TECHNICAL NOTES

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WEEDS – DESCRIPTIONS of SELECTED SPECIES, CONTROL, HERBICIDE TECHNOLOGY, and WASHINGTON STATE NOXIOUS WEED LISTS

This Technical Note is a compilation of several old Technical Notes and various references.

Technical Note #17 is subdivided into the following Sections:

SECTION 17.1 Pacific Northwest 2005 Weed Management Handbook

http://weeds.ippc.orst.edu/pnw/weeds

This information is revised annually by the Extension Services of Oregon State University, Washington State University, and the University of Idaho

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SECTION 17.2 Biology, History, and Suppression of Reed Canarygrass (Phalaris arundinacea L.)

Stannard and Crowder, 2001

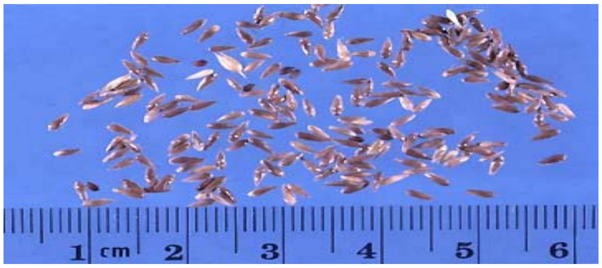
- **It is native to North America, Europe, Asia and Africa.**
- **Reed canarygrass is perennial, rhizomatous, and effectively excludes other vegetation.**
- **It is tremendously productive on moist soils and will sequester large amounts of soil nutrients.**
- **It has been in use as a pasture grass since the early 1800's in North America, and has been in use in the Pacific Northwest since the 1880's.**
- **It is a popular plant for pollution control of municipal & industrial waste water.**
- **Reed canarygrass does not tolerate ponded water, repeated tillage, repeated defoliation, or dense shade.**
- **Several herbicides will kill reed canarygrass but only one is labeled for use in wetlands.**
- **Much of its competitiveness resides in its ability to shade out competitors and in its stand persistence.**
- **Effective control integrates suppressing growth and filling the void to prevent reinfestation.**

Biology

Reed canarygrass is a cool-season grass that primarily occurs across the northern tier states. It is native to North America, northern Europe, Mongolia, Japan, China, the former Soviet Union, northern Afghanistan, and even South Africa (Tsvelev 1983). David Douglas (1830's), David Lyall (1860), and the Fremont expedition (1844) either collected or documented the occurrence of reed canarygrass in the Pacific Northwest before 1860.
In the Pacific Northwest, it can be found from coastal estuaries to high mountain meadows along the west flank of the Rocky Mountains. It occurs primarily in lowland sites where water is not limiting. It will grow in uplands if competing vegetation is removed.

Hardinggrass (*Phalaris aquatica* L.) is a similar appearing species that occurs west of the Cascade Range. The seedhead is more compact and the rhizome spread is less pronounced (Wheeler 1950). Hardinggrass does not occur east of the Cascade Range because it lacks winter-hardiness. It is commonly grown in the southern USA as a winter forage.

Reed canarygrass seed is quite small, very dense, and resembles timothy seed because both are small, heavy, and naked. Fully sodded stands produce only 30-50 pounds seed/acre (Schoth 1938). Old stands tend to have a higher proportion of vegetative culms than reproductive culms. Seed heads are borne on long culms and seeds mature from the top of the head down. Fully ripe seeds are highly viable and shatter readily. Indeterminate maturation allows for a prolonged period of seed dispersal, which reduces seed predation. It also increases the chances of some seed being dispersed by an episodic event such as an animal brushing against a plant and some seed catching in its coat.



Rhizomes account for much of the localized spread of reed canarygrass. Rhizomes grow outwardly from a mother plant until the terminal bud develops a shoot (Evans and Ely 1941). This is unlike quackgrass, which develops shoots all along the rhizome axis. This allows reed canarygrass to rapidly expand its local territory and a single rhizome or stem can infest an entire drainage.

Reed canarygrass culms are also capable of rooting and establishing stands (Hovin et al. 1973). Hovin and his coworkers reported that the nodes of reed canarygrass culms become meristematically active once the panicles are removed, and stage of development of the panicle affected the percent survival of the new plants. Pre-anthesis culms rooted poorly while culms from post-anthesis plants rooted better. Bank erosion and transport of culms allows for yet another means of establishing plants along a watercourse.

Seed, on the other hand serves several functions; it provides for long distance dispersal, exchanges genetic information, creates multiple genotypes, and persists for long periods. Multiple genotypes increase the chances that a particular genotype will flourish and spread in harsh environments (Morrison and Molofsky 1998). Seeds can remain viable in the soil for at least several months, and seed will retain very high viability for ten or more years in climate controlled storage (D. Stout, pers. comm.).

Seeds require several days at cool temperatures for a high percentage of the seeds to germinate. The rate and amount of germination is typical for most cool season pasture grasses, but pales in comparison to many annual weeds. For comparison, yellow starthistle and cheatgrass can achieve 75% germination within 2 days. Seedling development of reed canarygrass is similar to other cool season pasture grasses. The seedlings lack vigor and are very sensitive to competition. Morrison and Molofsky (1998, 1999) reported that reed canarygrass seedlings were more sensitive to interspecific competition then they were to decreased water availability.

Growth of reed canarygrass begins early in the spring, senescence occurs with summer drought, and limited vegetative growth resumes in the fall if moisture is available. Sprouts will frequently be seen growing in ephemeral ponded water in the spring. Carbohydrate reserves stored in the rhizomes fuel the growth of these sprouts (Hovin et al. 1973). The roots are not contributing to the growth in this situation because the ponding causes an anaerobic condition. If the water remains on the stand for a prolonged period the roots will eventually die because the reducing environment will not only deprive roots of oxygen but will also remove oxygen from the roots.

The culms are very tall and individual leaves grow from nodes along the culm. The leaves of the lower culm become light deprived as the plant grows and are replaced with new leaves higher up the culm. If the stand is cut, new leaves will sprout from either rhizomes or from exposed nodes on the shortened culm.

Biomass production is exceedingly high (as high as 9 tons/acre) but it requires a tremendous amount of nutrients to sustain this growth. Riparian soils tend to be very rich in nutrients, allowing reed canarygrass to thrive. Limiting its growth by removing nutrients has not been practical on a field scale. Indeed, there are stands that are hayed every year and a large amount of nutrients subsequently removed, and yet these stands continue to proliferate for decades.

Reed canarygrass is very competitive once established and will frequently develop a solid monoculture. Tall growth enables reed canarygrass to compete with other herbaceous species by depriving them of light. Native herbaceous species that initiate growth late in the spring are especially impacted by reed canarygrass.

Reed canarygrass is a classic weed in many environments but in environments subject to frequent & severe disturbances it has some value. It persists very well in spite of grazing. The grazing period lasts nine months west of the Cascades (Wheeler 1950). Few if any grasses can tolerate grazing pressure this long. It also withstands grazing periods as frequent as 2 weeks between rests with little detrimental effects. It withstands annual burning and spring flooding very well. It also tolerates heavy applications of wastes. It is ecologically “stable state”. The up-side -- it is not very prone to give way to noxious weeds. The down-side -- natural transition to a higher seral “more native” state is unlikely.

History

The first reference of reed canarygrass occurred in a thesis written in 1749. Hesselgren, a student of Linnaeus, undertook a livestock feeding study of over 600 Swedish plants and reported that reed canarygrass was one of the most preferred species. Reed canarygrass cultivation was documented in England in 1824 and in Germany in 1850 (Schoth 1938).

Much of the initial use of reed canarygrass in North America was centered along the Atlantic seaboard states and much of the germplasm was initially local native seed. The New England Farmer in 1834 reported trials of ribbongrass, a variegated-leaf biotype of reed canarygrass by Connecticut and New Hampshire farmers. Approximately 20 years later, native reed canarygrass stands were commonly managed for livestock forage.

The demand for seed in North America eventually exceeded what could be practically hand stripped from native stands. The European seed companies exported seed to North America until about 1924. The first documented seed production of Reed canarygrass in the West occurred in 1885 in the Coquille Valley of Oregon (Schoth 1938). The literature suggests that the seed used for making this planting was probably local stock. Schoth (1938) stated that most of the reed canarygrass grown in the Pacific Northwest could be traced to the Coquille Valley seed.

The first registered variety of reed canarygrass was ‘Ioreed’. It was released in 1946 by the Iowa Agricultural Experiment Station with the Soil Conservation Service participating in the release. ‘Ioreed’ was a 10-clone synthetic comprised of 86% North American germplasm and 14% German germplasm. Certified seed of ‘Ioreed’ is no longer available.

Six additional reed canarygrass varieties are listed in USDA Handbook 170 “Grass Varieties in the United States” (1994). Three are Canadian varieties, two are varieties developed by Land O’Lakes Inc., and the remaining variety, ‘Vantage,’ is a 1972 release from the Iowa Agriculture and Home Economics Experiment Station.

Use of reed canarygrass in the Pacific Northwest basically began at the turn of the century. Farming commonly followed logging operations and reed canarygrass was frequently used as the “breaking in” crop (Wheeler 1950). Stumps & logging debris and clearing operations left the land unsuitable for planting crops such as small grains. Reed canarygrass was planted in these areas to allow time for the stumps and debris to degrade and be more easily removed at a later date.

Reed canarygrass popularity in the Pacific Northwest was a composite of many factors. It is an extremely productive grass. Reports of production far exceeding other grasses are common in the early literature. It is very easy to establish and it persists very well. Most plantings occurred during a period of history when farms were more self-reliant. Livestock were pastured on the farm, and hay was grown on the farm rather than purchased from hay brokers. It was a reliable, productive forage.

A second wave of interest in reed canarygrass occurred when wastewater management became an important issue. Reed canarygrass has the ability to respond exceedingly well to applied nutrients and one study showed a yield response to levels as high as 920 pounds N/acre (Schmitt et al. 1999). Zeiders (1976) reported, “*reed canarygrass is the most popular species for irrigation with wastewater from municipal and industrial sources as a pollution control measure*”.

The most recent wave of interest in reed canarygrass is occurring in Europe. Reed canarygrass is being cultivated in northern Europe as a biofuel and about 10,000 acres are in production in Scandinavia (Kätterer et al (1998).

It is a plant with many uses. Unfortunately, reed canarygrass has proven to be too aggressive in the Pacific Northwest. It moves out of pastureland and into stream bottoms, wetlands, and canal banks. It persists in areas where it is not desirable and is the bane of wetland restorationists.

Suppression & Revegetation

Several methods are effective in suppressing reed canarygrass. The method used in any particular site will be dependent on available funds, personnel, equipment and landowner choices/objectives. Complete eradication is frequently impractical. The site should be revegetated in some manner to adequately treat erosion problems inherent in these sites and slow reinvasion. Revegetation should be done with the objective of providing plants that are well adapted and suppress the spread and growth of reed canarygrass to an acceptable level. This process may take several years, depending on methods selected, and requires follow-up treatments in most cases.

Tillage Reed canarygrass can be eliminated with tillage, as can most perennial rhizomatous grasses. Most rhizomes are in the upper 6 - 8 inches of the soil. Tillage kills top growth so eventually below ground energy reserves are exhausted. Several tillage operations at about 2-week intervals are required.

Advantages: Tillage is relatively cost effective. The results are evident within a few days. Tillage also serves to create a more desirable seedbed for reseeding.

Disadvantages: Physical access to the site may be reduced by flooding, and wet soils, and tillage may not be a viable option. Soil is left unprotected increasing erosion potential until the site is revegetated. Riparian areas are particularly vulnerable to erosion following tillage due to potential stream flooding events.

Flooding Reed canarygrass can withstand periodic flooding quite well, especially flowing water. It does not withstand continual ponding, especially during warmer weather. Once reed canarygrass vegetation is killed, the site must be revegetated.

Advantages: Ponding frequently creates and/or improves wetland habitat. Remnant wetland plants should respond and colonize the site and may reduce the need to revegetate.

Disadvantages: Any attempt to eliminate reed canarygrass by flooding will require that water levels be controlled artificially. Ponding water in riparian areas is frequently not feasible. It may be too costly and securing permits to alter a stream may be impossible.

Chemical The States of Idaho, Oregon and Washington currently have only one approved herbicide, Rodeo^{tm} (glyphosate), for emersed, marginal and bank weeds in aquatic environments (ponded or flowing water) where fish are a concern. This chemical must be used with a state approved surfactant to be effective. An application approval permit may be required from the appropriate state regulatory agency. Check label instructions for application requirements. The chemical is effective on reed canarygrass however, follow-up treatment may be required. Also, a pesticide applicator's license for aquatic application may be required. All applicable rules, regulations, etc., pertaining to pesticides must be followed.

The application should be made uniformly to the foliage. This can be problematic if done at flowering or just before flowering because reed canarygrass can reach 7 feet in height. Earlier application around boot or late boot stage may be more practical for spray coverage of the foliage by equipment. (See label recommendations for timing of application).

Other chemicals may be appropriate, depending on the site. See the current Pacific Northwest Weed Control Handbook that is available through the Cooperative Extension Service.

NRCS staff in several field offices observed good control of reed canarygrass with applications of Rodeo^{tm} applied in the spring. Spring applications can aggravate other weed problems. Summer weeds such as Canada thistle that are suppressed by reed canarygrass may be released and cause a weed shift. Vegetation managers with the South Columbia Basin Irrigation District in Pasco, WA typically apply Rodeo^{tm} when the grass is actively growing for good control. They reported that applications made at full growth were ineffective and very early spring applications amounted to nothing more then a "chemical mow". Rates needed to be increased with height and good coverage was paramount. Rope wick applicators failed to provide the coverage needed. The Pullman PMC conducted an applicator trial with glyphosate and acquired similar results.

Advantages: Herbicides applications are relatively inexpensive. Revegetation is more successful because competition is controlled. Properly applied herbicides will provide excellent control of reed canarygrass.

Disadvantages: Most of the effective herbicides on reed canarygrass are nonselective thus necessitating revegetation. Timing of applications is critical and may coincide with other important activities. Public perception is frequently not supportive of pesticide applications. Improper selection of a herbicide may interfere with revegetation.

Defoliation (mowing, grazing) The strategy ideally depletes much of the carbohydrate root reserve. Mowing should occur when large amounts of above ground biomass are produced, but before transfer from above ground parts is made to the roots. Usually this timing is at or near flowering. Depletion of carbohydrate reserves in the rhizomes inhibits active growth of rhizomes and forces translocation of resources to develop new tillers for photosynthesis. The plant will respond by producing more shoots. Mowing should be done when stubble height is at 4 inches or less if possible, so the active growing points are removed and the plant is forced to develop new ones.

Reed canarygrass is a pasture grass, but some grazing practices can negatively affect it. Early-season heavy grazing will continually remove photosynthetic leaves but this practice can aggravate water quality problems. The fields will be wet and the livestock will generate a lot of mud. Livestock are not effective at controlling reed canarygrass when the plants get large. The stems are too coarse and the plants may have accumulated alkaloids that will deter grazing.

Several field offices have experimented with weed whacking. Whacking reduced shading but the results were short-lived, and the practice did little to curb rodent predation on shrub transplants.
Mowing in conjunction with shading or herbicide treatment may produce more favorable results than mowing alone. Follow-up treatment will be needed.

Advantages: Defoliation is easy to gauge and animal numbers and/or mowing severity can be altered. Desirable plants may be released from the shading effect of reed canarygrass. Producer might realize some profit by grazing reed canarygrass with livestock.

Disadvantages: Many areas where reed canarygrass grows are not suitable for mowing or haying equipment. Livestock grazing requires fencing and management to prevent undesirable impacts such as bank trampling. The effect can be short-lived if the practice is not repeated frequently enough and complete control via grazing is unattainable. Undesirable vegetation such as poison hemlock may be released by grazing.

Shading Reed canarygrass is susceptible to shading. Shade requirements for suppression are usually 41% or greater shade. Forman (1998) found that 41%, 51% and 81% shade produced significant reduction in total biomass (tops + roots) when compared to no shade. The above-ground biomass was not significantly affected by shading, but the below-ground biomass was significantly reduced by 41%, 51% and 81% shade.

Shade may be provided by natural means (shrubs, trees, etc.) or by artificial means. Deciduous trees and shrubs are less able to limit light early and late in the season. Evergreens are more effective at limiting light throughout the year, but few species are adapted to wetland environments. Artificial methods include mulching with bark, weed barrier, black plastic, etc. These methods have drawbacks. Mulching will not necessarily keep rhizomes from increasing and spreading. Black plastic breaks down and is susceptible to rhizomes growing up through the material. Weed barrier is superior to black plastic because it resists UV breakdown and rhizomes find it difficult to penetrate. These materials are more effective when used in conjunction with woody vegetation plantings.

Several offices have utilized various barriers to control reed canarygrass. Cloth barriers proved ineffective because the old vegetation made it difficult to place the barrier on the surface. Heavy barrier mats have proved more effective because their weight overcame the difficulty with the old vegetation.

Advantages: Little equipment is required. The control can be targeted to very small areas. Materials are readily available and little expertise is required to install shade materials. There are several barrier products that have very low photodecomposition rates. Revegetation via transplants is easily accommodated because the barriers can be fit around the plants.

Disadvantages: Large areas can not be treated due to cost. Light barriers like shade cloth are not permanent and may break down before the reed canarygrass is fully controlled. Barriers provide refugia for rodents that feed on transplants. Rodent baits may be needed to reduce predation.

Burning Burning in many areas requires a permit. Burning in Reed canarygrass can be done in some areas in early spring before much green growth is apparent. Many areas such as ditch banks and irrigation canals are burned annually in the spring by landowners and irrigation districts. Reed canarygrass is still present in those areas.

Advantages: In practicality, the main benefit from burning is removal of residue. Follow-up treatments such as herbicide application and shrub/tree establishment can then be done more efficiently. Burning is very inexpensive. Burning may open up the canopy and release suppressed native plants such as sedges.

Disadvantages: Other treatments in addition to burning will be required for control or suppression. Wet meadows present a special problem because spring snow melt runoff, subsequent flooding and ability of reed canarygrass to produce early green growth all hinder spring burning. Fall burning may be hazardous because the fire can spread to surrounding slopes. Heavy dew, slow drying, and regrowth frequently make late fall burning ineffective. Burning permits may be required and difficult to obtain.

Competition Light is an important limiting factor so competing vegetation should reduce the amount of light available to reed canarygrass. Plants that limit light will be taller then reed canarygrass. Species that develop foliage earlier in the spring will be superior competitors because reed canarygrass makes much of its growth in mid-spring. Dense shrubs, deciduous trees and evergreens are good candidates for decreasing light availability for reed canarygrass. For instance, one study reported that reed canarygrass gives way to willow, chokecherry and Redosier dogwood (Harrison et al. 1990). Another study reported that reed canarygrass successfully invaded and dominated shaded upland oak savanna sites in Wisconsin (Henderson 1991). Oak begins growth later in the season than other woody plants, allowing reed canarygrass time to grow prior to oak leaf out.

Plants that establish fast and regrow rapidly after cutting can be good competitors. Sheaffer et al. (1990) and others have shown that reed canarygrass stands deteriorate in alfalfa mixtures if the field is clipped too frequently. The Pullman PMC has observed that reed canarygrass is being replaced by creeping foxtail in a field that is hayed each summer. The July haying operation removes all of the photosynthetic tissues of the reed canarygrass. However Creeping foxtail still maintains some photosynthetic leaves after haying. This probably explains why it is encroaching on the reed canarygrass.

Advantages: Reed canarygrass is controlled and replaced thus filling the void before weeds fill the niche. Plant succession can be ‘steered’. The process should require less human input.

Disadvantages: Competition is never absolute. The time needed may extend beyond the timeframe desired. The competing vegetation and/or succeeding vegetation may become undesirable.

Biocontrol Reed canarygrass is suppressed by several pathogens. For example, *Helminthasporium* can cause severe damage but it also causes damage to orchardgrass and tufted hairgrass, an important native wetland grass (Zeiders 1976). The likelihood of the development a biocontrol agent specific for reed canarygrass is very low.

Advantages: Biocontrol can be very cost effective. Biocontrols tend to persist and provide control for many years. Biocontrol agents spread beyond their introduction sites.

Disadvantages: Development of a biocontrol agent takes many years and can be very expensive. Biocontrol agents must be very host specific. Biocontrol does not eradicate its host. Biocontrol agents are effected by the environment and climatic/cultural conditions may inhibit their efficacy.

Scalping In theory, scalping the top 12” of soil will remove the rhizomes and culms. To be most effective, the operator of the equipment must do an extremely thorough job of scalping the soil and not spill the load when emptying the soil into the dumpsite. This practice is being used in western and southeastern Washington with good short-term results. Reinvasion is almost certain if the scalped area is not revegetated with species that will effectively exclude reed canarygrass or covered with a good weed barrier mat. Planting rooted woody materials while more costly then sprigging unrooted poles and whips, greatly increases the odds of establishment. Failed plantings simply allow undesirable vegetation (such as reed canarygrass) to fill the void and complicate future revegetation efforts.

Advantages: Scalping can be accomplished with a variety of implements. Seed, culms and rhizomes of reed canarygrass can be completely removed from a scalped area. Scalping can shape and/or smooth the site and make it easier for reseeding and transplanting operations. Banks can be reshaped with most scalping equipment. Other undesirable vegetation can be removed at the same time.

Disadvantages: Scalped areas must be revegetated. A skilled operator is needed. The spoil material must be dealt with. Scalping can remove much of the topsoil. Permits may be needed and difficult to obtain. Scalping leaves the soil bare and prone to erosion.

Combination Treatments Combining treatments is the most effective means of controlling reed canarygrass because the effects are cumulative.

Forman (1998) found that 41% shading in combination with two mowings at about 1 inch stubble height significantly reduced reed canarygrass total biomass production (greenhouse study). This practice severely depletes carbohydrate reserves and limits the amount of photosynthetic area.

Kilbride (1999) found that spring application of Glyphosate (Roundup) followed by fall disking had the most effect on reed canarygrass stem densities in southwest Washington.

Grazing, if under strict control, can be effective in reducing reed canarygrass competition while shrubs and trees are establishing. The grazing must be done while reed canarygrass is palatable (during vegetative growth stage) to the grazing animals (cattle). Grazing should be done before the plants become stemmy because as the grass plants become less palatable to livestock, they will move over to the green shrub growth. Mechanical damage to shrubs and trees must be prevented and considered when planning grazing activity.

Irrigation Canal Managers report that spraying followed by reseeding with tall fescue will suppress reed canarygrass for 5 years before they have to repeat the operation. They have observed that purple loosestrife as well as other highly undesirable weeds will occupy sprayed areas if not effectively revegetated.

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"The Nature Conservancy" http://tncweeds.ucdavis.edu/photos/phaar04.jpg

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Section 17.3 History, Biology, Ecology, Suppression and Revegetation of Russian-Olive (*Elaeagnus angustifolia* L.) Sites

Stannard, Ogle, Holzworth, Scianna, and Sunleaf, 2002

- **Russian-olive is native to southern Europe and Asia.**
- **It was introduced to North America in colonial times and was promoted for plantings in the western United States as early as 1906.**
- **It has been a popular shrub for windbreaks and shelterbelts in semi-arid and saline environments because of its adaptability.**
- **It is very invasive in wet-saline environments and certain riparian environments, and has the ability to displace native species.**
- **It has been promoted as a source of food and cover for some wildlife species. Research has determined that benefits are not as great as those provided by native species.**
- **Plants are generally produced from stratified seed, but plants can grow from stump sprouts, stem cuttings, and root pieces.**
- **Russian-olive tolerates infrequent fire, temporary flooding, browsing, and mechanical cutting.**
- **Several herbicides will kill Russian-olive, but repeat applications over a span of 1-2 years are needed for good control.**
- **Effective control integrates removing top growth, suppressing regrowth, and filling the void with desirable, shade-producing vegetation.**

History

Russian-olive is native to southern Europe, central Asia, and the western Himalayas (Bailey 1914). It was introduced to North America during colonial times (Elias 1980) and was widely planted in the western United States. The first references for planting Russian-olive in the West occurred in New Mexico, Nevada, and Arizona in 1903, 1906, and 1909, respectively (Christiansen 1963). By the 1940s, it was a common ornamental plant growing in many cities of the West. It was promoted as an excellent species for windbreaks, erosion control, and wildlife enhancement as early as 1939 (Van Dersal 1939). Many agencies recommended landowners use Russian-olive for conservation plantings in cropland environments that required trees and shrubs that tolerated dryland arid to semi-arid conditions. Some of the same agencies that promoted it years ago are now spending large amounts of time and money to control it.

Russian-olive was one of the very few medium-height trees that were commercially available for use in dryland windbreaks and shelterbelts up until the 1970s. Native trees that are as drought tolerant and as easily established as Russian-olive were largely not commercially available. More recently, the choices of tree species for dryland conservation practices have improved. Interestingly enough, sales of Russian-olive seedlings have remained fairly stable over the last several years in states that have not listed it a weed.

The first documentation of Russian-olive escaping cultivation occurred in 1924 in Utah, and by 1954 it had escaped cultivation in each adjoining states (Knopf and Olsen 1984, Christiansen 1963). It has been especially invasive in wet-saline riparian environments, yet it continues to be grown and planted in the West. In the Intermountain West, northern Great Plains and Great Basin states, it is primarily in dryland windbreaks and shelterbelts, saline areas, and urban ornamental plantings.

Russian-olive and saltcedar (*Tamarix pentandra* Pall.) are particularly troublesome in western riparian areas (Christiansen 1962, - 1963, Carman and Brotherson 1982). Several of the larger nurseries that produce trees and shrubs for the conservation market have removed Russian-olive from their sales lists. Russian-olive is not listed on the Federal Noxious Weed List. New Mexico and Colorado are the only states currently listing it as legally noxious (based on PLANTS.usda.gov information and G. Beck comm., respectively). Utah has also listed it as a noxious weed in several counties.

Russian-olive replaces native cottonwood and willow stands in wet saline bottomlands. Once established, Russian-olive stands are very stable.

Biology and Ecology

Russian-olive is classified as either a shrub or small tree. When grown close together, it forms a dense thicket or shrub-hedge. Single plants grow as trees and may reach a height of up to 45 feet. It has silvery leaves and small fruits that are generally silver in color. It has commonly been included in urban landscape plantings to contrast green foliage species. Younger stems have stout spines that make it an ideal plant for use as a barrier hedge. The spines are tough and easily penetrate tires.

There are 45 members of the *Elaeagnus* genus and only one, silverberry (*E. commutata*), is native to North America. Silverberry is similar in appearance to Russian-olive, but is a much shorter root-sprouting shrub with the younger stems dark rather then soft and silvery. It occurs primarily east of the Rocky Mountains, but is also found in Idaho and Utah. Buffaloberry (*Shepherdia*) species are closely related, and silver buffaloberry (*Shepherdia argentea*) is an important native conservation plant. Observable differences between silver buffaloberry and Russian-olive include leaf and bud arrangement, fruit, habit, and stature. Russian-olive leaves have alternate leaf and bud arrangement whereas buffaloberry leaves and buds have an opposite arrangement. Silver buffaloberry fruit have smaller, red-orange ovoid berries. Silver buffaloberry tends to form short thickets about 10-feet tall after 20 years (USDA 2000). Silver buffaloberry also is frequently found occupying the same wet saline sites invaded by Russian-olive. Caution should be exercised when attempting to selectively control Russian-olive in mixed woody plant stands to avoid nontarget losses.

Brown (1990) compared native willow sites to Russian-olive sites along the Snake River in Idaho. Willow sites had higher species richness and density, and more foraging guilds and nesting guilds than Russian-olive sites. Brown also noticed an absence of insects is one of the characteristics of Russian-olive that is implicated in its negative effects on avian communities. The shift from native to exotic dominated riparian habitats may result in regional loss of avifaunal diversity (Brown 1990). Knopf and Olson (1984) compared wildlife use of stands dominated by Russian-olive versus use in adjacent native riparian communities in Colorado and Utah. They observed 505 individuals of 56 species in native riparian vegetation, and 458 individuals of 40 species in Russian-olive. Clearly, avian species richness and diversity is less in Russian-olive stands. Although Russian-olive provides food and cover for many species, it negatively impacts cavity-nesting birds (Olson and Knopf 1986). Lesica and Miles (1999) study conducted in north-central Montana showed limited use of Russian-olive by beaver. Beavers prefer poplar (*Populus*) and willow (*Salix*) species such as cottonwood (Lesica and Miles 1999), quaking aspen (*P. tremuloides*), and willow species. Lesica and Miles proposed that this preference might accelerate the replacement of cottonwood by Russian-olive.

Russian-olives grow well in uplands that receive as little as 8 inches of mean annual precipitation (Laursen and Hunter 1986), and consequently, it was commonly included in multi-species windbreaks and shelterbelts throughout the West. Rocky Mountain juniper (*Juniperus scopulorum*) and Siberian peashrub (*Caragana* species) are equally as drought tolerant.

Birds and mammals readily eat Russian-olive fruit. Each fruit has a single seed in the center.

Russian-olive also grows well in wet-saline soils. It frequently colonizes sites that are occupied by inland saltgrass (*Distichlis stricta*). The "wet-saline niche" is not a hospitable environment for many native woody species, which allows Russian-olive to grow with minor competition from other woody species. However, Russian-olive loses its competitive edge on non-saline hydric soils. Cottonwood (*Populus* species) and certain tall willows grow well in this environment and shade the shorter Russian-olive. Sodic soils that supported greasewood (*Sarcobatus vermiculatus*) are also suitable for Russian-olive survival, but Russian-olive gives way to saltcedar (*Tamarix*) on soils with elevated sodium levels (Carman and Brotherson 1982).

Based on the relative observed salt tolerance of trees to various salt ions and methods of exposure (e.g., soil salinity, irrigation water, ocean and de-icing salt spray), Russian-olive is generally described as 'tolerant' to 'very tolerant' of salt injury. In one replicated study, the total germination and germination energy of Russian-olive seed did not noticeably decline with high salt concentration (maximum Electrical Conductivity [EC] of 16.6 mmhos/cm) under controlled environmental conditions (Tinus 1984). In the same study, Russian-olive did not reach a threshold for reduction in growth (25 percent reduction) until an EC of 8.3 mmhos/cm was reached. Russian-olive leaf length and percentage survival did not reach a threshold for reduction even at the upper limit of testing (16.6 mmhos/cm). Russian-olive is considered tolerant of most salt ions encountered in field situations to EC levels in the 6-12-mmhos/cm range (Zelazny 1968, Carpenter 1970, Strange 1997).

Individual Russian-olive seeds, achenes, are produced in small, fleshy fruits that are roughly one-half inch long. The seeds are hard and are the size of a typical olive pit, and the outer layer of the seedcoat is impermeable to digestive juices (Tesky 1992).   Establishment of plants from fruits consumed by birds has been implied in several reports (USDA 1974, Shafroth et al.1995, Lesica and Miles 1999). Coyotes, deer, and raccoons also consume the fruit and disseminate seed (personal observation). Also, the fruits float (Heekin, personal observation), and very probably dispersed via water transport.

Seeds do not readily germinate and generally require either 60-90 days of cold stratification or fall planting (USDA 1974). Hardseed can also be soaked in sulfuric acid prior to cold-chilling in order to break dormancy. Seeds remain viable for up to 3 years under ordinary storage conditions.

Russian-olive readily propagates from vegetative structures (Bailey 1914). Stump sprouting commonly occurs after cutting down the tree, and excavation of the entire stump can trigger root sprouting. Stem cuttings also will root and have been used to propagate Russian-olive.

Russian-olive has also been identified as a community type in the "Classification and Management of Montana's Riparian and Wetland Sites" (Hansen et al. 1995). From a plant succession point of view, the Russian-olive community type seems to represent a seral stage of many different habitat types such as green ash/common chokecherry (*Fraxinus pennsylvanica/ Prunus virginiana*), box-elder/common chokecherry (*Acer negundo/Prunus virginiana*), Ponderosa pine/redosier dogwood (*Pinus ponderosa/Cornus sericea*) or Douglas fir/redosier dogwood (*Pseudotsuga menziesii/Cornus sericea*) (Hansen et al. 1995). It should be noted that Russian-olive communities tend to be a very stable state and generally will require active manipulation (i.e. application of one or more suppression measures) to initiate a transition to a different community type.

Decline of native cottonwood gallery forests and invasion by Russian-olive invasion are frequently associated with a change of the natural disturbance regime of riparian areas, frequently as a result of river regulation (Knopf and Olson 1984, Shafroth et al. 1995, Lesica and Miles 1999). Transition of a watercourse to a cottonwood community type from a Russian-olive community is retarded by several factors. Periodic flooding is frequently associated with cottonwood recruitment because it exposes bare soil needed for seedling establishment and moves whole pieces of cottonwood that root after the water recedes. Damming and de-watering of streams has reduced flood effects. The demise of cottonwood has allowed for the proliferation of Russian-olive. Improper irrigation water management in some cases has elevated the water table and aggravated the accumulation of excess salts in the soil. This condition is not favorable for woody species that do not grow well in saturated, saline soils (e.g., cottonwood, most willows, redosier dogwood).

Suppression

Several methods are relatively effective in suppressing Russian-olive. Suppression is subjective so it is a good idea to define what "suppression" is to prevent misconceptions. Some may define suppression as total eradication while others may define suppression as the reduction of top growth to a tolerable level.

An appropriate method(s) for any particular site will depend on the physical conditions of the site(s), available funds, personnel, equipment, proximity to water bodies or desirable vegetation, and landowner choices and objectives.

Complete eradication of Russian-olive is frequently impractical. However, it is practical for small isolated stands where the total cost of control and time investment is small. Reduction of top growth and containment of spread is usually practiced in areas where infestations are large and eradication is cost prohibitive.

Regardless of the level of suppression, each site should be revegetated in some manner to adequately treat erosion problems inherent in these sites and to slow re-invasion. Revegetation should be done with the objective of providing plants that are well adapted and suppress the spread and growth of Russian-olive. This process may take several years, depending on methods selected, and will require followup treatments in most cases. Grasses are preferred over forbs in herbaceous groundcover revegetation if broadleaf herbicides are planned for followup treatment.

Mowing Saplings. Russian-olive saplings are easily mowed. The stems are erect and most branching occurs above a typical mower height. The stem material is easily cut and does not wind around mower blades. Once the stems get much larger than 1 inch in diameter, mowing becomes impractical. Research in Wyoming has shown that a "wet rotary blade" with glyphosate has provided effective control without harming understory vegetation (Whitson, pers. comm.)

Advantages: Mowing is relatively fast and the results are highly visual. No specialized equipment is required unless the saplings are too large to cut with a conventional tractor-powered mower. Repeated mowing will eventually reduce Russian-olive populations to acceptable levels. Mowing can also improve pasture quality.

Disadvantages: Mowing will need to be repeated at least annually. Mowing must be frequent enough so the saplings do not exceed 1 inch in diameter. Desirable woody species such as cottonwood are indiscriminately mowed as well. Stumps, uneven terrain, and wet soils limit accessibility. Cut pieces will need to be disposed, or they may root and resprout.

Cutting. Standing Russian-olive is relatively soft and is easily cut with chain saws, axes, power shears, etc. Cutting at the base will eliminate top growth for a short period. Sprouts will develop from the base of the stumps- sometimes within a few weeks. Continual pruning of the sprouts can eventually starve the root system. The stumps can be removed or treated to prevent resprouting.

Advantages: Cutting is relatively cost effective and the results are immediately evident. Cutting provides a means of moving the top growth off-site for destruction or disposal. It opens up the canopy and allows desirable understory species to grow under better light conditions. Cutting allows selective removal of trees.

Disadvantages: Cutting provides little long-term suppression. Gaining access to the base of the tree can be very difficult due to the presence of spines. The cut wood must be either burned or hauled off site because the branches do not readily breakdown. They may also root and resprout.

Girdling. Girdling severs the phloem tissues and prevents transport of photosynthates to the root system. This effectively starves the whole plant.

Advantages: Girdling is a very effective technique to kill woody vegetation. Several non-specialized tools can be used and the task is relatively simple. It is well suited for larger diameter trees, which can be difficult to safely cut down. Desirable woody vegetation can be retained.

Disadvantages: Girdling may stimulate root sprouting. The dead top growth must be removed because it may be a fire hazard but burning in place will injure desirable vegetation. Piling carcasses using a crawler can result in severe ground disturbance. Girdling is not well suited for multistem crowns because the thorns on low-lying branches can make the task almost impossible.

Flooding and Ponding. Russian-olive withstands periodic flooding quite well, especially flowing water. It does not withstand continual ponding.

Advantages: Flooding can expose bare soil and improve establishment of cottonwood seedlings. Ponding frequently creates and/or improves wetland habitat. Remnant wetland plants should respond and colonize the site and may reduce the need to revegetate.

Disadvantages: Eliminating Russian-olive by flooding and ponding requires that water levels to be controlled artificially. Ponding water in riparian areas is frequently not feasible. It may be too costly and securing permits to alter a stream may be very difficult. Also, there is the risk that Russian-olive pieces may be moved downstream and start a new colony.

Chemical. Russian-olive is sensitive to 2,4-D ester, triclopyr, 2,4-D + triclopyr, imazapyr, and glyphosate. However, effective Russian-olive control with these compounds almost always requires followup treatments for 1 to 2 years (Bovey 1965, Ohlenbusch and Ritty 1978, Bussan et al. 2001, Parker 2001). Edelen and Crowder (1997) applied Imazapyr [Contain^{tm}] as a foliar spray and reported poor control of mature trees but good control of saplings. Russian-olive began to recolonize the treated area two years after application. The Washington Department of Fish & Wildlife has reported good initial control using an aerial application of Triclopyr [Garlon^{tm}]. They retreat each year to control seedlings (Kent, WDFW, pers. observation).

2,4-D ester is applied to the foliage. It requires good coverage for acceptable results. 2,4-D + Triclopyr [Crossbow^{tm}] is applied either as a foliar spray or a directed spray to the basal bark of the tree. Triclopyr [Garlon^{tm}] is applied as a directed spray to the basal bark of the tree. Basal applications require good saturation of the bark and diesel fuel is frequently used as the carrier. Imazapyr [Arsenal^{tm}, Contain^{tm}] is applied undiluted to frill cuts made in the stem. Glyphosate is also applied to frill cuts. Glyphosate has provided very good control using a glyphosate “Hack and Squirt” treatment that is applied during the winter months (Kent, WDFW, pers. observation). Trees are “hacked” with a hatchet that injects glyphosate into the wound.

The States of Idaho, Oregon, and Washington currently have only one approved herbicide, Rodeo^{tm} (glyphosate), for emersed, marginal, and bank weeds in aquatic environments (ponded or flowing water) where fish are a concern. To be effective, this chemical must be used with a state-approved surfactant. An application approval permit may be required from the appropriate state regulatory agency. Also, a pesticide applicator’s license for aquatic application may be required.

NOTE: Always consult the label before applying any chemical product.

Advantages: Herbicide applications are relatively inexpensive. Desirable vegetation may be retained if applications are targeted to individual Russian-olive plants. Application equipment such as aerial, pump-up sprayers and backpack sprayers can be used in locations inaccessible to tractors and other power equipment.

Disadvantages: Most of the effective herbicides for Russian-olive control are nonselective, thus requiring careful placement in order to avoid nontarget losses. Timing of applications is critical and may coincide with other important activities. Public perception is frequently not supportive of pesticide applications. The time interval for effective control may be as long as 3 years.

Shading. Russian-olive is shade intolerant so it is less of a problem in riparian areas that support dense stands of tall cottonwood and willow trees and shrubs. However, Russian-olive will frequently grow along the periphery. Russian-olive produces two types of leaves: full-sun leaves, and shade leaves. This would suggest that individual Russian-olive trees have the ability to adapt to reduced light conditions by simply producing more shade leaves.

<u>Advantages</u>: Promoting the growth and recruitment of tall cottonwoods and willows is ecologically desirable.

<u>Disadvantages</u>: Managing cottonwood and willow populations for adequate height to shade Russian-olive may take several years. Also, Russian-olive will grow in areas that will not support cottonwood, willow, or other desirable tall trees and shrubs.

Burning. Burning Russian-olive is practical when conditions support a hot fire. Saplings are most sensitive. The fire must be hot enough and burn long enough to incinerate the stumps of larger trees. Spring and winter burns are usually less effective than summer or early fall burns.

<u>Advantages</u>: Burning is inexpensive, and the results are highly visual. It is a very effective method of clearing an area of top growth.

<u>Disadvantages</u>: Burning is rarely effective by itself since Russian-olive can resprout from crowns. Other treatments, in addition to burning will be required for control or suppression. Burned areas, especially where Russian-olive was pile- or windrow-burned, can become sites for weed invasion. Burning is nonselective and will damage or kill desirable vegetation, such as cottonwood or riparian shrubs. Competitive desirable plants need to be used for revegetation immediately following the burn. Burning permits may be required and difficult to obtain.

Tillage. Russian-olive is sensitive to repeated tillage, especially its saplings. Periodic renovation of pastures is an effective means of preventing Russian-olive from dominating a site. Disks and plows effectively sever the roots. Sweep cultivators are less effective because they will slide around the roots and do an incomplete job of severing. Root sprouting may occur after the first tillage operation and two separate operations are usually needed. By using tillage in concert with broadleaf weed control spraying, Russian-olive saplings may be effectively controlled.

<u>Advantages</u>: Reestablishing pastures, especially with a grain cleanup crop, is usually cost effective. Tillage equipment is readily available and easy to use. Tillage controls existing plants and stimulates germination and root sprouting that can be controlled with subsequent tillage or herbicide operations.

<u>Disadvantages</u>: Russian-olive occurs in areas other than pasturelands and cropland. Physical access to the site may be reduced or prohibited due to steep slopes, flooding, or wet soils, therefore tillage may not be a viable option. Tillage and re-establishing pastures require that all existing vegetation be fully controlled. This leaves the soil bare and susceptible to invasion by other species. It may also aggravate salt accumulations at the soil surface. Riparian areas are particularly vulnerable to erosion following tillage due to potential stream flooding events.

Biocontrol. Russian-olive was promoted for use as an ornamental and windbreak plant because it is relatively free of disease and insect problems. There are reports of fungal diseases, however, causing stem die-back and even death of plants (Peterson 1976, Carroll et al. 1976, Krupinsky and Frank 1986). Effective fungal inoculation was frequently associated with injury to the bark prior to inoculation.

Tubercularia canker (*Tubercularia ulmea*) overwinters on infected stems and spreads via rain-splash, animals, or pruning implements to open wounds in the bark. Infected tissue becomes discolored or sunken. Entire stems may be girdled and killed, and the disease can deform or kill stressed plants over time (Herman et al. 1996, Jackson et al. 2000). Cankers on Russian-olive sometimes exude gum at the margins. Phomposis canker (*Phomopsis arnoldiae, P. elaeagni*) kills seedlings and saplings, causing dieback and cankers on larger plants (Sinclair et al. 1987). Many of the symptoms resemble those of *T. ulmea*. In addition to canker development and gum exudation, prominent amber-brown nodules develop that spread during wet weather and can darken and dry, forming a near black incrustation. Over time, pycnidia emerge from the lesion. These pimple-like eruptions darken with age and remain prominent for a year or more. *Lasiodiplodia theobromae* (syn. *Botrydiplodia theobromae*, *Diplodia natalensis*) is the pycnidial state of *Botryosphaeria rhodina*, a pathogen that causes cankers and dieback in many woody and herbaceous species. It often attacks plants weakened by environmental stress or other pathogens and has caused death of Russian-olive in windbreaks and shelterbelts in the Great Plains. This fungus often strips the dead bark up to several meters long, sometimes with small dead branches along the killed strip.

Advantages: Biocontrol can be very cost effective because the direct cost to the land manager usually is minimal. Biocontrols tend to persist and provide control for many years.

Disadvantages: Development of a biocontrol agent takes many years and requires a considerable labor and capital investment by the releasing agency. They are very host-specific and will not eradicate their host. Biocontrol agents are affected by the environment, and climatic/cultural conditions may inhibit their efficacy.

Chaining. Chaining is more commonly associated with control of mesquite and juniper. Two crawlers pull an anchor chain across the site and the woody vegetation is uprooted. Some revegetation technicians have modified surplus battleship chain by welding on short steel bars or cultivator disks to enhance the ripping and cutting action (Larson 1980).

Advantages: Chaining uproots large diameter plants very rapidly. Larson reports that as much as 40 acres an hour can be achieved with 2 ample powered crawlers and a large chain. Chaining rate is dependent on terrain, size of the vegetation, and stand density. Impact to herbaceous vegetation can be minimal in many situations.

Disadvantages: Chaining is not practical on moist soils because the trees will lean over rather than be uprooted. Chaining is not effective on saplings. Anchor chains are not readily available. Chaining is also indiscriminant, causing damage or mortality to desirable species.

Dozing. Dozing stands eliminates top growth and stumps. It requires a steel-tracked crawler (dozer) because the activity lays a lot of spiny stems on the surface. The crawler operator usually windrows or piles the trees, which are to be burned at a later date. Dozing severs the stumps from the roots, and new plants may establish from the root pieces and seed.

Advantages: Dozing is very effective at removing top growth and stumps. A thorough job will smooth the site and make it possible for the operation of revegetation equipment. Dozing can be accomplished at almost any time of the year providing that the soil is not frozen or too wet to support a crawler. Crawlers can access sites that wheeled implements cannot. Many crawlers are capable of ripping to a depth of 1-3 feet, which damages roots. Other undesirable vegetation can be removed at the same time.

Disadvantages: A skilled operator is needed. Followup treatment will be required to control root sprouts. The spoil material must be dealt with by piling and/or burning. Burn permits may be needed and difficult to obtain. Dozing can be indiscriminant, causing damage or mortality to desirable species. Dozing leaves the soil bare and prone to erosion and weed invasion. Soil compaction and profile disturbance frequently occur, and complicate reclaiming the site.

Dozing of Russian-olives near Richland, WA. Severed top growth was piled and burned. Soil disturbance was considerable.

Combination Treatments. Combining treatments is the most effective means of controlling Russian-olive because the effects are cumulative and will act on the plant at all life-stages.

Treatments such as dozing, burning, and cutting effectively eliminate the existing stand but do little to control recruits. Combining these treatments with an application of herbicide and/or tillage can greatly suppress recruits. Recruits are easier to control if secondary treatments are applied when the plants are small. For example, studies conducted by the Pullman Plant Materials Center have shown that mowing, followed by an application of triclopyr [Garlon^{tm}] when the regrowth is 2 feet tall, provides very effective long-term control. Regrowth and/or saplings are much easier to spray than mature stands. Maneuvering in mature stands is difficult and applying herbicides efficiently is almost impossible.

Revegetation

The revegetation of sites previously occupied by Russian-olive is influenced by site conditions, availability of equipment and labor, intended land use and cost.

Russian-olive tends to heavily invade two types of sites; wet saline areas and riparian zones. It is far less invasive in dry, upland environments. Although Russian-olive provides several conservation benefits on wet saline sites, the aggressive nature of the species often results in a monoculture that provides few agronomic returns, other than perhaps cordwood, and acts as a source of inoculum for adjacent noncontaminated areas. In riparian areas, it competes with native vegetation, reducing biodiversity and negatively affecting habitat function.

Always consult a soil survey before initiating any revegetation. Soil surveys provide historic vegetation information, range ecological site classifications, land management considerations, climatic information, as well as detailed soil information.

Wet Saline Pastureland and Hayland. If the site is to be managed as pastureland or hayland, Russian-olive removal should not occur when the ground is frozen or so wet that equipment operation is difficult. Large woody material must be removed or burned.

Most suppression/removal operations will severely disturb the herbaceous understory and will necessitate reseeding. Burn piles and windrows will particularly need revegetation. Weeds, volunteer Russian-olive suckers and seedlings, as well as unproductive forage grasses will need to be controlled in order to establish a high quality pastureland/hayland planting. If a permanent, desirable vegetative cover cannot be established in a timely manner, an interim alternative is to seed a barley cover crop if the soil salinity is less than 15 mmhos/cm. Barley is easy to establish, weed control options are numerous, and a barley crop aids in building a good perennial grass seedbed.

Several species can be used to revegetate wet saline sites for pastureland and hayland, depending on the electrical conductivity (saltiness) of the soil (see table 1). Seed small disturbances at a rate of at least 25 seeds per square foot. Periodic maintenance with labeled broadleaf herbicides or mechanical removal of plants should keep subsequent Russian-olive invasion in check. Volunteer seedlings may arise from seed produced prior to plant removal from both on- and off-site plants. Seed may continue to be distributed on-site from off-site sources, from animals, and from water transport (irrigation and natural waterways) after on-site removal.

A complete seedbed preparation following removal of Russian-olive improves establishment of pastureland and hayland species.

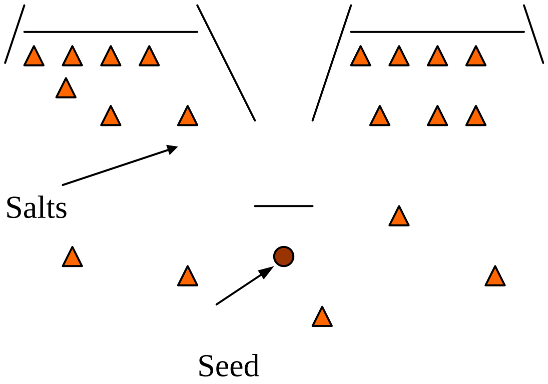
Seedbed preparation must accomplish two critical objectives: (1) control existing vegetation, and (2) allow placement of the seeds at the appropriate depth and ensure good seed-to-soil contact. Wet saline soil is a unfavorable environment for seedling establishment. Coupling this condition with existing vegetation means that poor establishment of pasture and hay species is almost guaranteed. Control of the existing vegetation (i.e., existing herbaceous species, as well as Russian-olive) may need to be started as early as 1 year prior to seeding. This will allow time to control of secondary and tertiary weed flushes, breakdown of organic debris, and improvement of soil tilth.

Seeding should be conducted when the soil and climatic conditions are favorable for seeding operations. Seeding should not occur in the summer. Salts may accumulate at the soil surface during this period and injure seedlings. Deep-furrow seeding technology may be appropriate for wet saline seedings. In that method, the seeds are placed in the furrow where moisture conditions are favorable and the salts migrate to the tops of the furrows (figure 1).

Additional seedbed preparation and seeding guidance is described in the NRCS Field Office Technical Guide, Section IV, Standards:

- Pasture and Hayland Planting (512)
- Toxic Salt Reduction (610).

Figure 1. Seed placement in furrow bottom – Salt accumulation primarily on ridge tops.



Wet Saline Wildlife Habitat and Site Stabilization.

If the site is to be managed for a nonagronomic purpose, several factors should be considered. Few woody plants, especially trees, grow as well as Russian-olive in a soil salinity above 10 mmhos/cm (in fact, many of those sites did not support large woody species historically, and planting trees on those sites may not be an effective revegetation technique). Soil salinity and water table depth tests should be conducted in late summer during the planning stage in order to determine which species are likely to grow on the site (see table 2). Extensive use of broadleaf herbicides to control Russian-olive may not be desirable in some situations if native forbs and woody plants also occupy the sites. All disturbed areas should be seeded after Russian-olive removal to prevent weed invasion and soil erosion. A temporary cover of barley can be used if soil salinity is less than 15 mmhos/cm. Since forbs and woody plants are typically important components of wildlife and rangeland renovation projects, followup control of Russian-olive should entail spot applications of herbicide or mechanical removal of individual plants to avoid injury or mortality of desirable plant species. Although the cost of planting is higher than the cost of seed, the installation of bareroot or containerized woody plants is recommended over seeding, due to speedier establishment and increased survival. The roots of containerized stock grow in a desirable media that can serve as a buffer or transition period until roots can emerge into the surrounding native soil. Most northern temperate woody plants have seed dormancy mechanisms that delay germination and may delay or reduce establishment and competition with other plants. Reestablishment of Russian-olive may happen before desirable seedlings can establish. Also, the seed of large-seeded species is often lost to rodents.

High water tables, either seasonal or yearlong, are common in areas where Russian-olive has invaded. Gleying is a good indicator of a high water table if water is not actually standing in the soil pit. Choose species for revegetation that are adapted to the hydrologic conditions of the soil.

Additional site preparation, and seeding and planting guidance is described in the NRCS Field Office Technical Guide, Section IV, Standards:

- Channel Vegetation (332)
- Range Planting (550)
- Riparian Forest Buffer (391A)
- Tree/Shrub Establishment (612).

Non-saline Riparian Sites. In general, riparian areas should be revegetated with native species in order to maximize habitat function. In some cases, severe site degradation may warrant the use of noninvasive, introduced species. Land ownership, public vs. private, may, in part, dictate specie selection.

If substantial disturbance to the site occurs during the removal of woody debris, stumps, and roots, the site should be seeded with a well-adapted herbaceous species to reduce weed invasion. If the disturbance is minimal, it may be possible to plant tree and shrub seedlings directly (see table 3). Care must be taken to flag the desirable seedlings to prevent indiscriminant injury resulting from followup control of Russian-olive root sprouts and seedlings.

Additional site preparation, and guidance on seeding and planting techniques are described in the NRCS Field Office Technical Guide, Section IV, Standards:

- Range Planting (550)
- Riparian Forest Buffer (391A)
- Riparian Herbaceous Cover (390)
- Tree/Shrub Establishment (612).

Dry Upland Sites. *Russian-olive is less likely to become invasive on dry upland sites. It is well adapted to this environment and local recruitment is minimal (although dryland plantings may serve as a seed source for more vulnerable sites). It may be necessary to remove Russian-olive trees from windbreak and shelterbelt systems and replace them with more desirable species. Depending on the design of the windbreak, wind protection may decrease until replacement trees reach a functional size. Replacement trees should function well as a medium-sized component (~15 to 20 feet in height) in windbreak systems. Other criteria such as soil salinity, shade intolerance, and drought tolerance, etc., need to be considered during the selection of replacement plants. Use well-adapted seed sources or cultivars, and follow standard bareroot or container installation and maintenance practices.*

For additional information on windbreak plantings, consult the NRCS Field Office Technical Guide, Section IV, Standards:

- Windbreak/Shelterbelt Establishment (380)
- Windbreak/Shelterbelt Renovation (650).

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Table 1. Saline tolerant herbaceous species for pasture renovation after Russian olive removal.

Latin Name	Common Name	Native Status (N/I)†	Adapted Cultivar	Thresh - Hold Salinity‡ *mmhos/cm*	Maximum Salinity *mmhos/cm*	Seeds/ Pound	PLS Seeding Rate *lbs/A*
Leymus multicaulus	Beardless wildrye	N	Shoshone	12	26	180,000	7
Elytrigia pontica	Tall wheatgrass	I	Alkar, Largo, Jose	12	26	79,000	12-14
Elytrigia repens X Pseudoroegneria spicata	Hybrid wheatgrass	I	NewHy	10	24	135,000	8
Elymus trachycaulus	Slender wheatgrass	N	Pryor, San Luis	10	22	130,000	8
Festuca arundinacea	Tall fescue	I	Kenmont, Fawn, Goar, Alta	7	18	240,000	6
Pascopyrum smithii	Western wheatgrass	N	Rosana, Rodan, Arriba, Walsh	6	16	95,000	8
Trifolium fragiferum	Strawberry clover	I		6	16	300,000	8
Alopecurus arundinaceus	Creeping foxtail	I	Garrison, Retain	5	12	720,000	3
Bromus biebersteinii	Meadow bromegrass	I	Fleet, Paddock, Regar	4	10	80,000	12
Astragulus cicer	Cicer milkvetch	I	Lutana	4	10	135,000	8
Dactylis glomerata	Orchard grass	I	Paiute, Potomac, Latar, Napier	3	8	600,000	4

† – N indicates native; I indicates introduced.

‡ – Thresh hold salinity indicates the level of salinity at which plant performance begins to be impacted negatively.

Reference: Majerus, M.E. 1996. Plant materials for saline-alkline soils. Plant Materials Technical Note No. 26 (revised), Bridger, MT. U.S. Department of Agriculture, Natural Resources Conservation Service, Bridger Plant Materials Center, 5 pp.

Table 2. Saline tolerant species for wildlife habitat and site stabilization after Russian olive removal.

Latin Name	Common Name	Native Status†	Adapted Cultivar	Thresh - Hold Salinity‡	Maximum Salinity	Seeds/ Pound	PLS Seeding Rate
		(N/I)		*mmhos/cm*	*mmhos/cm*		*lbs/A*
Leymus multicaulus	Beardless wildrye	N	Shoshone	12	26	180,000	7
Elytrigia pontica	Tall wheatgrass	I	Alkar, Largo, Jose	12	26	79,000	12-14
Elytrigia repens X Pseudoroegneria spicata	Hybrid wheatgrass	I	NewHy	10	24	135,000	8
Elymus trachycaulus	Slender wheatgrass	N	Pryor, San Luis	10	22	130,000	8
Festuca arundinacea	Tall fescue	I	Kenmont, Fawn, Goar, Alta	7	18	240,000	6
Pascopyrum smithii	Western wheatgrass	N	Rosana, Rodan, Arriba, Walsh	6	16	95,000	8
Trifolium fragiferum	Strawberry clover	I		6	16	300,000	8
Alopecurus arundinaceus	Creeping foxtail	I	Garrison, Retain	5	12	720,000	3
Bromus biebersteinii	Meadow bromegrass	I	Fleet, Paddock, Regar	4	10	80,000	12
Astragulus cicer	Cicer milkvetch	I	Lutana	4	10	135,000	8
Dactylis glomerata	Orchard grass	I	Paiute, Potomac, Latar, Napier	3	8	600,000	4
Shepherdia argentea	Silver buffaloberry	N	Sakakawea	8	10-12	-	plants
Amelanchier alnifolia	Serviceberry	N		8	12	-	plants
Fraxinus pennsylvanica	Green ash	N	Cardan	8	10	-	plants
Prunus virginiana	Chokecherry	N		8	10	-	plants
Pinus ponderosa	Ponderosa pine	N	Hunter-Germplasm	6	8-9	-	plants
Elaeagnus commutata	Silverberry	N	Dupuyer, Pondera	5	8	-	plants
Atriplex X aptera	Fourwing saltbush	N	Wytana, Snake River Plain Germplasm	6-8	10	-	plants
Atriplex gardneri	Gardner saltbush	N		6-8	10	-	plants
Krascheninnikovia lanata	Winterfat	N	Northern Cold Desert Germplasm, 9063535	6-8	10	-	plants

† - N indicates native; I indicates introduced.

Reference: Majerus, M.E. 1996. Plant materials for saline-alkline soils. Plant Materials Technical Note No. 26 (revised), Bridger, MT. U.S. Department of Agriculture, Natural Resources Conservation Service, Bridger Plant Materials Center, 5 pp.

Table 3. Native, woody species for riparian restoration in the northern Great Plains after Russian-olive removal.

Latin Name	Common Name	Recommended Cultivar or Source	Saline Tolerance	Riparian Zone Use
Populus species	cottonwood species	Daniels County source	fair	transitional
		local ecotypes	fair	transitional
Salix species	willow species	local ecotypes	fair	bank-overbank
Fraxinus pennsylvanica	green ash	Cardan	fair	transitional-upland
		MITOSIS source	fair	transitional-upland
Acer negundo	boxelder	local ecotypes	fair	transitional
Juniperus scopulorum	Rocky Mt. juniper	Bridger-Select	fair	transitional-upland
		local ecotypes	fair	transitional-upland
Elaeagnus commutata	silverberry	Dupuyer Streambank	fair-good	overbank-transitional
		Pondera Floodplain	fair-good	transitional-upland
		local ecotypes	fair-good	overbank-transitional
Shepherdia argentea	silver buffaloberry	Sakakawea	good	transitional
		local ecotypes	good	transitional
Prunus virginiana	chokecherry	Schubert or Canada Red	fair	transitional
		local ecotypes	fair	transitional
Amelanchier alnifolia	serviceberry	local ecotypes	fair-good	transitional-upland?
Prunus americana	American plum	local ecotypes	fair	transitional-upland
Symphoricarpos albus	snowberry	local ecotypes	good	overbank-transitional
		MITOSIS source	good	overbank-transitional
Cornus sericea	red stem dogwood	local ecotypes	low	bank,overbank,transitional
Ribes species	currant	local ecotypes	fair	overbank-transitional
Rosa woodsii	Wood's rose	local ecotypes	fair	bank,overbank,transitional
Alnus species	alder species	local ecotypes	low	bank,overbank,transitional
Artemesia tridentata spp.wyomingensis	Wyoming big sagebrush	local ecotypes	good	transitional-upland
Rhus trilobata	skunkbush sumac	Big Horn	fair	transitional
		local ecotypes	fair	transitional
Betula species	birch species	local ecotypes	low	bank-overbank
Crataegus douglasii	black hawthorn	local ecotypes	low	overbank-transitional
Sambucus *species*	elderberry species	local ecotypes	low	transitional

Reference: Ogle, D.G., J.C. Hoag, and J.D. Scianna. 2000. Users guide to Description, Propagation and Establishment of Native Shrubs and Trees for Riparian Areas in the Intermountain West. Plant Materials Technical Note No. 32. Boise, ID. U.S. Department of Agriculture, Natural Resources Conservation Service, 22 pp.

SECTION 17.4 Overview of the Basic Biology, Distribution and Vegetative Suppression of Four Knapweed Species in Washington

Stannard, 1993

Well established stands of perennial vegetation can minimize the spread of many weeds. Knapweeds like other weeds function to fill voids. These voids may be actual bare ground or may be a missing key species in a plant community. It is extremely important that these voids be filled with desirable vegetation. If not, knapweed will simply recolonize the site or perhaps an even worse weed may colonize the site.

Vegetative suppression is a vital component in the weed control arsenal. A quick review of the knapweed research will indicate:

- **It is important to understand a few biological facts about the knapweed and the species to be used for suppression before implementing a program.**
- **There is no plant species which will suppress a knapweed species on all sites at all times. The "silver bullet plant" simply does not exist.**
- **Suppression species must remove a significant amount of moisture from the soil during periods when knapweeds are most vulnerable, ie. the seedling stage.**
- **Knapweeds severely compete with seedlings of other species and need to be controlled prior to establishing vegetation for suppression.**
- **Vegetative suppression alone will not provide lasting knapweed control. Lasting control requires an integration of chemical control, biological control, proper land management, and vegetative suppression.**

This review relays some information that pertains to the basic biology, distribution, and vegetative suppression of knapweeds.

INTRODUCTION

A 1987 Washington weed survey showed yellow starthistle, spotted, diffuse, and Russian knapweed occupied over 590,000 acres which resulted in an annual loss of grazeable forage valued in excess of $950,000 (Roche and Roche 1988). Knapweeds can reduce biomass production of neighboring plants as much as 90% and also can greatly reduce the species diversity of a site (Watson and Renney 1974, Myers and Berube 1983, Rice et al. 1992, Tyser and Key 1988, Watson 1980)

Knapweed impact is not restricted to only the plant community. Soil loss occurring in a spotted knapweed community was nearly three times the loss occurring on an adjacent grass community in a simulated rainfall experiment (Lacey et al. 1989). Fisheries will be impacted by increased sediments from erosion. Spoon et al. (1983) predicted that 220 head of elk would be lost annually on the Lolo National Forest due to loss of forage caused by knapweed displacement.

Vegetative suppression may entail filling voids left by successful knapweed control or secondly, occupying a site with desirable vegetation before knapweed invades. Unless filled by desirable species, voids created in the plant community by successful knapweed reduction will simply be replaced by another, and possibly more serious weed (Story 1989).

YELLOW STARTHISTLE (*Centaurea solstitialis*)--
Biology: Yellow starthistle is a winter-annual. Seeds germinate in the fall with the onset of fall moisture and grow as a small rosette. Little aboveground growth occurs during the winter but root growth can exceed 4 feet by mid-March (Roche 1989). Yellow starthistle rosettes resume growth early in the spring and the roots utilize stored soil moisture before other species resume growth. Plants bolt in late spring and usually develop a single stem. The stem may branch several times and flowers are borne on the ends. Each flower produces both plumed and plumeless seeds. Plumed seed are primarily wind disbursed and are shed soon after maturity. Plumeless seeds are held longer in the seedhead and are disbursed by mechanical destruction and/or disturbance of the seedhead. Seeds may remain viable in the soil for up to 10 years (Callihan et al. 1993).

Yellow starthistle is utilized by cattle and sheep prior to bolting but can cause chewing disease (Nigropallidal encephalomalacia) in horses (Cordy 1954). Utilization drops considerably after bolting due to low palatability and long, sharp spines on the seed bracts distract livestock grazing.

It is unclear if allelopathy is a major competitive factor (Kelsey and Bedunah 1989).

Geographic and Ecologic Distribution: Yellow starthistle occurred in all 20 eastern Washington counties in 1987 with the exception of Pend Oreille, Douglas, Lincoln, and Grant counties (Roche and Roche 1988). Much of the yellow starthistle acreage is located in the southeastern counties. Northcentral Idaho and northeastern Oregon are also heavily infested with yellow starthistle. Environmental conditions for yellow starthistle appear to reach the optimum in northern California where 7.9 million acres are infested (Maddox 1985).

Yellow starthistle is well adapted to areas with Mediterranean climates - cool, wet winters and hot, dry summers. Mediterranean type climates enable yellow starthistle to grow during the winter months, bolt in the spring, and escape the summer drought.

Seedlings require close to full sunlight to grow. As a result, yellow starthistle is found predominantly on south facing slopes (Roche 1989). Roche and Roche (1991) reported that 55% shading reduced yellow starthistle foliage production 80%.

Yellow starthistle does not perform well on shallow soils because it depletes soil moisture too rapidly to allow for flowering (Roche and Roche 1991). A typical Washington site has deep soils or shallow soils which receive supplemental moisture.

Vegetative Suppression: Successful establishment of desirable vegetation requires control of yellow starthistle prior to seeding. Prather and Callihan (1991) showed that yellow starthistle seedlings were more competitive than pubescent wheatgrass seedlings and were affected little by pubescent wheatgrass density. Greenhouse trials have shown root growth of yellow starthistle far exceeding growth of several other species including a perennial grass (Sheley et al. 1993). Cold soil temperatures encountered in the field would most likely amplify root growth differences since yellow starthistle is well adapted to cold soil. Suppression species must remove a significant amount of moisture in the rooting zone of starthistle seedlings and overlap the active growth period of starthistle in order to be effective (Larson and McInnis 1989).

Established stands of intermediate and pubescent wheatgrass generally provide good to excellent suppression in the northwest. Since neither species exhibits adequate seedling vigor to establish in stands of yellow starthistle as pointed out above, it is important that the starthistle competition be reduced. Unfortunately, both species are very large seeded and are poorly suited for broadcast seeding onto unprepared seedbeds. Removal of too much top growth of either species will enable yellow starthistle to recolonize a site because the shade furnished by the wheatgrass has been removed (Roche, B.F. pers. comm.).

Selection of species for suppression must be based on performance beyond first year results (Larson and McInnis 1989). For example, 'Ephraim' crested wheatgrass provided very good suppression the year of establishment but performed poorly the second year. 'Covar' sheep fescue, a slow establishing species, performed poorly the first year but was relatively free of starthistle the second year. 'Paiute' orchardgrass and 'Critana' thickspike wheatgrass performed similarly both years.

Idaho fescue and orchardgrass provide excellent moisture depletion early in the spring and have been shown to suppress yellow starthistle in trials conducted in southwestern Oregon (Borman et al. 1991, Borman et al. 1992). Both grasses initiate growth early in the spring, remain semiactive during the winter, and mature early in this region.

SPOTTED KNAPWEED (*Centaurea maculosa*)--

Biology: Spotted knapweed is a short-lived perennial that reproduces by seed. Seed disseminated in the fall readily germinates in the spring. A small percentage exhibit primary dormancy and can remain viable in the soil for at least 8 years (Davis et al. 1993). The fast growing taproot enables spotted knapweed to exploit soil moisture and nutrients. The seedlings grow as low growing rosettes which escape grazing and produce carbohydrate reserves for next year's growth. Flowering generally occurs after the first year and occurs each year until death of the plant. Flower heads are borne on the ends of the stems which arise from a single crown.

Early reports showed that spotted knapweed produced an allelopathic compound, cnicin, which inhibited plant growth and seed germination. As a result, allelopathy received considerable attention as an important competitive mechanism. Allelopathy is not a major factor in the competitiveness of spotted knapweed because concentrations of cnicin are too low to be herbicidal (Kelsey and Bedunah 1989). Prolific seed production, rapid seedling establishment, and depletion of soil nutrients are probably much more important competitive factors enjoyed by spotted knapweed. Spotted knapweed's ability to recolonize a site from dormant seed long after herbicides have degraded is another asset enjoyed by this species.

Spotted knapweed tolerates shade poorly and this can reduce its spread. It is also sensitive to several broadleaf herbicides, is readily utilized by sheep, and several insects (bioagents) have provided promising results in the reduction of spotted knapweed.

Geographic and Ecologic Distribution: Spotted knapweed was located in 19 counties in Washington in 1987 (Roche and Roche 1988). West of the Cascades and the arid-interior scablands appear to be the upper and lower climatic limits for spotted knapweed. Most of the spotted knapweed acreage in Washington is located in the Northeast corner of the state.

Disturbed areas such as roadsides, gravel pits, and abandoned cropland are frequently the first areas to be invaded by spotted knapweed. It also readily colonizes pasture and rangeland especially if overgrazing is evident. Overgrazing is not a prerequisite for invasion (Lacey et al. 1990). Spotted knapweed will invade pristine, excellent condition range in the complete absence of livestock grazing (Lacey et al. 1990, Tyser and Key 1988). It is less adapted to forested areas where sunlight is limited but readily invades open areas such as roadsides (Losensky 1989).

Vegetative Suppression: Reseeding knapweed infested sites without implementing a herbicide program to remove knapweed competition has been very ineffective in studies comparing the effects of several management practices (Roche 1991). Reseeding was unnecessary if a remnant stand of desirable grasses was present. Herbicide control of spotted knapweed and proper management of the remnant grasses would be more cost effective than reseeding the site.

Screening plant materials for suppression of spotted knapweed has received little attention. Losensky (1989) stated that a species mix which provides quick establishment and early growth was necessary for preventing spotted knapweed invasion onto disturbed forest roads. Annual wild rye, crested wheatgrass and yellow sweetclover were proposed as potential species. Persistence of these materials is questionable on highly disturbed, low fertility soils.

DIFFUSE KNAPWEED (*Centaurea diffusa*)--

Biology: Diffuse knapweed reproduces by seed and is generally a biennial. It grows as a vegetative rosette the first year and bolts after the rosette has acquired 6 or more leaves (Thompson and Stout 1991). Since vernalizing temperatures are also required, bolting rarely occurs the first year. Seedlings of diffuse knapweed readily emerge when favorable conditions occur in the spring and fall. Seedlings develop into rosettes and maximal root development occurs in this stage (Watson and Renney 1974). After overwintering, a single, many-branched stem develops from the crown. Flowers grow at the end of the branches in the summer and is followed by death of the plant. Dead plants break off at ground level and tumble with the wind, spreading the seed as it rolls (Watson and Renney 1974).

Allelopathy does not appear to be a important factor in diffuse knapweed's competitive ability. The concentrations of cnicin are too low to affect other vegetation (Kelsey and Bedunah 1989). Prolific seed production coupled with "tumble" distribution and high seedling vigor greatly aid in the spread of diffuse knapweed. It is also very adept at depleting soil moisture.

Geographic and Ecologic Distribution: Diffuse knapweed is the most drought tolerant of the four species and is the most widely spread knapweed in Washington. The 1987 weed survey showed diffuse knapweed occurring in 20 counties and occupying over 425,000 acres. Areas of highest occurrence include Stevens, Okanogan, Kittitas, Chelan, Ferry, and Yakima counties (Roche and Roche 1988). Typical habitat subject to diffuse knapweed invasion include disturbed sites such as transportation rights-of-ways, gravel pits, and industrial areas. Semiarid rangeland and dry open forest are subject to invasion especially if vigor of the site is low.

Overgrazing is not a prerequisite for diffuse knapweed invasion (Myers and Berube 1983, Lacey et al. 1990). Diffuse knapweed moved at a rate of 40 feet/year into good condition range in a study conducted in British Columbia (Myers and Berube 1983).

Vegetative Suppression: Diffuse knapweed will readily invade practically any disturbed site in the northwest. However, its competitiveness lies within a narrow moisture range (Berube and Myers 1982). They reported that crested wheatgrass provided very good long-term suppression in a region of British Columbia which receives 6" MAP (Berube and Myers 1982). However, suppression was poor on a site which receives 12" MAP. Fertilization of grass may greatly aid in suppression in areas where moisture conditions are suboptimal for diffuse knapweed (Berube and Myers 1982).

Seedling establishment is the critical period of diffuse knapweed and suppression efforts are most effective during this period. Species which extract moisture in the spring from the top few inches of soil will stress diffuse knapweed seedlings.

RUSSIAN KNAPWEED (*Acroptilon repens*)--
Biology: Russian knapweed is a long-lived perennial which reproduces by seed and creeping horizontal roots. Russian knapweed was originally classified as *Centaurea repens*. It does not share some characteristics common to the *Centaurea* genus and has been placed in the *Acroptilon* genus.

Russian knapweed is a very poor seed producer and germination of Russian knapweed seed rarely occurs in the field (Selleck 1964). Reproduction is primarily accomplished by spreading of horizontal roots. Roots of Russian knapweed may reach 2.5 meters by one year and reach 7 meters by the second year (Watson 1980).

Russian knapweed is extremely competitive and dense patches will totally exclude other vegetation. Plants grow radially and a patch can cover an area of 12 m2 within 2 years. The presence of Russian knapweed in wheat is very detrimental to yield and flour quality. Wheat seed contaminated with even small amounts of will impart a bitter taste to the flour (Watson 1980).

Russian knapweed is allelopathic and can cause chewing disease in horses (Kelsey and Bedunah 1989, Young et al. 1970). The allelopathic compound, cnicin, is contained in the leaves and is released into the soil after leaves fall. Grazing animals generally avoid Russian knapweed due to the bitter taste.

Geographic and Ecologic Distribution: Russian knapweed is native to Eurasia and was introduced to North America as a contaminant of alfalfa seed. It is widely distributed throughout eastern Washington with only Pend Oreille county reporting no Russian knapweed in a survey conducted in 1987 (Roche and Roche 1988). Areas of highest occurrence in 1987 were the Columbia Basin and the Yakima and Okanogan valleys. It is less abundant than the other three major knapweeds in Washington.

Russian knapweed is commonly found on deep soils or soils which receive supplemental moisture. Basin wildrye (Leymus cinereus) appears to be an indicator species for sites susceptible to Russian knapweed invasion (Roche 1990). Russian knapweed is also tolerant of poorly drained and saline/alkaline soils (Roche and Roche 1991). However, it is drought tolerant and will survive on sites that receive as little as 10" MAP (Watson 1980).

Russian knapweed is well adapted to cropland and is a severe problem in dryland crops of the former USSR (Watson 1980). Cultivation can spread root fragments which regenerate new plants and mowing simply stimulates underground buds to replace lost aboveground foliage (Watson 1980, Roche and Roche 1991). Russian knapweed performs poorly in heavily forested areas or dense stands of irrigated alfalfa due to its low tolerance to shading (Roche and Roche 1991).

Vegetative Suppression: Studies have shown that a season of intense cultivation followed by a crop of smooth brome or crested wheatgrass that is sprayed with 2,4-D will eliminate a high percentage of Russian knapweed (Derscheid et al. 1960). However, if either cultivation or 2,4-D were omitted, neither grass provided effective suppression. Cultivation prior to seeding of alfalfa or alfalfa/grass did not give the crop enough advantage to suppress Russian knapweed (Derscheid et al. 1960).

Early emergence, rapid dense growth, and maintenance of high vigor until frost are attributes required by species for suppression of Russian knapweed (Rogers 1928). Few range grasses exhibit these characteristics. Pasture species which provide season-long production are probably better candidates. Trees and shrubs might also be considered.

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SECTION 17.5 Washington State Noxious Weed Lists and Monitor List

An Overview of Washington's Weed List

Each year, the State Noxious Weed Control Board (Board) coordinates and influences noxious weed control activities throughout Washington. The Board adopts, by rule, the state noxious weed list. None of the weeds on the Washington State Noxious Weed List are native to the state. The list determines which plants will be considered a noxious weed and where in Washington control will be required. This approach allows control activities of landowners, public and private, to be prioritized toward the protection and enhancement of Washington's agricultural and natural resources in the most cost-effective manner.

http://www.nwcb.wa.gov/weed_list/weed_listhome.html