ELEMENT STEWARDSHIP ABSTRACT
for

Acroptilon repens (L.) De Candolle
(*Centaurea repens* (L.))

Russian knapweed

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SPECIES CODE
PDASTD2010

SCIENTIFIC NAME
Acroptilon repens (L.) De Candolle
Centaurea repens (L.)

Russian knapweed was originally, and sometimes still is, classified as *Centaurea repens* by North American taxonomists. However, it does not share some characteristics common to the genus *Centaurea*, and has been placed in the genus *Acroptilon*. Features that distinguish Russian knapweed from *Centaurea* species include a sub-basal attachment scar on the achene, rather than a lateral scar, and a chromosome number ($2n = 26$) that is restricted to a group of several species that are often referred to as a segregate genus (Watson 1980).

The genus name *Acroptilon*, meaning feathery tip, refers to the plume-like bristle at the tip of the flower head bracts. The specific epithet, *repens*, refers to the creeping growth of the rootstocks (Allred and Lee 1996).

COMMON NAMES

Russian knapweed is the most commonly used name in North America. Additional common names include Mountain Bluet, Turkestan thistle, and creeping knapweed (Allred and Lee 1996, Zimmerman 1996).

DESCRIPTION AND DIAGNOSTIC CHARACTERISTICS

Acroptilon repens is a perennial herbaceous plant of the aster (sunflower) family (Asteraceae). It is characterized by its extensive root system, low seed production, and persistence. Russian knapweed spreads through creeping horizontal roots and seed.

The following stem and floral description is from The biology of Canadian weeds, *Acroptilon repens* (Watson 1980) unless otherwise noted.

The stems of *Acroptilon repens* are erect, thin, stiff, corymbosely branched, 45-90 cm (18 to 36 in) tall, and when young are covered with soft, short, gray hair. Lower stem leaves are narrowly oblong to linear-lanceolate, and deeply lobed. The upper leaves are oblong, toothed, and become progressively smaller. Rosette leaves are oblanceolate, irregularly pinnately lobed or almost entire, 5-10 cm long, and 1-2.5 cm broad.

The flower heads of Russian knapweed are urn-shaped, solitary, 15-17 mm high, and composed of disk flowers only (Zimmerman 1996). Involucres are 12-14 mm high, 5-7 mm broad, ovoid, entire, and greenish at the base with a papery, finely hairy tip. Flowers are numerous, all tubular. The petals are 12.5-13 mm, pink or purple, turning straw colored at maturity. Anthers are 4.5-5.5 mm long, tails absent. The stigma is 3.5 mm long. The pollen diameter is 48-51 μm, spherical, 3-pored, thin-walled, about 2 μm thick and finely granular.

Achenes (seeds) are 2-3 mm long, oval and compressed, 2 mm broad and 1 mm thick (Watson 1980). Achenes are grayish or ivory, with long white bristles (pappus); 6-11 mm long at the tip when young, but these fall from the seed as it matures (Allred and Lee 1996). Achenes are slightly ridged longitudinally with a sub-basal scar immediately lateral to the tip of the base of the seed (Watson 1980).

Acroptilon repens has a well-developed root system, which functions as the major means of propagation and spreading. The roots of *Acroptilon repens* can extend more than 7 meters below the soil surface with 2-2.5 meters of growth occurring the first year and 5-7 meters in the second year (Zimmerman 1996). The roots are easily recognizable by their black or dark brown color and presence of small alternately arranged, scale leaves which support buds in their axils (Zimmerman 1996). These buds develop into adventitious shoots, enabling the plant to spread rapidly, and form dense colonies.

STEWARDSHIP SUMMARY

Russian knapweed can commonly be found along roadsides, riverbanks, irrigation ditches, pastures, waste places, clearcuts, and croplands. Russian knapweed does not establish readily in healthy, natural habitats. It typically invades disturbed areas, forming dense single-species stands. Once established, Russian knapweed uses a combination of adventitious shoots and allelopathic chemicals to spread outward into previously undisturbed areas.

The most effective method of control for Russian knapweed is to prevent its establishment through proper land management. The healthier the natural community, the less susceptible it will be to Russian knapweed invasion. Areas should be monitored three times a year (spring, summer, and fall) and all plants should be destroyed immediately. Since Russian knapweed is so persistent, it is important to kill all of the plants in the targeted area.

Pulling, cutting, and discing can be used to control and reduce an infestation, but used alone will not permanently eliminate a stand of Russian knapweed. Aggressive monitoring, followed by a combination of mechanical, chemical, and biological control, is needed to remove an infestation.

Picloram (Tordon™) has been determined to be the most effective herbicide on Russian knapweed regardless of the time of application (Duncan 1994).

In North America, *A. repens* is relatively free of parasites and is not extensively attacked by generalist feeders (Watson and Harris 1984). Only two biological control agents have been approved for release on Russian knapweed; *Subanguina picridis*, a gall-forming nematode, and *Aceria acroptiloni*, a gall-forming mite.

IMPACTS (THREATS POSED BY THIS SPECIES)

A. repens is a strong competitor and can form dense colonies in disturbed areas. Dense patches of Russian knapweed may have up to 100-300 shoots/m^2 (Watson 1980). The plant extends radially in all directions and can cover an area of 12 m^2 within two years (Watson 1980).

Russian knapweed invades many disturbed western grassland and shrubland communities, as well as riparian forests. Once established, Russian knapweed can dominate an area and significantly reduce desirable vegetation (e.g. perennial grasses).

A. repens contains an allelopathic polyacetylene compound which inhibits the growth of competing plants (Watson 1980). Tests conducted with alfalfa (*Medicago sativa*), barnyard grass (*Echinochloa crusgalli*), and red millet (*Panicum miliaceum*) indicated Russian knapweed effectively inhibits root length elongation of grasses as well as broad-leaved plants by 30% when the polyacetylene compound is at a soil concentration of 4 parts per million (Stevens 1986). This allelopathic effect, combined with dense vegetative reproduction, allows for Russian knapweed to quickly colonize and dominate new sites.

A. repens was designated a noxious weed in the Federal Seeds Act of Canada in 1967. In the United States, *A. repens* is considered a restricted noxious weed in Arizona, a designated undesirable species in Colorado, a candidate species for the noxious weed list of New Mexico, and a designated weed species in Utah (Zimmerman 1996).

On rangeland, the reduction in forage following invasion of Russian knapweed can threaten the stability of ranching operations. Russian knapweed is generally avoided by grazing animals due to its bitter taste. *A. repens* is poisonous to horses and can cause a neurological disorder called "chewing disease" (Allred and Lee 1996). The symptoms resemble those of Parkinson's disease in humans and are characterized by an acute inability of the animal to eat or drink (Robles *et al*. 1997). This disease is limited to horses and does not occur in cattle, sheep, or goats.

On agricultural land, *A. repens* has caused serious reductions in yields, crop value, and may even significantly devalue the land itself. Shoot densities of 11-64 shoots/m^2 have reduced grain yields by 28-75% (Watson 1980). Shoot densities of 19, 32, and 65 shoots/m^2 have reduced the fresh weight yield of corn by 64, 73, and 88% respectively (Watson 1980).

Infestations of Russian knapweed can survive indefinitely through their root system (Watson 1980). A stand in Saskatchewan has survived for almost 100 years (Allred and Lee 1996), and Watson (1980) reported that stands of Russian knapweed have been reported to survive for more than 75 years.

GLOBAL RANGE

Acroptilon repens is native to Mongolia, western Turkestan, Iran, Turkish Armenia, and Asia Minor. It is now found on every continent, except Antarctica. Russian knapweed is listed as a serious noxious weed of dryland crops in the southern former Soviet Republics (Watson 1980).

Russian knapweed was first introduced into Canada around 1900 as a contaminant of Turkestan alfalfa seed (Watson and Harris 1984). It did not become a serious weed in Canada until 1928, and its spread is linked to the distribution of knapweed-infested hay (Maddox *et al.* 1985). It is now widespread in the southern portions of the four western provinces and southern Ontario.

The introduction of Russian knapweed into the United States is also thought to be the result of impure Turkestan alfalfa seed, and possibly sugarbeet seed (Maddox *et al.* 1985). It was first introduced in California between 1910-1914. Since then, it has become widespread in the United States and is currently found in at least 412 counties in 21 states (Maddox *et al.* 1985). It is most common in the semi-arid portions of the western U.S. and adjacent Canada, but infestations have also been reported in South Dakota, Minnesota, and Virginia (Maddox *et al.* 1985). The worst-infested states are California, Idaho, Montana, Oregon, and Washington.

In California, 32 counties reported infestations of Russian knapweed, but only two (Tulare and Sutter) reported heavy infestations (over 405 ha) (Maddox *et al.* 1985). Idaho reported infestations in 13 counties, most of which are in the southern part of the sate (Maddox *et al.* 1985). Oregon reported that seven of their counties were infested, with the heaviest infestations in the eastern half of the state (Maddox *et al.* 1985). Montana reported infestations in 39 counties throughout the state totaling 23,232 ha (Maddox *et al.* 1985). Washington reported that 20 counties were infested, twelve infested heavily, and almost all of these were in the eastern half of the state (Maddox *et al.* 1985). Colorado reported that 22 counties were infested totaling 20,234 ha (Maddox *et al.* 1985). In Colorado, the most severe infestations occur in the mountain and western slope counties, with lighter infestations on the eastern plains.

HABITAT

Russian knapweed has become widespread in the United States, particularly in the semi-arid west. It is more competitive than other weedy species in occupying disturbed areas (Maddox *et al.* 1985). It is commonly found along roadsides, riverbanks, irrigation ditches, pastures, waste places, clearcuts, and croplands. Russian knapweed is indifferent to crop association and is able to survive in almost any crop. It is sensitive to decreased amounts of sunlight (Dall'Armellina and Zimdahl 1988). This study indicated that Russian knapweed would not compete well under a heavy canopy, and is more suited to open areas.

Russian knapweed invades disturbed grassland and shrubland communities, as well as riparian forests. Examples of some perennial grass species that are commonly driven out by Russian knapweed include rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), western needlegrass (*Stipa occidentalis*), and Richardson's needlegrass (*Stipa richardsonii*) (Rice *et al.* 1992). An example of a riparian community in which Russian knapweed can commonly be found is the Freemont cottonwood (*Populus freemontii*)/skunkbrush (*Rhus trilobata*) community.

A. repens is not restricted to any particular soil but does especially well in clay soil. Watson observed that Russian knapweed infestations increased in dry locations but decreased in moist locations due to competition with perennial grasses (Maddox *et al.* 1985).

BIOLOGY-ECOLOGY

Shoots emerge early in spring shortly after soil temperatures remain above freezing. All shoot development originates from root-borne stem buds (Watson 1980). These buds arise adventitiously at irregular intervals along the horizontal roots. Plants form rosettes and bolt in late May to mid-June. Russian knapweed flowers from June to October in the United States and from July to September in Canada (Zimmerman 1996).

A. repens does not appear to reproduce extensively from seed but just one plant may produce 1,200 seeds per year. Seeds of Russian knapweed germinate over a wide range of temperatures, with an optimum germination occurring from 20-30°C (Watson 1980, Zimmerman 1996). The viability of *A. repens* seed is subject to some disagreement. Watson (1980) and Maddox *et al.* (1995) report that Russian knapweed seed remains viable for 2-3 years. However in an experiment, Selleck (1964) had successful germination from seeds that were up to 8 years old (Zimmerman 1996). Seed dispersal is passive and the major means of seed dispersal is probably via contaminated hay and other seed (Watson 1980).

Russian knapweed reproduces primarily vegetatively. The root system consists of the original root (taproot), one to many horizontal roots, and their vertical extensions. Buds on the horizontal roots can form adventitious shoots that may grow to be independent plants. Watson (1980) reported that the plant extends radially in all directions and can cover an area of 12 m^2 within 2 years. Zimmerman (1996) stated similar growth statistics in that the roots of *Acroptilon repens* can extend horizontally more than 7 meters with 2-2.5 meters of growth occurring the first year and 5-7 meters in the second year. Stands of Russian knapweed can grow to densities of 100-300 shoots/m^2, which can completely crowd out competing plant species.

A. repens has been found to have allelopathic effects that inhibit the growth of crops and other plants (Watson 1980). *A. repens* contains several polyacetylene compounds in its roots. Studies have shown at least one of these compounds to be an allelopathic inhibitor (Stevens 1986). The examination of soil surrounding Russian knapweed roots revealed the presence of an inhibitor in sufficient concentration to have an appreciable effect on the surrounding plant community. When polyacetylenes were present in the soil at levels of just

4 parts per million, root-lengths of alfalfa. Barnyard grass, and red millet were reduced by 30% (Stevens 1986).

A controlled greenhouse experiment (Dall'Armellina and Zimdahl 1988) indicated light availability affected growth and development of Russian knapweed. Flower production declined with decreasing light levels. The leaf area of Russian knapweed actually increased as light intensity decreased from 520 to 325 $\mu mol \cdot m^{-2} \cdot s^{-1}$, but the total dry matter of Russian knapweed shoots and roots decreased as light decreased. This study suggests that knapweed plants that emerge with other plants are more competitive than plants that emerge under the canopy of growing plants.

RECOVERY POTENTIAL

The recovery potential of areas cleared of Russian knapweed has not been determined. The resurgence of native and non-native annual grasses, forbs, and residual native perennial forbs may be hindered by residual allelopathic compound present in the soil. This compound can remain in the soil at some level for several years. Tilling can overcome the residual allelopathic effects of Russian knapweed, but is not possible or appropriate for most natural areas (Beck 1996). Since natural recovery might be slow to develop, areas should be replanted with native species to suppress knapweed re-infestation. The non-native smooth brome (*Bromus inermis*) competes well with young knapweed shoots and is somewhat tolerant to the growth inhibitors in the soil (Beck 1996). Unfortunately, smooth brome is itself invasive in many grassland and meadow habitats across North America.

MONITORING REQUIREMENTS AND PROCEDURES

Monitoring should be conducted during the spring, summer, and fall of each year. The spring search should be conducted in late May to mid-June when the plants have recently bolted. The summer search should be conducted in July, when any missed plants have flowered and are easily recognizable. The fall search should be conducted in late August or early September. The fall search should focus on any late blooming plants that might have regrown from the root system of plants that had been pulled during an earlier search. Any knapweed plants that are found should be destroyed immediately.

Monitoring should focus primarily on the most disturbed areas of a site, particularly along roadsides, parking lots, fence lines, and river/stream beds. If an infestation is found, closely search the surrounding area to determine the size and extent of the infestation. Patches of Russian knapweed should be marked, and special attention should be given to these locations during follow-up visits.

MANAGEMENT PROGRAMS

There is no single "silver bullet" control method for Russian knapweed. Lasting control requires an integration of mechanical control, chemical control, biological control, proper land management, and vegetative suppression. An effective management program must first control existing infestations, and then promote repopulation by native plants. Continued monitoring and follow-up treatments should be conducted annually to eliminate any re-infestation of knapweed.

The keys to controlling Russian knapweed are to 1) stress the weed and cause it to expend nutrient reserves in its root system, 2) eliminate new seed production, and 3) control its vegetative spread. If sufficient human resources are available, mechanical control is good place to start. Pulling Russian knapweed plants two to three times annually contained, but did not eliminate, an infestation in Washington (Youtie 1998). Cutting, mowing or discing several times annually will also control the existing topgrowth. Often, the plants that do re-emerge are smaller in size and lower in vigor. This is a good indication that the plants are under stress and that their nutrient reserves are declining.

If an infestation is too large to be treated mechanically, herbicides can be applied for effective control. Tordon™ (picloram), Transline™ (clopyralid), Curtail ™ (clopyralid + 2,4-D), and Roundup® (glyphosate) are herbicides that have been shown to be effective (Beck 1996, Duncan 1994). Timing the application of herbicides can be critical and is dependent upon the particular herbicide and surrounding environmental conditions.

Biological control agents can place additional stress on Russian knapweed plants. Two biological agents for Russian knapweed have been released in the United States; *Subanguina picridis*, a gall forming nematode, and *Aceria acroptiloni*, a seed gall mite.

Once the initial infestation has been controlled, native species should be replanted to act as a vegetative suppressant. Suppresser species must remove a significant amount of moisture from the soil during the seedling stage, when knapweeds are most vulnerable. Early emergence, rapid dense growth, and maintenance of high vigor until frost are attributes required by plant species to suppress Russian knapweed.

BIOLOGICAL CONTROL

Currently, the USDA approves only *Subanguina picridis* and *Aceria acroptiloni* as biological controls of Russian knapweed. You must obtain a permit from the USDA Animal and Plant Health Inspection Service (APHIS) before you can transport these agents between states. If these agents are already present in your state, but not on your site, you can collect and transport them within the state without a permit from the USDA. Information on how to obtain a permit can be found at the end of this section under (*Obtaining permits for field releases*). Other authorities that can be contacted for more information about these agents are also listed at the end of the section. Nature Conservancy (TNC) policy forbids the release of biological control agents on lands owned by TNC without written permission of the national Director of Conservation Science. Contact TNC’s weed specialist for information on how to request permission for a release.

Subanguina picridis (Russian knapweed gall nematode)

Subanguina picridis is a gall forming nematode native to Asia, and is now established in Colorado, Montana, Oregon, Utah, Washington, and Wyoming. The microscopic nematode is worm-like and about 1.5 mm (.06 in) long. It induces the production of galls on the stems, leaves, and root collars of infected plants causing a reduction in plant growth and seed production. Galls on the stems of the plant often visibly distort plant growth.

Larvae of *Subanguina picridis* feed, mature, and reproduce within the galls. Two or more generations are completed during the growing season, and second-stage larvae become dormant and overwinter in the soil.

In early spring, the infective-stage larvae are activated by moisture, and leave the deteriorating galls. They penetrate immature leaves and stems of new shoots, and galls eventually form at the infected sites. Nematodes multiply within these galls until August when the mature galls contain primarily second-stage larvae. These second-stage larvae disperse and overwinter in the soil as the galls disintegrate. The following spring these larvae usually become infective after at least a month in moist soil (Rees *et al*. 1996).

Under most conditions, *Subanguina picridis* needs to overwinter in the soil before it is able to attack its host. Therefore the fall seems to be the best time for application. *Subanguina picridis* likes moist areas during the winter and spring infection periods and does not flourish in dry areas.

The range of *Subanguina picridis* is limited because the nematodes can not travel far from their host plants. Human intervention is needed to introduce the nematode to a new site. Galls can be collected in the fall and placed upon the soil to permit the nematode larvae to emerge from the wet, disintegrating galls and penetrate the young knapweed shoots when they break through the soil in the spring (Rees *et al*. 1996).

Aceria acroptiloni (Russian knapweed mite)

Aceria acroptiloni is a gall-forming mite native to Eurasia and the former Soviet Union. The mites form galls in the flower heads of Russian knapweed and feed on the inner bracts, the receptacles of the flowers, and the deformed structures of the flowers. Females lay eggs in the receptacle of the flower and inner bracts.

Two or more generations are formed during a single season. The first generation (spring) females are morphologically different from the summer and winter females that appear later. Male *acroptiloni* mites do not differ morphologically between generations (Kovalev *et al.* 1975). The mites overwinter in the upper ends of the inner leaflets and the deformed flower structures.

Plants that have been infested with *Aceria acroptiloni* are underdeveloped and noticeably stunted. The formation of new shoots ceases and seed production is hindered.

Contacts for information on the biocontrol agents described above:

- Eric M. Coombs: Oregon Department of Agriculture, 635 Capitol St. NE, Salem, OR 97310-0110; telephone: (503) 986-4624; e-mail: ecoombs@oda.state.or.us

- Gary L. Piper: Department of Entomology, Washington State University, Pullman, WA 99164-6382; telephone: (509) 335-5504; e-mail: glpiper@wsu.edu

Obtaining permits for field releases

To introduce one of the biological agents described above to your state, you must first obtain a permit from the USDA-APHIS-PPQ. To obtain a permit you must complete a form PPQ-526, "Application and Permit to Move Live Plant Pests or Noxious Weeds", and send it to the Department of Agriculture in the state where you hope to make the release. The form must be signed and sent for processing to the USDA-APHIS-PPQ office, Biological Assessment and Taxonomic Support (BATS), 4700 River Road, Unit 113, Riverdale, MD 20737. When this is signed by PPQ, a copy will be returned to the applicant as an approval record.

To find the phone number and address of the APHIS-PPQ State Plant Health Office in your state check on-line at: (http://www.aphis.usda.gov/oa/ppqoffice.html). For more information about the permit process, to download forms, check the status of your permit, or to search the Code of Federal Regulations, you can browse the APHIS-PPQ home page at: (http://www.aphis.usda.gov/ppq/bats/permits/). Finally, an expedite list of all insects, mites, and nematodes that require APHIS permits can be found on-line at: (http://www.aphis.usda.gov/ppq/bats/weedagen.htm).

The Nature Conservancy's policy on intentional releases of biocontrol agents on TNC preserves may be found in TNC's Policies and Procedures Manual. The policy's purpose is to minimize risks of damage to valued non-target plants and animals by a biocontrol agent on the preserves. For more information on the policy and how to apply for permission to make a release on a TNC preserve contact John Randall at TNC's Wildland Weeds Management & Research, 124 Robbins Hall, University of California, Davis, CA 95616.

BURNING

There are no studies available that tested controlled burning on infestations of Russian knapweed. However, based on the results of similar control methods a hypothesis can be developed: like mowing, burning will not effect the root system of the plants and will allow the plant to regenerate. Also, Russian knapweed is a strong competitor in disturbed soils and burning may only lead to a larger infestation. Therefore, one would expect that burning would not control Russian knapweed and may even promote its spread locally.

CHEMICAL

Several herbicides are effective against *A. repens*. Picloram (Tordon™) is widely used on Russian knapweed and is effective. Clopyralid (Transline™) is also effective against Russian knapweed and will kill other composites, legumes and smartweeds but has little or no impact on many other forbs. Timing of applications to the late bud and fall growth stage is critical with most herbicides to achieve good control of knapweed. A backpack sprayer or a wick is highly recommended to minimize damage to non-target plants.

Picloram (Trade names: Tordon™, Grazon™)

The results of an application-timing study indicated 2 of picloram per acre provided the most consistent chemical control regardless of time of application (Duncan 1994). When applied during bolting, budding, and in the fall, picloram provided 98, 98, and 100% control respectively (Duncan 1994). Additionally, this control lasted two years with between 93-94% control the second year (Duncan 1994).

Picloram is a synthetic-auxin type herbicide that disrupts plant growth. Auxin is a naturally occurring plant hormone but many broadleaved plants exhibit an 'auxin-overdose' response when treated with synthetic-auxin herbicides and in essence die as a result of their own disorganized and out-of-control growth (Ross and Childs 1998). Picloram and the other synthetic-auxin type herbicides do not harm most grasses or monocots. Herbicides of this type are used for control of annual, perennial, and creeping broad-leaved plants. (Ross and Childs 1998).

Picloram does not bind to soil and may leach into groundwater. The half-life of picloram in soil ranges from 55-100 days, while the half-life in water is 2.3-41.3 days (1)[1]. Picloram is not expected to bioconcentrate in aquatic organisms.

In humans, the EPA has found that acute exposures to picloram could cause weakness, diarrhea, weight loss, and central nervous system damage. Long-term exposure above safe drinking water levels has the potential to cause liver damage (1).

Although picloram is effective at managing Russian knapweed, it is a relatively non-selective compound and has been observed to have a residual effect on other perennial broad-leaved plants. This herbicide should be applied carefully to minimize the damage to non-target plants. Also, picloram will inhibit the germination of perennial grasses, and reseeding should be postponed until the year after treatment.

Picloram is produced and marketed by DowAgrosciences (formerly DowElanco) under the names Tordon™ K, Tordon™ 22K, and Grazon™ PC. DowAgrosciences also sells mixtures of picloram and 2,4-D, another synthetic-auxin type herbicide, under the names Tordon™ 101 mixture, Tordon™ RTU and Pathway™.

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[1] Internet references from unknown authors have been numbered and can be found under the heading INTERNET REFERENCES (UNKNOWN AUTHORS) at the end of this document.

Clopyralid (Trade names: Transline™; Stinger™, Curtail™ [clopyralid + 2,4-D])

Clopyralid applied at 1.3 pints per acre during bud-growth stage and fall controlled Russian knapweed by 96 and 100% respectively (Duncan 1994). Second year control was not quite as high with only 88% control in both application periods (Duncan 1994).

Clopyralid is a synthetic-auxin type herbicide like picloram. Clopyralid, however, is more selective than picloram and kills only certain groups of broad-leaved plants. It is effective against many composites (Asteraceae), legumes (Fabaceae) and smartweeds (Polygonaceae) but has little or no impact on grasses nor on many types of broad-leaved plants including crucifers (Brassicaceae). Stems of plants treated with clopyralid thicken, curl, or twist and their leaves wither and stop functioning (5). Water intake, plant metabolism, and nutrient translocation are all disrupted.

Clopyralid may leach into groundwater and should be used carefully near streams and rivers. If not applied carefully, it can damage or kill other broad-leaved, non-target plants, particularly other composites, legumes or smartweeds.

Clopyralid is the active ingredient in the herbicides Transline™ and Stinger™, which are produced by DowAgrosciences. Curtail™ is the trade name for an herbicide produced by DowAgrosciences, which contains a mixture of clopyralid and 2,4-D. Both clopyralid and 2,4-D are auxin-type herbicides and both have little or no impact on grasses but 2,4-D is effective against a wider range of broad-leaved plants.

Curtail™ applied at 3 quarts per acre during bud-growth stage and fall controlled Russian knapweed by 89 and 96% respectively (Duncan 1994). However, the following year Curtail™ only provided 68 and 80% control (Duncan 1994).

Curtail™ may leach into groundwater and should be used carefully near rivers and streams. It will damage most perennial broad-leaved plants and so should be applied carefully to minimize the damage to non-target plants.

Glyphosate (Trade names: Roundup®, Roundup® Ultra, Rodeo®, Accord)

Glyphosate applied at 1 quart per acre during the bud-growth stage can be used to control the topgrowth of Russian knapweed (Beck 1996, Watson 1980). However, abundant regrowth from the root systems will occur the following year and additional applications may be necessary.

Glyphosate is an amino acid inhibitor. It is a relatively non-selective compound and is used to control broad-leaved weeds and grasses. In fact, glyphosate will kill or damage most plants that it contacts. Damage to non-target plants can be minimized by applying the herbicide with a wick or carefully spraying it with a handheld applicator directly to the leaves of the targeted knapweeds.

Glyphosate is rapidly inactivated upon contact with soil and so will not suppress germination or seedling emergence if applied to the soil (Ross and Childs 1998). It biodegrades in soil and has a half-life of about 60 days. The half-life in water is a few days, and glyphosate is not expected to bioconcentrate in aquatic organisms (2).

In humans, acute exposure to glyphosate can cause lung congestion and an increased breathing rate. Long-term exposure to glyphosate above safe levels has the potential to damage the kidneys and/or reproductive systems of mammals, including humans (2).

Glyphosate is produced and marketed by Monsanto as Roundup®, Roundup® Ultra, Rodeo® and Accord. Rodeo® is the only one of these compounds that is registered for use over water or wetlands. The other compounds contain surfactants or other adjuvants that can be toxic to fish and other aquatic animals.

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More information on chemical control of Russian knapweed can be obtained from the Weed Management Library at 1-800-554-WEED, or from your State Weed Specialist.

Arizona: Everett Hall: Arizona Department of Agriculture, Plant Services, 1688 West Adams St., Phoenix, AZ 85007; telephone: (602) 542-3309; e-mail: adaphyx18@getnet.com

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CUTTING

Cutting or removal of the above ground portion of the plant reduces the current year growth, and may eliminate seed production, but it will not kill Russian knapweed. Cutting three times a year (spring, summer, and fall) stresses Russian knapweed plants and forces them to use nutrient reserves stored in the root system. The plants that re-emerge are usually smaller in size and lower in vigor. Cutting is slightly less effective than pulling since when you cut, you do not remove any of the root. If you plan to use cutting alone as a control method, you must repeat this process annually, as knapweed populations will rebound vigorously if just one year is missed.

GRAZING, DREDGING, AND DRAINING

Grazing is not a method of control for *A. repens*. Russian knapweed is generally avoided by grazing animals and can be poisonous to horses. When *A. repens* is present on horse pasture it should be removed or fenced-off to prevent horses from eating it.

We found no studies that indicate dredging or draining have been tested, or are effective methods of Russian knapweed control.

MANIPULATION OF WATER LEVEL AND SALINITY

Not tested.

MOWING, DISCING, AND PULLING

Mowing effects Russian knapweed like cutting. It removes topgrowth and prevents or postpones seed production but unless repeated frequently the mown plants recover vigorously the following year (Beck 1996). Mowing could damage surrounding plants and should be used carefully in natural areas.

Discing and or plowing can be an effective method of control on agricultural land. This process should be repeated for at least three years at a minimum depth of 30 cm (Watson 1980).

Pulling was used to control, but not eliminate, an infestation of knapweed on the Lindsay Prairie Preserve in Washington (Youtie 1998). After several years of pulling the plants that did emerge were smaller in size and lower in vigor. Try to extract as much of the root as possible in order to create the greatest amount of stress on the plant. Any pulling program should be conducted three times a year (spring, summer, and fall), every year, in order to control an infestation.

******NOTE OF CAUTION:****** An e-mail message broadcast widely among natural area and forest mangers in September 1997 reported that several knapweed species, including Russian knapweed, may contain a carcinogenic compound (Niefoff 1997). No other references to this compound were found in literature despite extensive searching. As a precaution, anyone working with Russian knapweed should wear protective gloves and avoid getting knapweed sap into open cuts or abrasions. Workers should wash their hands and exposed skin with soap water following contact with this plant.

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