TECHNICAL NOTES

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HISTORY, BIOLOGY, ECOLOGY, SUPPRESSION AND REVEGETATION OF RUSSIAN-OLIVE SITES (*Elaeagnus angustifolia* L.)

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- **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 its wildlife 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 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 all 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 used 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.

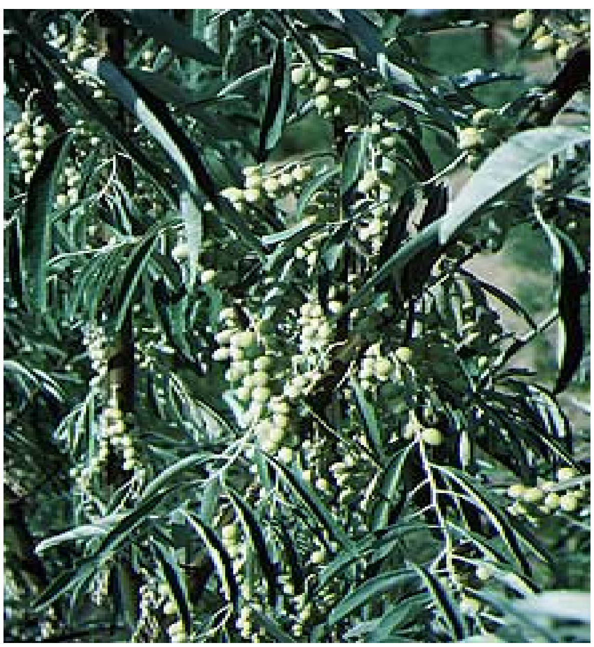
Biology and Ecology

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 non-target 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 as 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.



Russian-olive fruit are readily eaten by birds and mammals. 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 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, and 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 follow-up treatments in most cases. Grasses are preferred over forbs in herbaceous groundcover revegetation if broadleaf herbicides are planned for follow-up 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 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 follow-up 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 and 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 non-target 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.

Advantages: Promoting the growth and recruitment of tall cottonwoods and willows is ecologically desirable.
Disadvantages: 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.

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

Disadvantages: 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 other 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.

Advantages: Reestablishing pastures, especially with a small 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.

Disadvantages: 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 dieback 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.

<u>Advantages</u>: 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.

<u>Disadvantages</u>: 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).

<u>Advantages</u>: 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.

<u>Disadvantages</u>: 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.

<u>Advantages</u>: 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.

<u>Disadvantages</u>: A skilled operator is needed. Follow-up 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 occurs, and complicates reclaiming the site.

Dozing 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 innoculum for adjacent non-contaminated 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 project. 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.

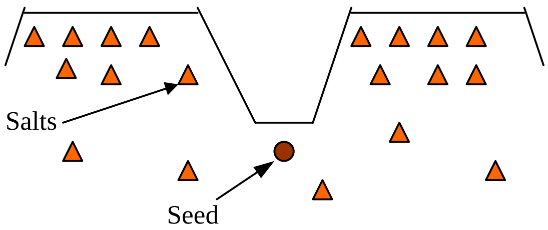
Seedbed preparation must accomplish two critical objectives: (1) control existing vegetation, and (2) allow placement of the seeds at the appropriate depth and ensure good seed-to-soil contact. Wet saline soil is an unfavorable environment for seedling establishment. Coupling this condition with existing 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 secondary and tertiary weed flushes, breakdown organic debris, and improvement 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 non-agronomic 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, follow-up 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 quicker 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 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 follow-up 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‡	Maximum Salinity	Seeds/ Pound	PLS Seeding Rate
				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	orchardgrass	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	orchardgrass	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
Kraschenínnikovia 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.