Weed Technology 2008 22:156–159

Postharvest Control of Russian thistle (*Salsola tragus*) with a Reduced Herbicide Applicator in the Pacific Northwest

Frank L. Young, Joseph P. Yenish, Glenn K. Launchbaugh, Larry L. McGrew, and J. Richard Alldredge*

Russian thistle is a severe problem in fields after crop harvest in the Pacific Northwest (PNW) and is controlled either by tillage or broadcast applications of various herbicides. A study was conducted in Washington in 2000 and 2001 at four sites to compare the efficacy of two herbicide treatments applied with a light-activated, sensor-controlled (LASC) sprayer and a conventional broadcast sprayer for postharvest Russian thistle control. Additionally, simple economic comparisons, excluding fixed costs, were made among herbicide treatments and application methods. Both herbicide applicators controlled Russian thistle similarly within each herbicide treatment. Weed control was unacceptable ($\leq$ 75%) when glyphosate plus 2,4-D was applied with either applicator. In contrast, Russian thistle control was $>$ 90% with paraquat plus diuron regardless of applicator. The overall reduction in chemical use was 42% with the LASC compared with the broadcast applicator when averaged over the four sites. Herbicide and surfactant cost savings, using 2007 prices for the LASC compared with the broadcast applicator, ranged from $6.68/ha to $18.21/ha with the paraquat plus diuron treatment and averaged $13.27/ha less for the four sites. The use of the LASC for postharvest Russian thistle control can reduce growers' input costs, increase growers' profits, and improve environmental quality by reducing the amount and area of a restricted-use chemical.

Nomenclature: Glyphosate; 2,4-D; paraquat; diuron; Russian thistle, *Salsola tragus* L.
Key words: Chemical fallow.

Russian thistle infests an estimated 41 million ha in the arid and semiarid regions of the western United States (Young 1991). This weed is a particular problem in the Pacific Northwest (PNW) where it infests about 1.8 million ha of cropland and costs growers more than $50 million annually in control measures, reduced crop yield, and inferior crop quality (Young 2006). In the low- and intermediate-rainfall zones, where winter wheat (*Triticum aestivum* L.) fallow is the major crop rotation, Russian thistle is the major pest preventing growers from adopting or adapting alternative broadleaf crops, such as canola and mustard (*Brassica* spp.) and dry pea (*Pisum sativum* L.) into their rotation (Young 2006).

Generally, an excellent stand of winter wheat will reduce the germination, emergence, and establishment of Russian thistle (Young 1986). However, in the PNW, grower interest in no-till, spring cropping systems has increased because of winter annual grass weed infestations and severe wind erosion that plague the winter wheat–fallow system (Young and Thorne 2004). In comparison to winter wheat, spring wheat competes poorly with Russian thistle, and this poor competition is reflected in dramatic growth of Russian thistle after spring wheat harvest (Young 1986). During the spring wheat growing season, Russian thistle can reduce crop yield more than 50% (Young 1988) and reduce soil moisture by 70 L/plant (Schillinger and Young 2000). Russian thistle populations have developed that are resistant to sulfonylurea herbicides (Stallings et al. 1994), resulting in no effective herbicides to provide season-long control in PNW cropping systems, especially if growers want to produce alternative crops. Because Russian thistle can germinate, emerge, and establish through June after light showers (Young 1986, Young et al. 1995), it can reinfest fields previously sprayed with foliar herbicides without residual activity. These weeds continue to grow, depleting the soil of moisture, with the plant carcasses eventually becoming a physical problem after crop harvest. Until recently, researchers showed that Russian thistle populations would continue to increase in no-till cropping systems (Anderson et al. 1998; Blackshaw et al. 1994). However, a recently concluded study (Young and Thorne 2004) has suggested that Russian thistle can be managed in spring cereals, although a very intensive management program, including postharvest control, was required to reduce the populations. If Russian thistle is allowed to grow following wheat harvest, large quantities of seed will be produced (Young 1986; Schillinger and Young 2000), and more than 100 L/plant of soil moisture are depleted from the soil, which can prohibit crop production in the following crop year (Schillinger and Young 2000). Major benefits of postharvest control of Russian thistle include soil moisture conservation and reduced seed bank.

Postharvest control of Russian thistle in the PNW is generally accomplished by tillage or broadcast applications of nonselective herbicides (Young and Whitesides 1987). Controlling Russian thistle in the PNW with weed-sensing technology appears to be an ideal opportunity. The brown/gold background color of the soil and wheat stubble, combined with the brilliant green of the Russian thistle foliage, allows for easy calibration of the sensor. This technology has been used previously to reduce pesticide costs and control weeds in summer fallow (Blackshaw et al. 1998; Ahrens 1994) and in row crops (Hanks and Beck 1998). The

DOI: 10.1614/WT-07-096.1

* First, third, and fourth authors: Research Agronomist, former Biological Science Technician, and Biological Science Technician, U.S. Department of Agriculture–Agricultural Research Service, Department of Crop and Soil Sciences, Washington State University, P.O. Box 646420, Pullman, WA 99164-6420; second author, Associate Professor, Department of Crop and Soil Sciences, Washington State University, P.O. Box 646420, Pullman, WA 99164-6420; fifth author, Professor, Department of Statistics, Washington State University, P.O. Box 643144, Pullman, WA 99164-3144. Corresponding author's E-mail: youngfl@wsu.edu

Table 1. Description of Russian thistle plants at time of application at Ralston, WA, in 2000 and 2001.

	2000		2001	
Plant information	Site 1	Site 2	Site 3	Site 4
Height (cm)	18	40	21	22
Diameter (cm)	< 30	> 30	< 30	15 to > 30
Density (no/m^2)	25	3	5	3

operation of our particular light-activated, sensor-controlled (LASC) has been described in detail by Hanks and Beck (1998), and before their use in row crops, it was used for weed control primarily in orchards and vineyards (Hanks and Beck 1998). No research has been reported with LASC technology for postharvest Russian thistle control.

The objective of this study was to evaluate an LASC herbicide applicator for efficacy and subsequent reduction in chemical dose per area for postharvest Russian thistle control compared with a conventional broadcast applicator.

Materials and Methods

A 2-yr study was conducted at Ralston, WA, in 2000 and 2001 to evaluate postharvest Russian thistle control with the LASC (Weed Seeker™ model PhD 600).[1] Treatments were established in spring wheat stubble in late August of both years, on a Ritzville silt loam (coarse-silty, mixed mesic, Calcidic Haploxeroll) with 2% organic matter. Soil texture was 30% sand, 62% silt, and 8% clay. Each year, plots were established in two separate but adjacent areas based on Russian thistle diameter, for a total of 4 yr-by-site experiments (Table 1). Russian thistle plant heights were measured, and density was counted. Plots were 4.5 m wide and 30 m long.

Treatments included either a tank mix of glyphosate (0.84 kg ae/ha) plus 2,4-D amine (0.14 kg ae/ha) or a commercial premix of paraquat (0.56 kg ai/ha) plus diuron (0.28 kg ai/ha). A nonionic surfactant (NIS) was added to each treatment at 0.5% v/v. Herbicide treatments were applied with either a conventional broadcast sprayer or the LASC sprayer. Both sprayers were tractor-mounted with 4.5-m-wide booms, and nozzles were spaced 50 cm apart for the broadcast sprayer and 30 cm apart for the LASC sprayer. Sprayers were calibrated (speed, pressure, nozzle type) to apply, as close as possible, the same volume of spray solution for each experiment for each year. In 2000, the broadcast and LASC sprayers were calibrated to deliver 187 L/ha at 240 kPa and 187 L/ha at 265 kPa, respectively. In 2001, the broadcast and LASC sprayers were calibrated to deliver 187 L/ha at 240 kPa and 205 L/ha at 275 kPa, respectively. Differences in calibrated delivery for the LASC sprayer between years were because of difficulty getting the identical pressure between the 2 yr and slight (> 10%) differences in tractor speed due to soil conditions, slope, and other physical factors. A nontreated control was included in the study.

The LASC operates on the concept of differences in spectral characteristics of soil and of chlorophyll in plants to detect weeds and, therefore, applies herbicides only to an area with weeds present. In our equipment setup, the control box and two 11.3-L water tanks were mounted on the boom. The spray system pressure was provided by regulated CO_2, and electronics were operated from the tractor battery.

Four weeks after herbicide application, Russian thistle control was visually evaluated on a scale of 0%, no weed control, to 100%, complete weed control (Frans et al. 1986), by comparison to the nontreated plots. For each site and year, the herbicide mixture was measured before the initial plot was sprayed and again after each subsequent plot for both sprayers. Based on the amount of spray solution used compared with each sprayer's calibrated output for the plot area, simple comparison economics, excluding fixed costs, determined the herbicide cost of each treatment for each sprayer. The current year's (2007) cost of materials (herbicides and surfactants) was used, with no equipment costs listed.

The experimental design was a randomized complete block with each treatment replicated four times at both sites each year. Visual estimates of Russian thistle control from individual experiments were rank-transformed (Conover 1980) before statistical analysis and then subjected to ANOVA procedures using the MIXED procedure in SAS (SAS 1999). Mean comparisons were made with the Bonferroni method for simultaneous comparisons (Dean and Voss 1999).

Results and Discussion

In this study, Russian thistle was the most dominant weed species at all sites during both years. Postharvest Russian thistle infestations will vary in plant size and population density, depending on location in the field, in-crop herbicides

Table 2. Control of Russian thistle with LASC and broadcast sprayers and two herbicide treatments 4 weeks after treatment at Ralston, WA, in 2000 and 2001.[a]

		2000		2001	
Herbicide[b]		Site 1	Site 2	Site 3	Site 4
		%[c]			
Glyphosate + 2,4-D + NIS	LASC	73 b	63 b	51 b	34 b
	Broadcast	75 b	58 b	45 b	43 b
Paraquat + diuron + NIS	LASC	92 ab	99 a	97 a	99 a
	Broadcast	94 a	98 a	98 a	99 a

[a] Abbreviations: NIS, nonionic surfactant; LASC, light-activated, sensor-controlled (LASC).

[b] Glyphosate + 2,4-D was applied at 0.84 + 0.14 kg ae/ha; paraquat + diuron was applied at 0.56 + 0.28 kg ai/ha, respectively.

[c] Means within a column followed by the same letters are not significantly different.

Table 3. Comparison of herbicide quantity[a] and herbicide plus NIS costs[b] for the LASC and broadcast sprayer application of two herbicide treatments at Ralston, WA, in 2000 and 2001.[c]

		2000				2001			
		Site 1		Site 2		Site 3		Site 4	
Herbicide[d]	Sprayer	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
		%	$/ha	%	$/ha	%	$/ha	%	$/ha
Glyphosate + 2,4-D + NIS	LASC	43	6.47	84	12.63	51	8.23	56	9.03
	Broadcast	100	15.04	100	15.04	100	16.14	100	16.14
Paraquat + diuron + NIS	LASC	45	12.52	76	21.15	42	13.18	59	18.52
	Broadcast	100	27.83	100	27.83	100	31.39	100	31.39

[a] Herbicide quantity is expressed as percentage of that used in the broadcast treatment.

[b] Cost includes herbicide and NIS only and is expressed in U.S. dollars based on local dealer survey at time of application.

[c] Abbreviations: NIS, nonionic surfactant; LASC, light-activated, sensor-controlled (LASC).

[d] Glyphosate + 2,4-D was applied at 0.84 + 0.14 kg ae/ha; paraquat + diuron was applied at 0.56 + 0.28 kg ai/ha, respectively.

used, and environmental conditions (Young 1988) during the crop-growing season. Normally, Russian thistle populations are most dense in field draws and borders, and less dense and scattered throughout the remainder of the field (authors' personal observations). Russian thistle population density and plant size in our study were representative of those in typical fields in the low- to intermediate-rainfall areas of the PNW wheat-producing region, ranging from small plants and high populations (site 1) to large plants and low populations (sites 2 and 4) (Table 1). As is typical of the region, no rainfall occurred immediately before, during, or in the 4 to 5 wk following harvest.

There was a treatment-by-site interaction for 2000; therefore, data for visual control were analyzed separately within each site (Table 2). Mean values are presented in the original (nontransformed) scale. Even though glyphosate plus 2,4-D has provided less-than-acceptable control for postharvest Russian thistle with broadcast applications (Young and Whitesides 1987), the treatment was chosen because it is inexpensive as a broadcast application. A grower may be able to increase the rate by using the spot-treatment, labeled rates with the LASC and possibly achieve acceptable control. In contrast, the commercial premix of paraquat plus diuron has controlled Russian thistle postharvest with broadcast applications (Young and Whitesides 1987) and is used widely in the PNW.

Both applicators controlled Russian thistle similarly within a herbicide treatment (Table 2). We doubled the rate of glyphosate in this study, which improved Russian thistle control slightly compared with previous research (Young and Whitesides 1987); however, control was still $\leq 75\%$ regardless of the applicator used (Table 2). In contrast, paraquat plus diuron effectively killed Russian thistle. Overall, weed control was similar for both applicators, with the exception of small Russian thistle (< 8 cm tall and < 4 cm diam). Evidently, plants of this size were not detected by the LASC because, generally, they did not exhibit injury symptoms. This may be an inherent problem with weed-sensing technology. Using a different weed-sensing system, small plants were missed in both Canadian (Blackshaw et al. 1998) and northern U.S. Great Plains (Ahrens 1994) studies. Ahrens (1994) found that kochia (*Kochia scoparia* L.) of similar width and height to our Russian thistle was not detected. It is not surprising that our system did not detect small Russian thistle because leaves of this weed are considerably smaller and narrower than kochia leaves. The small, nontreated plants in our study were either mature and flowering or vegetative in growth at the time of control evaluation. Any additional plant growth or seed production would be insignificant because of the limited fall growing period remaining for those small plants.

The overall reduction in the quantity of herbicide used (expressed as percentage of broadcast) for the sites was 42% with the LASC compared with the conventional broadcast sprayer (data not shown). The greatest reduction (Table 3) occurred when plants were small, < 30 cm in diameter, regardless of whether populations averaged 5 or 25 plants/m^2 (sites 1 and 3) (Table 1). The least amount of chemical saved was at site 2 (Table 3), where plants were tall and broad (Table 1) and, therefore, would have had the most ground cover. Chemical savings with the LASC compared with the broadcast sprayer averaged only 20% for the two treatments at this site–year. This result was similar to Ahrens (1994), that is, that the spray volume increased with increased ground cover by the weeds. At some Russian thistle populations or plant sizes, the amount of spray area and herbicide quantity used with the LASC will approach the amount of chemical used by the broadcast sprayer.

When averaged over the 4 site–yr (data not shown), the cost of chemicals (including NIS) was reduced by the LASC an average of $6.50/ha for the glyphosate plus 2,4-D treatment and $13.27/ha for the paraquat plus diuron treatment, with no difference in weed control for the applicators. In the economic comparisons, if the most ground-cover (site 2), which approaches the amount of chemical used by the broadcast sprayer, is not included in the comparison, the savings were even more dramatic for the LASC. Cost savings for the LASC compared with the broadcast applicator ranged from $2.41/ha to $8.57/ha and $6.68/ha to $18.21/ha for the glyphosate plus 2,4-D and paraquat plus diuron treatments, respectively. Russian thistle populations and plant size in our experiment collectively represent what wheat growers would experience in their fields in the PNW. A reduction of $13.27/ha for excellent postharvest Russian thistle control with paraquat plus diuron would be a great benefit to the growers of the region. In addition, diesel fuel requirements would be reduced greatly with LASC compared with using an undercutter (tillage) for postharvest Russian thistle control. Using an off-road fuel price of $0.51/L (2006 price), the undercutter requires $4.79 of fuel/ha, whereas a herbicide sprayer requires $0.53 of fuel/ha (Zaikin et al. 2007). Also, an average reduction of 46% of the amount and area of restricted-use chemical application would reduce environmental impacts. This technology controls Russian thistle, reduces pesticide use, and decreases off-farm inputs in addition to benefits previously listed, such as reduced weed seed production and germination (Young and Whitesides 1987) and increased soil moisture retention (Schillinger and Young 2000).

Growers in the arid and semiarid regions of the PNW continue to be interested in chemical fallow in lieu of traditional or reduced-tillage fallow. They need to make their farming systems more efficient and less labor intensive in the future. Current growers are becoming older (Forte-Gardner et al. 2004), sons and daughters are not returning to the farms, and hired farm hands are becoming more scarce to till fields required to establish the dust mulch in fallow for next year's wheat crop (C. Hennings, personal communication). The LASC system for controlling Russian thistle postharvest would be the first step for establishing chemical fallow.

Sources of Materials

[1] Weed Seeker™ NTech Industries, Inc., 740 South State Street, Ukiah, CA 95482.

Acknowledgments

Partial funding for this research was from a U.S. Environmental Protection Agency Region 10 grant. U.S. Department of Agriculture and the Agricultural Research Service do not endorse any particular company, organization, or product unless by explicit exception. In general, the USDA's use of any particular product or service does not constitute an endorsement thereof.

Literature Cited

Ahrens, W. H. 1994. Relative costs of a weed-activated versus conventional sprayer in Northern Great Plains fallow. Weed Technol. 8:50–57.

Anderson, R. L., D. L. Tanaka, A. L. Black, and E. E. Schweizer. 1998. Weed community and species response to crop rotation, tillage, and nitrogen fertility. Weed Technol. 12:531–536.

Blackshaw, R. E., F. O. Larney, C. W. Lindwall, and G. C. Kozub. 1994. Crop rotation and tillage effect on weed populations on the semi-arid Canadian prairies. Weed Technol. 8:231–237.

Blackshaw, R. E., L. J. Molnar, and C. W. Lindwall. 1998. Merits of a weed-sensing sprayer to control weeds in conservation fallow and cropping systems. Weed Sci. 46:120–126.

Conover, W. J. 1980. Practical nonparametric statistics. 2nd ed. New York: J. Wiley. 493 p.

Dean, A. and D. Voss. 1999. Design and analysis of experiments. New York: Springer-Verlag. 740 p.

Forte-Gardner, O., F. L. Young, D. A. Dillman, and M. S. Carroll. 2004. Increasing the effectiveness of technology transfer for conservation cropping systems through research and field design. Renew. Agric. Food Syst. 19:199–209.

Frans, R., R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. Page 37 *in* N. D. Camper, ed. Research Methods in Weed Science. 3rd ed. Champaign, IL: Southern Weed Science Society.

Hanks, J. E. and J. L. Beck. 1998. Sensor-controlled hooded sprayer for row crops. Weed Technol. 12:308–314.

SAS. 1999. SAS/Stat User's Guide, Version 8. Cary, NC: SAS Institute. 3884 p.

Schillinger, W. F. and F. L. Young. 2000. Soil water use and growth of Russian thistle after wheat harvest. Agron. J. 92:167–172.

Stallings, G. P., D. C. Thill, and C. A. Mallory-Smith. 1994. Sulfonylurea-resistant Russian thistle (*Salsola iberica*) survey in Washington state. Weed Technol. 8:258–264.

Young, F. L. 1986. Russian thistle (*Salsola iberica*) growth and development in wheat (*Triticum aestivum*). Weed Sci. 34:901–905.

Young, F. L. 1988. Effect of Russian thistle (*Salsola iberica*) interference on spring wheat (*Triticum aestivum*). Weed Sci. 36:594–598.

Young, F. L. 2006. Russian thistle (*Salsola* spp.) biology and management. Page 145–147 *in* Managing Weeds in a Changing Climate: Papers and Proceedings of 15th Australian Weeds Conference. Adelaide, Australia: Weed Management Society of South Australia.

Young, F. L. and M. E. Thorne. 2004. Weed-species dynamics and management in no-till and reduced-till fallow cropping systems for the semi-arid agricultural region of the Pacific Northwest, USA. Crop Prot. 23:1097–1110.

Young, F. L., R. Veseth, D. Thill, W. Schillinger, and D. Ball. 1995. Managing Russian thistle under conservation tillage in crop-fallow rotations. Moscow, ID: University of Idaho, Pacific Northwest Extension Publication PNW-492. 12 p.

Young, F. L. and R. E. Whitesides. 1987. Efficacy of postharvest herbicides on Russian thistle (*Salsola iberica*) control and seed germination. Weed Sci. 35:554–559.

Young, J. A. 1991. Tumbleweed. Sci. Am. (March issue):82–87.

Zaikin, A. A., D. L. Young, and W. F. Schillinger. 2007. Economic comparison of undercutter and traditional tillage systems for winter wheat-summer fallow farming. Pullman, WA: Washington State University, Washington State University Extension Publication EB2022E. 25 p.

Received June 20, 2007, and approved November 20, 2007.