaved toadflax, wild snapdragon) and yellow toadflax (synonyms: butter-and-eggs, common toadflax, toadflax, Jacob's ladder, common linaria, wild snapdragon) were brought from the Mediterranean region to the western U.S. as ornamentals and have since escaped to become widely growing invasive plants. Currently, large infestations occur in California, Colorado, Washington, Oregon, Idaho, Montana, Nevada, Utah, and Wyoming. These short-lived perennials produce new plants from adventitious buds on a resprouting root system that is both extensive and deep. Flowers of both plants are snapdragon-like. While similar in appearance, Dalmatian toadflax grows taller and produces new plants mainly from seed whereas yellow toadflax spreads mostly from root buds. Table 1 lists growth characteristics of both toadflax species.

Ecology

Impacts/threats – These aggressive weeds are highly adaptable and can out-compete winter annuals or shallow rooted perennials for soil moisture. A high density of toadflax reduces the availability of quality forage and diversity of flora and fauna species. Dalmatian and yellow toadflaxes contain glucoside compounds that are poisonous, especially to cattle; however, these plants are typically not grazed by animals.

Table 1. Growth characteristics

Species	Life Span	Growth and Root Habit	Vegetative Appearance	Flower Appearance	Reproductive Method and Seed Appearance
Dalmatian toadflax	Short-lived perennial (generally < 5 years)	Averages 3 feet tall; up to 25 stems per crown during first year of growth; taproot and creeping lateral roots.	Waxy, blue-green oval to heart-shaped; leaves clasp upper stem; rough, woody stem at base that becomes smooth, waxy and herbaceous near the top.	0.75 to 1.5 inches long yellow, two-lipped flowers with an orange bearded throat and a long spur; flowers in leaf axils. Fruit 2 celled and irregular shaped.	Reproduces mainly by seed and partly by adventitious root buds. Black, sharply angled seeds that are slightly winged. Produces 500,000 seeds per plant.
Yellow toadflax	Same as above.	1.5 to 3 feet tall; has taproot and extensive system of vertical roots with creeping laterals. Grows in tight clumps.	Pale green, soft linear lanceolate leaves that are sessile and do not clasp stem; Upright, unbranched stem that is woody at the base and smooth at the tip.	1-inch long yellow flowers with 5 fused petals (2 upper lobes and 3 lower), an orange bearded throat, and a yellow spur; flowers in leaf axils. Fruit 2 celled and globe shaped.	Reproduces primarily by adventitious buds on lateral roots. Seeds are dark brown to black, long, flattened, and winged. Produces 30,000 seeds per plant.

Location – Disturbance favors toadflax establishment. Both species thrive in degraded areas such as roadsides, cleared lots and fields, gravel pits, heavily grazed rangeland, and riparian zones. These weeds often establish in naturally occurring openings within sagebrush, ponderosa pine, and other woodland or parkland plant communities at higher elevations. Dalmatian toadflax favors cool, semiarid climates and coarse, dry soils with a neutral pH. Yellow toadflax favors moist soils and can tolerate subarctic conditions. In New Mexico, Dalmatian toadflax is typically found at elevations between 5,000 and 6,000 feet, whereas yellow toadflax occurs at higher elevations between 6,000 and 9,500 feet. Infestations of both species are expanding in Arizona and New Mexico.

Spread – Yellow toadflax produces shoots from underground stems as early as March from which new, independent plants can form later during the growing season. Seed viability in yellow toadflax is quite low; therefore, the spread and persistence of plants in the field are due mainly to vegetative reproduction. Unlike yellow toadflax, Dalmatian toadflax spreads vegetatively and by seed with shoots emerging from these two sources in early April through May. Seed viability for Dalmatian toadflax is high with germination rates near 75 percent.

Invasive Features – Yellow toadflax can grow new shoots on lateral roots as far as 10 feet away from the parent plant. A single Dalmatian toadflax plant can produce 500,000 seeds from July through October depending on location, aspect, and availability of water. Seeds are viable in the soil for up to 10 years, and roots are easily spread by machinery.

Management

Early detection and preventing a population from expanding is the first priority for managing Dalmatian and yellow toadflaxes. The seedling stage is most vulnerable, and seedlings should be removed upon discovery. Once the root system is established, these plants are extremely competitive for water and resources; and they are difficult to control/eradicate. Management of established plants should focus first on smaller infestations in otherwise healthy sites, and measures should be taken to prevent seed formation and vegetative spread. Larger infestations are very difficult to manage and cannot be effectively controlled within a single year or by using only one method. Complete control will likely require 10 to 15 years of repeated treatment and followup management. The following actions should be considered when planning a management approach:

- Maintain healthy plant communities to reduce or limit toadflax infestations. This may involve using improved grazing management strategies to prevent overgrazing.
- Check hay and straw for presence of toadflax seed. Only certified weed-free hay and pellets should be fed to horses used in back-country areas.
- Detect, report, and eradicate new populations of toadflax as early as possible.
- Map known infestations. Keep annual records of reported infestations.
- Combine mechanical, cultural, biological, and chemical methods for most effective toadflax control.
- Implement monitoring and a followup treatment plan for missed plants and seedlings.

Table 2 summarizes management options for controlling Dalmatian or yellow toadflax under various situations. Choice of individual control method(s) for these toadflaxes depends on the degree and density of 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 the number of years needed to achieve control. More than one control method may be needed for a particular site.

Physical Control

Physical methods to control toadflax should focus on destroying the root system. Surface treatments (such as

Table 2. Management Options*

Site	Physical Methods	Cultural Methods	Biological Methods	Chemical Methods
Roadsides and noncrop areas	In level terrain, use repeated cultivation with disk or sweep-type cultivators about 8 to 10 times the first year followed by 4 to 5 times the second year. Follow up with chemical control.	Educate road crews to identify and report infestations along roads; implement requirements for vehicle operations.	Use beetles, moths, or weevils as classical biological control agents (see table 3). Effectiveness of biological control agents may be limited when disturbance from road operations interrupts an agent's life cycle.	Apply in fall during late flowering stages. Use truck or ATV-mounted spraying equipment. Wash under vehicle after application to prevent spread.
Rangelands	In level terrain, use repeated cultivation with disk or sweep-type cultivators about 8 to 10 times the first year followed by 4 to 5 times the second year. Follow up with chemical control.	Use certified weed-free hay. Check animals, clothing, and vehicles for seeds. Corral sheep for 11 days before moving to uninfested areas. Reseed treated areas if necessary to make desirable plants more competitive. Fertilization and/or irrigation may help establishment of desirable plants. Plant certified seed.	Use beetles, moths, or weevils as classical biological control agents (see table 3). Closely manage grazing to prevent overuse.	For extensive and dense infestations, use ground or aerial broadcast spraying. For less dense infestations, consider individual plant treatment with crews using backpack sprayers.
Wilderness or natural areas	Repeated hand-pulling, digging, or hoeing for seedlings and regrowth. Anticipate need to repeat treatments and monitor for ~10 years.	Use certified weed-free hay. Check animals, clothing, and vehicles for seeds. Corral sheep for 11 days before moving to uninfested areas. Post signs warning visitors to inspect and remove seed from clothing, animals, and vehicles. Reseed treated areas if necessary to make desirable plants more competitive. Fertilization and/or irrigation may help establishment of desirable plants. Plant certified seed.	Same as above	Use backpack or hand-held sprayers. Broadcast spraying by aerial or ground methods may be used on thicker stands if allowed.

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

cutting or mowing) used to reduce flowering and seed production can suppress toadflax populations but will not kill the plants.

Manual Methods

Hand pulling, digging, or hoeing can be effective for seedlings or small infestations of toadflax. These methods are easier if done in sandy or moist soils. Removal of the root is very difficult but is necessary for maximum effectiveness. These treatments should be repeated several times per growing season, and the site should be revisited for many years to assure new plants have not grown from dormant seed. Proper disposal of debris is important to reduce further spread. If flowers or seed are present, they

will continue to mature. Therefore, debris should be destroyed by burning or else bagged and removed from the site. If flowers or seed are not present, plants may be pulled and left onsite.

Mechanical Methods

Mowing, chopping, or cutting plants can suppress toadflax; but these practices are not generally recommended since new shoots can resprout rapidly from adventitious root buds in response. Repeated cultivation with a disk or a sweep-type cultivator can be effective if done for 2 or more consecutive years. However, mechanical control with these two implements is typically limited to agronomic settings since the terrain must be suitable for their use. Starting in May or June, cultivation should be done through the growing season as often as required to eliminate green growth. Do not allow new growth to be visible for longer than 7 to 10 days before repeating cultivation. Generally, 8 to 10 cultivations are required during the first season and at least 4 to 5 times in the second year. Consider reseeding the next spring or fall with a variety of desirable perennial forage species of varying root depths and growth habits. It will probably be necessary to use a followup chemical treatment to control new toadflax seedlings and resprouting of roots. Plan to periodically monitor the treated site for as many as 10 years, and then spot treat or hand pull plants as they emerge.

Prescribed Fire

Wildfire or controlled burns can destroy toadflax canopies, but plants taller than 2 inches tend to have well-developed roots and are usually not killed by heat from fire. Typically, there is prolific sprouting from Dalmatian and yellow toadflaxes after fire; therefore, burning is not recommended. However, burning Dalmatian toadflax seedlings less than 2 inches high with a propane torch has been used with some success in Oregon and eastern Washington.

Cultural Control

Early detection and plant removal are critical in preventing establishment of Dalmatian and yellow toadflaxes. Land managers, the local public, and road crews should be educated in identifying these species (especially in the seedling stage) so they can help report all suspected infestations. Farm, rangeland, and outdoor recreation equipment can transport seeds; care should be taken to clean the equipment thoroughly before moving from infested areas to uninfested areas. If possible, weed screens should be used on irrigation water intakes in infested areas to prevent seed transportation in ditches or canals. Reseeding of treated areas may help establish desirable competitive plants if native plants are not already present. However, native grasses generally increase rapidly in the season following herbicide treatment.

Biological Control

Grazing

Toadflaxes contain glucosides that are poisonous to livestock when consumed in high quantity, but animals typically avoid eating these species. Care should be taken not to overgraze infested areas since overgrazing allows toadflax plants to become more competitive and abundant than desirable grazed species. Short-term, intensive grazing by sheep during spring and late season can suppress Dalmatian toadflax and limit seed production as shown by field trials in Montana. However, followup herbicide treatments were still needed to control toadflax further.

Classical Biological Control

Several insect species have been investigated and permitted for release in the United States as biocontrol agents for both Dalmatian and yellow toadflaxes. Table 3 lists agents recently released in southwestern states; however, the long-term success of these agents is largely unknown. For further information on biological control of Dalmatian and yellow toadflaxes, see Wilson et al. (2005) in the "References 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.

Table 3. Classical biological control agents

Species	Type of Agent	Site of Attack	Impact	Use/Considerations for Release
Brachypterolus pulicarius	beetle	shoot and flower	Adults feed on shoot tips and axillary buds; lays eggs in buds; larvae feed on immature seeds. Can reduce seed set by 74 percent.	Well established in the Northwest. Impacts both toadflaxes.
Calophasia lunula	moth	leaves	Active in larval stage; defoliates leaves, thereby reducing seed production and root carbohydrate levels.	Established in Idaho, Montana, and Washington. Impacts both toadflaxes. More effective if used in combination with stem boring weevils.
Eteobalea intermediella	moth	root	Adults lay eggs in lower leaf axils at base of yellow toadflax and on nonflowering Dalmatian toadflax stems. Larvae bore into stem or root.	Impacts both toadflaxes.
Rhinusa antirrhini (formerly *Gymnaetron*)	weevil	seed capsule	Adults eat leaf buds, young leaves, and young shoot tips. After bloom, adults eat floral tissue and lay eggs in floral ovaries; larvae eat seeds.	Well established in the Northwest. Impacts both toadflaxes.
Rhinusa netum (formerly *Gymnaetron*)	weevil	seed capsule	Similar to *R. antirrhini*. Both species impact seed production and may reduce toadflax by 85 to 90 percent.	Impacts both toadflaxes.
Rhinusa linariae (formerly *Gymnaetron*)	weevil	root	Adults feed on stem tissue and sap, lay eggs in root crown near soil surface; larvae form galls and feed on root.	Impacts both toadflaxes.

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 on the APHIS Web site 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.

Chemical Control

Herbicide spraying can be an important component for restoring rangeland infested with Dalmatian and yellow toadflax. Before spraying, evaluate each area closely to determine if seeding may be necessary or if the plant community will return naturally. Seeding is not typically needed when native grasses are common beneath toadflax as grasses will increase rapidly in the following season after spraying (i.e., spray release). If seeding is needed following a spray treatment, then additional herbicide treatment can be used to complement seeding of desirable competitive species.

Most herbicide treatments are recommended for application during the flowering or postflowering stage in fall. Yellow toadflax is usually more difficult to control with herbicide spraying than Dalmatian toadflax, although repeated treatments over several years are often needed to control either species. Followup monitoring and spot treatment of toadflax regrowth and seedlings should be anticipated

for at least 3 to 4 years and possibly longer if complete eradication of toadflax is desired.

All herbicides recommended in table 4 will control or suppress both toadflax species when properly applied, although these herbicides may also impact nontarget species such as forbs, shrubs, or trees. Control results will vary due to weather variables and the plant's growth stage, so special care should be taken to follow label directions closely. Each herbicide product will have different and unique requirements and restrictions according to the herbicide label. Read and understand the label prior to any application. Consult the registrant if you have questions or need further details.

The best performing herbicides for toadflax control are chlorsulfuron (e.g., Telar XP) and picloram (e.g., Tordon 22K) either alone or in combination. Other herbicides listed in table 4 will control toadflax, but plants often recover from a single treatment so anticipate that spraying may need to be repeated. Herbicide control experiments with Dalmatian toadflax in northern Colorado and southern .Wyoming

Table 4. Herbicide recommendations

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Picloram [3]	Tordon 22K	1–2 quarts	0.5–1%	Late flower to post-bloom stage in the fall.	Persistent, selective herbicide. Re-treatment for several years may be required. Labeled for rangeland use.
Dicamba	Banvel, Clarity, Vanquish	1–2 quarts	3–5%	Same as above.	Same as above
Chlorsulfuron	Telar XP	2–2.6 ounces	Consult label	Same as above.	Apply as a high volume foliar spray using a minimum of 24 gallons of water per acre.
Aminocyclopyrachlor + chlorsulfuron	Perspective	7.5–8 ounces	Add 5–9 grams of dry flowable powder to 1 gallon of water. Consult label for directions.	Apply to fall rosettes for best control.	Persistent; selective; may cause temporary injury to some grass species. Labeled for noncrop use.
Imazapic	Plateau	8–12 fluid ounces Plateau + 1 quart methylated seed oil (MSO)	0.25–1.5%	Same as above.	Persistent, selective herbicide. Re-treatment for several years may be required. Use lower rate when cool season grasses are present.

[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 toadflax.

[2] 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 ounces 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.

[3] Piclorum is a restricted use pesticide. A certified applicator's license is required for purchase and use.

showed Telar XP at 2 oz/a gave excellent control over 5 years while Tordon 22K at 2 pt/a gave good control. Treatments made on yellow toadflax were somewhat site dependent and required higher rates of Telar XP (2.5 to 3 oz/a) or Tordon 22K (2 to 4 pt/a) to be effective. When mixing Telar XP, use a quality nonionic surfactant (NIS) or silicone-based adjuvant at the labeled rate. According to the Colorado-Wyoming study, control of yellow toadflax with Telar XP can be improved by using methylated seed oil at 1 percent v/v instead of a NIS, but injury to native forbs and shrubs may increase.

Herbicides shown in table 4 may be applied by backpack sprayers, ATV or UTV sprayers, or conventional boom sprayers that are pulled or attached to a tractor or truck. For individual plant treatment (IPT), wet the foliage and stems thoroughly with a single nozzle, hand held or backpack sprayer. Consult the herbicide label for mixing directions.

Control Strategies

Because treatment situations can vary, management of either Dalmatian or yellow toadflax on a particular site must involve detailed planning. A management plan should be developed that considers the condition and composition of native plants together with a combination of methods necessary for toadflax control. Initial treatments should attempt to eliminate live toadflax plants and disrupt seed and/or root production as much as possible. Later treatments should strive to enhance establishment and competition of native plants to further reduce toadflax populations. Failure to perform followup monitoring and management may result in recolonization and return to pretreatment levels of invasion.

Adaptive Management – Toadflax species are difficult to control, and it should be anticipated that ongoing management will be required for many years. Therefore, realistic goals and objectives should be established to manage toadflax infestations occurring extensively throughout a given landscape. To improve long-term success, consider using an adaptive management strategy with the overall goal of restoring desirable plant communities. The stepwise process for adaptive management involves:

1. Assessment of the overall weed problem,
2. Establishing management goals and objectives,
3. Implementation of control strategies,
4. Monitoring the effectiveness of management actions,
5. Evaluating actual outcomes in relation to expected results, and
6. Adjusting practices as necessary.

Steps of this process should be repeated in sequence as part of a continuous learning cycle that improves management planning and strategy by learning from the outcomes of previous management actions. In general, an adaptive management strategy may be considered to be successful if:

1. Stakeholders are actively involved and remain committed to the process,
2. Monitoring and assessment are used to adjust and improve management decisions, and
3. Management goals and/or objectives for the resource are being achieved.

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Suggested Web Sites

Herbicide labels online:

http://www.cdms.net/labels/msds/lmdefault.aspx

Encycloweedia Datasheets by California Department of Food and Agriculture:

http://www.cdfa.ca.gov/phpps/ipc/weedinfo/linaria.htm

For more information or other field guides, contact:

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

Or visit:

http://www.fs.usda.gov/main/r3/forest-grasslandhealth

USDA

United States Department of Agriculture

Forest Service

Southwestern Region

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Field Guide for Managing Russian Olive in the Southwest

Cover Photos

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Bottom: USDA-NRCS Plants Database

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Russian olive (*Elaeagnus angustifolia* L.)

Oleaster family (Elaeagnaceae)

Russian olive is widespread throughout the United States as a tree and is listed as a noxious weed in New Mexico. This field guide serves as the U.S. Forest Service's recommendations for management of Russian olive in forests, woodlands, and rangelands associated with its Southwestern Region. The Southwestern Region encompasses 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

Over the past century, Russian olive (synonyms: oleaster, wild olive, and silver berry) was widely planted throughout the United States as an ornamental and windbreak tree that has since escaped into natural areas. It is a hardy, fast-growing, deciduous tree that grows to about 30 feet in height. Russian olive is silvery in appearance and highly aromatic; its thorny branches are loosely arranged in a rounded shape.

Growth Characteristics

- Deciduous tree (10 to 40 feet tall) or long lived, multistemmed shrub.
- Trunk has a circumference of 4 to 20 inches; has dark, smooth, or sometimes shredded-looking bark.
- Branches are loosely arranged; reddish-brown with silvery scales; twigs are thorn tipped with silvery scales; 1- to 2-inch thorns.
- Alternate, simple, lance-shaped leaves, 0.8 to 4 inches long; upper surface is pale green with silvery, star-shaped hairs; lower leaf has dense, silvery-white scales.
- Roots can grow as deep as 40 feet; symbiotic nitrogen-fixing bacteria in roots allow Russian olive to grow on bare-mineral substrate.
- Fragrant, yellow flowers arranged in clusters; flowers May to July.
- Clusters of small, hard, olive-like, yellowish to red-brown fruits (drupes, 0.5 inch long) with a dusting of silver scales; fruit matures August to October.
- Reproduces primarily by seed, although sprouting from buds at the root crown and suckers from lateral roots also occur.
- Seeds are brown, oval shaped 0.25 to 0.5 inch long; seed produced after tree is 4 to 5 years old; seed viable for 3 years.

Ecology

Impacts/threats – Russian olive is problematic in the Southwest because it favors riparian communities and other moist environments. As populations increase, Russian olive crowds out desirable native riparian trees such as cottonwood and willow, thereby reducing flora and fauna species diversity. Because of its ability to colonize streambanks, Russian olive can alter the natural flooding regime and reduce availability of nutrients and moisture.

Location – Russian olive prefers areas where the water table is near the soil surface such as in riparian zones, flood plains, and valley bottoms. It commonly grows near water tanks, irrigation ditches, and springs; along roads, railways, and fence lines; and in subirrigated pastures and grasslands. It occurs from sea level to about 8,000 feet of elevation and is semishade tolerant.

Spread – Russian olive seed is relished by birds, and bird droppings with the seed contribute greatly to the tree's spread. Coyotes, deer, and raccoons consume the fruit as do small mammals which value the seed as a food source as they widely carry and stockpile seed. The fruit floats and is easily transported and dispersed along waterways. Russian olive also grows and spreads from stump sprouts, stem cuttings, and root pieces, especially after parent trees have been cut.

Invasive Features – Russian olive tolerates a wide range of environmental conditions including high winds, flooding, drought, extreme temperatures (- 50 °F to 115 °F), saline or

alkaline soil conditions, and competition from other trees and shrubs. Russian olive can become the dominant species in areas after invasion due to its adaptability, aggressive reproduction, and rapid growth rate. It may form dense, monotypic stands that can impede establishment of willow and cottonwood seedlings.

Management

Russian olive is viewed by some people as a horticulturally desirable species, and the tree is still sold in nurseries. In the past, it was promoted by various agencies for conservation plantings in cropland environments. Some of these same agencies are now spending large sums of money to control it. While the popularity of using Russian olive as a drought-resistant planting option is not as common as it was in the past, public education is still needed to raise awareness of the tree's invasive shortcomings.

It is extremely difficult to restore native plant communities in areas where Russian olive has become well established. The first priority in Russian olive management is to prevent establishment by monitoring for its first appearance. Small infestations on otherwise healthy sites should be treated early, and the goal should be to remove all trees. Control efforts must focus on the destruction of the root system. Treatments such as dozing, burning, and cutting can effectively eliminate aboveground growth but do little to control the root system and limit recruits. It may be impractical to eradicate Russian olive completely when growing in larger infestations, but trees should be controlled to the best extent possible. Russian olive management requires a long-time commitment that will likely take 3 or more consecutive years of treatment followed by 1 to 2 years of monitoring for regrowth. Strategies to contain and reduce Russian olive populations are best developed through long-term planning and integrated management.

The following actions should be considered when planning an overall management approach:

- Maintain healthy and diverse plant communities.
- Provide landowners with ideas for noninvasive alternatives to Russian olive for soil stabilization, windbreaks, and ornamental use.
- Limit disturbance and/or promptly revegetate disturbed areas with desirable riparian plant species, such as cottonwood and willow.
- Where possible, maintain or simulate seasonal flooding in riparian areas.
- Detect, report, and map known infestations. Keep annual records of reported infestations.
- Eradicate new populations of Russian olive as early as possible.
- Combine mechanical, cultural, and chemical methods for most effective Russian olive control.
- Implement monitoring and followup treatment plan for missed plants and seedlings.

Table 1 summarizes some management options for common situations involving Russian olive. Choice of which method(s) to use for Russian olive control will depend on a number of factors including the age, size, and density of trees. Site conditions (land use, accessibility, terrain, climate, other flora and fauna present, etc.) where the infestation occurs will greatly influence control decisions. Other considerations include treatment effectiveness, cost, and the number of years needed to achieve control. More than one control method may be needed for a particular site.

Special Considerations – Along with saltcedar (Tamarix spp.), Russian olive potentially serves as nesting habitat for the endangered southwestern willow flycatcher (Empidonax traillii extimus) which is protected under the Endangered Species Act of 1973. To avoid harm to this endangered species, information should be obtained from the U.S. Fish and Wildlife Service (Arizona, phone (602) 242-0210; New Mexico, phone (505) 248-6920) before implementing treatment of Russian olive stands of 0.25 acre or more in riparian or wetland areas within Arizona or New Mexico. A formal survey for flycatcher nesting habitat by a surveyor with a scientific permit may be required for a site with

Table 1. Management options*

Site	Physical Methods	Cultural Methods	Biological Methods	Chemical Methods
Roadsides, irrigation ditches, fence lines, or noncrop areas	Saplings (< 3.5 inch diam.): dig up with shovel, hoe, or weed tool. Larger trees (> 3.5 inch diam.): extract with an excavator or backhoe. Anticipate the need to control resprouts.	Educate the public, road crews, and others to identify and report infestations. Implement requirements for vehicle operations.	If allowed, consider using trained goats to graze Russian olive seedlings and young trees selectively in a short-term prescribed grazing approach.	Light infestations: use basal bark treatment for stems < 5 inches diam. For stems > 5 inches diam., use cut-surface with herbicide (cut-stump, girdle, or injection). Dense, monotypic infestations: use foliar application with backpack sprayer; truck- or ATV-mounted sprayer. Wash under vehicle after application to prevent spread.
Rangelands, pastures, or riparian corridors	Seedlings: hand pull or burn. If feasible, use physical methods in a combined strategy with prescribed grazing by using older male goats. Saplings (< 3.5 inches diam.): grub with hoe or weed tool. Larger trees (> 3.5 inches diam.): use heavy equipment. Consider a combined approach with chemical spraying.	Implement an early identification and reporting program with rapid response for new infestations. Use weed screens on irrigation canals. Check vehicles for seeds. Reseed with certified, weed-free seed; if possible, fertilize and irrigate to make desirable plants more competitive.	Consider using trained goats to graze Russian olive seedlings and young trees selectively in a short-term prescribed grazing approach.	Consider using individual plant treatment (i.e., spot spraying foliage; basal bark applications; cut-stump, girdling, or injecting with herbicide) for light infestations, areas with difficult access, or areas with desirable native plants. For dense infestations with few desirable plant species present, use ground or aerial broadcast spraying.
Wilderness, natural areas, and/or small infestations	Seedlings and sprouts: hand pull. Saplings (< 3.5 inches diam.): grub with hoe or weed tool. Larger trees (> 3.5 inches diam.): combine physical methods with herbicide spraying.	Post signs informing visitors to watch for and report Russian olive seedlings or plants. After passing through infested areas, inspect and remove any seeds from animals, clothing, and vehicles before entering treated or uninfested areas.	Consider using trained goats to selectively graze Russian olive seedlings and young trees in a short-term prescribed grazing approach.	Use basal bark treatment, cut-surface with herbicide, or individual plant foliar treatment with a backpack or hand-held sprayer. Broadcast spraying of foliage by aerial or ground methods may be used on thicker stands if allowed.

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

Russian olive prior to treatment if the nesting status of the site is undetermined. Within occupied or suitable flycatcher habitat, Russian olive treatment operations (including ground or aerial herbicide spraying) should not occur during the flycatcher nesting period of April 15 to August 30. When nesting habitat of the southwestern willow flycatcher is present, a no-treatment buffer of 0.25 mile is necessary around the nest(s). Migratory birds other than the flycatcher may also nest in Russian olive from April through August, and treatment of Russian olive during this period should be avoided if possible.

Physical Control

Physical methods to control Russian olive should focus on reducing seed production and preventing germination, mainly through removal or impairment of seed producing

plants. Methods that stress and/or remove the root system should also be employed. These methods usually have to be followed up with repeated treatment of seedlings and root resprouts. Long-term effectiveness may be increased by applying herbicide after cutting (see the "Chemical Control" section).

Manual Methods

Hand removal – Small trees (< 3.5 inches diameter) may be hand grubbed with a shovel, hoe, or weed tool such as the Weed Wrench™ or Root Talon™ .

Mechanical Methods

Suppression of saplings by mowing – Where sapling stems do not exceed 1 inch in diameter, use a tractor fitted with a brush mower to shear plants close to the ground surface. Gather and pile cut material for burning or shredding. Mowing will not kill Russian olive trees, and plants can become multistemmed and brushy if mowing is not repeated. Repeat mowing before saplings reach a diameter of 1 inch (likely annually). A wet-rotary blade with glyphosate may also be considered for a combined approach.

Tillage – Russian olive is sensitive to repeated tillage, especially its seedlings and saplings. This approach is only practical in agronomic situations and should be done in coordination with reseeding and pasture renovation. Disks and plows effectively sever shallow roots. Root sprouting may occur after the first tillage operation so this practice usually has to be repeated. By using tillage in concert with broadleaf weed control spraying, Russian olive saplings may be effectively control.

Large-scale clearing – In areas that are densely infested with Russian olive, consider removing trunks and stems in the winter with heavy machinery (such as an excavator). Pulled material should be immediately destroyed by shredding or else piled for later burning. This method is efficient at removing top growth and most root material. However, sprouting often occurs from root parts that remain in the soil (especially from lateral roots). Therefore, consider this approach as being more effective when combined with followup chemical control.

Prescribed Fire

Burning will modestly control saplings and can reduce top growth of larger, more mature Russian olive. Since trees will vigorously resprout at a later time after burning, prescribed fire should always be considered to be a suppression technique rather than as a method for eradication. Spring and winter burns are usually less effective than summer or early fall burns.

Debris Management

Russian olive can develop new roots from adventitious buds that come in contact with the soil so it is important to remove as much of the plant material as possible. All root and stem remnants should be removed or piled and then destroyed by using fire, shredding, or mulching.

Cultural Control

Prevention, early detection, and plant removal are critical for limiting Russian olive establishment. Vehicles, humans, and livestock should be discouraged from traveling through infested areas. Wherever feasible, a program to check and remove seed from vehicles and livestock after travel through infested areas should be implemented to help stop spread. To prevent seed from being transported by irrigation canals, use weed screens on irrigation water intakes inside infested areas if possible.

Biological Control

Grazing

Mature, trained goats will selectively graze Russian olive seedlings and young trees. A short-term, prescribed grazing approach with goats may not completely eradicate Russian olive but could be one component in a successful management strategy.

Classical Biological Control

Research is currently being done to identify biological control agents for Russian olive; however, none of these agents are currently approved for release at this time.

Chemical Control

Herbicide control—used either alone or in combination with another method—has been applied with varying success on Russian olive. Sites planned for spraying should be closely evaluated in advance before proceeding with a herbicide control program. Choice of which herbicide to use and the best method of application are influenced by many factors including the time of year to be sprayed, plant growth form (i.e., a low growing, multistemmed shrub versus a mid-sized, single-stem tree), site accessibly, and other considerations. The density of the Russian olive population and the proximity of invasive trees or shrubs to desirable plants further complicates how best to proceed with herbicide control. Herbicide spraying is rarely successful as a one-time treatment, so it is important to anticipate that sites will need to be monitored for several years and new resprouts and seedlings will require further treatment in the future.

Herbicides may be applied by a number of methods including backpack sprayers, ATV or UTV sprayers, boom sprayers that are pulled or attached to a tractor or truck, and by aerial spraying with a helicopter or fixed-wing aircraft. Treatment options include foliar application, basal bark, and cut-surface methods, which are described in greater detail below. Most compounds available for Russian olive control

Table 2. Herbicide recommendations

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Glyphosate	Rodeo, RoundUp Pro, others	Rodeo: 3–7.5 pints Roundup : 1.5–3.3 quarts	Rodeo: 1.5–3.5% RoundUp: 5%	Foliar spot treatment: spring (April to May). Frill or injection: winter	Nonselective herbicide; can injure surrounding plants and open more area for weeds. Frill, girdle, or injection: 50–100% concentration. Follow label for mixing instructions.
Imazapyr	Habitat, Arsenal, others	2–4 pints	1.0%	Summer to fall (Aug. to Sept.); when actively growing and fully leafed.	Use foliar spray for seedlings and saplings. Frill or girdle: use undiluted. Cut-stump: use 10% with 90% methylated seed oil. Habitat okay for riparian use. Nontarget plants may be killed or injured by root transfer of imazapyr between intertwined root systems.
Imazapyr + glyphosate	Arsenal + Rodeo	1.5 qt. + 1.5 quarts	1/2–1 gallon + 1/2–1 gallons (1–2 pounds + 2–4 pounds per 100 gallons water with 0.25% surfactant and a blue indicator dye)	Same as imazapyr.	Same as imazapyr.

Table 2. Herbicide recommendations (continued)

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Triclopyr	Garlon 4, others	1–3 quarts	Low volume: 1.0 % High volume: 0.5% Resprouts: 25%	Basal bark: winter to early spring; Foliar spot treatment in early summer; use when tree is actively growing and fully leafed.	Selective, systemic broadleaf herbicide; low soil activity. For basal bark or cut-surface, use 25-50% v/v triclopyr with 50-75% carrier oil. Follow label for mixing instructions. Garlon 4 volatilizes above 86 °F.
Triclopyr + 2,4-D[3]	Crossbow	2 gallons	High volume: 1.5%	Basal bark: winter to early spring. Foliar: After full leaf (late spring to early summer).	Foliar or basal bark; low volatility; wait 3 weeks to reseed since it may inhibit germination and growth.
Aminopyralid + triclopyr	Milestone + Garlon 4	7 ounces + 2 quarts	In 100 gallons mix with water, add 7 ounces Milestone and 3 quarts Garlon 4; add 1 quart nonionic surfactant.	Foliar spot spray on healthy foliage in spring or summer.	Treatments can be made to smaller trees < 6 feet in height or to root and stem sprouts previously cut.

[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 Russian olive.

[2] 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 ounces of herbicide until a volume of 1 gallon is reached (4 oz ÷ 128 oz/gal = 0.03 or 3 percent).

[3] 2,4-D is a restricted use pesticide in New Mexico only. A certified applicator's license is required for purchase and use

have postemergent activity and provide limited preemergent control (see herbicide recommendations in table 2.). Each herbicide product will have different requirements and restrictions according to the label. Read and understand prior to any application. Consult the registrant if you have questions or need further detail.

Foliar Treatment Methods

IPT or foliar spot spraying may be used to control seedlings, saplings, and mature Russian olive that are generally less than 6 feet in height. The practicality of using this approach is influenced primarily by the density and access to the trees to be sprayed. Care needs to be taken to direct spraying so that desirable nearby, nontarget plants are not harmed. When mixing the herbicide solution, consult the label on the need to add a nonionic surfactant (usually 0.25 percent by volume is added). Also, adding a blue indicator dye (0.5 percent) to the mixture is recommended to help view coverage on sprayed plants. Thoroughly wet all green leaves and shoots, especially near the top of the shrub or tree. Plants should be wetted without allowing dripping to occur.

Resprouts are common after Russian olive top growth has been removed by operations that involve cutting, tillage, extracting, or shredding; spot spraying is an effective way

to control new or returning plants. Wait until plants are about 3 feet tall and have sufficient foliage to allow uptake of herbicide. This may be a year or two after original trees were removed. One successful way for treating resprouts across a large area is to use a team approach whereby each member equipped with a backpack sprayer walks side-by-side about 10 feet apart and sprays plants within their zone. Treated areas should be revisited after 2 or 3 years to respray surviving or missed plants. A 5 percent v/v solution mix using Roundup early in the season, or a mixture of Milestone plus Garlon 4 or imazapyr used later in the season as described in table 2 are effective herbicide treatments.

Airplane or helicopter applications can be used to spray mature Russian olive in selected situations. Aerial spraying is usually most practical on mature Russian olive growing in dense, nearly monotypic stands. The aircraft used should be equipped with a satellite guidance system and an onboard GIS display system for spraying in wildland situations. Areas to be sprayed should be premapped and the onboard computer spray system should be preprogrammed to apply herbicide only on defined treatment areas. Helicopters can spray difficult, "tight" areas that require precision application such as edges of meandering rivers or Russian olive stands interspersed with nontarget vegetation. Fixed-wing aircraft are better for spraying large, monotypic blocks of Russian olive where an overlapping spray pattern can be delivered at a lower operational cost than by a helicopter.

Herbicides available for aerial application will defoliate and suppress Russian olive but complete control is rare. Anticipate that followup treatments, such as mechanical control, may be needed in later years. When aerially spraying large trees, the spray volume should be sufficiently high to insure maximum spray coverage. Spray nozzles should be fitted to deliver moderate to large-sized droplets ranging from 450 to 1,200 µm. As indicated in table 2, a spray mixture may include 2 quarts of imazapyr or a 1.5 quart imazapyr plus 1.5 quart glyphosate mixture applied in water. A nonionic surfactant (0.25 percent by volume) and a drift control agent (0.07 percent by volume) should be added to the mixture. For optimum plant control, an aerial application should leave the entire Russian olive canopy glistening with spray liquid long after spraying has occurred. This can partially be accomplished by equipping the aircraft with the correct spray system and by spraying under optimal environmental conditions. Moderate temperatures (60 to 80 ºF), high relative humidity (65 to 90 percent), and light winds (3 to 7 m.p.h.) are ideal to maximize herbicide activity. Late summer (August–September) is usually the best time to spray Russian olive by aircraft. Plants to be sprayed should be in a healthy state with full foliage that has not been stressed by drought, damaged by hail, or is beginning to turn yellow late in the season.

Bark Treatment Method

IPT basal bark treatments are most effective on Russian olive that has a stem diameter of 5 inches or less. Apply a solution of 25 to 50 percent triclopyr combined with carrier oil using a low volume, hand-held sprayer fitted with an adjustable nozzle (X0 to X1 orifice size) to deliver a mist spray. Spray around the entire circumference of the stem between ground level and 12 to 15 inches up the stem until bark is wet but not running off. The basal bark method can be used any time of year but is often done in winter when surrounding plants are dormant and impacts to nontarget plant species can be minimized. Adding a dye to the chemical solution will aid in determining continuous and adequate coverage. Leave treated trees in place following spraying.

Combined Cut-Surface Methods

There are several different cut-surface methods that can be used to treat Russian olive especially when it is interspersed with sensitive, nontarget plants. These include:

Cut-stump with herbicide – This method allows specific trees to be immediately removed and can be used any time of year except under freezing conditions. Cut the trunk as close to the ground as possible and apply the herbicide solution to the cut surface using a paint brush, wick applicator, or a

low volume hand-held or backpack sprayer. The cut surface should be horizontal to the ground to minimize runoff, and any residual sawdust over the cut surface should be removed prior to herbicide application. A solution of triclopyr ester or imazapyr mixed with bark or crop oil must be immediately applied within 15 minutes. The herbicide:oil mixture ratio can vary from 33:67 to 50:50 v/v depending on the number and size of plants to be treated and the application technique used. Lower ratios (e.g., 33:67) are typically used when applications are made with a low volume backpack sprayer or hand-held spray bottle, whereas higher ratios (e.g., 50:50) are used when the solution is brushed directly onto the cut stump. Cut surfaces of plants with less than 4 inches diameter must be thoroughly wetted with herbicide to kill the roots; however, the herbicide should be applied to the cambial layer just inside the bark ring if the diameter of the Russian olive stump exceeds 4 inches. A blue indicator dye should be added to the spray mixture to show prior treatment of stumps. Disposal of trunks, limbs, and other top growth should follow acceptable practices (e.g., stack piles or mulch debris).

Girdling with herbicide – Use an ax, saw or chain saw to make two horizontal cuts through the bark and cambial tissue around the entire trunk; cuts should be 3 to 4 inches apart. Using a blunt object (such as the ax head), knock off the bark between the cuts. Spray or paint the cut surface of the girdled area with a 50 to 100 percent concentration of chemical herbicide (such as imazapyr or triclopyr) until the cut surface is thoroughly wet. During the summer, the most effective time to girdle and apply chemical treatment is when Russian olive is fully leafed out and actively growing. Leave tree in place for 2 to 3 years following treatment.

Injection (hack-and-squirt) – This method is not recommended for trees with trunk diameters less than 2 inches. A number of specialized tools are available for this method, including the Hypo-hatchet® and tree injector. However, a simple hatchet and quart-sized spray bottle can also be used. Make a circle of unconnected, nonoverlapping, downward-angled cuts (each cut 2 inches wide) into the sapwood; allow 1 to 2 inches of uncut bark between each cut. On average, there will be one hack/cut per each inch of diameter plus one extra cut. Place a small amount of herbicide in each cut as it is made. Each herbicide label will specify the exact quantity of chemical to use within each cut. Generally, 1 to 2 squirts from a quart or pint trigger spray bottle will be equivalent to 1 to 2 milliliters (1/4–1/2 teaspoon). Apply herbicide so cut is wet, but herbicide is not running out. Triclopyr, imazapyr, glyphosate, and 2,4-D with picloram can be used for injection methods.

Frilling with herbicide – Similar in approach to hack-and-squirt; however, cuts are connected and slightly overlapping with the bark still attached at the base of the cut to make a frill.

Control Strategies

Strategies used for Russian olive control and site restoration must involve careful planning. Numerous research and practical integrated approaches—each with varying success—have been developed to manage Russian olive. Successful long-term management programs (typically more than 5 years) usually include a combination of mechanical, fire, and chemical control methods. A combination of methods is particularly necessary if the primary objective is to achieve long-term stability of native plants. The following strategy is an example of an approach that could be used to contain and reduce populations of Russian olive:

General combined strategy – In late fall or winter, use a chain saw to cut Russian olive with stem diameters of 4 inches or greater and then remove the debris. Within 5 minutes of cutting each tree, apply triclopyr to the cut surface. For stems < 8 inches in diameter, use a 50 percent solution with carrier oil. For stems > 8 inches in diameter, use a 75 to 100 percent solution. Gather and pile dead debris and burn material under safe conditions. After large trees have been removed, evaluate the need to mulch the area by using a mobile, high horsepower tractor that operates a high-speed, rotating drum equipped with cutting teeth. As an alternative, a tractor equipped with a flail-type mower attachment can be used to mow smaller diameter stems and debris that remain. Monitor the area closely to determine the best followup strategy for control. In situations where the return of Russian olive resprouts is low or moderate, a team approach to foliar spray regrowth may be effective. With this approach, members equipped with backpack sprayers move through an area and spot treat seedlings and resprouts for at least 3 consecutive years. Followup treatment options may include spraying with 5 percent glyphosate solution in early summer or a 1 percent imazapyr or aminopyralid + triclopyr mixture later in the season. Continue to monitor for regrowth in later years and hand treat as necessary. In certain areas, goats can be used for a limited time during the spring in a controlled intensive grazing approach on seedlings and resprouts. Fencing may be necessary to confine goats to areas of infestation. Another followup option is to perform a prescribed burn on regrowth using a high heat fire in the late summer to early fall. Monitor for return of Russian olive and spot spray new plants.

Regardless of the initial strategy used, the key to long term Russian olive control is to plan and conduct followup treatments on resprouts and seedlings. Once Russian olive has been removed, aggressive revegetation is often required. Without special planning and care, treated areas may be rapidly reinvaded by Russian olive or other invasive species. Always consider the possible need for seeding or replanting desirable plants before initiating any Russian olive control activities. Managers should understand the revegetation requirements of a site after Russian olive treatment, and include restoration as part of a control strategy. Sustainable control over the long term is best accomplished by planting competitive native plants that have a high exclusionary capability.

Adaptive Management – It is important to establish realistic goals and objectives in managing Russian olive, especially when infestations of the tree occur widely across a given landscape. To improve long-term success, consider using an adaptive management strategy with the overall goal of restoring desirable plant communities. The stepwise process for adaptive management involves:

1. Assessment of the overall weed problem,
2. Establishing management goals and objectives,
3. Implementation of control strategies,
4. Monitoring the effectiveness of management actions,
5. Evaluating actual outcomes in relation to expected results, and
6. Adjusting practices as necessary.

Steps of this process should be repeated in sequence as part of a continuous learning cycle that improves management planning and strategy by learning from the outcomes of previous management actions. In general, an adaptive management strategy may be considered to be successful if:

1. Stakeholders are actively involved and remain committed to the process,
2. Monitoring and assessment are used to adjust and improve management decisions, and
3. Management goals and/or objectives for the resource are being achieved.

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Suggested Web Sites

For information on invasive species:

http://www.invasivespeciesinfo.gov/

http://www.invasive.org/weedus/index.html

For information about calibrating spray equipment:

NMSU Cooperative Extension Service Guide A-613 Sprayer Calibration at http://aces.nmsu.edu/pubs/_a/A-613.pdf

Herbicide labels online:

http://www.cdms.net/LabelsMsds/LMDefault.aspx

For more information or other field guides, contact:

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

Or visit:

http://www.fs.usda.gov/main/r3/forest-grasslandhealth

USDA

United States Department of Agriculture

Forest Service

Southwestern Region

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Field Guide for Managing Saltcedar in the Southwest

Cover Photos

Upper left: Eric Combs, Oregon Department of Agriculture, Bugwood.org
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Saltcedar (*Tamarix* spp.)

Tamarisk family (Tamaricaceae)

Saltcedar is an invasive plant common to southwestern states and has been listed in New Mexico as a noxious weed. This field guide serves as the U.S. Forest Service's recommendations for management of saltcedar in forests, woodlands, rangelands, and riparian areas associated with its Southwestern Region. The Southwestern Region encompasses 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

Saltcedar (synonyms: salt cedar, salt-cedar, tamarix, tamarisk) is an invasive plant in the Tamaricaceae, which has 4 genera with 54 species worldwide. Saltcedar taxonomy is somewhat disputed, and scientific writers can use nomenclatures that are different from each other. The common names of saltcedar and tamarix have been applied to many species of the *Tamarix* genus; however, these terms usually refer to *T. chinensis* or *T. ramosissima* in the southwestern United States. Although these species can hybridize, many taxonomists consider them to be the same species since they are indistinguishable from one another; in which case, *T. chinensis* is the more appropriate taxonomic name.

Growth Characteristics

- Perennial, deciduous, small shrub or tree, 5 to 25 feet tall.
- Small, scaly, bluish-green, flat leaves resemble evergreen "needles."
- Reddish-brown branches; smooth, slender, and flexible but snap off easily; bark furrowed and ridged with age.
- Rooting system with shallow, lateral rhizomes and deep roots that penetrate to a depth of 30 feet or more.
- Flowers March through October; many tiny, pink-to-white flowers with five petals.
- Extremely small, short-lived seeds resembling pepper; seed tips with tufts of hair that aid in wind and animal dispersal.
- Reproduces by seed and sprouting which commonly occurs from disturbed root crowns or from stems or roots lying near the soil surface.
- Shade intolerant.

Ecology

Impacts/threats – Saltcedar alters the ecology and hydrology of native riparian systems and generally diminishes habitat quality; however, saltcedar can provide nesting sites for birds and may be an important pollen source for honeybees. Leaf drop from saltcedar increases soil salinity and lessens microbial activity. Evapotranspiration rates for saltcedar are higher than native riparian species which may reduce streamflows. Soils become drier under dense saltcedar stands.

Location – Saltcedar is found throughout most of the United States except for parts of New England, Middle Atlantic States, and the Midwest. It is common along disturbed and undisturbed streams, riverbanks, desert springs, flood plains, drainages, and irrigation waterways.

Spread – Rapid colonization and expansion of saltcedar most commonly occurs with flood events or water inundation. Seeds float on water and require damp soil moisture for germination and seedling survival.

Invasive Features – Saltcedar can reproduce by both seed and sprouting. The saltcedar root system is dominated by a root crown that lies 12 to 18 inches below the soil surface. Buds on the root crown and shallow lateral roots will sprout new stems rapidly when aerial portions of the plant are removed.

Management

Control and restoration of saltcedar infested areas over the long term requires an integrated management approach that involves more than one control method. These methods

are based either on individual plant treatment (IPT) or stand treatment. Control methods that target and destroy the root system are the only techniques that provide complete control of saltcedar. Methods that damage or remove aboveground growth without destroying the root crown will suppress saltcedar but will not kill the plant. Aboveground control methods include fire, mowing, grazing with goats or other livestock, defoliating herbicides, etc. Choice of an effective control method depends on specific stand and site characteristics. Land use and current site

Table 1. Management options*

Site	Site Factor	Physical Control	Cultural Control	Biological Control	Chemical Control
Streambanks or narrow riparian corridors	Accessibility may be limited.	Excavation, grubbing	NA	Grazing with goats. Tamarisk beetles *(Diorhabda carinulata)* are currently restricted as biological control agents for saltcedar (see "Biological Control" section).	Cut stump method, individual plant treatment (IPT) foliage spray, aerial application of herbicide by helicopter.
Flood plains, valley bottoms, or other flat areas	Emergent saltcedar seedlings on tillable land.	Shallow disking	Prolonged flooding	Tamarisk beetles *(Diorhabda carinulata)* are currently restricted as biological control agents for saltcedar (see "Biological Control" section).	Low volume broadcast spray.
	Sparse to moderate stands of young saltcedar or regrowth.	Excavation, grubbing	NA	Grazing with goats. Tamarisk beetles *(Diorhabda carinulata)* are currently restricted as biological control agents for saltcedar (see "Biological Control" section).	IPT or broadcast foliage spray.
	Open saltcedar stands; goal is to suppress.	Mowing, shredding, mulching, scraping, prescribed burning.	NA	Same as above.	Sublethal herbicide application that defoliates but does not kill the tree. To prevent developing herbicide resistance, avoid repeated applications with the same herbicide.
	Open saltcedar stands; goal is to eradicate or provide high mortality.	Excavation, grubbing, root plowing/raking.	NA	Same as above.	Targeted application with a lethal herbicide. Methods include cut-stump, foliage spray, and aerial herbicide application.
	Old saltcedar growth in dense, uniform stands.	Large-scale clearing with root plowing/raking.	NA	Same as above.	Aerial herbicide application by helicopter or fixed-wing aircraft.
Wilderness, natural areas, or other protected areas	Use of mechanical equipment may be restricted.	Hand removal or selective mechanical removal if allowed.	NA	Same as above.	Cut stump method, IPT foliage spray, aerial herbicide application if allowed.

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

conditions (accessibility, terrain, climate, other flora and fauna present, etc.) must be considered. Other important considerations include treatment effectiveness, overall cost, and the number of years needed to achieve control. Table 1 summarizes management options for some common situations involving saltcedar. More than one control method may be needed for a particular site.

Since saltcedar is difficult to eradicate completely, saltcedar control programs should be based on the degree of control necessary to achieve management objectives. The following actions should be considered when planning an overall management approach:

- Maintain healthy plant communities to prevent or limit saltcedar infestations. This may involve using improved grazing management to prevent excessive grazing and reseeding areas with desirable grasses and forbs after disturbance.
- Detect, report, and map known infestations. Keep annual records of reported infestations.
- Eradicate new populations of saltcedar as early as possible.
- Combine mechanical, cultural, biological, and chemical methods for most effective saltcedar control.
- Implement a monitoring and followup treatment plan for missed plants and seedlings.

Assessing revegetation potential is a critical first step before proceeding with saltcedar control. Costs for saltcedar control and revegetation are expensive, and careful selection of areas with a high potential for reestablishment is necessary to provide sustainable saltcedar control in the long term. In some situations, a treated area will recover naturally after aerial spraying without revegetation. In other situations, artificial plantings or seeding may be necessary. Sites that have dense saltcedar stands, poor hydrologic integrity, elevated salinity, or related conditions may have limited revegetation potential. A soil survey may be used to determine the soil texture, ground water depth, salinity levels, and other related soil factors that can ultimately influence replacement of the vegetation community.

Special Considerations – Saltcedar potentially serves as nesting habitat for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) which is protected under the Endangered Species Act of 1973. To avoid harm to this species, information should be obtained from the U.S. Fish and Wildlife Service (Arizona, phone (602) 242-0210; New Mexico, phone (505) 248-6920) before implementing treatment of saltcedar stands of 0.25 acre or more in riparian or wetland areas within Arizona or New Mexico. A formal survey for flycatcher nesting habitat by a surveyor with a scientific permit may be required for a saltcedar site prior to treatment if the nesting status of the site is undetermined. Within occupied or suitable flycatcher habitat, saltcedar treatment operations (including ground or aerial herbicide spraying) should not occur during the flycatcher nesting period of April 15 to August 30. When nesting habitat of the southwestern willow flycatcher is present, a no-treatment buffer of 0.25 mile is necessary around the nest(s). Migratory birds other than the flycatcher may also nest in saltcedar from April through August, and saltcedar treatment during this period should be avoided if possible.

Physical Control

Manual Methods

Digging or hoeing can be used to target individual plants in relatively small areas. Some commercially available hand implements are practical for uprooting small saltcedar plants; however, a shovel or hoe is most commonly used. The root crown and associated layered roots must be entirely removed from the soil. Uprooted material should be stacked into piles and dried before burning or mulching.

Mechanical Methods

Mechanical methods to treat saltcedar range in scale from individual plant excavation (from hand-operated equipment to excavators) to broadscale clearing (from tillers to bulldozers). Clearing saltcedar stands with a mechanical method often requires repeated applications.

Grubbing with a tractor-mounted implement is particularly useful for control of scattered individual trees. A grubbing tool mounted on a tractor's hydraulic system drives a blade into the soil to sever roots below the root crown and force the root crown onto the surface. To prevent rerooting, grubbed saltcedar should be piled, dried, and then burned or mulched rather than left on the surface.

Excavating can be used to remove individual trees selectively. Operators of excavating equipment must be skilled in placing the extracting bucket beneath the root crown of the target plant and grasping the tree with an opposing hydraulic arm so that it can be pulled directly upward in a vertical motion. Extracting the tree vertically rather than sideways minimizes excessive breakage of the root material at or near the ground surface.

Mulching and excavating can be used in combination by first eliminating top growth of saltcedar quickly through mulching and then using excavation to destroy the remaining root system. Mulching by itself may be used to reduce fuel loading for fires by clearing significant acreage of saltcedar in a relatively short period of time. Mulching requires mobile, high horsepower machinery to operate a high speed rotating drum equipped with cutting teeth. The mulching equipment shreds saltcedar top growth to ground level and simultaneously grinds it into fine segments. Mulching operations leave the roots intact; therefore, saltcedar will resprout when growth conditions become favorable. The sprouts will typically reach 2 to 5 feet in height within the first or second season after mulching. A track-mounted excavator may be used to remove the remaining live root crowns and layered roots as indicated by the resprouting.

Root plowing and raking is a combined mechanical treatment designed to clear large, mature saltcedar stands on relatively level areas. A two-phase approach is generally followed. In the first phase, aerial trunks and stems are cut at the soil surface and piled using a D-7 or D-8 class bulldozer equipped with a front mounted brush blade. An articulated loader equipped with a brush rake working in tandem with a bulldozer may be used to facilitate piling. Piles should be allowed to dry for a month or longer prior to burning. The work may be accomplished during winter months to avoid overheating of equipment and summer nesting of birds. The second phase of control should occur during hot and dry summer months (usually May and June) when root material will dry out after removal from the soil. A 12-foot-wide root plow pulled by a bulldozer (e.g., D-7 class) can be used to sever the root crown from the remaining root system about 12 to 18 inches below the soil surface depending on the maturity of the saltcedar stand. Root material near the soil surface can then be raked by a bulldozer (e.g., D-8 class) equipped with a 21-foot-wide hydraulic root rake containing teeth that are 4 feet in length and are spaced 15 inches apart. The material can then be windrowed and piled using an articulated loader. The piles are subsequently burned.

Prescribed Fire

Prescribed fire as a single control method is not recommended for long-term saltcedar management since saltcedar is fire adapted and regrows rapidly. Natural or prescribed fires in mature or decadent stands of saltcedar are hazardous as flame lengths in these fires can be extremely high and crown fires can be difficult to stop with standard firefighting methods. However, burning may be useful or necessary to remove brush piles or any dead saltcedar left standing after herbicide spraying.

Cultural Control

Education and monitoring can be important components to saltcedar control. Some nurseries still stock saltcedar as a decorative plant which could serve as sources of escaped stock in noninvaded areas.

Biological Control

Grazing

Livestock will browse saltcedar, but the foliage has little nutritional value and is usually not preferred. Grazing with goats may be used to suppress resprouting after other treatments have been made.

Classical Biological Control

Saltcedar is typically damaged by a number of organisms in its native Mediterranean and Asian habitat. The northern tamarisk beetle *(Diorhabda carinulata)* and allied *Diorhabda* species are host-specific species that have been used as biological control agents for saltcedar (see table 2). Both adult beetles and larvae consume the foliage of saltcedar which can kill the plant over a period of several years. Different species of the *Diorhabda* beetle with specific biotic requirements for climate and day length were released in the United States according to their corresponding needs. Four other insect species feed on saltcedar (including the cicadellid leafhopper, *Opsius stactogalus*), but these insects have not been observed to cause anything more than marginal damage.

Table 2. Biological control agents

Species	Type of Agent	Site of Attack	Impact on Host	Use/Considerations for Release
Diorhabda carinulata and allied species	beetle	Larvae and adults feed on foliage.	Varies by *Diorhabda* species	Has been released in Nevada, Utah, Colorado, California, and Texas. These particular beetle species should not be released as biological control agents since they can potentially impact saltcedar habitat of the endangered southwestern willow flycatcher.

Expansion of tamarisk beetles from original release sites threatens to impact the endangered southwestern willow flycatcher *(Empidonax traillii extimus)* which nests in saltcedar dominated areas that have replaced the original native willow communities. The beetle has moved into Arizona and New Mexico from outlying states, and this advancing migration could damage critical nesting habitat used by the flycatcher. The USDA Animal and Plant Health Inspection Service (APHIS) has suspended further releases of *Diorhabda* beetles pending review by the U.S. Fish and Wildlife Service. 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 on the APHIS Web site at http://www.aphis.usda.gov/ppq/permits/.

Chemical Control

Herbicides are a primary method of saltcedar control and can be applied by a number of ways including fixed-wing aircraft, helicopter, tractor, truck or ATV-mounted boom sprayers, power sprayers, backpack sprayers, and carpet rollers. Treatment success depends on care taken during herbicide application. Most compounds available for saltcedar control have postemergence activity and provide limited preemergence control (see "Table 3. Herbicide recommendations").

Herbicide Control Methods

IPT basal bark treatment can be made on individual saltcedar plants by using herbicide mixed with oil in a backpack sprayer that is fitted with an adjustable nozzle (X0 to X1 orifice size) to deliver a mist spray from the base of the stem up to 6 inches above the ground. Triclopyr ester herbicide mixed with crop oil in a 50:50 v/v (volume to volume) ratio is an effective mixture. Imazapyr with crop oil may also be used for this application. Although basal bark treatment provides fair control, it is very tedious and time consuming, especially when the saltcedar is multistemmed. Applications on older stems with thick, furrowed bark should be avoided since success may be limited. Basal bark treatments are more easily made in winter when foliage is shed; however, summer treatment is recommended in Texas.

IPT cut stump treatment is often used in areas where mechanical treatments or foliar applied herbicide spraying are restricted due to logistical considerations or when there is a need to be highly selective and protect nontarget

vegetation. The treatment involves hand cutting or chain sawing the saltcedar trunk or stems as close to the ground surface as reasonable, and then applying herbicide to the cut stump surface by paintbrush, hand-held spray bottle, or backpack sprayer. The cut surface should be horizontal to the ground to minimize runoff, and any residual sawdust over the cut surface should be removed prior to herbicide application. A solution of triclopyr ester or imazapyr mixed with bark or crop oil must be immediately applied within 15 minutes. The herbicide:oil mixture ratio can vary from 33:67 to 50:50 v/v depending on the number and size of plants to be treated and the application technique used. Lower ratios (e.g., 33:67) are typically used when applications are made with a low volume backpack sprayer or hand-held spray bottle, whereas higher ratios (e.g., 50:50) are used when the solution is brushed directly onto the cut stump. Cut surfaces of plants with less than 4 inches diameter must be thoroughly wetted with herbicide to kill the roots; however, the herbicide should be applied to the cambial layer just inside the bark ring if the diameter of the saltcedar stump exceeds 4 inches. A blue indicator dye should be added to the spray mixture to show prior treatment of stumps. Disposal of trunks, limbs, and other top growth should follow acceptable practices (e.g., stack piles or chips).

Mortality rates from cut-stump treatments are directly related to care taken when treating cut surfaces. Control can be 60 to 80 percent under optimal conditions, but plant kills may be less than 40 percent due to difficulties associated with this method. Therefore, followup treatment using ground-based foliar applications should be anticipated.

IPT foliar spray may be used to control small saltcedar plants that are less than 5 feet in height and are relatively small in acreage. Saltcedar foliage should be completely covered, and the terminal ends of all branches (including blooms) should be wetted without allowing dripping to occur. The interior of the plant should then be laced with the spray solution to complete treatment. Ground application of 1 percent imazapyr solution by volume to saltcedar foliage can be made with a variety of spraying equipment such as hand-held pump-up or backpack sprayers, tractor-towed tank sprayers, or ATV-mounted low and high powered sprayer systems. An adjustable cone nozzle (X6 to X8 orifice size) can be used to deliver a coarse spray (large droplets). A nonionic surfactant (0.25 percent by volume) and a blue indicator spray dye should be added to the mixture. Since absorption of herbicide into the foliage is relatively slow, chemical penetration into the plant should be increased by spraying during weather conditions of low wind, high relative humidity, and low air temperature. After treatment, the top growth should remain undisturbed for at least 2 years. Although plants may appear dead (i.e., completely defoliated) in the first growing season after spraying, they will still try to grow. If top growth is removed too early after spraying, saltcedar will shift stored carbohydrate reserves toward apical root buds and will resprout.

Airplane or helicopter applications can be used to spray saltcedar successfully if the aircraft is equipped with the proper spray system. Helicopters can spray difficult, "tight" areas that require precision application such as edges of meandering rivers or saltcedar stands interspersed with nontarget vegetation. Fixed-wing aircraft are better for spraying large, monotypic blocks of saltcedar where an overlapping spray pattern can be delivered at a lower operational cost than by a helicopter. Aircraft should be equipped with a satellite guidance system, a variable rate flow meter, and an onboard GIS display system for spraying in wildland situations. Areas to be sprayed should be premapped, and the onboard computer spray system should be preprogrammed to apply herbicide only on defined treatment areas. Swaths should be overlapped to prevent streaking whereby plants are left untreated or slightly damaged.

For aerial applications, the spray volume should be sufficiently high to insure maximum spray coverage. Spray nozzles should be fitted to deliver moderate to large-sized droplets ranging from 450 to 1,200 µm. As indicated in table 3, a spray mixture may include 2 quarts of imazapyr

Table 3. Herbicide recommendations

Common Chemical Name	Product Example[1]	Product Example Rate per Acre	Individual Plant Treatment (IPT)	Time of Application	Remarks
Triclopyr ester	Garlon 4, Remedy, Ultra, Others	NA	50:50 mixture of triclopyr and crop oil with a blue indicator dye.	Anytime	For cut stump treatment, apply to fresh cut stump within 15 minutes of cutting.
Imazapyr	Arsenal, Habitat, Others	2 quarts	1 percent mixture for foliage spray (1 gallon per 100 gallons of water with 0.25 percent surfactant and a blue indicator dye).	Late summer to early fall when plants are taking up nutrients; plants should be healthy and not stressed.	For IPT, spray to wet all foliage especially the terminal ends of branches. For aerial broadcast spraying, add 0.25 percent nonionic surfactant. Use a high spray volume; 15 gallons per acre total solution when applied by helicopter. Allow two full growing seasons before followup treatment. In addition to overspray, death or injury may occur from transfer of imazapyr between intertwined root systems.
Imazapyr + glyphosate	Arsenal + Rodeo	1.5 quarts + 1.5 quarts	1/2 to 1 gallon + 1/2 to 1 gallon (1–2 pounds + 2–4 pounds per 100 gallons of water with 0.25 percent surfactant and a blue indicator dye).	Same as imazapyr.	Same as imazapyr.

[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 saltcedar.

or a 1.5 quarts imazapyr plus 1.5 quarts glyphosate mixture applied in water. A nonionic surfactant (0.25 percent by volume) and a drift control agent (0.07 percent by volume) should be added to the mixture. For optimum plant control, an aerial application should leave the entire saltcedar canopy glistening with spray liquid long after spraying has occurred. This can partially be accomplished by equipping the aircraft with the correct spray system and by spraying under optimal environmental conditions. Moderate temperatures (60 to 80 °F), high relative humidity (65 to 90 percent), and light winds (3 to 7 m.p.h.) are ideal to maximize herbicide activity. Late summer (August–September) is usually the best time to spray saltcedar by aircraft. Plants to be sprayed should be in a healthy state with full foliage that has not been stressed by drought, damaged by hail, or is beginning to turn yellow late in the season.

Control Strategies

Saltcedar may be managed to enhance downstream waterflow, recreation, fire prevention, grazing, flood control, and aesthetics. Strategies to control saltcedar often vary depending on specific management objectives and location within a watershed. For example, an eradication strategy in headwater areas may be used to prevent the downstream spread of saltcedar along waterways. In transitional zones, such as river edges or riparian areas, saltcedar may be

removed to enhance waterflow and channel characteristics. In depositional or flood plain areas, goals for saltcedar control can vary widely and may include enhancing wildlife habitat, minimizing potential fire hazard, regenerating native riparian communities, or meeting other multiple use needs.

Numerous research and practical integrated approaches have been developed to manage saltcedar. Successful long-term management programs (typically more than 5 years) usually include a combination of mechanical, fire, and chemical control methods. A combination of methods is particularly necessary if the primary objective is to achieve long-term native plant stability. The **herbicide–burn–mechanical** control program, for example, has emerged as a practical strategy for controlling saltcedar in large, monotypic tracts on valley bottoms and flood plains. The initial intervention step is to apply herbicide aerially which typically provides 70 to 90 percent saltcedar mortality. After 2 years, prescribed burning is used to remove dead aerial trunks and stems. When prescribed burning cannot be done, mechanical treatments such as chaining, cabling, bulldozing, or roller chopping may be used to drop standing dead debris. Surviving saltcedar plants can then be removed in the fourth or fifth year after spraying with an excavator, grubber, or root plow and raking. In some instances, IPT foliage spraying may be needed to control saltcedar resprouting.

Once saltcedar has been removed, aggressive revegetation is often required. Managers should understand the revegetation requirements of a site after saltcedar treatment and include restoration as part of a control strategy. Without special planning and care, treated areas may be rapidly reinvaded by saltcedar or other invasive species. In such instances, sustainable control over the long term is best accomplished by planting competitive native plants that have a high exclusionary ability. Native riparian woody species such as cottonwood (*Populus deltoides*), Goodings willow (*Salix gooddingii*), and coyote willow (*S. exigua*) have a rapid growth potential under conditions of low environmental stress and are good candidate species for plantings.

Adaptive Management – A persistent commitment over many years is required for successful control of saltcedar. Consideration should be given to the ongoing expansion of *Diorhabda* beetles before implementing saltcedar control projects in Arizona or New Mexico. Realistic goals and objectives should be, therefore, established to manage saltcedar infestations occurring extensively throughout a given landscape before undertaking a project. If saltcedar control is still necessary, consider using an adaptive management strategy with the overall goal of restoring desirable plant communities. The stepwise process for adaptive management involves:

1. Assessment of the overall weed problem,
2. Establishing management goals and objectives,
3. Implementation of control strategies,
4. Monitoring the effectiveness of management actions,
5. Evaluating actual outcomes in relation to expected results, and
6. Adjusting practices as necessary.

Steps of this process should be repeated in sequence as part of a continuous learning cycle that improves management planning and strategy by learning from the outcomes of previous management actions. In general, an adaptive management strategy may be considered to be successful if:

1. Stakeholders are actively involved and remain committed to the process,
2. Monitoring and assessment are used to adjust and improve management decisions, and
3. Management goals and/or objectives are being achieved for the resource.

References and Further Information

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Suggested Web Sites

For information on invasive species:

http://www.invasivespeciesinfo.gov/

http://www.invasive.org/weedus/index.html

For information about calibrating spray equipment:

NMSU Cooperative Extension Service Guide #A-613 Sprayer Calibration at http://aces.nmsu.edu/pubs/_a/A-613.pdf

Herbicide labels online:

http://www.cdms.net/LabelsMsds/LMDefault.aspx

For more information or other field guides, contact:

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

Or visit:

http://www.fs.usda.gov/main/r3/forest-grasslandhealth

USDA

United States Department of Agriculture

Forest Service

Southwestern Region

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Field Guide for Managing Teasel in the Southwest

Cover Photos

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Teasel (*Dipsacus fullonum* L.)

Teasel family (Dipsacaceae)

Teasel is an invasive plant that has been listed as a noxious weed in New Mexico. This field guide serves as the U.S. Forest Service's recommendations for management of teasel in forests, woodlands, and rangelands associated with its Southwestern Region. The Southwestern Region encompasses 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

Common teasel (synonyms: Fuller's teasel, wild teasel, Venus' basin (or cup), barber's brush) is a weedy biennial with prickly stems and a distinctive cone-shaped flower head. Teasel was introduced from Europe and is valued as a horticultural plant; it has also been used medicinally and its dried seed heads were used for wool "fleecing." The spiny, egg-shaped seed heads of teasel are commonly used in floral arrangements. It is widespread in the Pacific Northwest and is currently becoming more common in New Mexico and Arizona. In the rosette stage, it is similar in appearance to other thistles, common burdock (*Arctium minus*), and broadleaf dock (*Rumex obtusifolius*). As teasel matures, it can be distinguished from these other plants by its wrinkled leaves.

Growth Characteristics

- Biennial or short-lived perennial (dies after it flowers for the first time).
- Rosette leaves are wrinkled, scalloped, oval shaped; older rosette leaves are often hairy.
- A flowering stalk grows when the plant has accumulated enough energy reserves in the roots, usually after growing as a rosette for at least 1 year. The erect branching stem may grow up to 7 feet tall with simple, stalkless, opposite lanceolate leaves with conspicuous veins. Upper leaves have entire margins, grow to 10" long, slightly clasp the stem, and may hold water near the leaf axil. Leaf mid-ribs and elongated stem have downward pointing prickles.
- Flowers occur from early summer until early fall; oval-shaped flower heads with rings of small, densely packed lavender flowers. Stiff, spiny, upward pointing bracts (~2" long) extend from the end of the stem, below the flower head. Each flower usually lives only 1 day.
- Taproot during rosette stage; 2 feet deep. Fibrous roots extend from taproot (up to 1 foot wide).
- Reproduces mainly via seed; prolific seed producer (2,000 seeds per plant; viable for 2 years).

Ecology

Impacts/threats – Teasel can be an aggressive competitor allowing it to displace desirable plants and form a monoculture. Its presence reduces forage availability and contributes to decline in species diversity and range quality. In New Mexico, it has similar habitat preferences to the Sacramento Mountain thistle (*Cirsium vinaceum*) and may out-compete this endangered plant species locally.

Location – Teasel prefers open, sunny habitats; it is often common in disturbed sites, pastures, and along interstate highways. It grows in both moist and arid soils though it is most often found in mesic soil types. In New Mexico, it prefers elevations between 4,000 and 7,000 feet and has been mapped in the Lincoln National Forest in Otero County. However, distribution maps likely underestimate the presence of teasel because its large stature and prickles deter frequent specimen collection.

Spread – Teasel prolifically produces seed that remains viable in soil for at least 2 years. Usually, seeds establish near the parent plant, in spaces previously occupied by the basal rosette leaves. However, seeds may be transported by birds or via waterways, such as irrigation ditches or streams/rivers. Seeds are also spread by adhering to the undercarriages of vehicles or mowing equipment used along interstate highways.

Invasive Features – Although teasel is not known to have allelopathic properties, it is aggressively competitive. An opening within the vegetation coupled with light soil disturbance is an invitation for invasion. Its taproot allows access to nutrients and soil moisture deeper within the soil profile. Teasel's biennial life history allows it to claim space within the plant community while it stores resources for reproduction. The stored resources result in increased seed production and greater germination success.

Management

Prevention and early detection are the best management tools for teasel. Management should focus on maintaining healthy native plant communities and managing teasel before it can produce seed. Priority should be given to monitoring for teasel and eradicating small, new, and isolated infestations that become established on otherwise healthy sites. Control and containment methods should be practiced with larger teasel infestations. Generally, the perimeter of large infestations should be treated first to prevent the infestation from spreading. For an isolated plant, the seeds will generally fall within 4 to 5 feet from the parent plant. However, as population density increases, the potential area where seed may fall expands.

Strategies to contain, reduce, or eradicate teasel populations require long-term planning, integrated management, and followup monitoring. A combination of methods and repeated treatments will improve effectiveness. The following actions should be considered when planning an approach:

- Maintain healthy plant communities to prevent or limit teasel infestations. This may involve using improved grazing management strategies to prevent excessive grazing; or reseeding areas with desirable grasses and forbs after disturbance.
- Detect, report, and map known infestations. Keep annual records of reported infestations.
- Eliminate new populations of teasel as early as possible, especially when in the seedling or rosette stage.
- Combine mechanical, cultural, and chemical methods for most effective teasel control.
- Implement a monitoring and followup treatment plan for missed plants and seedlings.
- Use certified weed-free seed and hay; use pellets for horses used in the back country.

Choice of control method(s) for teasel depends primarily on the density, degree, and location of the infestation. Land use and current site conditions (accessibility, terrain, climate, other flora and fauna present, etc.) must also be considered. Other considerations include treatment effectiveness, cost, and number of years needed to achieve control. Table 1 summarizes approaches for the most common situations involving teasel. More than one control method may be needed for each site.

Special Considerations – The Sacramento Mountain range in southern New Mexico serves as habitat for the endangered Sacramento Mountains thistle (*Cirsium vinaceum*) which is protected under the Endangered Species Act of 1973. Portions of the mountain range within Otero County are also inhabited by local populations of Wright's marsh thistle (*C. wrightii*) which is a New Mexico listed endangered species and a Federal candidate for listing. Wright's marsh thistle is also found in Eddy, Chaves, Guadalupe, and Socorro Counties in New Mexico. Both thistle species occur in wetland habitats such as spring seeps and marshy edges of streams and ponds. Information should be obtained from the U.S. Fish and Wildlife Service at (505) 346-2525 before implementing treatment of teasel in the Sacramento Mountains and the aforementioned counties that possibly could involve habitat of these endangered species.

Physical Control

Physical control methods work best on seedlings, rosettes, and partially established stands of teasel. In general, the

Table 1. Management options*

Site	Physical Methods	Cultural Methods	Biological Methods	Chemical Methods
Roadsides, fence lines, noncrop areas	Mowing just after flower heads open but before seeds enlarge will prevent production of viable seed. Monitor and mow again if plants resprout and flower.	Clean mowing equipment after use. Train road crews to identify and report infestations along roads. Use weed screens on irrigation water intakes.	None available.	Use truck or tractor-mounted spraying equipment. Wash underneath vehicle after application to prevent spread.
Pasture, rangeland, or riparian corridors	Teasel rarely persists in settings where repeated cultivation is practiced. For densely infested sites, a prescribed burn in spring can prepare the site with herbicide application as a followup treatment.	Use certified weed-free seed and hay. Inspect and remove seed from clothing, animals, and vehicles before entering treated or uninfested areas. Closely manage grazing to prevent overuse. Reseed with perennial grasses after disturbance or treatment. Avoid driving vehicles and equipment through infested areas; wash if traveling through infestations was unavoidable.	See above.	Broadcast spraying via truck or ATV-mounted sprayer; backpack spraying may be more practical in areas difficult to access.
Wilderness, natural areas, and/or small infestations	Cut or hoe roots at least 1 to 2 inches below the soil surface. Hand pull if soil conditions allow for removal of most of the taproot. Use a hand-held propane torch for seedlings and isolated plants.	In addition to the above, use pellets for horses in the back country. Post signs warning visitors to remove seeds after passing through infested areas.	See above.	Use backpack or hand-held sprayers. Broadcast spraying with ground methods may be used on thicker stands if allowed.

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

effectiveness of physical control methods can be increased by combining physical methods with chemical spraying for long-term management of teasel.

Manual Methods

Hand pulling or cutting – Hoe or dig plants at the rosette to early bolt stage, cutting the taproot 1 to 2 inches below the soil surface. When soil conditions allow it, hand pulling can be effective for smaller, less established infestations. Removal is generally easier and more effective when soil is moist and plants are beginning to bolt, but before seed set. It is very important to pull up as much of the taproot as possible. Properly dispose of debris by burning or bagging and burying in a landfill to prevent spread. Immature seed heads may ripen if left onsite.

Mechanical Methods

Tillage – Disking or plowing infestations will disrupt and discourage growth. In an agronomic setting, teasel will not persist if cultivated repeatedly.

Mowing – If properly timed, mowing can severely reduce the amount of viable seed that is produced. Mow during bolting or when flower heads are just being produced, but before seed has matured. If performed after seed has matured, mowing will facilitate spread. Monitor the site after mowing and repeat if teasel resprouts and grows new flower stalks.

Prescribed Fire

Fire research with teasel is limited. However, broadcast burning is usually not considered a viable option because

bare ground interspaces between teasel plants prevent a sustainable fire. Since the growth region of teasel is located just below the surface, fires that significantly increase belowground temperatures are more likely to kill the plant. A propane torch may be considered for individual plant treatment, especially for seedlings or plants in the rosette stage. Fire is also an acceptable way to dispose of debris.

Cultural Control

Preventing teasel introduction to an area can save time and energy required for control measures. Consider educating florists and the local public as to the potential impact of teasel introduction. Dried flower arrangements left at cemeteries are a common means of introducing teasel to a previously uninfested area. Also, consider educating land managers, road crews, and the local public on identification of teasel so that they can help prevent establishment by reporting all suspected infestations. Early detection and plant removal are critical for preventing establishment of teasel.

Biological Control

Grazing

While teasel does not withstand moderate to heavy grazing, it is not highly palatable or serve as desirable forage. Most foraging animals (including cattle, sheep, and goats) avoid teasel and will not graze it.

Classical Biological Agents

Biological control agents are not available for teasel.

Chemical Control

Herbicides are an effective and economical way to manage teasel. However, new populations often return within a few years of spraying from seed that is still abundant in the soil. Anticipate the need to monitor and use followup herbicide applications for several years to deplete the seed bank and attain long-term control.

All herbicides recommended in table 2 will control emerged teasel when properly applied. The most commonly recommended herbicides for effective control include 2,4-D (alone or combined as a mixture), triclopyr, clopyralid, or aminopyralid. Glyphosate is nonselective and may be considered if control of other plants (especially grasses) is acceptable. Caution should be taken with all herbicides if nontarget plants—including woody species—need to be protected. Each herbicide product will have different requirements and restrictions. Thus, it is important to read the label carefully and follow all instructions and guidelines when mixing and applying any chemical. Grazing restrictions following treatment as specified on the label should always be followed.

Table 2. Herbicide recommendations

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
2,4-D Amine [3]	Many products	2–4 pints	2%	During active growth; rosette to bolt, especially late fall to early winter or spring.	Broadleaf-specific herbicide. Clover and creeping bent grass may also be impacted. Not recommended for direct application to water. Avoid spraying seedling grasses until roots are established. Limit grazing for 7 days following treatment.

Table 2. Herbicide recommendations (continued)

Common Chemical Name (active ingredient)	Product Example[1]	Product Example Rate per Acre (broadcast)	Backpack Sprayer Treatment Using Product Example[2]	Time of Application	Remarks
Aminopyralid	Milestone	1/4–1/3 pint	5–10%	See above.	Broadleaf-specific herbicide; does not harm grasses. Labeled for use up to water's edge. Some grazing recommendations. Best applied as a coarse, low-pressure spray. If stand is taller than 6 feet, use a high-volume spray. Use 0.25–0.5% v/v NIS[4] when conditions are adverse (high heat, low relative humidity, or dusty conditions) or on mature stands; may be used in combination with 2,4-D.[3]
Imazapic	Plateau	1/2–3/4 pints	0.5–1% + 1% MSO	Spring/fall on rosettes or early summer when it bolts.	Inhibits growth of most plants; more likely to kill boradleaved plants. Acceptable for use in riparian areas. Adding 2 pints per acre methylated seed oil improves effectiveness, especially on broadleaved plants.
Clopyralid	Curtail	2–3 quarts	1–3%	Spring from 6 to 10 inches growth until early bud; or fall at rosette.	Broadleaf-specific herbicide; does not harm most established grasses. Not recommended for highly permeable soils or shallow groundwater areas. Can be used on rangeland, irrigated pasture or meadow, but not applied directly to water. Wait 30 days to establish perennial grasses. May be used in combination with 2,4-D.[3] May use up to 0.5% v/v NIS.[4]
	Transline	1/4 to 1-1/3 pints	1–3 %		
Triclopyr	Remedy	1–2 pints	2%	During active growth.	Broadleaf-specific herbicide; does not harm grasses. Uptake is by foliage and roots. Not recommended for areas with highly permeable soils or areas of shallow groundwater. Adequate soil moisture and healthy leaf material is required for optimal herbicide effectiveness.
Triclopyr + clopyralid	Redeem R&P	1.5–2 pints	1–2%	Rosette stage	See recommendations above.
Glyphosate	RoundUp, many products	4–4.8 quarts	1.5–2%	Rosette to early bud; late fall to early winter.	Non-specific herbicide; will damage any actively growing plant material it contacts. Apply during late fall or early winter or use a spot treatment or wipe method when desirable plants are present.

[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 teasel.

[2] 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 ounces of liquid herbicide until a volume of 1 gallon is reached (4 oz ÷ 128 oz/gal = 0.03 or 3 percent).

[3] 2,4-D is a restricted use pesticide in New Mexico only. A certified applicator's license is required for purchase and use.

[4] NIS is an abbreviation for nonionic surfactant, an additive commonly recommended by herbicide labels for postemergent foliar herbicide application.

The most effective growth stage to spray teasel is at rosette stage in fall or spring. Spraying after the plant has bolted is less effective, and spraying after seed heads have formed is counterproductive. This is because seed heads will continue to mature after herbicide treatment and will likely contribute to further spread.

Herbicides may be applied in several ways including by backpack, ATV, or UTV sprayers, or conventional boom sprayers that are pulled or attached to a tractor or truck. For repeated treatments, rotation of herbicide active ingredients on a year-to-year basis should be considered to prevent development of resistance.

Reseeding an area following herbicide treatment can improve long-term control by increasing competition with teasel. In areas where reseeding is planned, glyphosate can be broadcast sprayed for site preparation. Glyphosate is most effective when applied sequentially at about 1-month intervals during the summer, coupled with a fall grass seeding. Make the first application in early summer (June or July) and the second about a month later, provided green shoots are present. Sow perennial grass seed in late autumn as a dormant seeding (i.e., grass seedlings will not emerge until the following spring).

Control Strategies

Because each treatment situation is unique, the strategy adopted for managing teasel must involve careful planning and consideration of the local site conditions. Persistence and a long-term commitment is a must for teasel control. Treated areas should be monitored periodically and measures taken to control missed plants and newly emerged seedlings. It is also important to monitor the return of desirable native plant species. Teasel prefers open sunny habitats, thus encouraging competition from grasses while maintaining litter cover will help minimize its reestablishment.

Experience with integrated methods for controlling teasel is limited. As is the case in managing most weed infested areas, integration of techniques such as mowing and herbicide should be beneficial since the impacts of combined control measures are often cumulative. Integrating revegetation through broadcast seeding or a no-till drill to increase competitive pressure on teasel should always be considered where feasible.

Consider addressing smaller populations or isolated plants on otherwise healthy sites first. Next, the plants at the perimeter of heavily infested areas should be treated. The larger, denser cores of the infested area should be addressed in the final stage of treatment. Regardless of the strategy used, a key to successful long-term control of teasel is to encourage vigorous competition from desirable perennial plants, especially grasses.

The following strategies have been used to contain and reduce teasel populations in certain situations, but local conditions dictate the best approach.

Combined mechanical and chemical strategy – One example of a combined control strategy is to mow in early spring and follow with a herbicide treatment about 50–60 days later. If soil moisture is adequate, consider reseeding in the fall with a competitive perennial grass mixture. Always use followup monitoring and spot treat any new plants or regrowth. Grazing should be deferred for two growing seasons to favor establishment of desirable perennial grasses.

Broadcast or individual plant treatment for localized infestations – Use a handgun power sprayer to broadcast treat teasel growing in larger areas. Spray in late fall or early spring, when surrounding desirable plants are mostly dormant, but teasel is green. For smaller sparse populations, one person or a small team can spray teasel using a backpack sprayer fitted with an adjustable spray nozzle. Plants should be spot sprayed by wetting the foliage and stems without allowing dripping to occur. Consider using a 2 percent solution of triclopyr + clopyralid.

Strategy for an early infestation with grass understory present – Perform a late winter or early spring prescribed burn to prepare a site by removing old debris and opening up the canopy to make teasel rosettes more visible. Followup with a broadleaf-specific herbicide—such as triclopyr or clopyralid—on teasel rosettes to increase competitive advantage for grasses.

Regardless of the initial strategy used, it will likely require 4–6 years of repeated control efforts to contain or eliminate teasel. Long term integrated planning and a commitment to repeated management actions is a must. Always monitor treatment areas on an annual basis and consider reseeding to encourage competition from desirable plants, especially perennial native grasses.

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Suggested Web Sites

USDA Plants Database. 2010. http://plants.usda.gov/index.html

Virginia Tech Weed ID Guide: http://www.ppws.vt.edu/scott/weed_id/diwsi.htm

For information about calibrating spray equipment:

NMSU Cooperative Extension Service Guide A-613 Sprayer Calibration at http://aces.nmsu.edu/pubs/_a/A-613.pdf

Herbicide labels online:

http://www.cdms.net/LabelsMsds/LMDefault.aspx

For more information or other field guides, contact:

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

Or visit:

http://www.fs.usda.gov/main/r3/forest-grasslandhealth