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Russian Thistle

Management in a Wheat-Fallow Crop Rotation

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Introduction

Russian thistle (*Salsola tragus L.* — synonym of *Salsola kali L.*, *Salsola australis R. Br.* and *Salsola iberica* Sennen & Pau) is the most economically important summer-annual broadleaf weed found in the low-precipitation zone of the inland Pacific Northwest.

Russian thistle infestations on 4.5 million acres cost growers more than $50 million annually in control measures, reduced wheat yield and impacts on wheat quality. This weed causes serious management problems in wheat after the harvest and during summer fallow.

In conventional tillage systems, an average of three rod weedings are typically performed over the course of the fallow year for weed control. Intensive tillage has a range of well-documented negative effects in the region, including dramatically increased wind erosion and soil quality losses, and public health and safety concerns.

No-till farming, also known as direct seeding, has become an important conservation tool in northeastern Oregon and parts of eastern Washington over the last decade. It reduces soil erosion caused by wind and water. In addition, it is potentially cost-effective, as fewer tillage operations not only reduce fuel and labor costs but also improve water infiltration. These benefits are being threatened by the ongoing development of herbicide resistance in Russian thistle.

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Photo: F. L. Young, USDA-ARS

Figure 1. Russian thistle seedlings develop from the fully differentiated, coiled seed, which permits rapid early growth during short periods of favorable growing conditions.

Photo: Judit Barroso, ©Oregon State University

Figure 2. Russian thistle seedling with the two cotyledons (indicated by yellow arrows) and two true leaves.

Russian thistle biology

Russian thistle is an herbaceous annual with a deep, extensive, and water-depleting root system. Stems are multiple to numerous, spreading, curved (arcuate), and often striped with vertical red to purple lines. Plants are 6 inches to 3 feet tall, often growing into a bushy, spherical shape and becoming stiff and spiny at maturity. After senescence, plants often break off at the base of the stem and become tumbleweeds, aided in wind dispersal by their shape and stiff, springy branches.

Russian thistle reproduces only by seed. It is an indeterminate species that flowers and produces seed as long as environmental conditions allow. Russian thistle uses an efficient carbon-fixation pathway, resulting in high water-use efficiency that contributes to its drought tolerance and competitive ability in warm, moisture-limited conditions. Roots can grow to a depth of 5 feet and have a lateral spread of up to 6 feet.

Seed germination and emergence

Russian thistle does not produce a true seed with endosperm. Instead, the seed is a coiled, fully differentiated seedling in the form of a spiral helix (Figure 1). Germination consists of uncoiling and can be quite rapid — on the order of hours under favorable conditions. After a short, internally controlled, after-ripening period, germination can occur under a wide range of soil moisture and temperature conditions. This after-ripening requirement helps ensure that seeds do not germinate under typical early autumn conditions in the Pacific Northwest but are ready for spring germination.

Optimal temperatures for Russian thistle germination range from 45°F to 95°F. Seeds can germinate under cooler conditions when nighttime temperatures are below freezing and daytime temperatures are above freezing. However, young seedlings (Figure 2) are very susceptible to frost. Seedlings can commonly be seen under Russian thistle plants of the previous year. Emergence typically begins in late March or early April, extending through the summer if sufficient precipitation occurs.

Russian thistle seeds require only a short moist period to germinate rapidly and emerge from the soil. It can emerge in significant numbers after very light rains (about 0.1 inch) on dry soil (Figure 3). Another factor affecting Russian thistle establishment is seed depth in soil (Figure 4, page 3). Emergence is optimal at depths less than 1 inch, although some seedlings can emerge from depths of 3 inches under favorable conditions. Russian thistle establishment can be limited by compacted soils. The

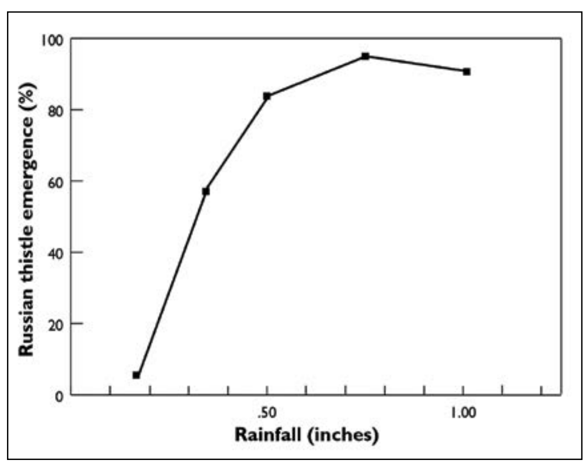

Figure 3. Russian thistle emergence with increasing amounts of rainfall.

Source: Dwyer D.D. and Wolde-Yohannis K. 1972. Germination, emergence, water use and production of Russian thistle. *Agronomy Journal* 64: 52-55

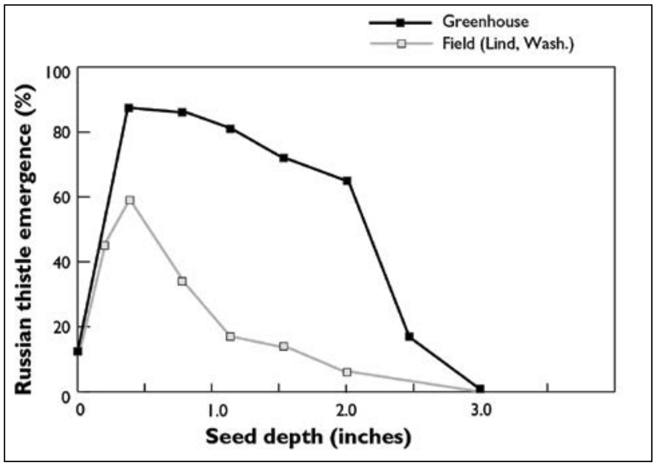

Figure 4. Russian thistle emergence from seeds buried at increasing depths in sandy loam soil compacted to a bulk density similar to that of a planted field.

Source of greenhouse data: Evans R.E. and Young J.A. 1972. Germination and establishment of *Salsola* in relation to seedbed environment – II. Seed distribution, germination, and seedling growth of *Salsola* and microenvironmental monitoring of the seedbed. *Agronomy Journal* 64: 219-224). Source of field data from Lind, WA. (Young F.L. 1982. Unpublished data

roots cannot effectively penetrate compacted soil as the coiled embryo unwinds during germination. In addition, shoot emergence can be restricted by crusted surface soil, even if seeds are buried shallowly. However, seedlings can emerge through cracks in the soil surface.

Seed dormancy and longevity

In the Great Plains, Russian thistle seed longevity has been found to be only one year for most of the seeds in the two locations studied. Under irrigated conditions at Prosser, Washington, about 99% of Russian thistle seeds either germinated the first year or died before germinating. Research has been initiated to confirm the short seed life in soils and environmental conditions in the dryland production regions of the inland Pacific Northwest. Russian thistle seed is soft and porous, and that likely contributes to its lack of longevity and ability to germinate rapidly.

Seedling establishment and the influence of soil disturbance and mycorrhizal fungi

Russian thistle seedlings establish best in disturbed and eroded soils, including cropland and areas adjacent to roads. Disturbed and cultivated soils generally have reduced populations of mycorrhizal fungi. While most plants can establish relationships with these mycorrhizal fungi, some plants, like Russian thistle, do not.

In fact, Russian thistle root tissue dies where these fungi attempt to enter root tissue (Figure 5). Intact rangelands maintain higher fungal populations and lower Russian thistle populations, reducing Russian thistle movement from rangeland to cropland.

Plant development

Russian thistle usually remains small when growing in a competitive winter wheat crop but grows rapidly immediately after wheat harvest. Russian thistles grow larger in a less competitive crop, such as spring wheat, or in low-density stands of winter wheat, particularly under drought conditions.

Flowering begins in midsummer with pollination primarily occurring by wind and seed produced both via self- and cross-pollination (Figures 6a and 6b, page 4). There is evidence that some insect pollination may also occur, based on the high diversity and number of insects observed on plants.

Flowering increases greatly after harvest, when about 90% of Russian thistle growth and most of the seed set commonly occur. Russian thistles can regrow quickly

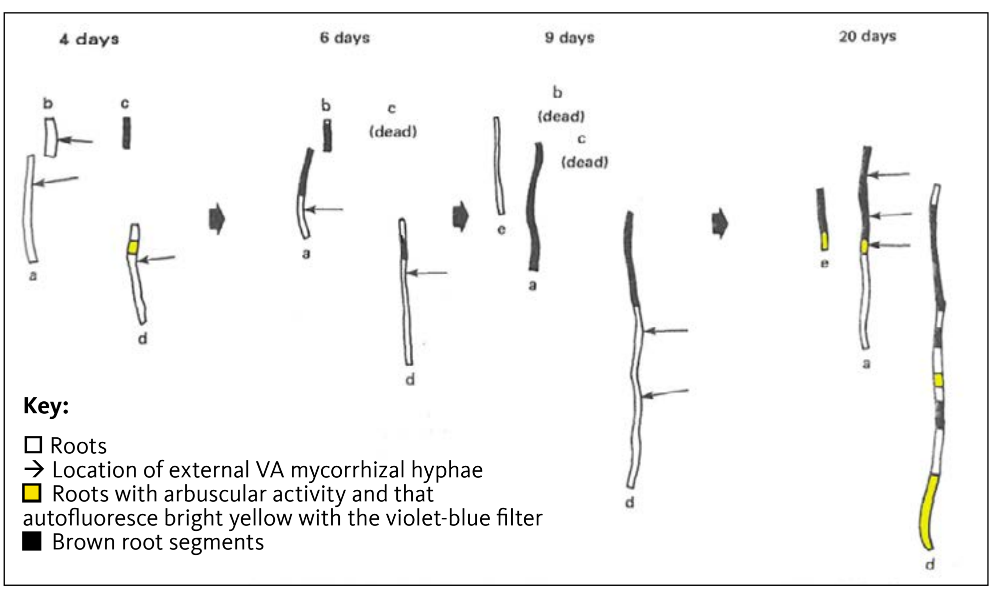

Figure 5. Root maps of an individual *Salsola kali* seedling. The maps are from four, six, nine, and 20 days following seed germination with the spatial locations designated to directly overlap. Specific roots are labeled with letters so that changes with time can be observed.

Source: Allen M.F., Allen E.B., and Friese C.F. 1988. Responses of the non-mycotrophic plant *Salsola kali* to invasion by vesicular-arbuscular mycorrhizal fungi. *New Phytologist* 111: 45-49.

after harvest, extracting soil water that was unavailable to wheat, even though their top portions are cut and removed by the combine (Figure 7).

Seed production

Uncontrolled Russian thistle plants in fallow produce about 150,000 seeds per plant. Seeds from uncontrolled plants in winter wheat and spring wheat are about 4,500 and 17,000 per plant, respectively.

Preliminary work on Russian thistle seed production after spring wheat in the Pacific Northwest showed significant year-to-year variability, but no viable seed is produced before the second week of September. Viable seed production is stopped by the first killing frost, which usually occurs sometime in October.

Seed dispersal

Due to a special layer of cells where the stem joins the roots, mature Russian thistle plants break at ground level and disperse seeds when the plant tumbles in the wind. Researchers found that over six weeks in early fall, Russian thistle plants traveled on average 0.6 to 1.9 miles.

However, they can travel greater distances before accumulating in ditches or becoming lodged in crop stubble, fences or other obstacles. About 60% of each plant's seeds are dispersed by tumbling, while remaining seeds stay attached to the mother plant or are dispersed nearby.

Plant diversity

Russian thistle is known to be highly variable morphologically (Figure 8, page 5). Several subspecies (races) may be recognized within *S. tragus* (Figures 9a and 9b, page 6). In a preliminary screening of plants

Photo: Judit Barroso, © Oregon State University

Figure 7. Regrowth of Russian thistle plants after harvest.

collected throughout eastern Washington and northeast Oregon, only a single species (*Salsola tragus*) with a high level of genetic diversity and no population structure or subdivision was found.

No studies have evaluated a potential different response of the phenotypic and genetic diversity in Russian thistle populations to herbicide treatments.

Impacts and crop competition

The largest impact of Russian thistle in wheat crops is direct yield loss resulting from competition for soil moisture. Years with low moisture have greater yield reduction than years with higher precipitation — likely

Photos: Judit Barroso, © Oregon State University

Figures 6a (left) and 6b (right). Flowering stage of Russian thistle.

due to Russian thistle's ability to outcompete wheat under dry, hot conditions.

Healthy stands of winter wheat compete effectively with Russian thistle, and severe infestations often occur when winter wheat stands are poor or plants are stressed as a result of winter kill, disease or drought. In contrast, spring cereals are highly susceptible to infestation and often suffer severe reductions in yield — up to 50% in heavy infestations. In a study conducted at Lind, Washington, in 1982 and 1983, the dry weight of Russian thistle plants grown in winter wheat was 75% less than plants grown in spring wheat and 98% less than plants grown in fallow with no weed or crop competition (Figure 10, page 6).

Winter wheat reduced Russian thistle emergence 44%, seedling survival 42%, and seed production 74% compared with spring wheat. Even though spring wheat is less competitive against Russian thistle than winter wheat, management practices that increase spring wheat's competitiveness can help suppress the weed. A 1983-85 study in Lind, Washington, revealed the importance of early spring wheat establishment (Table 1). Although Russian thistle density was highest in 1984, wheat yield loss was much lower than in 1983 or 1985. This can be partially attributed to seeding the spring wheat one week earlier in 1984 and to spring wheat emergence two weeks ahead of Russian thistle, compared with one week ahead in 1983 and 1985. Although weed densities were similar in 1983 and 1985, Russian thistle was much more competitive in 1985 when rainfall was low.

Russian thistle infestations can also result in dockage due to contamination of grain or elevated grain moisture levels (its foliage is green at harvest), as well as reduced harvest efficiency. Uncontrolled plants will resume growth after harvest, resulting in substantial biomass accumulation due to a lack of crop competition. These plants might interfere with later tillage or seeding operations. It has been estimated that individual plants use approximately 18 gallons of soil water while growing in spring wheat, and an additional 26 gallons of soil water for post-harvest growth.

Control and management

Management and control of Russian thistle in wheat-fallow cropping systems can be divided into three distinct periods over the course of the crop rotation:

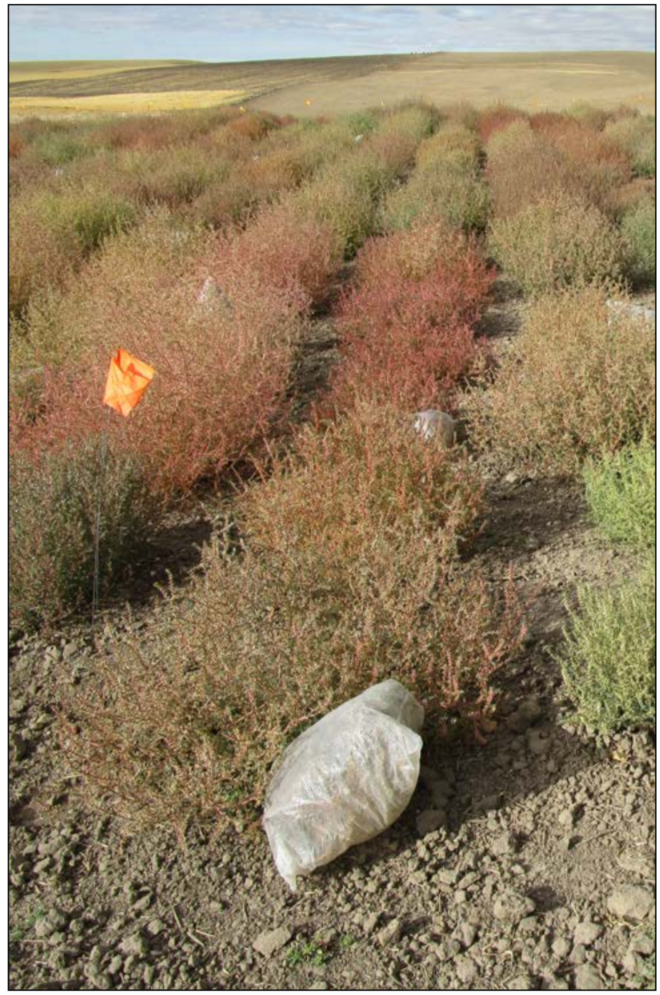

Photo: J. Spring © Washington State University

Figure 8. Phenotypic diversity of Russian thistle in a common garden in Pullman, Washington.

Table 1. Spring wheat yield losses from Russian thistle competition, 1983-85 WSU Dryland Research Unit, Lind, WA.

Year	Russian thistle density (plants/sq ft)	Seeding date	Wheat emergence ahead of Russian thistle	March–June rainfall (inches)	Wheat yield loss (%)
1983	5	March 18	1 week	3.9	31
1984	10	March 9	2 week	5.5	11
1985	4	March 15	1 week	1.8	55

Source: Young, F.L. 1988. Effect of Russian thistle (*Salsola iberica*) interference on spring wheat. *Weed Science* 36: 594-598.

Photos: Judit Barroso, © Oregon State University

Figures 9a (left) and 9b (right). Two variant plant architectures of Russian thistle.

in-crop, the time between wheat harvest and killing frost (post-harvest), and the fallow year.

In-crop control

In the wheat crop, the most effective management practice is ensuring a competitive crop. Healthy winter wheat stands provide effective control through competitive suppression. Timely planting, adequate crop densities, narrow row spacing, and agronomic practices that promote a vigorous crop stand can improve competitive suppression of Russian thistle in spring wheat as well. Multiple herbicides with various degrees of effectiveness and cost are available for in-crop control (some are indicated in Table 2, page 7). See the product labels and the current PNW Weed Management Handbook (https://pnwhandbooks.org/weed) for specific herbicide recommendations. Most recommended herbicides control Russian thistle best when applied to small plants 2 inches or shorter.

Post-harvest control

Russian thistle control is recommended within two weeks following grain harvest to minimize water use and seed production.

Noninversion tillage with wide, overlapping sweep blades (undercutter) that cut Russian thistle roots while leaving surface crop residue largely intact can halt plant growth and prevent most seed production. Although Extension agents have actively promoted use of the undercutter implement in the region, adoption has been

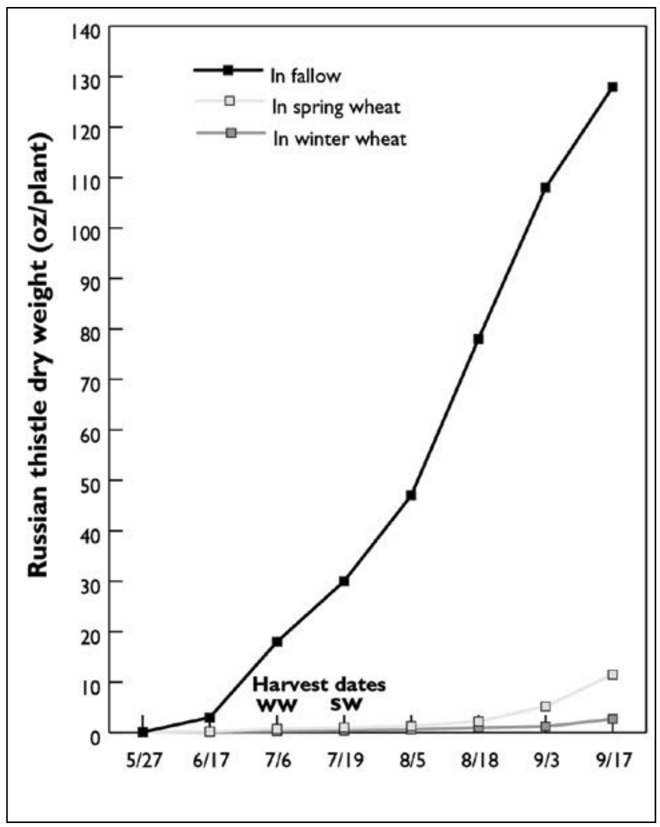

Figure 10. Russian thistle growth in fallow, in spring wheat, and in winter wheat at Lind, Washington. Winter and spring wheats were harvested on July 6 and July 19, respectively.

Source: Young, F.L. 1986. Russian thistle (*Salsola iberica*) growth and development in wheat. *Weed Science* 34: 901-905.

Table 2. Some of the post-emergence herbicides available to control Russian thistle in wheat in Idaho, Oregon, and Washington.

Common name (active ingredient/s)	Group	Commercial name	Manufacturer
Bromoxynil	6	Brox® 2EC, Moxy® 2E	Albaugh LLC, WinField United
Bromoxynil + bicyclopyrone	6+27	Talinor™	Syngenta Crop Protection LLC
Bromoxynil + MCPA	6+4	Bromac® Advanced	Loveland Products Inc
Bromoxynil + pyrasulfotole	6+27	Huskie®	Bayer CropScience
Bromoxynil + fluroxypyr	6+4	Starane® NXT	Dow AgroSciences LLC
Bromoxynil + 2,4-D	6+4	Deadbolt®[1], Maestro® D	Wilbur-Ellis Company LLC, Nufarm Agricultural Products
Clopyralid + fluroxypyr	4+4	WideMatch®	Dow AgroSciences LLC
Clopyralid + 2,4-D	4+4	Curtail®	Dow AgroSciences LLC
Carfentrazone	14	Aim® EC	FMC Corporation
Dicamba	4	Banvel®, Clarifier®, Clarity®, Dicamba XP, Rifle®, etc.	Arysta LifeScience LLC, WinField United, BASF Ag Products, Dupont Crop Protection, Loveland Products Inc
2,4-D	4	2,4 – D LV 6	Albaugh LLC/Agri Star
2,4-D + bromoxynil + fluroxypyr	4+6+4	Kochiavore™	WinField United
Fluroxypyr	4	Starane® Ultra	Dow AgroSciences LLC
Metribuzin	5	Dimetric® DF 75	WinField United

The source of this information is from multiple field trials conducted at the Columbia Basin Agricultural Research Center during 2017 and 2018 and the PNW Weed Management Handbook. Notes: Read the product labels for application rates, application times and other requirements. Group 2 herbicides are not listed because Russian thistle biotypes resistant to that mode of action are very common in the Pacific Northwest.
[1] This herbicide is not available in Idaho.

limited. A number of growers adopted and continue to use undercutters, but the majority of growers that choose tillage for post-harvest control use a heavy double-disk or achieve weed control as a secondary outcome of fall fertilizing using an applicator with straight shanks and cultivator points.

Dislodged by tillage, killed Russian thistle plants are typically moved out of the field by wind, and although they do not contain viable seed at this time, the resulting loss of residue is a possible soil conservation concern in extremely low-residue situations.

When chemical control is selected, a 2017 survey conducted with 27 growers from Gilliam, Morrow, Umatilla, and Union counties in northeastern Oregon found that 57% of the growers used glyphosate as the only herbicide, 14% used glyphosate in a tank mix with other herbicides, and 29% used paraquat as the only herbicide to manage Russian thistle.

The use of paraquat for post-harvest control has recently increased with the discovery of glyphosate-resistant biotypes of Russian thistle (see Herbicide resistance section on page 8).

Paraquat is a restricted-use herbicide that requires personal protective equipment while tank mixing. Read the label for required protective equipment and know the symptoms of paraquat exposure. Application of paraquat also requires a well-sealed, enclosed cab vehicle with an air filtration system set to recirculate the cab air.

Under good application and environmental conditions, chemical control, particularly with paraquat, is as effective as tillage. But often poor application conditions (large, dusty, and moisture-stressed plants) and herbicide-resistant plants can make chemical control inconsistent. Even though biomass accumulation and soil moisture consumption are limited with herbicide use, in many cases some viable Russian thistle seed is produced.

Control in the fallow year

In the fallow year, broadleaf weed control (of which Russian thistle is generally the largest component) can be conducted with tillage, herbicides or a combination of both. A conventional, tillage-based fallow system will have an early season primary tillage with a heavy double-disk or sweep plow and two or more secondary tillage operations with a rod weeder throughout the season.

Many growers now use lighter primary tillage and most substitute a nonselective herbicide application (typically glyphosate) for at least some of the traditional secondary tillage, in what is known as a reduced tillage fallow system. A no-till or chemical fallow system will rely solely on herbicides for weed control. In 2018, a research study with residual herbicides applied at different times (late November, mid-March, or both in a split application using half rate each time) showed that there are several herbicide options to rotate with, including sulfentrazone (Spartan® Charge), flumioxazin + pyroxasulfone (Fierce®), or metribuzin (several trade names available). These options can provide residual control of Russian thistle and reduce the need for additional post-emergence herbicides or tillage (or both) during summer fallow (Figure 11). Adequate precipitation following application of these herbicides is required to achieve acceptable control. According to the Spartan Charge herbicide label, the length of residual control will increase in basic (pH greater than 7), coarse, and low-organic-matter soils. The soil indicated in Figure 11 had a pH of 5.4, a silt-loam texture (65% silt, 27% sand, and 8% clay), and an organic matter of 1.8% as an average of soil samples taken at three different depths: 0–4 inches, 4–8 inches and 8–12 inches.

Commercial spot-spraying systems that regulate individual nozzles based on the presence of green plant tissue in the spray path can help reduce herbicide use during the fallow and post-harvest periods. These systems maintain levels of control equivalent to broadcast application in controlled field trials. The main disadvantage of these systems is that their initial cost is prohibitively high for many growers. However, these application systems may allow the use of herbicides that have been too expensive for many growers to use as a broadcast application in fallow.

Herbicide resistance

Russian thistle control improved in the 1980s with registration of sulfonylurea (Group 2, ALS inhibitors) herbicides. However, repeated and widespread use of these products set the stage for development of a significant resistance problem. By 1992, resistance to Group 2 herbicides had spread to 75% of Russian thistle populations in farm fields of the inland Pacific Northwest.

Results from 2017 dose-response studies confirmed glyphosate (Group 9; EPSP synthase inhibitors) resistance in three of 10 Russian thistle populations collected from Oregon. The same outcome was validated for one population from Montana and another from Washington.

Ongoing development of glyphosate resistance highlights the need to diversify Russian thistle control

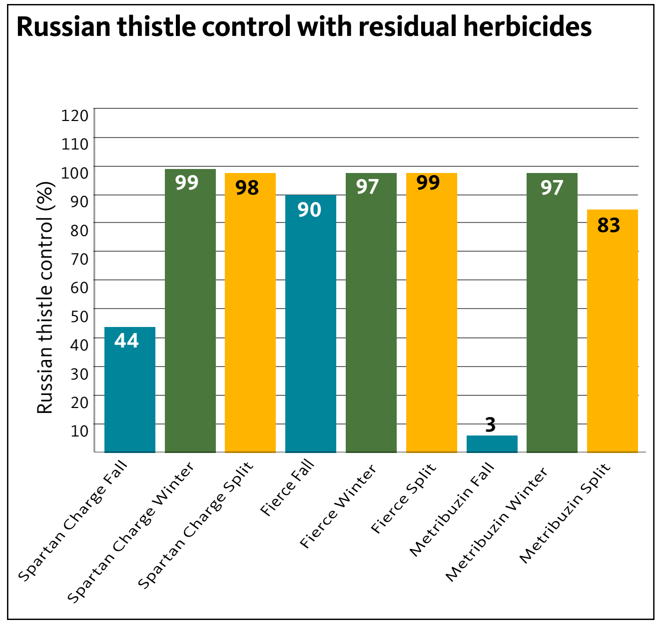

Chart: Judit Barroso, Oregon State University

Figure 11. Russian thistle control with residual herbicides in fallow applied at different times (Fall=Nov. 16, Winter=March 12, Split=using the same total rate but evenly split between late fall and late winter applications) at the Columbia Basin Agricultural Research Station in 2018. Spartan® Charge was applied at 8 fl oz/acre, Fierce® at 4.5 oz/acre and Metribuzin 75 at 10.5 oz/acre. The average Russian thistle infestation in the control plots was one plant per square foot.

strategies. The failure to do so will threaten the sustainability of semi-arid cropping systems of the Pacific Northwest. For more information on preventing and controlling herbicide-resistant weeds, see *Herbicide-Resistant Weeds and Their Management (*PNW 437).

Tips for Russian thistle control in a wheat-fallow cropping system

Management strategies for Russian thistle that focus on preventing seed production throughout the wheat-fallow rotation can reduce a serious Russian thistle infestation to a manageable one.

The major weak points in the Russian thistle life cycle are its short seed longevity and the lack of seedling vigor and competitiveness. Preventing seed production and controlling plants while they are small are the keys to effective control of Russian thistle.

Management in the crop year

- **Seed winter wheat rather than spring wheat if possible.** Winter wheat is more competitive and will help reduce Russian thistle emergence, survival, growth and seed production.
- **If a spring cereal has to be planted, barley is preferable over spring wheat because it is more competitive with Russian thistle than**

spring wheat. For spring crops, use management practices that optimize competition with Russian thistle, such as:

- ❑ Seeding early (late February, early March) so the crop emerges at least two to three weeks before the weed.
- ❑ Seeding as shallowly as possible to encourage rapid crop emergence.
- ❑ Placing fertilizer below and near seed rows for early wheat root access and vigorous crop growth.
- ❑ Spacing rows narrowly (6–7 inches) to increase crop competition.

- ■ **Use broadleaf herbicides to control Russian thistle in crop.** A tank mix of herbicides with different modes of action can reduce populations and the development of herbicide resistance, but only if all partners in the herbicide mix are effective at controlling Russian thistle. Apply herbicides in spots where Russian thistle may concentrate, such as drill skips, winter-killed areas, and draws where wind-blown Russian thistle plants collect. Herbicides should be applied before the Russian thistle plants exceed 2–3 inches in height. The first Russian thistle plants to emerge will be the most competitive. The goal is to kill or suppress Russian thistle to minimize competition with the crop, improve harvest efficiency, and reduce the potential for seed production later in the season. Complete control is not required. Lower-cost treatments may be adequate as long as they provide a reasonable level of control. However, in a severe Russian thistle infestation, it may be more effective to strive for optimal control rather than suppression. Herbicides containing bromoxynil work well to control Russian thistle in early stages of growth.
- ■ **Consider a preharvest herbicide application if Russian thistles were not controlled effectively early in the growing season.** Russian thistle will already have competed with the crop, but seed production can be reduced greatly, and soil water conserved for the following crop. A preharvest application of 2,4-D, carfentrazone (Aim® EC), dicamba + 2,4-D, glyphosate, or saflufenacil (Sharpen®) often controls Russian thistle better than post-harvest applications. A preharvest treatment can:

- ❑ Save time at harvest and improve efficiency.
- ❑ Reduce Russian thistle size, seed production and soil water use.
- ❑ Eliminate the need for post-harvest tillage for Russian thistle control or at least the need for intensive tillage to manage Russian thistle residue.

Management in the fallow year, beginning after harvest

- ■ **Consider a post-harvest application if in-crop and preharvest applications were not used or were not effective.** Herbicides should be applied within two weeks after harvest to minimize Russian thistle water use and seed production.
- ■ **If a post-harvest herbicide is not applied, consider tillage within two weeks after harvest to minimize water use, seed set, and spread of large plants in the wind.** Tillage with a sweep or wide-blade undercutter can kill Russian thistle without excessive loss of surface residue.
- ■ **In spring, alternate Russian thistle control practices among years and herbicides when possible.** A delay of the first spring tillage until after the first heavy flush of Russian thistle seedling emergence will reduce soil erosion and potentially the number of subsequent rod weeding passes. Avoid excessive tillage that reduces surface residue and roughness to prevent soil erosion and favor water infiltration. Research has shown that operating rod weeders at 4 inches causes less pulverization of soil clods than operating at 2 inches. Consider using soil-residual herbicides to rotate with post-emergence herbicides to prevent the selection of herbicide-resistant biotypes.

Management in field borders and roadways

Control Russian thistle along field borders, roadways and other noncropped areas to prevent introduction or reinfestation of the weed. Because of the high mobility of Russian thistle plants and their seed distribution, an areawide Russian thistle control strategy, including cooperation by neighboring upwind producers, could help control the weed.

Roadside management can be enhanced by fostering a perennial plant community adjacent to roads. Perennial plants have strong associations with the mycorrhizal fungi, and high populations of these fungi can kill roots of establishing Russian thistle seedlings. Roadside management of Russian thistle can help reduce movement from roads into cropland. Russian thistle herbicides registered for roadsides are listed in the *PNW Weed Management Handbook* (https://pnwhandbooks.org/weed/non-cropland-right-way/vegetation-control).

Future research that can help with Russian thistle control

- ■ Russian thistle plants have a high potential to move with the wind and spread seed over large distances due to their rounded shape and the brittle stem-root junction at maturity. A few plants that are not completely killed can regrow to produce seeds, which are dispersed downwind as the plants tumble across fields. Therefore, it may only take a few plants per acre each year to maintain an infestation, even on fields and farms where Russian thistle was not present the previous year. Research on agronomic practices that prevent Russian thistle from moving and dispersing seed (such as stubble height or stubble management) is a critical component of new approaches to improve Russian thistle management.

- Research on community-based efforts among growers and public entities to control Russian thistle and Russian thistle movement could be evaluated as a more integrated approach to improve agricultural sustainability in the Pacific Northwest.
- In addition, improved knowledge of the spatial dynamics of this species might help delay the spread of glyphosate resistance and provide new perspectives on potential integrated weed management practices.

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