Ecology and Control of Russian Thistle after Spring Wheat Harvest

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ABSTRACT

Russian thistle is the most problematic broadleaf weed for spring-sown crops in the low-precipitation (< 14 in/yr) region of the Inland Pacific Northwest, USA. A 6-year field experiment beginning in 2000 was conducted at Lind, Washington to evaluate 3 post-harvest control strategies for Russian thistle in continuous annual spring wheat. Post-harvest treatments were (i) tillage with low-disturbance overlapping undercutter V-blade sweeps, (ii) Surefire™ herbicide (paraquat + diuron) at the labeled rate, and (iii) check (letting Russian thistle grow unhindered). The undercutter V-sweep consistently killed all Russian thistle with essentially no residue burial, and no seed was produced. In contrast, the Surefire treatment halted Russian thistle dry biomass production, but plants continued to extract soil water and produce an average of 30 seeds/ft^2 on the lower branches. In the check, Russian thistle produced an average of 625 lb/ac post-harvest dry biomass and 525 seeds/ft^2. The undercutter V-sweep treatment had both significantly greater spring wheat grain yield and more water in the 6-foot soil profile at time of wheat harvest, after killing frost in October, and in mid-March compared to the herbicide and check treatments. Results consistently showed that post-harvest tillage with an undercutter V-sweep achieved 100% control of Russian thistle, retained ample wheat residue on the surface to control erosion, and was by far the most effective treatment in this experiment.

INTRODUCTION

Russian thistle is a C_4 summer annual broadleaf weed with a deep and aggressive root system and prolific seed production that presents a formidable obstacle to successful dryland spring cropping in the western United States and Canada. Winter wheat-summer fallow (one crop every other year) is the dominant crop rotation in the less than 14 in/yr region of east-central Washington and north-central Oregon. This region covers about 4.0 million dryland crop acres. Some farmers are interested in substituting a spring crop (mostly spring wheat) for summer fallow in years when there is ample over-winter moisture storage in the soil. However, Russian thistle infestation is most severe in spring wheat (Young 1986) and other spring-sown crops that have slow early growth and canopy closure compared to winter wheat that grows vigorously in early spring. Infestation is most acute if crop competition is reduced by poor stands, drought, inadequate fertility, and late growth.

Russian thistle seedlings first emerge in March or April, flower in June, and produce seed beginning in August. Infestation in spring wheat is generally greatest during drought years and can reduce grain yield by 50% (Young 1988). After wheat is harvested in late July or early August, Russian thistle reinitiates root elongation (Pan et al. 2001) and rapidly produces aboveground biomass (Photo 1). The root system of Russian thistle can extend 15 feet in diameter and at least 6 feet deep (Holm et al. 1997) and can extract soil water down to 2% by volume, well beyond the available range for wheat that rarely extracts water below 4%.

Schillinger and Young (2000) reported that individual Russian thistle plants allowed to grow in a grid pattern without competition from other weeds used 20 gallons of soil water growing within a spring wheat crop and an additional 27 gallons of soil water between wheat grain harvest and killing frost in late October.

Farmers and scientists have many questions concerning mechanical versus chemical methods for post-harvest control of Russian thistle after wheat harvest. Given the large quantity of

Photo 1. Uncontrolled Russian thistle plants in spring wheat stubble 14 days after grain harvest.

Russian thistle seed spread throughout the region every year[1], some question whether post-harvest control is even practical. This 2000–2005 study was conducted in consultation with an advisory committee of 22 regional dryland wheat farmers. The farmers asked for this research on post-harvest ecology and control of Russian thistle.

MATERIALS AND METHODS

Treatments

A 6-year field study was conducted during the 2000 through 2005 crop years at the Washington State University Dryland Research Station at Lind, Washington. The objective of the study was to compare post-harvest control methods on the growth and seed production of Russian thistle, soil water dynamics, and subsequent effects on grain yield of continuous spring wheat. Treatments were (i) tillage at a depth of 3 inches with a low-disturbance overlapping adjustable-pitch and 32-inch-wide V-blade Haybuster[2] undercutter sweeps with 28-inch centers conducted 7 days after wheat harvest (Photo 2), (ii) application of 22 fluid ounces of Surefire

[1] At maturity, Russian thistle plants often break off at the soil line and tumble long distances with the wind, widely dispersing seed for several miles (Stallings et al. 1995).

[2] The Haybuster 3200 undercutter V-sweep, DuraTech Industries International Inc., PO Box 1940, Jamestown, ND 58401

herbicide (paraquat + diuron) with nonionic surfactant in 20 gallons water/acre 7 days after wheat harvest, and (iii) untreated check (do nothing after wheat harvest, let Russian thistle grow). The Haybuster undercutter retains more than 90% of wheat stubble on the soil surface because the wide, narrow-pitch, overlapping V-blades slice through the soil with minimum lifting and stirring compared to traditional sweep implements. Surefire[3], at the rate used in this experiment, is the most widely recommended and commonly used herbicide for post-harvest control of Russian thistle in the Inland Pacific Northwest (J.P. Yenish, Washington State University, personal communication). All 3 treatments provide excellent control of wind erosion by providing year-round vegetative surface cover.

The experimental design was a randomized complete block with 4 replications and

Photo 2. Front (top) and rear (bottom) views of the wide-blade undercutter sweep implement used for effective post-harvest control of Russian thistle in spring wheat stubble.

24-by-200-foot plots. Treatments were maintained continuously on the same parcel of land throughout the study to determine the cumulative long-term effects of the 3 post-harvest treatments in annual spring wheat production. The soil is Shano silt loam more than 6-feet deep with no rocks or restrictive layers and a slope of less than 1%. The 85-year mean annual crop-year (1 Sept to 31 Aug) precipitation is 9.53 inches. Crop-year precipitation during the 6-year study was 87% of this long-term average (Table 1).

Field layout

In late February or early March, 16 oz/ac of glyphosate herbicide was applied across the entire experiment area to control winter-annual grass weeds and volunteer wheat. Between March 10 and March 25, the entire experiment area was uniformly planted with no prior tillage to 'Alpowa' soft white spring wheat at 60 lb/ac (approximately 20 seeds/ft^2) with a custom-built no-till drill equipped with Cross-slot™ notched-coulter openers on 8-inch-wide row spacing. Liquid fertilizer and seed were delivered simultaneously in the same row with fertilizer placed 0.75 inch below and 1.25 inches to the side of the seed. Over the 6 crop years, an average fertilizer rate of 19 lb N, 12 lb P, and 6 lb S/ac was applied based on available soil water in March and soil fertility testing. Excellent wheat stands were achieved every year.

In-crop broadleaf herbicides were applied with a commercial-size spray applicator across the entire experiment area between the spring wheat tillering and jointing stage (Large 1954) in May. Weeds present were Russian thistle with lesser quantities of tumble mustard, tansy mustard, horseweed, prickly lettuce, and common lambsquarters[4]. In-crop herbicides used were 24 fluid oz/ac Buctril™ (2000), 12 fluid ounces of 2,4-D ester + 4 fluid ounces dicamba/ac (2001, 2003, and 2005), and 0.5 fluid ounces of Aim™ + 4 fluid ounces dicamba/ac (2002 and 2004).

[3] Surefire, UAP-Loveland Products, Inc., PO Box 1286, Greeley, CO 80632

[4] Downy brome, the most troublesome annual grass weed in winter wheat, was completely controlled with glyphosate prior to planting spring wheat and therefore not a factor in the study.

Table 1. Precipitation at Lind, Washington during 6 crop years (2000–2005) compared to the 85-year average (1920–2005).

Year	Precipitation (inches)					
	Aug–March	April	May	June	July	12-mo total
2000	7.54	0.45	0.69	0.78	0.46	9.92
2001	5.53	1.16	0.29	0.78	0.06	7.82
2002	6.55	0.36	0.89	0.73	0.37	8.90
2003	7.12	1.15	0.18	0.00	0.00	8.45
2004	5.95	0.58	0.61	0.29	0.00	7.43
2005	5.22	0.37	0.95	0.41	0.37	7.32
6-yr avg	6.32	0.68	0.60	0.50	0.21	8.31
85-yr avg	6.93	0.71	0.79	0.79	0.28	9.53

These herbicide combinations, rates, and year-to-year rotations with different modes of action are commonly used by regional farmers for in-crop broadleaf weed control in dryland wheat.

Grain yield and Russian thistle measurements

In late July–early August, spring wheat grain yield was determined by harvesting a swath through each 200-foot-long plot with a Hege™ 140 plot combine with 5-foot-wide cutting platform operated 8 inches above the ground (Photo 3). The plot combine was equipped with a custom-built blowing air system to uniformly distribute straw and chaff. Immediately thereafter, a commercial combine equipped with a straw chopper and chaff spreader was used to harvest the entire experiment area by cutting 8 inches above the ground. The tops of some Russian thistle growing in the wheat crop were cut off during harvest.

Within 2 days following grain harvest, the above-ground portion of all Russian thistle within a 3-foot-diameter sampling hoop randomly positioned in each plot was clipped, gathered, placed in paper bags, allowed to air dry in a low-humidity greenhouse, and weighed. This same procedure was repeated in mid-to-late October after Russian thistle had been killed by frost.

Russian thistle from the mid-to-late October samplings was hand-threshed and screened, and the seed was collected, cleaned, counted, and weighed. To most efficiently process data, a seed

Photo 3. Grain harvest of spring wheat at Lind, Washington. Russian thistle plants (top) are small and barely discernable in the standing wheat, but present in large numbers (bottom) and will begin rapid growth after wheat harvest.

count maximum of 500 per sample was set. This amount was then weighed and divided into the total seed weight of the sample to determine the number of seeds produced within each sample unit area. Seed germination was determined by placing 50 seeds from each sample between 2 sheets of moistened germination paper (pH 7.0) in a petri dish and storing in a darkened 70ºF enclosure for 7 days. Germination was considered to have occurred when the seeds uncoiled and the cotyledons and radicals emerged.

Soil water measurement

Following the application of the post-harvest tillage and herbicide treatments 7 days after harvest, 3 neutron probe access tubes were installed at distances of 50, 100, and 150 feet from the edge of each plot (total of 36 access tubes). A water-absorbing bentonite material was applied around each access tube to prevent movement of precipitation down the outside surface of the tube during the wet winter months. The inner surface of each access tube was sealed with a rubber stopper throughout the winter. Soil water content was measured to a depth of 6 feet in early August soon after grain harvest, in late October after Russian thistle was killed by frost, and again in mid-March just prior to spring planting. Volumetric soil water content in the 1- to 6-foot depth was measured in 6-inch increments by neutron thermalization (Photo 4, Hignett and Evett 2002). Volumetric soil water content in the 0- to 1-foot depth was determined from two 6-inch core samples using gravimetric procedures as described by Topp and Ferre (2002). Access tubes were removed from the experiment site prior to planting spring wheat.

Statistical procedures

Analysis of variance was conducted for (i) Russian thistle dry matter on both early August and mid-to-late October sampling dates, (ii) Russian thistle seed production in mid-to-late October, (iii) germination percentage of Russian thistle seed, (iv) volumetric water content in the 6-foot soil profile in early August, late October, and mid-March, and (v) grain yield of spring wheat in late July-early August. Since the treatments were kept on the same plots for the entire study (i.e., no re-randomization of treatments occurred from year to year), a repeated-measure analysis was conducted with years as the repeated measure[5]. Treatment means were considered significantly different at the 5% probability level.

Photo 4. Research technician measuring soil water in spring wheat stubble heavily infested with Russian thistle.

RESULTS AND DISCUSSION

Ecology and control of Russian thistle

All weeds except Russian thistle were completely controlled with in-crop broadleaf herbicides, while approximately 70% of Russian thistle plants were killed and the remainder severely stunted. Stunted Russian thistle tended to renew growth within 2–4 weeks after herbicide application. In addition, new flushes of Russian thistle germinated and emerged following rainfall events of 0.1 inch or more in late April, May, and early June.

Russian thistle frequently produces greater dry biomass than the spring wheat crop that it infests by the time of grain harvest (Schillinger et al. 1999). Over the 6 years of this study, the average Russian thistle dry biomass at time of grain harvest ranged from 800 lb/ac for the tillage treatment to 1070 lb/ac for the check (Photo 5, Figure 1a). The greatest Russian thistle dry biomass at grain harvest in all treatments was produced in 2002 (average of 1725 lb/ac), presumably due to emergence flushes after ample May and early June rainfall (Table 1).

5 Repeated measures refers to multiple measurements on the same experimental unit.

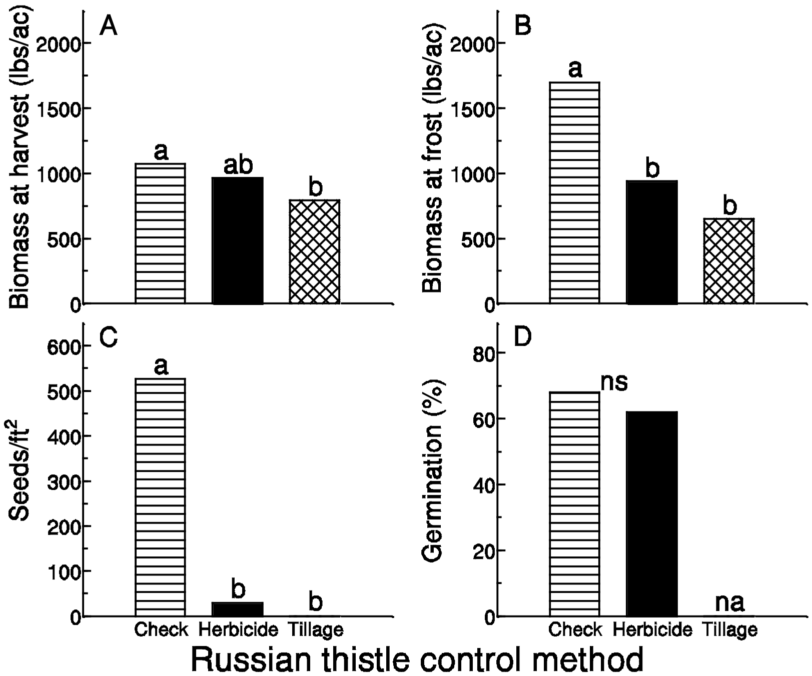

Figure 1. Growth of Russian thistle as affected by 3 post-harvest control methods measured by: (A) dry biomass at time of wheat harvest in late July or early August, (B) dry biomass after killing frost in October, (C) seed produced between wheat harvest and killing frost, and (D) seed germination percentage. Six-year averages followed by the same letter are not significantly (ns) different at the 5% probability level. na = not applicable

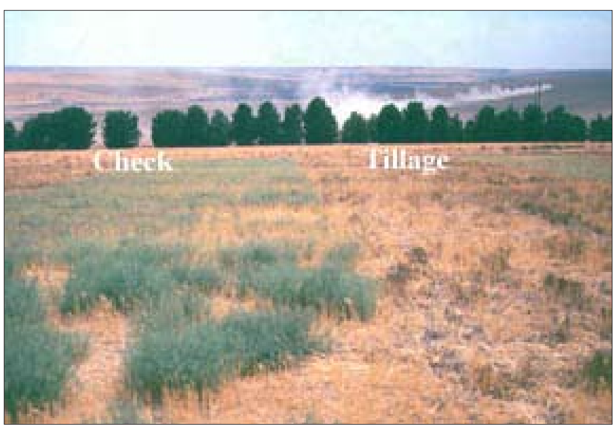

Photo 5. Check and undercutter tillage treatments 20 days after wheat harvest.

By the mid-to-late October killing frost, Russian thistle dry biomass in the check had increased an average of 625 lb/ac (63% net gain) since grain harvest (Photo 6), considerably less than the 7-fold increase in post-harvest dry biomass produced by individual Russian thistle plants reported by Schillinger and Young (2000) during years when over-winter precipitation and corresponding water infiltration deep into the soil profile were much greater than average. In all years there was no increase in post-harvest dry biomass of Russian thistle in the herbicide treatment, and a decline in the tillage treatment, because some dead Russian thistle plants were carried from the field by wind after their roots were severed by the undercutter sweep implement (Figure 1a and 1b).

Averages of 525, 30, and 0 Russian thistle seed/ft^2 were produced in the check, herbicide, and tillage treatments, respectively, by the time of killing frost (Figure 1c). Seed production in the check ranged from 145 (2005) to 1530 (2003) seeds/ft^2. Most of the seed in the herbicide treatment was produced on the lower branches where the herbicide did not fully penetrate the canopy.

Russian thistle seed germination averaged 68% and 62% percent for the check and herbicide treatments, respectively (Figure 1d), but ranged from 40- to 88% over the 6 years (data not shown). Although Young and Thorne (2004) suggested that Russian thistle may not be as problematic in no-till spring wheat compared to

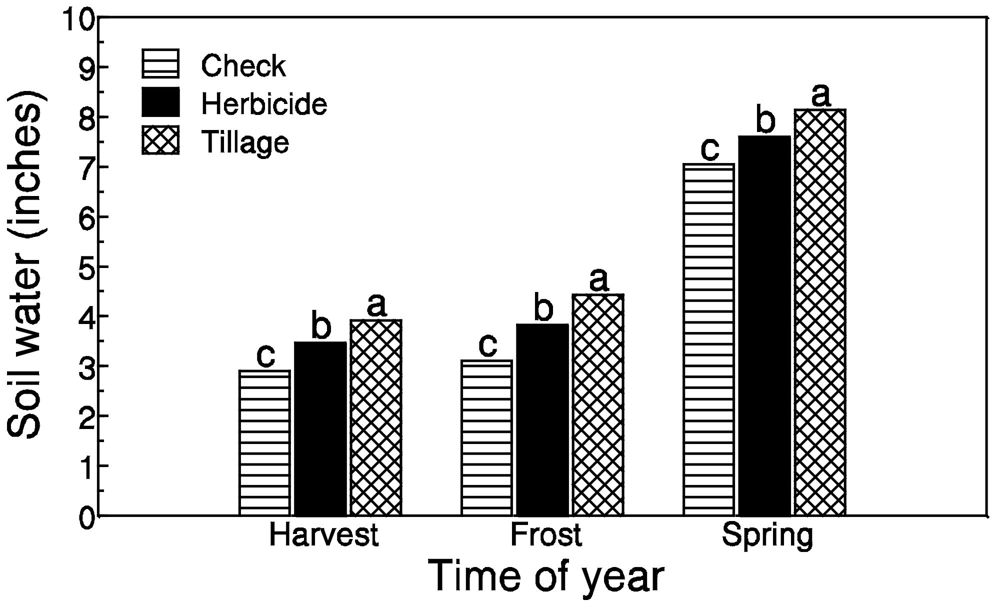

Figure 2. Water content in the 6-foot soil profile in early August just after wheat harvest, at the time of killing frost in mid-to-late October, and in early spring as affected by 3 post-harvest Russian thistle control methods. Within-time-period averages followed by a different letter are significantly different at the 5% probability level. Data are the average for the 6-year study.

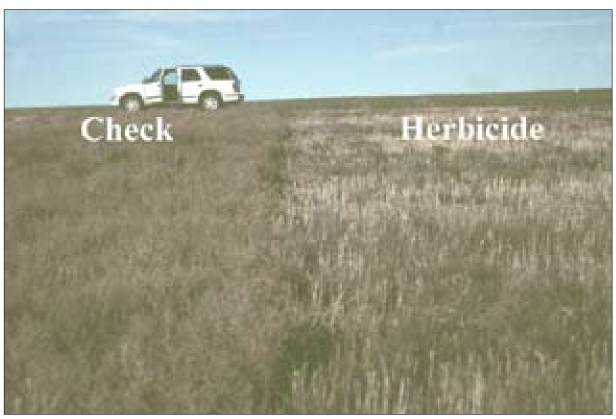

Photo 6. Check and herbicide treatments after killing frost in mid-October.

tilled spring wheat because tillage is more likely to stimulate Russian thistle germination, this does not appear to be the case in this or other related studies at Lind where Russian thistle was always present in spring wheat regardless of tillage regime.

Soil water content

Soil water content among treatments at grain harvest was significantly different every year except 2002. The tillage and herbicide treatments averaged 1.02 and 0.57 inches more soil water, respectively, than the check (Figure 2).

At the time of killing frost in October the check, on average, had gained only 0.21 inch of soil water since grain harvest because Russian thistle had used residual soil water, as well as some of the rain that occurred after harvest, to produce additional dry biomass (Figure 1a and 1b). After grain harvest, Russian thistle dry biomass accumulation in the herbicide treatment ceased, but still gained less soil water (0.36 inch) from harvest to killing frost compared to the tillage treatment that gained 0.51 inch during the same period (Figure 2). This indicates that Russian thistle continued to extract soil water after herbicide application to produce seed (i.e., not vegetative biomass).

Between late October and mid-March, slightly more precipitation was stored in the check compared to the herbicide and tillage treatments. This compensated for some of the water used by Russian thistle in the check from August to October and was probably due to two factors: (i) a dry soil will store a greater portion of over-winter precipitation than a wetter soil, and (ii) over-winter precipitation storage will generally

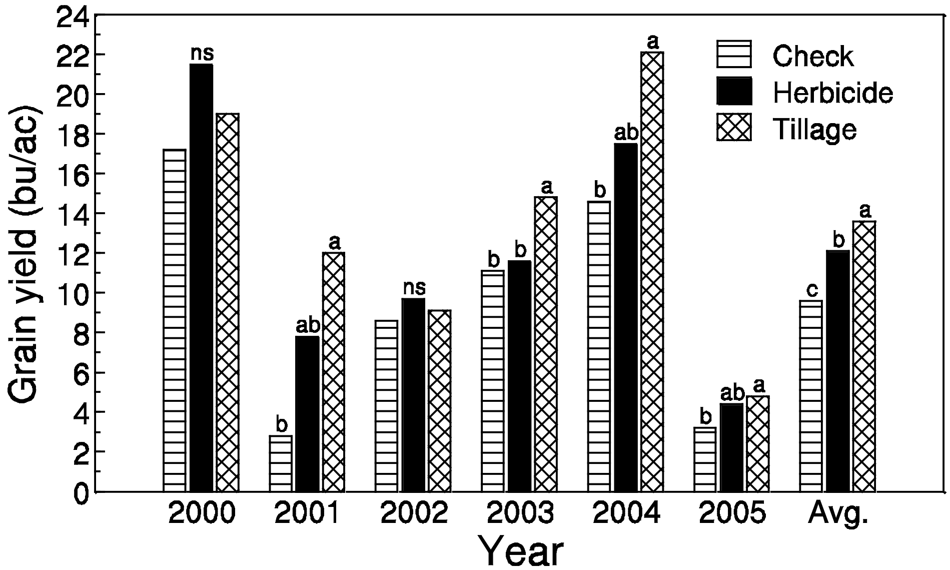

Figure 3. Spring wheat grain yield as affected by 3 post-harvest Russian thistle control methods. Within-year and 6-year-averages followed by the same letter are not significantly (ns) different at the 5% probability level.

increase with added surface residue (in this case, dead Russian thistle plants) (Papendick and McCool 1994). Over-winter precipitation storage efficiency (the percentage of precipitation that occurred from grain harvest until mid-March that was stored in the soil) was 66% for all treatments when averaged over the 6 years. Thus, the significant differences in soil water content among treatments that occurred beginning in year one of the experiment remained proportionally the same from grain harvest until mid-March throughout the 6 years (Figure 2).

Wheat grain yield

Annual crop-year precipitation during the study ranged from 7.32 to 9.92 inches and averaged 8.31 inches compared to the 85-year-average of 9.53 inches. Growing-season (April, May, June) precipitation, which is more important than stored soil water for wheat grain yield (Leggett 1959), was 78% of the long-term average (Table 1).

The 6-year average spring wheat grain yield was 13.6, 12.1, and 9.6 bu/ac for the tillage, herbicide, and check treatments, respectively. Drought curtailed grain yield in all years, especially 2005 (Table 1, Figure 3). Although there were no differences in grain yield among treatments in 2000 and 2002, the 6-year average reflects significant differences among the tillage, herbicide, and check plots. A simple linear regression coefficient of determination for the relationship of water content and grain yield showed ($P < 0.001$) that 51% of the difference in spring wheat grain yield among treatments was attributable to soil water content at time of planting in mid-March.

Although economic assessment was not included in this study, production of continuous annual spring wheat was clearly not economically viable during the drought years of the study. During the same years, winter wheat-summer fallow grain yield averaged 35.7 bu/ac (one crop every other year) in adjacent fields. In a long-term dryland cropping systems experiment located 10 miles northeast of the Lind Research Station during the same years of this study, Nail et al. (2005) reported that continuous annual spring wheat was not economically viable compared to winter wheat-summer fallow when annual precipitation is less than average. Schillinger (2005) recommended a minimum of 5 inches of plant-available soil water at the time of planting for farmers considering growing dryland spring cereals in the Inland Pacific Northwest. This equates to 8.5 inches of total water in a 5 foot soil profile since spring wheat generally does not extract water below 6% by volume (i.e., it is less efficient at extracting water than winter wheat; Schillinger et al. 2007). Below this soil water level, farmers are encouraged to summer fallow in lieu of planting spring cereals. This minimum recommended level of plant-available soil water for planting spring wheat was not present in any year of the study.

SUMMARY AND CONCLUSIONS

Post-harvest use of low-disturbance undercutter sweeps retained more than 90% of wheat stubble on the soil surface and provided 100% control of Russian thistle with significant soil water savings and enhanced grain yield of the subsequent wheat crop compared to herbicide and check treatments. Surefire, the most widely used herbicide by regional farmers for post-harvest control of Russian thistle, damaged the upper and middle branches and halted dry biomass production, but Russian thistle continued to deplete soil water and produce an average of 30 seeds/ft^2 prior to killing frost. The check had the greatest post-harvest soil water use and Russian thistle dry biomass and seed production (525 seeds/ft^2), along with the lowest wheat grain yield.

Effective post-harvest control of Russian thistle is a prerequisite for successful spring wheat production. If plant-available soil water is less than 5 inches, the authors recommend that farmers not plant spring wheat due to low grain yield potential and associated high likelihood of Russian thistle infestation; conservation tillage summer fallow is more appropriate in this case.

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