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Nevada's Priority Agricultural Weeds: Russian Knapweed

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INTRODUCTION

Russian knapweed (*Acroptilon repens*) is a non-native perennial forb (wild flower) that arrived in the United States in the late 1890s. This weed is well adapted, growing in damp to poorly drained soils with high salinity and/or alkalinity. In the year 2000, Russian knapweed infested about 1.2 million acres across the 17 Western states. This included about 425,000 acres in Idaho, 85,000 acres in Oregon, 60,000 acres in Utah, 500,000 acres in Washington and 64,000 acres in Montana. Russian knapweed probably affects well over 10,000 acres in Nevada, but the exact figure is unknown.

Individual infestations in Nevada often are quite large and occur in native grass-hay meadows, riparian areas, rangelands, agronomic crops, field borders and fence lines, canal and ditch banks, roadsides and other linear corridors used to transport commerce and energy, and waste areas. In addition to displacing more desired forage and crop species, even small contamination in grains (0.01%) can reduce flour quality.

Twenty-three percent of agricultural producers in Nevada rated Russian knapweed as a serious problem. At least 14% of all agricultural producers in every county rated the weed as problematic. Those in the following counties rated Russian knapweed even more problematic: Pershing (61% of producers); Humboldt (45%); Lander and Eureka (40%); Churchill (26%); Douglas and Carson City (25%); Nye, Esmeralda and Mineral (24%); and White Pine (20%). Generally, the north-central and central regions of the state consider the weed most problematic. This coincides with counties that have the greatest amount of agronomic cropland, as well as large expanses of grass-hay meadows. Just over 53% of the public land managers in Nevada rated Russian knapweed as a problematic weed on public lands.

Russian knapweed becomes problematic when a few initial plants rapidly expand their population and establish a nearly complete monoculture. Dense stands can persist for over 75 years, and the typical outcome is reduced crop and livestock production on the affected property. The yield of grain and corn crops has declined as much as 75% to 85%. Desired species are excluded because mature Russian knapweed plants are excellent competitors for soil moisture and nutrients and may have allelopathic properties that inhibit the growth of many desired plants.

PLANT BIOLOGY

Russian knapweed is a long-lived, relatively shade-intolerant plant, with a maximum height of about 3 feet. Widespread reproduction from seed seldom occurs, but is possible. Most populations typically increase from vegetative reproduction by rapidly expanding lateral roots. The roots of Russian knapweed may reach depths of 8 feet their first growing season and 23 feet their second growing season. Their radial spread can cover as much as 130 square feet after two growing seasons. Every 1-

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inch root segment may have a bud capable of producing a new shoot (**Figure 1**), and root segments as short as 1 inch have produced new shoots when buried as deep as 6 inches. Tillage that cuts the root system into many small segments typically creates hundreds of new plants.

Figure 1. New shoots growing from buds on a lateral root of a Russian knapweed plant. This root was about 6 inches deep when harvested. The lens cap above the root is 2 inches in diameter.

The buds on the root crown and the creeping roots tend to grow during late fall through March. This growth feature tends to make Russian knapweed susceptible to soil-active herbicides from late fall through the dormant season, as long as the soil is not frozen and there is enough soil moisture to move the herbicide into the root zone, where the active ingredient can be absorbed by the buds.

Buds on the root crown and lateral roots start to develop shoots in March and April, when the ground thaws and soil temperature remains above freezing. The new shoot initially develops a basal rosette of leaves, followed in May and June by a bolting floral stem. Most of the carbohydrates produced by the leaves during this period are reinvested in additional stems and leaves, and not moved to the root system. Flowers develop shortly thereafter, and flowering may continue all summer if soil moisture is adequate for continued growth.

The roots of Russian knapweed store a large amount of soluble carbohydrates as energy reserves. Plants use the energy reserves to keep their roots and buds alive during winter dormancy and to initiate new growth the following spring. Stored energy reserves typically peak at the end of the growing season and are smallest when Russian knapweed initially flowers in the spring or early summer. Russian knapweed moves more carbohydrates to the root crown and the creeping roots at full flowering, with continued movement to the roots through the late summer and fall, as the plants slowly senesce.

A single Russian knapweed plant can produce about 1,200 seeds, but typical seed production is 100 to 300 seeds per plant. Most of the seed is viable for only two to three years, but a small percentage may remain alive in the soil for about eight years. Seed germination rates are greatest when the soil remains wet for at least seven days, with peak germination requiring about 25 to 32 days of moist soil. These conditions often occur in seasonally flooded hay meadows and irrigated crop sites, particularly beneath pivot systems with short rotation intervals. A layer of soil or plant litter above the seed facilitates germination. The initial establishment of Russian knapweed occurs most often in disturbed areas where the desired perennial vegetation (or crop) has been thinned or lost due to disturbance or improper vegetation management.

The flowers and seed of Russian knapweed lack adaptations for long-distance dispersal. Flooding, however, can transport the seed or dislodged root segments long distances. Mud that contains viable seed can move that seed long distances, in a short period of time, when it becomes attached to animals, vehicles, farm equipment or even your boots. Construction activities that transport fill dirt to new locations can break large roots into small segments and facilitate establishment long distances away in previously uninhabited areas.

CONTROL METHODS

Nonchemical Control

Mechanical Tillage

A single treatment that severs Russian knapweed's roots does not kill the plant and typically increases the number of new plants. However, one study in Russia found that multiple cuttings of the roots to at least 12 inches deep, over a three-year period, destroyed the root system in the top 3 feet of the soil. Root fragments up to 16 inches long showed high mortality when buried at least 12 inches deep. This suggests possible control with repeated deep plowing.

Root carbohydrate reserves are lowest when Russian knapweed begins to flower. A deep plowing treatment that coincides with flower initiation should have a greater chance of success than deep plowing later in the season, when stored energy reserves are larger.

Shallow tillage usually enhances an existing infestation, because new shoots readily emerge from short root segments (1 to 2 inches long) that are buried 6 inches deep, or shallower. Shallow tillage can effectively control young seedlings that have not yet developed buds (i.e., become perennial). This treatment should be successful where seedlings of Russian knapweed have recently emerged in fallow fields or in fields where an annual crop was harvested early in the growing season.

Mowing

Infrequent or single-mowing events generally stimulate Russian knapweed to produce new shoots from the buds located on the root crown and the creeping roots. Research in a grain field in Russia that was infested with Russian knapweed found that when the crop was harvested for silage for four consecutive years, the control of Russian knapweed reached 99%. Mowing the grain crop at a relatively early growth stage coincided with the flowering stage of the Russian knapweed, which was when plants had their lowest stored energy reserves. Repeated harvest when energy reserves were lowest slowly depleted the plants' energy reserves, and they essentially starved to death.

Fire

Fire is not recommended as a direct control method. Burning eliminates the top growth of Russian knapweed, but does not kill the buds on either the root crown or the roots. Removal of the shoots may stimulate development of a large number of buds and increase Russian knapweed abundance, particularly if the fire also removes any overstory plants that shade the knapweed. Russian knapweed grows very well in high-sunlight environments, and any additional sunlight after an unsuccessful control treatment probably benefits the Russian knapweed.

Flaming or other heat treatments that kill the top growth can control current seed production if the plants are treated at flowering or the early stage of seed formation. After a flaming treatment, regrowth of new shoots from the buds is possible if soil moisture is adequate; therefore, several treatments per season may be necessary. The initial regrowth after flaming, however, comes from stored energy in the roots. The plant uses the stored energy for growth until the bud to early flowering stage. Application of a systemic herbicide at this time may result in better control than an herbicide-only treatment because stored energy reserves in the root are low, which may increase bud mortality. Burning the standing dead material can remove physical barriers that reduce herbicide placement on the leaves or soil surface. This should place more of the active ingredient on the leaf surface or the soil (for soil-active herbicides), which should improve treatment efficacy. Burning can also be a valuable seedbed preparation treatment when it removes plant litter that could adversely affect the seeding of desired species.

Grazing

Grazing treatments generally do not work well when they are a stand-alone management tool, and at best are only one component of an integrated weed management program. Cattle typically avoid the weed due to its bitter taste, unless it is the only forage available. Cattle forced to consume large quantities of Russian knapweed, particularly if it is a novel forage for them, are likely to be less productive, due to less forage intake. Russian knapweed's high protein content may permit its use as a protein supplement when cattle are on low-quality forage at the mid-gestation stage. Sheep and goats will graze Russian knapweed more readily than cattle, and may provide control if the plants are heavily grazed three or more times throughout the growing season, for at least three consecutive years. (Longer treatment periods often are necessary.)

Within a single grazing season, the best control of Russian knapweed occurs when livestock can regraze the weed when shoots reach 8 to 10 inches tall. When residual perennial grasses are present, grazing treatments should allow residual grasses to increase in density, biomass and vigor, so the desired vegetation can fully occupy the site and competitively exclude the Russian knapweed. Russian knapweed in large quantities (60% of body weight over two months) is toxic to horses, and horses should not be placed in pastures that have a large population of Russian knapweed.

Cultural Techniques

To achieve a permanent decline in Russian knapweed, treated sites must establish a dense and vigorous stand of desired vegetation. For most pasture and rangeland settings, this means a dense stand of tall and robust perennial grasses. Annual or perennial crops also must be managed to maintain a high density and cover of the crop. Annual crops that are harvested early on sites that will have sufficient soil moisture for continued growth of the Russian knapweed, usually will need a postharvest treatment (herbicide or other tools) to reduce the knapweed. The vegetation/crop management goal is twofold: 1) provide at least partial shade of the Russian knapweed; and 2) for the crop or pasture plants to have a large, robust root system to extract more soil moisture and soil nutrients than are consumed by the knapweed. For many range and pasture systems, the widespread establishment of Russian knapweed coincided with one or more management actions that either thinned the perennial grasses or maintained previously thinned stands in a degraded state (regardless of the initial cause of the degradation). On these sites, vegetation management (e.g., grazing management, harvest management, fertilization, etc.) probably must change to provide perennial grasses an opportunity to increase and eventually outcompete Russian knapweed. Without a change in management, the weed will probably return and expand toward and possibly exceed its previous level.

Biological Control

There is no effective biocontrol of Russian knapweed at this time. A number of insects have been approved for release, but their establishment generally has been poor and there are few, if any, documented cases of successful treatment. The saprophytic fungus, *Boeremia exigua* isolate FDWSRU 02-059, may cause substantial damage (not necessarily mortality) to Russian knapweed plants, but further study is needed. At best, these biological agents stress the Russian knapweed plants but do not effectively reduce existing populations when they are the only treatment applied. There has been little, if any, research on the influence of biological control agents when their application occurs sequentially or in conjunction with other treatments.

Chemical Control

There are about a dozen active ingredients labeled for application on Russian knapweed (**Table 1**). Most are labeled for range, pasture and noncrop sites; the environmental setting in Nevada where large infestations typically occur. The majority of labeled herbicides are selective, causing little or no damage to desired perennial grasses when applications occur according to instructions on the product label. None of the active ingredients, however, are safe to apply to broadleaf crops when they are actively growing. Many should not be applied when the crops are dormant because the active ingredients have a long period of soil activity.

Soil-active herbicides with a long period of soil activity are important for the control and management of Russian knapweed. These chemicals can effectively kill buds that form in the fall on Russian knapweed's roots and root crown. They are effective after the plants become completely senescent, as long as the soil remains unfrozen and moist.

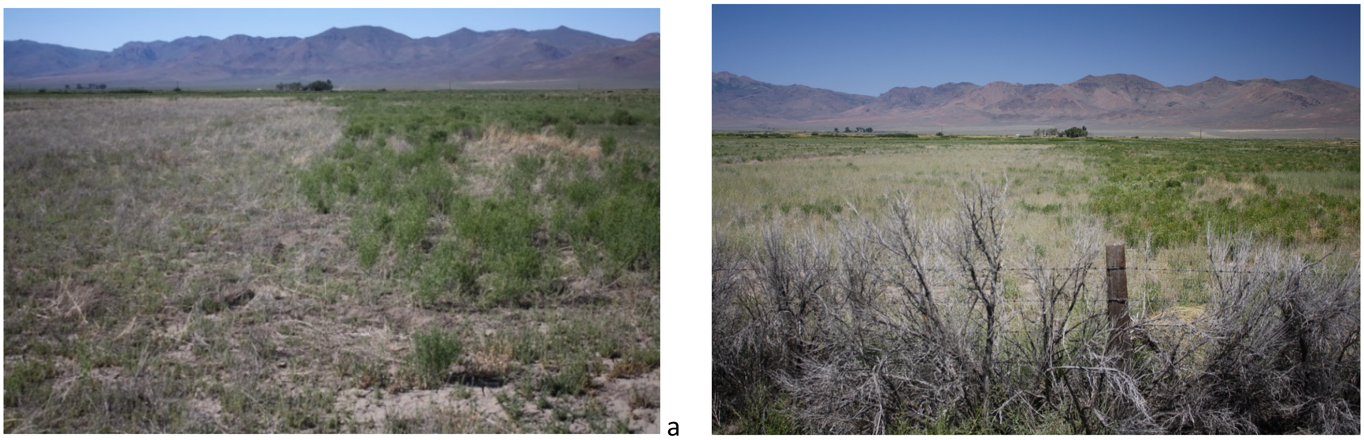
Research completed several years ago in Paradise Valley, Nevada, found that completely senescent plants treated the last week of November (**Figure 2**) resulted in 90% control with aminocyclopyrachlor (specific products were not named at the time of this work) and almost 80% control with 7 ounces of Milestone (aminopyralid), eleven months after treatment. Many soil-active herbicides are still active until spring and continue to kill viable buds and roots. Although numerous herbicides can be applied from the bud stage through fall dormancy, treatments completed after fall senescence begins, through complete dormancy, generally are more effective.

Figure 2. A dense, completely senescent stand of Russian knapweed in Paradise Valley, Nevada, that was treated with herbicides on Nov. 24, 2009. Control ranged from nearly 90% with aminocyclopyrachlor, to almost 80% with Milestone.

The movement of a foliar-applied herbicide, to and then through the large root system, largely follows the movement of carbohydrates from the leaves to the rest of the plant. For Russian knapweed, the plant typically moves more carbohydrates to the root crown and roots in the late summer to early fall, than in the spring through the flowering period. For a foliar herbicide treatment to be effective, however, the leaves must be actively photosynthesizing, which requires adequate soil moisture. The mere presence of green leaves in late summer or early fall does not guarantee the plant is photosynthesizing and moving carbohydrates to the roots. Herbicide applications to green plants under dry soil conditions typically are much less successful than when soil is moist.

It is important to have good to excellent growing conditions at the time of herbicide application and for a couple of weeks thereafter. The ideal conditions include soil that is moist (not saturated) and warm air temperatures, where moisture flows easily from the soil through the plant. Only about 10% of picloram (Tordon®) applied to leaf surface is taken up by the leaves, and most uptake occurs within 30 minutes of application. High photosynthetic rate at time of application is important for maximum uptake and treatment success. Furthermore, only about 10% of absorbed Picloram is translocated out of leaf within four days of application, with about half moving toward the roots, and half toward the shoots. As growing conditions decline shortly after herbicide application, control is likely to decline. All herbicide applications should use a surfactant to improve chemical uptake. Consult the label of the product you use to identify the specific type of surfactant best suited for that herbicide.

Figure 3a and 3b. The area in both photos shows the same treated and untreated Russian knapweed infestation on July 7, 2010. The left side of each photo was treated with Milestone (Aminopyralid) in November 2009 when plants were completely senescent. On July 7, 2010, (**3a**) there were no Russian knapweed plants visible in the treated area, and plants in the untreated area were 12 to 18 inches tall. The light-green plants in the treated area are poverty weed. On Aug. 19, 2010, (**3b**) the same area is shown and the treated area had scattered tall, dark green Russian knapweed plants that had emerged sometime after July 2, 2010.



a b

There is no single active ingredient listed in **Table 1** that is the best herbicide for all Russian knapweed infestations. Some factors to consider are: 1) do you need an herbicide that is selective and not going to adversely affect the residual desired species that occupy the site?; 2) are your short- and mid-term management objectives compatible with a chemical that leaves a residual amount of the active ingredient in the soil?; 3) what will Russian knapweed's growth stage(s) be when you have the time to fit an herbicide treatment into your overall farming or ranching operation?; and 4) can you make the commitment to any follow-up treatment that is needed? Glyphosate-based herbicides and 2,4-D typically result in less long-term control than the other active ingredients listed in **Table 1**. Treatment of Russian knapweed with these two chemicals is more likely to need one or more follow-up applications.

An important question of any herbicide treatment is, was I successful? The level of success cannot be determined until the middle of the first growing season after application of the treatment, and perhaps even later. **Figures 3a and 3b** show a field that was nearly a complete monoculture of Russian knapweed when it was treated with Milestone (aminopyralid) the previous November, after the plants were dormant. The following year, in early July there were no Russian knapweed plants in the treated area, and knapweed growth in the untreated area was 12 to 18 inches tall (**Figure 3a**). By mid-August, numerous Russian knapweed plants had emerged on the treated area (**Figure 3b**). Without a follow-up treatment, these relatively few plants will expand and the site eventually will become re-infested with Russian knapweed, or some other weed. The knapweed plants emerged in the treated area about four months after plants in the untreated area, because the treatment killed most of the buds on the shallow roots, but not all the buds on the deeper roots. It took about four months for the surviving plants to move stored energy to the surviving buds and to grow a shoot through the soil until it emerged aboveground. The effectiveness of an herbicide treatment on any weed that has a deep root system with buds that can grow into new plants should not be judged too soon after treatment. The full effect, or lack thereof, of an herbicide treatment may take a year or more to appear.

INTEGRATED WEED MANAGEMENT

Weeds are complex organisms, and they establish and grow across complex landscapes. Very seldom does a single type of treatment or management address this complexity. The result is that using only one treatment action, even multiple times within or across years, eventually fails, and weeds persist.

Any weed management program for Russian knapweed (or any weed) should develop a long-term integrated management approach. An integrated management strategy uses two or more methods of weed control across a series of years, while also deploying strategies to prevent weeds from establishing in areas not infested.

Figure 4a illustrates that an integrated weed management program uses both proactive strategies and reactive approaches. Where Russian knapweed (or any weed) is not present, management should focus on preventing its establishment. This may occur through management actions that prevent seed from being introduced on the site, controlling seed banks if viable seed has been introduced or remains after an effective treatment, or managing the crop or vegetation to competitively exclude the weed.

When weed prevention fails and one or more populations inhabit the area, the next proactive strategy is to identify all locations inhabited by the weeds, and document the scope and context of the infestation. Pairing this information with the biology of the weeds allows one to make decisions about which direct control methods to use for the specific situation being addressed. Prevention, however, should still be emphasized on areas that remain uninfested, as well as areas with successful treatments.

The best direct weed control actions are going to be infestation specific, and should identify which mechanical, cultural, biological and/or chemical approaches overlap and complement one another (**Figure 4b**). The application of multiple control methods, based on the weed's biology and ecology, that reinforce one another are likely to be more effective across a longer timeframe, than any single approach applied only once or even annually.

For Russian knapweed, elimination of root buds is needed to reduce the population to a manageable level that permits one to meet production goals and objectives for the farm or ranch. The strategy also should include management actions that limit the spread of seed or root fragments onto the site, and that reduce the potential for seed to germinate and/or seedlings to establish should viable seed disseminate onto your property.

All treatment and management approaches, except the purposeful maintenance of bare ground, must consider how to increase, and in some cases establish (seed) a high density of desired species on the infested area. A dense, vigorous stand of desired herbaceous species provides the least risk for reinfestation of a site. For rangelands, meadows and pastures, deep-rooted perennial grasses that occupy most of the soil surface and root zone are the best option for preventing large-scale seed germination and subsequent seedling survival of Russian knapweed and other weed species.

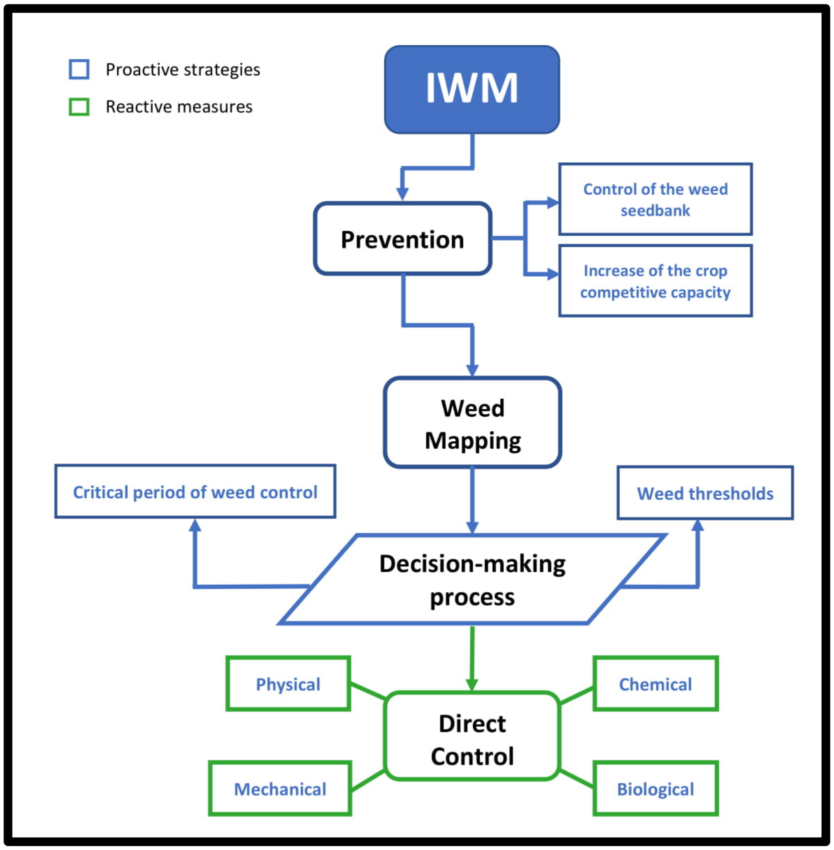


Figure 4a. Conceptual approaches to integrated weed management from prevention of new infestations or reinfestation of successfully treated areas. There are both proactive strategies to reduce the risk of infestation and reactive actions once an infestation occurs. Direct control measures should complement one another, and strengthen the effectiveness of the overall treatment program.

Diagram from Scavo and Mauromicale (2020: 3a) and Mark VanGessel (Ed: 2019 rev; 3b).

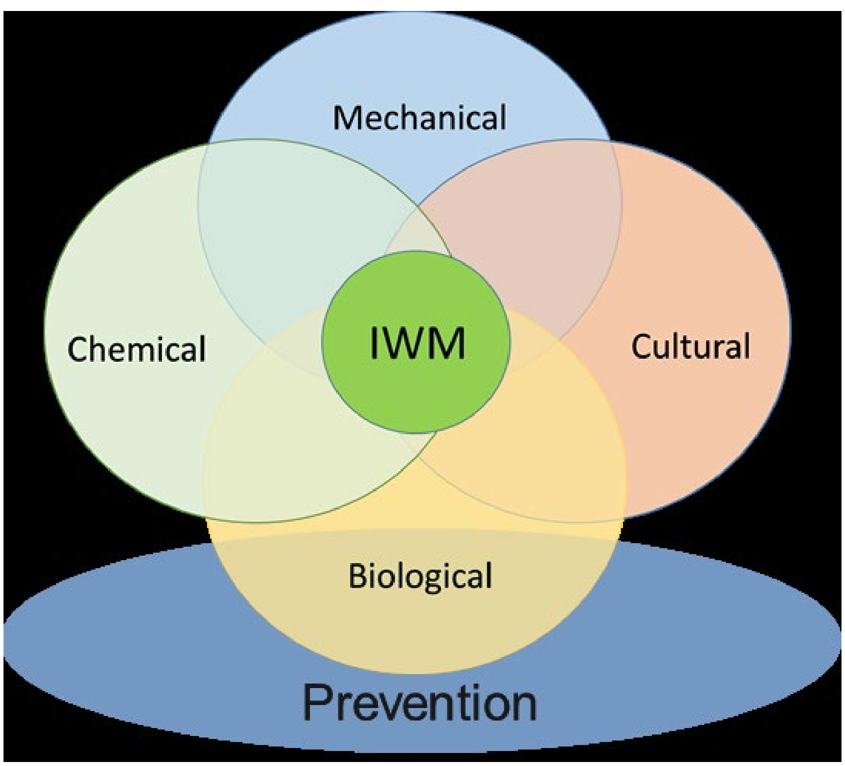


Figure 4b. Prevention is always an ongoing strategy, as there almost always are some areas that remain weed-free, and management should try to keep these areas weed-free. Prevention strategies also should occur on successfully treated areas to preclude the need for repeated direct control approaches.

Diagram from Scavo and Mauromicale (2020: 3a) and Mark VanGessel (Ed: 2019 rev; 3b).

Table 1. The table below identifies active ingredients and many representative products known to control Russian knapweed in the general sites or crops for which the active ingredient is labeled. Use the information in this table to determine potential products for use based upon your specific needs. Product selection should occur only after you have read all current product labels and identified appropriate products for their specific situation. Many of the active ingredients listed in this table are available in premixed formulations with other active ingredients. These premixed packages (products) are not listed in this table. A complete list of all active ingredients and products labeled to control Russian knapweed can be searched for at the Crop Data Management Systems (CDMS) website http://www.cdms.net/LabelsMsds/LMDefault.aspx?pd=7607&t=. The order of chemicals below does not reflect any preference or efficacy. Across the spectrum of available products, some may only suppress Russian knapweed (generally means no seed production).

Active Ingredient	Representative Products	Range and Pasture	Noncrop	Fallow	Bare Ground	Small Grains	Corn	Alfalfa	Mint	Potatoes	Selective	Soil Residual	Growth Stage
2,4-D	Many	x	x	x	x	x	x	x		x	Yes	No	Postemergence to seedlings, and bud through flowering for mature plants
Aminocyclopyrachlor	Method 50 SG or several premixed formulations with other products	x	x								Yes	Yes	Postemergence from bud to senescence. Buds on root crown of senescent plants are very susceptible to this herbicide
Aminopyralid	Milestone	x	x								Yes	Yes	Postemergence from bud to senescence. Buds on root crown of senescent plants are very susceptible to this herbicide
Chlorsulfuron	Telar XP	x	x								Yes	Moderate, but long for sensitive crops	Postemergence from bud to full flowering, or on fall rosettes
Chlopyralid	Clean Slate Stinger Transline	x	x								Yes	Moderate	Postemergence from bud to senescence. Buds on root crown of senescent plants are very susceptible to this herbicide
Dichlobenil	Barrier Casoron		x								No	Yes	Apply to soil in the fall with or without incorporation, and in spring with incorporation
Glyphosate	Accord, Roundup and many others	x	x	x		x	x	x	x	x	No	No	Postemergence to rapidly growing plants at the late-bud to flower-growth stage, particularly in late summer or fall

Active Ingredient	Representative Products	Range and Pasture	Noncrop	Fallow	Bare Ground	Small Grains	Corn	Alfalfa	Mint	Potatoes	Selective	Soil Residual	Growth Stage
Imazapic	Imazapic 2SL Plateau	x	x								Yes	Yes	Postemergence in the fall after senescence starts. Variable results if applied after completely dormant
Imazapyr	Arsenal, Habitat, Polaris	x	x		x						No	Yes	Postemergence in the fall after senescence starts
Metsulfuron-methyl	Escort, Patriot	x	x			x					Yes	Moderate, but long in soils with high pH	Postemergence from bud to full flowering, or on fall rosettes
Picloram	Tordon 22K	x	x	x							Yes	Yes	Postemergence from bud to senescence. Buds on root crown of senescent plants are very susceptible to this herbicide
Tebuthiuron	Spike	x	x								Var-iable	Yes	Soil surface application in the fall/dormant season when rainfall incorporates into the soil

All Photos by Brad Schultz unless otherwise noted.

Listing a commercial herbicide does not imply an endorsement by the authors, University of Nevada, Reno Extension or its personnel. Product names were used only for ease of reading, not endorsement. Herbicides should be selected for use based upon the active ingredient and the specific bio-environmental situation.

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