All My Invasive Weed Trials

-or-

Noxious Weeds I Have Known

Results from control trials conducted from
1997 through 2018

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Noxious and Specific Weed Trials

Butterflybush
2006-2007

Two concurrent trials were conducted for control of butterflybush (*Buddleja davidii*). One was conducted near Sequim, Washington and the second was conducted near Coos Bay, Oregon. A third demonstration trial was also conducted at the Sequim site. Products were similar at both sites, but there were differences in the applications, treatments, and conduct of the trials. Therefore, they are reported separately here.

Materials and Methods.
Sequim Trial. The trial was conducted in 2006-2007 along the west bank of the Dungeness River (inside a dike that was the property of the Dungeness Meadows Homeowners Association; Cathy Lucero, Clallam County Noxious Weed Board, and Gary Anderson and Chuck Fairchild, Dungeness Meadows, cooperators). Plots measured 20 by 20 ft and were centered on well-established butterflybush plants up to 10 ft tall; each plot contained from 3 to 31 butterflybush plants. Herbicides were applied as cut-stem treatments, using 33% solution in water (1 part herbicide, 2 parts water) with 0.5% (v/v) nonionic surfactant, applied immediately following clipping of the trunk of the plant at 3 to 6 inches above the rock surface. Herbicides tested were aquatically-registered glyphosate (Aquamaster), imazapyr (Habitat), and triclopyr amine (Renovate). Herbicides were applied at one of two timings: early (post-budbreak, April 18, 2006) and late (post-bloom, October 9, 2006). About 5 ml of herbicide mixture applied per cut stem. Butterflybush control was estimated 5 months after spring treatment (MAST, September 12, 2006) and 12 MAST/6 months after fall treatment (MAFT, April 27, 2007) as compared to noncut and cut, but not treated, butterflybush plants. Plots were washed out by the Dungeness River following the April evaluation. The statistical design was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

A second trial was conducted at this site using leftover herbicide from the cut-stem treatments. Single well-established, 8-ft tall butterflybush plants near the plot areas were treated with enough of the three tested herbicides to cover all foliage using a backpack sprayer. This was a nonreplicated trial and application rates are considered very high, so results are advisory only.

Coos Bay Trial. The trial was conducted on 20 by 20 ft plots, each centered on a single well-established butterflybush plant growing on timberland (Amy Peterson and Cassie Bouska, OSU-Coos County Extension, cooperators). Herbicides were applied as cut-stem treatments, using 33% solution in water (1 part herbicide, 2 parts water) with 0.5% (v/v) nonionic surfactant applied immediately following clipping of the trunk of the plant at about 6 inches above the rock surface. Herbicides tested were glyphosate (Touchdown), imazapyr (Chopper), and triclopyr ester (Garlon 4). Herbicides were applied pre- and post-bloom in 2006. About 5 ml of herbicide mixture applied per cut stem. Butterflybush control was estimated at 6 and 12 months after treatment (MAT) (dates and statistics not provided by the cooperator).

Results.

Sequim Trial. Spring and fall treatments with imazapyr resulted in 98 and 100% butterfly bush control at 5 and 12 MAST, respectively, and 99% at 6 MAFT (Table 1). Control with glyphosate was similarly effective, with 93 and 88% at 5 or 12 MAST, respectively, and 98% at 6 MAFT. Conversely, triclopyr amine only gave 60 and 63% control at 5 and 12 MAST, but 98% control at 6 MAFT. Butterflybush plants that were cut and not treated with herbicide had achieved 90% recovery by 5 or 6 MAST, but were still 82% controlled after the fall treatment. It appears the improved control to fall-applied triclopyr amine is likely more due to limited re-growth of butterfly bush occurring over the winter months rather than better control resulting from the fall timing. Most of these treatments did not cause injury to other vegetation in the plots, with the exception of imazapyr, which injured various willows (*Salix* spp.) growing within three feet of the treated butterfly bush stem.

Table 1. Percent control of butterflybush following pre-and post-bloom cut-stem treatments in Sequim, WA.

Active ingredient[a]	Trade name[a]	Percent butterflybush control[b]		
		5 MAST	12 MAST	6 MAFT
Glyphosate	Aquamaster	93 a	88 a	98 a
Triclopyr amine	Renovate	63 b	60 b	98 a
Imazapyr	Habitat	99 a	100 a	98 a
Cut only	---	10 c	10 c	82 b

[a]Treatments were a 33% concentration (1 part formulated product plus 2 parts water); products were mixed with 0.5% (v/v) DyneAmic nonionic surfactant prior to application; approximately 5 ml of herbicide mixture applied per cut stem. Plots were treated April 18 and October 9, 2006.
[b]Control estimated September 12, 2006 (5 months after spring treatment, MAST) and April 27, 2007 (12 MAST and 6 months after fall treatment, MAFT).

Foliar treatments applied in April were generally effective by 5 MAST, ranging from 70 to 85% control (Table 2). By 12 MAST, imazapyr and glyphosate were still providing good to excellent control (99 and 85% control, respectively), while triclopyr amine control had dropped to 45%. Both imazapyr and triclopyr amine rates were quite high, however, so a more typical application would likely not be this effective. Post-bloom treatments resulted in 80 to 95% control at 6 MAFT. Again, imazapyr and glyphosate were most effective; triclopyr amine, even at a very high rate of 7%, was providing 80% control.

Coos Bay Trial. Herbicides were remarkably effective in this trial (Table 3). Glyphosate, imazapyr, and triclopyr ester applied to cut stems provided 99 to 100% control at 12 MAT, whether applied pre- or post-bloom. Butterflybush plants that were cut had recovered to about half of their initial height at 12 MAT.

Table 2. Percent control of butterflybush following pre-and post-bloom foliar treatments in Sequim, WA.

Active ingredient[a]	Trade name[a]	Rate % product in water (spring, fall)	Percent butterflybush control[b]		
			5 MAST	12 MAST	6 MAFT
Glyphosate	Aquamaster	5%, 5%	85	85	90
Triclopyr amine	Renovate	5%, 7%	70	45	80
Imazapyr	Habitat	3%, 1%	85	99	95

[a]Products were mixed with 0.5% (v/v) DynAmic nonionic surfactant prior to application. Plants were treated April 18 and October 9, 2006.
[b]Control estimated September 12, 2006 (5 months after spring treatment, MAST) and April 27, 2007 (12 MAST and 6 months after fall treatment, MAFT).

Table 3. Percent control of butterflybush following pre- and post-bloom cut-stem treatments in Coos Bay, OR.

Active ingredient[a]	Trade name[a]	Percent butterflybush control[b]	
		6 MAT	12 MAT
Glyphosate	Touchdown	100	100
Triclopyr ester	Garlon 4	100	100
Imazapyr	Chopper	100	99
Cut only	---	68	53

[a]Treatments were a 33% concentration (1 part formulated product plus 2 parts water); products were mixed with 0.5% (v/v) nonionic surfactant prior to application; approximately 5 ml of herbicide mixture applied per cut stem. Plots were treated pre- and post-bloom in 2006.
[b]Control estimated 6 and 12 months after treatment (MAT).

Conclusions. Simply cutting the stem with no cut-stem herbicide application did not give adequate control of butterflybush in either trial. Sprouts of these plants grew back quickly, continuing to compete with desirable vegetation. Butterflybush was effectively controlled with 33% cut-stem herbicide applications of glyphosate, imazapyr, or triclopyr ester; control with triclopyr amine at this rate was inadequate.

Foliarly-applied glyphosate at 5% and imazapyr at 1% appear to provide excellent control of butterflybush, but more testing will be necessary to draw many conclusions from this preliminary trial. Triclopyr amine was reasonably effective at a 7% rate, which is higher than allowed for this product; a 5% rate provided inadequate control at 12 MAST.

Canada Thistle
1999-2000, 2001, 2003-2005, 2006

1999-2000 Canada Thistle in Blueberry Trial

<u>Materials and Methods</u>. The effectiveness of clopyralid on Canada thistle (*Cirsium arvense*) in blueberry was tested in a highly infested blueberry field near Mount Vernon, WA in 1999 and 2000. Clopyralid at two rates was applied at two timings (early and late) to Canada thistle plants May 5 and June 2, 1999 and April 11 and June 2, 2000. Canada thistle plants were 2 to 6 inches tall in the early application, and 12 inches tall in the late application. Blueberry plants ('Nelson') were in late bloom during the first application and post-bloom in the second. The same plots were used for both years of the trial. Canada thistle control was estimated July 14, 1999 and September 12, 2000. Berries were picked from a meter of row August 5, 1999 and August 8, 2000. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

<u>Results</u>. In 1999, early season response to clopyralid was good (Table 1). Control was generally better with the early timing at both rates, but some of this response may have been due to the relative short period of time elapsed between treatment and evaluation (1 month). After the second season of application, control was better from the late applications, with the 0.125 and 0.25 lb ai/a rates providing 86 and 97% control, respectively. These data indicate that a larger Canada thistle plant in early June will be easier to control with clopyralid than smaller plants in April or May. Blueberry yield and fruit size did not differ by herbicide treatment, indicating that two yearly applications of clopyralid at these rates and timings did not injure blueberry significantly.

Table 1. Canada thistle control and blueberry yield and fruit size following treatment with clopyralid at two rates and timings.

Treatment[a]	Rate	Timing	Canada thistle control[b]		Blueberry yield[c]		Fruit size[c]	
			7/14/99	9/12/00	1999	2000	1999	2000
	lb ai/a		%	%	g/m of row	g/m of row	g/berry	g/berry
Clopyralid	0.125	Early	95 ab	51 bc	263.0	1632.8	1.7	1.5
Clopyralid	0.25	Early	65 c	86 ab	315.5	1574.5	1.8	1.5
Clopyralid	0.125	Late	98 a	38 cd	204.0	924.3	1.7	1.6
Clopyralid	0.25	Late	86 b	97 a	218.8	1882.0	1.9	1.6
Nontreated	---	---	---	---	201.5	1733.3	1.7	1.7

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Plots treated May 5 and June 2, 1999 and April 11 and June 2, 2000.
[b]Control was estimated July 14, 1999 and September 12, 2000.
[c]Berries were picked from a meter of row August 5, 1999 and August 8, 2000; 50 berries were weighed to obtain fruit size.

2001 Canada Thistle in Raspberry Trial

Materials and Methods. The effectiveness of clopyralid and diclobenil on Canada thistle (*Cirsium arvense*) in raspberry was tested in a heavily infested raspberry field at WSU Vancouver in 2001. Clopyralid was applied at two rates and two timings (early and late) to Canada thistle plants April 27 and May 21, 2001. Canada thistle plants were 3 to 12 inches tall in the early application, and 12 to 36 inches tall in the bud stage of growth in the late application. Raspberry plants ('Meeker') were in early bloom during the first application and post-bloom in the second. Canada thistle control was estimated May 21 and July 23, 2001. Due to poor condition of floricanes in the plots, no yield was taken from these raspberry plants. The statistical design was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

Results. Diclobenil treatment resulted in excellent weed control (95% at both evaluations), even after emergence of Canada thistle plants and raspberry bud break (Table 2). Control from early clopyralid treatment at 0.25 lb ai/a was 87% at 1 month after treatment (MAT), while clopyralid at 0.125 lb ai/a was adequate to give 77 to 93% control by July 23 (3 MAT). Late applications did not provide good Canada thistle control in this trial, likely due to poor penetration of the herbicide into the thick thistle canopy. Raspberry was generally uninjured, although clopyralid at the 0.25 lb ai/a rate caused a few leaves to curl on primocanes growing among the thistle plants.

Table 2. Canada thistle control following treatment with clopyralid or diclobenil in raspberry.

Treatment[a]	Product	Rate	Timing	Canada thistle control[b]	
				May 21	July 23
		lb ai/a		%	%
Clopyralid	Stinger	0.125	Early	77 c	77 ab
Clopyralid	Stinger	0.25	Early	87 b	93 a
Clopyralid	Stinger	0.125	Late	---	63 b
Clopyralid	Stinger	0.25	Late	---	63 b
Diclobenil	Casoron 2G	4	Early	95 a	95 a
Nontreated	---	---	---	---	---

Means within a column followed by the same letter are not statistically different.
[a]Plots were treated April 27 and May 21, 2001.
[b]Control was estimated May 21 and July 23, 2001; late herbicides had not yet been applied at the May 21 evaluation.

2003-2005 Canada Thistle in Blueberry Trial

Materials and Methods. A comparison of four management systems for controlling established perennial weeds in blueberries, including Canada thistle (*Cirsium arvense*) and field horsetail (*Equisetum arvense*). These systems were (1) an organic system, (2) a low herbicide input system, (3) a high herbicide input system, and (4) a combination conventional/organic system. 'Elliott' was used in the first iteration of this two-year trial (which concluded in 2004) and 'Nelson' was used in the second iteration (which concluded in 2005). Each plot included one row of blueberry bushes and was 30 feet long. In each year, specified plots received initial sawdust mulch and diuron application in April; pine oil was applied in June, July, and August; a propane flamer was used in April, May, and October; Stinger was applied in June and October; and Roundup was applied in May and October. Berries were picked by hand twice each year in 'Elliott' plots and three times each year in 'Nelson' plots. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

Results. Yield data differed significantly between blueberry varieties, so data are presented separately for the two trials (Tables 3 and 4). Weed cover differed significantly between the two varieties, so data are presented separately for 'Elliott' and 'Nelson' trials (Tables 5 and 6).

There were no significant differences in blueberry yield or fruit size between systems for 'Elliott' during either year or for the two-year average yield parameters (Table 3). Increasing herbicide inputs did not result in significantly more or larger fruit, although those trends were apparent in the data. Perhaps more importantly, it did not appear that any system caused reductions in fruit yield or size during the either year of implementation.

The 'Nelson' yield data was also similar between treatments, except for the third pick fruit weight of 2004 which was reduced with high herbicide and combination programs compared to the low herbicide program, and the two-year average fruit weight in the high herbicide program producing significantly leas fruit than the low herbicide program (Table 4). Fruit size did not significantly vary among treatments.

Weed cover did not greatly differ between systems. In 'Elliott', Canada thistle cover increased in organic plots during the study, but decreased or stayed roughly the same in all other programs (Table 5). Field horsetail cover during the first season was greatest in the high herbicide system for both iterations, but cover in the second year did not differ. This likely resulted because none of the herbicides in that system used to date (diuron, Stinger, or Roundup) typically provide much control of that field horsetail. By the second year, field horsetail had been reduced to less than 10% cover in all programs. Other perennials and seedling/annual weeds were not generally a problem in 'Elliott', accounting for less than 10% cover in all programs in both years. There was a trend, however, toward increasing populations of these weeds in organic plots.

Growth of Canada thistle and other established perennials was reduced in herbicide systems during the first year in 'Nelson' plots compared to the organic program, but there was no

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difference in cover of annual weeds (Table 6). Canada thistle cover was the same or reduced in all programs over the two years, with the largest reduction occurring in organic plots (from 25% to 13% cover in fall of year 1 to summer of year 2, respectively). Field horsetail cover did not change much between years, except in the high herbicide program where the population decreased from 20% to 8% from year 1 to year 2. The cover of other perennial weeds were generally reduced in the organic program over the same time program, but they still constituted 30% cover in that system, and 27% cover in the combination program by August of the second year.

Table 3. Blueberry yield and fifty-berry weights blueberry for four weed control systems in 'Elliott'.

Treatment	Yield			Fifty-berry weights		
	1st pick	2nd pick	total	1st pick	2nd pick	Average
	kg/plot	kg/plot	kg/plot	g/50 berries	g/50 berries	g/50 berries
2003 Pick						
Organic	7.06	6.60	13.67	70.7	61.7	66.2
Low herbicide	6.21	8.00	14.21	72.7	65.0	68.8
High herbicide	7.38	8.67	16.04	75.7	62.3	69.0
Combination	6.33	5.91	12.24	76.3	57.0	66.7
2004 Pick						
Organic	10.71	2.14	12.85	69.7	55.7	62.7
Low herbicide	13.22	3.17	16.39	68.0	55.0	61.5
High herbicide	15.04	3.57	18.61	77.7	56.7	67.2
Combination	10.08	1.76	11.84	61.7	58.7	60.2
Total						
Organic	17.77	8.74	26.51	70.2	58.7	64.4
Low herbicide	19.42	11.18	30.60	70.3	60.0	65.2
High herbicide	22.41	12.24	34.65	76.7	59.5	68.1
Combination	16.41	7.67	24.08	69.0	57.8	63.4

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

Table 4. Blueberry yield and fifty-berry weights blueberry for four weed control systems in 'Nelson'.

Treatment	Yield				Fifty-berry weights			
	1st pick	2nd pick	3rd pick	total	1st pick	2nd pick	3rd pick	Average
	kg/plot	kg/plot	kg/plot	kg/plot	g/50 berries	g/50 berries	g/50 berries	g/50 berries
2004 Pick								
Organic	0.18	4.57	2.89 a	7.63	79.0	81.3	79.0	79.8
Low herbicide	0.20	4.76	3.82 a	8.78	71.0	86.7	70.1	76.1
High herbicide	0.24	2.58	1.17 b	3.99	75.7	84.3	74.7	78.2
Combination	0.20	3.69	1.57 ab	5.45	75.0	83.3	80.3	81.5
2005 Pick								
Organic	6.29	1.96	---	8.25	65.8	64.5	---	65.2
Low herbicide	6.24	2.12	---	8.37	57.7	60.1	---	58.9
High herbicide	3.22	0.99	---	4.20	60.9	57.1	---	59.0
Combination	4.23	1.24	---	5.47	67.8	56.0	---	61.9
Total								
Organic	6.46	6.53	2.89 a	15.88 a	72.4	72.9	79.0	73.9
Low herbicide	6.44	6.89	3.82 a	17.15 a	64.4	73.4	70.1	69.2
High herbicide	3.46	3.56	1.17 b	8.20 b	68.3	70.7	74.7	70.5
Combination	4.43	4.93	1.57 ab	10.92 ab	70.2	70.0	80.3	72.9

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

Table 5. Weed control for four weed management systems in 'Elliott' blueberries.

Treatment	Canada thistle		Field horsetail		Other perennials		Annuals	
	10/24/03	8/16/04	10/24/03	8/16/04	10/24/03	8/16/04	10/24/03	8/16/04
	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover
Organic	25	45	2 b	8	1	10	2	8
Low herbicide	30	13	18 b	4	0	0	10	0
High herbicide	10	7	43 a	4	2	0	2	0
Combination	27	15	5 b	7	0	3	4	3

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

Table 6. Weed control for four weed management systems in 'Nelson' blueberries.

Treatment	Canada thistle		Field horsetail		Other perennials		Annuals	
	11/19/04	8/31/05	11/19/04	8/31/05	11/19/04	8/31/05	11/19/04	8/31/05
	% cover	% cover	% cover	% cover	% cover	% cover	% cover	% cover
Organic	25	13	25	22	28 a	30	12	12 b
Low herbicide	7	3	15	12	8 b	8	20	8 b
High herbicide	5	7	20	8	15 ab	8	20	7 b
Combination	2	0	8	8	30 a	27	10	22 a

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

2006 Canada Thistle in Alternate Year Raspberry Trial

Materials and Methods. The trial was conducted in a raspberry field near Burlington, WA (Sakuma Brothers Farm, cooperator) infested with thick patches of Canada thistle (*Cirsium arvense*) and spotty infestations of white clover (*Trifolium repens*) and dandelion (*Taraxacum officinale*). The natural herbicides (Weed Pharm [vinegar product containing 20% acetic acid], Matran 2 [clove oil], and Interceptor [pine oil]) were applied to primocanes and weeds May 2, 10, and 18 and June 1, 2006 (all postemergence, preharvest). The conventional herbicides (Gramoxone Extra [paraquat], Goal [oxyfluorfen], and Rely [glufosinate]) were applied May 2 and June 1, 2006. Remaining Canada thistle stems were removed by hand July 1, 2006. Berries were sampled July 20, 2006 and postharvest herbicides (all conventional and natural products) were reapplied again August 7, 2006 (all POST). Weed control was evaluated May 4 and 12 and again on August 11, 2006. The experimental design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Fruit yield did not differ by herbicide treatments (Table 7), but fruiting was very spotty due to severe winter injury in the test row. Many gaps in the raspberry row were evident in May, and many of these gaps worsened during the growing season. Raspberry primocane growth following winter injury was poor enough to warrant removal of most of the block in late August. This project, therefore, was not continued into the non-bearing year (2007).

Canada thistle control in August was good with three applications with Gramoxone and Rely (75 and 80%, respectively), but poor with three applications of Goal or five applications with Weed Pharm, Matran 2, and Interceptor (35, 58, 30, and 33%, respectively) (Table 7). As noted above, the raspberry block was destroyed in late August, consequently full evaluation of Canada thistle control from these treatments could not be evaluated. Control of white clover in August was excellent with Gramoxone (90%), moderate with Rely (70%), but poor with other treatments (32 to 55% control) (Table 8). Similarly, control of dandelion was poor with all tested products in August (15 to 40% control) (Table 8).

Conclusions. Based on these data, it does not appear that non-selective herbicides provide good enough perennial weed control to expect successful control during the bearing year of an AY system. Continued testing of non-selective herbicides for this use does not therefore appear to be warranted.

Table 7. Canada thistle control and yield following application of several non-selective herbicides in raspberry.

Treatment[a]	Rate	Canada thistle control			Fruit yield[b]
		May 4	May 12	Aug 11	
	product/a	%	%	%	g/crown
Gramoxone Extra	2 pt	78 a	73 ab	75 a	606 b
Goal 2XL	12.8 fl.oz	45 bc	72 abc	35 b	1336 a
Rely	1 gal	8 d	85 a	80 a	486 b
Weed Pharm (vinegar, 20% acetic acid)	100%	45 bc	68 abc	58 ab	1100 ab
Matran 2 (clove oil)	20%	60 ab	50 c	30 bc	1019 ab
Interceptor (pine oil)	20%	35 c	53 bc	33 bc	697 ab
Non-treated	---	---	---	---	791 ab

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Herbicides were applied May 2 (all), May 2 (organics only), May 18 (organics only), June 4 (all treatments), and August 7 (all treatments), 2006. All non-organic treatments mixed with non-ionic surfactant at 0.25%, v/v; all organic herbicides mixed with Humisol and crop oil concentrate (both at 2%, v/v).
[b]Berries sampled July 20, 2006.

Table 8. White clover and common dandelion control following application of several non-selective herbicides in raspberry.

Treatment[a]	Rate	White clover control			Dandelion control[b]		
		May 4	May 12	Aug 11	May 4	May 12	Aug 11
	product/a	%	%	%	%	%	%
Gramoxone Extra	2 pt	85 a	78 ab	90 a	83 a	80	---
Goal 2XL	12.8 fl.oz	50 ab	75 ab	55 bc	68 abc	80	38 a
Rely	1 gal	51 ab	93 a	70 ab	29 d	81	40 a
Weed Pharm (vinegar, 20% acetic acid)	100%	30 b	78 ab	50 bc	35 cd	77	---
Matran 2 (clove oil)	20%	62 ab	60 b	32 c	72 ab	61	15 ab
Interceptor (pine oil)	20%	60 ab	60 b	55 bc	48 bcd	60	25 ab

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Herbicides were applied May 2 (all), May 2 (organics only), May 18 (organics only), June 4 (all treatments), and August 7 (all treatments), 2006. All non-organic treatments mixed with non-ionic surfactant at 0.25%, v/v; all organic herbicides mixed with Humisol and crop oil concentrate (both at 2%, v/v).
[b]An inadequate number of dandelion plants were present in Gramoxone or Weed Pharm plots in August to evaluate control of that species.

English Ivy
2011-2012

Materials and Methods. A trial was conducted at the National Park Service (NPS) campus in Marblemount, Washington (Todd Neel, US National Park Service, cooperator) to determine the sensitivity of English ivy (*Hedera helix*) to various herbicides applied with different concentrations of surfactant. English ivy was well-established at the site, covering 100% of the soil among large Douglas fir trees. The English ivy had been kept from growing up the tree trunks by NPS personnel. Plots measuring 8 by 15 ft were treated with several herbicides May 20, 2011, mixed with either 1 or 2% (v/v) nonionic surfactant prior to application. English ivy plants had initiated new spring growth and foliage was dry at the time of application. Ivy control was evaluated at 2, 4, 6, and 12 months after treatment (MAT). The statistical design was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. The only treatments providing English ivy control at 2 MAT were Roundup and Crossbow (Table 1). Surfactant added at 2% did not significantly increase Roundup performance compared to 1%, but increased Crossbow activity by 20 percentage points to 81%. By 4 MAT, Roundup was controlling 84-91% of treated English ivy, a level of control that remained similar though 12 MAT. Control with Crossbow did not differ by surfactant percentage for the remainder of the trial. By 12 MAT, control with Crossbow was 75-80%. Habitat was slow to cause symptoms on English ivy, with only slight foliar discoloring occurring through 4 MAT. By 6 MAT, however, control was 53-58% and had increased to 88% by 12 MAT. Increasing surfactant percentage to 2% did not improve control from addition of 1% surfactant. Milestone and Method did not provide English ivy control (6-21% by 12 MAT).

Table 1. English ivy control after treatment with several herbicides.

Treatment[a]	Rate	Surfactant rate	English ivy control[b]			
	product		2 MAT	4 MAT	6 MAT	12 MAT
Roundup Power Max	3%	1%	74 ab	84 ab	91 a	89 a
Roundup Power Max	3%	2%	85 a	91 a	72 ab	90 a
Habitat	1%	1%	5 c	20 cd	53 b	88 a
Habitat	1%	2%	10 c	31 c	58 b	88 a
Milestone	7 fl.oz/acre	1%	5 c	0 e	3 c	6 b
Milestone	7 fl.oz/acre	2%	16 c	16 cde	14 c	21 b
Method	8 fl.oz/acre	1%	4 c	0 e	0 c	9 b
Method	8 fl.oz/acre	2%	1 c	1 e	3 c	4 b
Crossbow	3%	1%	61 b	68 b	70 ab	75 a
Crossbow	3%	2%	81 a	73 ab	78 ab	80 a

Means within a column followed by the same letter are not statistically different.
[a]Plots treated May 20, 2011; products were mixed with R-11 nonionic surfactant prior to application.
[b]Estimated July 12, Sept. 9, Nov. 30, 2011 and May 2, 2012 (2, 4, 6, and 12 months after treatment, MAT).

European Coltsfoot
2018

Materials and Methods. A greenhouse trial was conducted to determine general sensitivity of European coltsfoot (*Tussilago farfara*) to various herbicides (Wendy DesCamp, Washington State Noxious Weed Control Board and Geraldine Saw, Snohomish County Noxious Weed Control Board, cooperators). Plants were collected from a field site near Arlington, Washington March 26, 2018. Plants were in early flowering at the time they were dug. Rhizomes and crowns were transplanted into 4-inch pots filled with potting soil and maintained in the greenhouse at WSU NWREC. Coltsfoot plants were treated after transplanted rhizomes had produced about 4 leaves (4 to 6 inches in spread). The experiment consisted of nine herbicides applied postemergence, plus a nontreated check. Herbicides were selected as likely to provide some control of this species, and all are available for noncropland weed control; most are labelled for use in pasture and natural areas as well. Rates were selected based on the herbicide label for similar plants in the field. Plants were treated May 1, 2018 and were rated for percent visual injury May 14, 2018 two weeks after treatment (WAT) as compared to nontreated plants. Coltsfoot plants in each pot were then clipped to the soil line and allowed to regrow for four weeks to assess herbicide effectiveness. Plant foliage was again clipped June 14, 2018 (6 WAT) and fresh weight of above-ground biomass was recorded. The experimental design of the trial was a randomized complete block consisting of one coltsfoot plant per treatment/pot and was replicated five times (50 plants total experiment). Means were separated using Tukey's Honestly Significant Different Test (P ≤ 0.05).

Results. All tested herbicides displayed excellent activity on European coltsfoot (Table 1). Streamline and Crossbow resulted in the greatest defoliation at 2 WAT, although control did not differ among any treatments by 6 WAT. In fact, all herbicides killed all treated plants except one plant treated with Rodeo. There were no significant differences in control between these products applied at tested rates at 6 WAT.

Conclusions. Greenhouse-grown plants are generally a little more sensitive to herbicides than field-grown plants, and certainly field-grown plants have larger root systems. Consequently, coltsfoot infestations in the field should probably be treated at the highest labelled rate to gain adequate control. But all these products appear to have excellent activity on European coltsfoot, so all could be considered for use against this species.

Table 1. Percent injury, percent control, and fresh weight of European coltsfoot plants after treatment with several herbicides in the greenhouse (2018).

Treatment[a]	Active ingredient(s)	Rate	Injury[b] (2 WAT)	Control[b] (6 WAT)	Biomass[c] (6 WAT)
		product	%	%	g/plant
Rodeo	glyphosate	2.5%	73 c	99 a	0.4 b
Habitat	imazapyr	0.75%	76 bc	100 a	0 b
Vastlan	triclopyr	2 qt/a	78 bc	100 a	0 b
Method	aminocyclopyrachlor	6 oz/a	76 bc	100 a	0 b
Milestone	aminopyralid	5 fl.oz/a	75 c	100 a	0 b
Streamline	aminocyclopyrachlor + metsulfuron	9.5 oz/a	93 a	100 a	0 b
Crossbow	triclopyr + 2,4-D	3 qt/a	88 ab	100 a	0 b
Transline	clopyralid	1 pt/a	72 c	100 a	0 b
Distinct	dicamba + diflufenzopyr	4 oz/a	72 c	100 a	0 b
Nontreated	---	---	0 d	0 b	28.8 a

Means within a column followed by the same letter are not significantly different.

[a]Treatments applied to 4- to 6-inch plants May 1, 2018. Herbicides mixed with 0.25% (v/v) nonionic surfactant prior to application.

[b]Injury rated May 14, 2018 and control rated June 14, 2018.

[c]Fresh above-ground biomass collected and weighed June 14, 2018.

Field Horsetail
1999-2000

Materials and Methods. A trial was conducted at the WSU Northwestern Washington Research and Extension Center to evaluate herbicide activity and effectiveness of mowing or tillage on field horsetail (*Equisetum arvense*). Plots measuring 8 by 35 ft were treated with several herbicides at various timings, with and without mowing or and rototilling. The first application was made to 8- to 12-inch horsetail fronds June 17, 1999. Plots were split into three sections the length of the plots (8 by 11.5 ft) July 9, 1999, with one mowed, the second rototilled, and the third receiving a second herbicide application to intact, previously treated plants. Mowed split-plots were received a second herbicide application and sprayed/rototilled plots were tilled a second time August 13, 1999. Horsetail control was evaluated at June 21 and July 7, 1999 and April 17, 2000. The statistical design was a split-split-plot, Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

Results. Initial horsetail response from one herbicide application was generally good (Table 1). Four days after treatment (June 21, 1999), control was best with Crossbow alone or mixed with Scythe, Weed-B-Gon + Scythe, Finale, or Casoron (80 to 95% injury). By three weeks after treatment (July 9, 1999) injury from these treatments was still excellent, with the addition of Weed-B-Gon alone (74 to 98% injury). The exception was Finale, where horsetail injury was only 56% at that evaluation. Due to variability in response among the treatments, however, horsetail control the following spring (April 17, 2000) did not significantly differ, ranging from 28 to 84%.

Table 1. Field horsetail control after treatment with several herbicides.

Treatment[a]	Rate	Field horsetail control[b]		
		6/21/99	7/9/99	4/17/00
	product/A	%	%	%
Scythe (twice)	5%	53 cde	16 ef	50
Casoron 2G fb Scythe	600 lb fb 5%	80 abc	98 a	71
Weed-B-Gon (twice)	7 pt	64 bcd	74 abc	73
Weed-B-Gon + Scythe (twice)	7 pt + 3%	89 ab	76 abc	70
Crossbow (twice)	1 gal	91 ab	92 ab	51
Crossbow + Scythe (twice)	1 gal + 3%	95 a	92 ab	79
Roundup + Scythe (twice)	3 pt + 1.5%	25 efg	16 ef	28
Roundup + Scythe (twice)	3 pt + 3%	43 def	35 def	37
Finale (twice)	3 qt	93 ab	56 bcd	35
Sedgehammer (twice)	1 oz	19 fg	41 cde	84

Means within a column followed by the same letter are not statistically different.
[a]Plots treated with herbicide June 17 and July 9, 1999; "fb" = followed by.
[b]Control estimated June 21 and July 7, 1999 and April 17, 2000. Herbicides had only
   been applied once at the time of the June 21 and July 7, 1999 evaluations.

Field horsetail control in the spring after herbicide application followed by mowing and then a second herbicide did not differ from two mowings only (Table 2). Control at that time ranged from 33 to 74%, with two mowings accounting for 42% control. This was similar to herbicide application followed by two tillages, as there was no difference between treatments by spring (Table 2). Control at that time ranged from 50 to 100%, with two tillages accounting for 74% control. Again, variability of horsetail response between plots was high, resulting in no statistical difference between treatments at the April 17, 2000 evaluation.

Table 2. Field horsetail control after treatment with several herbicides and/or mechanical control.

Treatment[a]	Rate	Field horsetail control April 17, 2000
	product/A	%
Herbicide fb Mow fb Herbicide		
Scythe (twice)	5%	59
Casoron 2G fb Scythe	600 lb fb 5%	44
Weed-B-Gon (twice)	7 pt	64
Weed-B-Gon + Scythe (twice)	7 pt + 3%	60
Crossbow (twice)	1 gal	35
Crossbow + Scythe (twice)	1 gal + 3%	41
Roundup + Scythe (twice)	3 pt + 1.5%	33
Roundup + Scythe (twice)	3 pt + 3%	43
Finale (twice)	3 qt	74
Sedgehammer (twice)	1 oz	63
Mow only (twice)	---	42
Herbicide fb Two Tillages		
Scythe	5%	65
Casoron 2G fb Scythe	600 lb fb 5%	74
Weed-B-Gon	7 pt	100
Weed-B-Gon + Scythe	7 pt + 3%	73
Crossbow	1 gal	100
Crossbow + Scythe	1 gal + 3%	65
Roundup + Scythe	3 pt + 1.5%	50
Roundup + Scythe	3 pt + 3%	50
Finale	3 qt	74
Sedgehammer	1 oz	98
Till only (twice)	---	74

Means within a column followed by the same letter are not statistically different.
[a]Plots treated with herbicide June 17, 1999; "fb" = followed by; plots were either mowed or rototilled July 9, 1999; mowed plots were re-treated with herbicide and rototilled plots tilled again August 13, 1999.

Treatment type, however, did cause differential control of field horsetail, regardless of herbicide application (Table 3). When averaged across all herbicide treatments, two tillages resulted in an average of 75% control, significantly higher than either combinations of mowing and herbicide application or two applications of herbicide alone. Mowing did not improve weed control compared to herbicide alone (49 and 57% control, respectively).

Table 3. Field horsetail control after treatment with several herbicides.

Treatment[a]	Field horsetail control[b]
	4/17/00
	%
Herbicide (twice)	57 b
Herbicide fb mow fb herbicide	49 b
Herbicide fb two tillages	75 a

Means within a column followed by the same letter are not
  statistically different.
[a]Plots treated with herbicide June 17, 1999; plots were either
  mowed or rototilled July 9, 1999; mowed plots were re-treated
  with herbicide and rototilled plots tilled again August 13, 1999.

Flowering Rush
2008-2009, 2010-2011

2008-2009 Flowering Rush Trial

<u>Materials and Methods</u>. A trial was conducted to determine the sensitivity of flowering rush (*Butomus umbellatus*) to three herbicides (Laurel Baldwin, Whatcom County Noxious Weed Control Board and Alison Halpern, Washington State Noxious Weed Control Board, cooperators). The trial was established at Silver Lake, near the Canadian border and north of Maple Falls, Washington. Plots measuring 20 by 20 feet were established in heavily infested coves of the lake, marked with flags and fishing bobbers. Herbicides were applied to flowering rush foliage August 5, 2008 when leaves were approximately 2 feet above the water surface. Treatments included Rodeo (3 and 5%), Habitat (1%), and Renovate (8 qt/a) mixed with 1% (v/v) nonionic surfactant (DyneAmic). Plants were rated for percent visual injury September 4, 2008 (1 month after treatment (MAT) and July 10, 2009 (11 MAT). The experimental design of the trial was a randomized complete block replicated four times. Means were separated using Fisher's Protected LSD (P ≤ 0.05).

<u>Results</u>. Renovate provided the quickest flowering rush injury, estimated at 81% at 1 MAT (Table 1). Rodeo and Habitat showed only 29 to 35% injury at the same evaluation date. By the following July (11 MAT), however, flowering rush had substantially recovered from Renovate treatment, rated at 56% control. Control with Habitat at 1% and Rodeo at 5% was similar, controlling flowering rush at 74 and 61%, respectively, while control with Rodeo at 1% was poor (44%), statistically similar to Rodeo at 5%. These data indicate that flowering rush needs to be treated with these products at higher rates or at different timings to achieve better control. Additionally, combinations of these herbicides should be tested to determine if they would perform better than these single-product treatments.

Table 1. Flowering rush control after treatment with three herbicides (2008-2009).

Treatment[a]	Rate	Flowering rush control[b]	
		1 MAT	11 MAT
	% or product/a	%	%
Rodeo	3%	29 b	44 b
Rodeo	5%	35 b	61 ab
Habitat	1%	29 b	74 a
Renovate	8 quarts	81 a	56 bc
Nontreated	---	0 c	0 d

Means within a column followed by the same letter are not statistically different.
[a]Treatments were applied August 5, 2008. Products were mixed with 1% (v/v) DyneAmic
  nonionic surfactant prior to application.
[b]MAT = months after treatment; percent weed control was estimated September 4, 2008
 and July 10, 2009.

_____

2010-2011 Flowering Rush Trial

<u>Materials and Methods</u>. A trial was conducted to determine the sensitivity of flowering rush (*Butomus umbellatus*) to various herbicides and herbicide combinations (Laurel Baldwin, Whatcom County Noxious Weed Control Board and Alison Halpern, Washington State Noxious Weed Control Board, cooperators). The trial was established at Silver Lake, near the Canadian border and north of Maple Falls, Washington. Plots measuring 20 by 20 feet were established in heavily infested coves of the lake, marked with flags and fishing bobbers. Herbicides were applied to flowering rush foliage August 25, 2010 when leaves were approximately 2 feet above the water surface. Foliage showed appreciable brown patches, however, due to weather conditions after emergence above the water. Treatments included Rodeo (5%), Habitat (1%), and two combinations of Rodeo + Habitat (3 + 0.75% and 4 + 0.5%, respectively). Treatments were mixed with 1% (v/v) nonionic surfactant (DyneAmic) prior to application. Plants were rated for percent visual injury September 21, 2010 (1 month after treatment (MAT) and October 24, 2011 (14 MAT). The experimental design of the trial was a randomized complete block replicated four times. Means were separated using Fisher's Protected LSD ($P \leq 0.05$).

<u>Results</u>. Flowering rush control was not estimable at 1 MAT due to dying back of foliage and high water covering all the foliage in the plots (data not shown). None of the treatments provided acceptable flowering rush control at 14 MAT (Table 2). There was no statistical differences in control among the four herbicide treatments at that rating date, with control ranging from 29 to 50%. There did not appear to be a benefit from combining herbicides, at least among these tested herbicides/rates. Higher rates, other herbicides, and/or better application timing appear to be necessary if some level of control of flowering rush is to be achieved.

Table 2. Flowering rush control after treatment with two herbicides (2010-2011).

Treatment[a]	Rate	Flowering rush control[b] 14 MAT
	% or product/a	%
Rodeo	5%	29 ab
Habitat	1%	40 a
Rodeo + Habitat	3% + 0.75%	45 a
Rodeo + Habitat	4% + 0.5%	50 a
Nontreated	---	0 b

Means within a column followed by the same letter are not statistically different.
[a]Treatments were applied August 25, 2010. Products were mixed with 1% (v/v)
   DyneAmic nonionic surfactant prior to application.
[b]MAT = months after treatment; percent weed control was estimated October 24, 2011.

Garden Loosestrife
2014-2016

<u>Materials and Methods</u>. Two iterations of a greenhouse trial was conducted to determine general sensitivity of garden loosestrife (*Lysimachia vulgaris*) to various herbicides (Ben Peterson, King County Noxious Weed Control Board, cooperator). Plants were collected from a field site near Ballard, Washington May 1, 2014, May 8, 2015, and May 10, 2016. Shoots were up to 6 inches tall at the time they were dug. Rhizomes and crowns were transplanted into gallon-sized pots filled with potting soil and maintained in the greenhouse at WSU NWREC. Garden loosestrife plants were treated after transplanted rhizomes were in the bud stage of growth, at which time they were up to 2 feet tall. The experiment consisted of six herbicides applied alone or in various combinations postemergence, plus a nontreated check. Aquatic herbicides were selected, given that this species infests near-aquatic habitat. All products were mixed with noninonic surfactant (DyneAmic) at 0.25% (v/v), prior to application. Garden loosestrife plants were treated June 7, 2014, June 29, 2015, and June 23, 2016 and were rated for injury about three weeks after treatment (WAT) as compared to nontreated plants. Plants in each pot were then clipped to the soil line and allowed to regrow for about four weeks to assess herbicide effectiveness. Plant foliage was again clipped August 4, 2014, August 25, 2015, and September 16, 2016 (2 months after treatment, MAT) and fresh weight of above-ground biomass was recorded. Plants were again allowed to grow, and a second biomass collected September 15, 2014, September 25, 2015, and October 28, 2016 (3 MAT). The experimental design of each trial was a randomized complete block consisting of one garden loosestrife plant per treatment/pot and was replicated four times (72 plants total experiment). Data from the three yearly trials were merged, and overall treatment means were separated using Tukey's Honestly Significant Different Test (P ≤ 0.05).

<u>Results</u>. Initial garden loosestrife injury (3 WAT) ranged from 26 to 76% (Table 1). The slowest-acting products were Rodeo, Habitat, Clearcast, and Method, with injury rated up to 56% at 3 WAT. At the first measured biomass (2 MAT), however, garden loosestrife regrowth was uniformly poor (= excellent control) from all but the low rate (1%) of Rodeo, which did not differ from the biomass of nontreated plants. Biomass ranged from 0 to 1 g/plant for most treatments, but was 6.3 g/plant in plants treated with 1% Rodeo. Partial recovery from some treatments was apparent at the time of the second biomass (3 MAT), with Rodeo at 2%, Garlon, Clearcast, and Method, as well as from combination treatments of Rodeo + Habitat and Clearcast. Biomass at 3 MAT from Rodeo at 1% again did not differ from the biomass of nontreated plants. Complete kill (no regrowth at 3 MAT) was achieved with Habitat at both rates, by combination treatments of Rodeo + Method or Milestone, and by Habitat + Garlon. Garden loosestrife treated with Milestone alone, Rodeo + Garlon, and Clearcast + Garlon, while not killed, showed very limited regrowth (biomass from 0.01 to 0.02 g/plant).

<u>Conclusions</u>. Since these were greenhouse grown plants, use rates on field infestations of garden loosestrife will likely need to be higher than those tested in these trials. Still, it appears that Habitat, mixtures of Rodeo with Garlon, Milestone, or Clearcast, and Habitat or Clearcast mixed

with Garlon should be capable of providing excellent control of this species in field environments.

Table 1. Percent garden loosestrife foliar injury and dry biomass after treatment with several herbicides and herbicide combinations in the greenhouse (3-year average, 2014-2016).

Treatment[a]	Rate	Injury 3 WAT[b]	Biomass 2 MAT[b]	Biomass 3 MAT[b]
	% product	%	g/plant	g/plant
Rodeo	1	26 g	6.3 a	7.7 a
Rodeo	2	42 efg	1.0 b	3.5 b
Habitat	0.5	37 fg	0.04 b	0 c
Habitat	0.75	51 c-f	0 b	0 c
Garlon	1	72 abc	0.7 b	1.8 bc
Garlon	2	75 ab	0.1 b	0.2 bc
Clearcast	0.5	56 a-f	0.7 b	1.3 bc
Clearcast	0.75	35 fg	0.9 b	2.3 bc
Method	0.16	46 d-g	0.03 b	0.2 bc
Milestone	0.25	61 a-e	0.03 b	0.02 c
Rodeo + Habitat	1 + 0.5	57 a-f	0.05 b	0.3 bc
Rodeo + Garlon	1 + 1	74 ab	0.2 b	0.02 c
Rodeo + Clearcast	1 + 0.5	53 b-f	0.03 b	0.7 bc
Rodeo + Method	1 + 0.16	76 a	0.2 b	0 c
Rodeo + Milestone	1 + 0.25	71 abc	0 b	0 c
Habitat + Garlon	0.5 + 1	72 abc	0 b	0 c
Clearcast + Garlon	0.5 + 1	67 a-d	0 b	0.01 c
Nontreated	---	---	7.0 a	7.2 a

Means within a column followed by the same letter are not statistically different.
[a]Treatments were applied in June of 2014, 2015, and 2016. Products were mixed with 0.25% (v/v) DyneAmic nonionic surfactant prior to application.
[b]WAT = weeks after treatment; MAT = months after treatment.

Giant Hogweed
1999

<u>Materials and Methods</u>. A trial was designed to determine the susceptibility of giant hogweed (*Heracleum mantegazzianum*) to several herbicides. The site was a creekside heavily infested with giant hogweed near Port Angeles, Washington (Cathy Lucero, Clallam County Noxious Weed Control Board, cooperator). Individual plants were marked with wire flags and herbicides applied April 23, 1999 when the hogweed had 4 to 5 leaves and was actively growing, ranging from 1 to 3 feet in height. Rain had fallen most of the previous week, but the weeds were dry at the time of application. Giant hogweed injury was visually estimated July 1, 1999. The experimental design was a Randomized Complete Block with four replicates. Means were separated using Fisher's Protected LSD ($P \leq 0.05$).

<u>Results</u>. Roundup and Plateau resulted in greater than 90% injury to giant hogweed in this trial (Table 1). Crossbow was slightly less effective, but still injured plants by 80%. Other treatments did not adequately suppress giant hogweed growth at tested rates.

Table 1. Control of giant hogweed by various herbicides.

Treatment[a]	Rate	Giant hogweed control[b]
	product/a	%
Weedar	2 qt	8 e
Weedar	3 qt	45 cd
Clarity	1 qt	66 bc
Roundup	1.5 qt	100 a
Weed-B-Gon	2 qt	34 d
Plateau + mso	12 fl.oz	97 a
Weedmaster	2 qt	50 cd
Curtail	2 qt	48 cd
Crossbow	3 qt	80 ab
Transline	1 pt	37 d

Means within a column followed by the same letter are not statistically
  different.
[a]Treatments were applied April 23, 1999 and Plateau was mixed with
  0.75% (v/v) SunIt II methylated seed oil (mso) prior to application.
[b]Control estimated July 1, 1999 (2 months after treatment).

Hairy Willow-herb
2006-2007

Materials and Methods. Hairy willow-herb (*Epilobium hirsutum*) infesting the Britton Loop area of Bellingham, Washington was treated with various herbicides on July 17, 2006 (Laurel Baldwin, Whatcom County Noxious Weed Control Board, cooperator). Hairy willow-herb plants were about five feet tall and predominantly in bud stage at the time of the treatment. Few open flowers were present in the infestation at that time. Treatments were applied using a single thin-line wand on a CO_2-pressurized backpack sprayer. Plots measured 12 by 25 ft. and 2 liters of solution was applied to each plot, resulting in an effective application rate of 76 gallons per acre. All treatments were mixed with 0.25% (v/v) DyneAmic surfactant prior to application. Hairy willow-herb plants in each plot were visually rated for percent control (100% = dead hairy willow-herb plants, 0% = healthy hairy willow-herb) on August 4 (three weeks after treatment, WAT) and September 11, 2006 (2 months after treatment, MAT), and on August 30, 2007 (13 MAT). The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Differences in product performance on hairy willow-herb at 2 and 13 MAT were slight (89 to 100% control at 2 MAT, 95 to 100% at 13 MAT) (Table 1). In fact, at 13 MAT, these differences are considered to be primarily due to skips in the application, as the living weeds in these plots were, for the most part, located at the far north side of the plots where weeds were somewhat screened from direct herbicide application occurring from the south side of the plots. Grass species (tall fescue (*Lolium arundinaceum*), quackgrass (*Elymus repens*), reed canarygrass (*Phalaris arundinacea*), and common velvetleaf (*Holcus lanatus*) were the predominant species still occurring in the plots at 13 MAT. There was also substantial amounts of native willow-herb species in the plots (*Epilobium* spp.) and scattered red alder (*Alnus rubra*). None of the plots were bare.

Conclusions. Based on these results, it appears that all of these herbicides at the tested rates provide excellent control of hairy willow-herb at a year after application.

Table 1. Hairy willow-herb (*Epilobium hirsutum*) control after treatment with several herbicides.

Treatment[a]	Rate	8/4/06 (3 WAT)[b]	9/11/06 (2 MAT)[b]	8/30/07 (13 MAT)[b]
	% product	%	%	%
Aquamaster	5.0	65	100 a	100 a
Habitat	0.5	15	99 a	100 a
Habitat	1.0	20	95 abcd	100 a
Clearcast	0.5	15	89 d	100 a
Clearcast	1.0	35	90 cd	100 a
Renovate	1.0	70	96 abc	100 a
Renovate	1.5	75	98 ab	100 a
Aquamaster + Habitat	3.0 + 0.5	60	95 abcd	100 a
Aquamaster + Clearcast	3.0 + 0.5	50	99 a	99 a
Aquamaster + Renovate	3.0 + 1.0	65	93 abcd	97 ab
Habitat + Renovate	0.5 + 1.0	75	91 bcd	95 b
Clearcast + Renovate	0.5 + 1.0	70	94 abcd	97 ab
Milestone	0.5	50	91 bcd	100 a

Means within a column followed by the same letter or not followed by a letter are not statistically different.

[a]All treatments were applied July 17, 2006 and were mixed with 0.5% DyneAmic surfactant (v/v) prior to application.

[b]WAT = weeks after treatment; MAT = months after treatment.

Herb Robert
2007-2009, 2015-2016

2007-2008 Herb Robert Herbicide Trial

Materials and Methods. An access road to the former Rayoner site in Port Angeles, Washington heavily infested by herb Robert (*Geranium robertianum*) was treated with various herbicides on October 4, 2007 (Cathy Lucero, Clallam County Noxious Weed Control Board, cooperator). Herb Robert plants ranged from older flowering plants to newly germinated seedlings up to 6 inches wide. A light misty rain occurred for about 5 minutes during the Curtail application, and again about the time the last treatment (Finale) was made. There was no additional rain for several hours following treatment. Plots measured 10 by 20 ft, placed end-to-end along the asphalt roadside. Herb Robert plants in each plot were visually rated for percent control (100% = dead hairy willow-herb plants, 0% = healthy hairy willow-herb) November 30, 2007 and April 10 and May 28, 2008. Herbicide treatments were re-applied May 28, 2008, and plots were again rated for herb Robert control June 13 and July 16, 2008 and January 22, 2009. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

Results. Nearly all treatments provided excellent control of herb Robert (Table 1). Control from the initial October application was quickest with Oust, Crossbow, Redeem, and Finale (94% or greater) in November, 2007 (about 1 month after treatment, MAT). By the following April (6 MAT), control was good to excellent for most treatments, ranging from 60 to 100%. Control with Banvel and Transline at that time was poor. Control in June, 2008 following the second (1 MAT) was again very good to excellent for most treatments, with only Banvel, Curtail, and Transline performing poorly. Control was progressively less through July, 2008 (2 MAT), with Banvel Weedmaster, Curtail, and Transline not as effective as other treatments. By January, 2009 (8 MAT), herbicides with appreciable soil activity was providing greater than 81% herb Robert control. Roundup and Finale, with no soil activity, was providing 75 and 76% control, respectively, even though both product provide excellent postemergence control of herb Robert. This indicates that the seed bank, while limited after two herbicide applications, still allowed herb Robert to continue to re-infest the plots even 15 months after the initial treatment. In general, the lowest activity of tested herbicides on herb Robert was with Banvel, Weedmaster, Curtail, and Transline.

Table 1. Herb Robert control following application of several herbicides.

Treatment	Rate	Herb Robert control[b]				
		11/30/07	4/10/08	6/13/08	7/16/08	1/22/09
	product/a	%	%	%	%	%
Oust	2 oz	94 ab	100 a	100 a	100 a	100 a
Banvel	1 qt	25 de	25 c	66 b	59 ef	88 a-e
Roundup	1 qt	65 a-d	100 a	95 ab	84 a-e	75 e
Weedmaster	1 qt	54 bcd	70 abc	83 ab	73 b-f	81 b-e
Curtail	1.6 pt	66 a-d	60 abc	35 c	68 c-f	88 a-e
Crossbow	3 qt	95 ab	100 a	100 a	100 a	99 ab
Garlon	1.5 pt	81 abc	88 ab	85 ab	86 a-d	83 a-e
Transline	8 fl.oz	8 e	50 bc	5 c	54 f	83 a-e
Plateau	12 fl.oz	49 cde	93 ab	80 ab	95 ab	94 a-d
Habitat	3 pt	74 abc	100 a	100 a	100 a	91 a-e
Redeem	1 qt	100 a	100 a	93 ab	91 abc	96 abc
Milestone	3 fl.oz	73 abc	73 ab	95 ab	91 abc	98 ab
Finale	3 qt	100 a	100 a	100 a	84 a-e	76 de

Means within a column followed by the same letter or not followed by a letter are not
  statistically different.
[a]Treatments were applied October 4, 2007 and again May 28, 2008. Plateau and Arsenal
  treatments were mixed with methylated seed oil (0.25%, v/v) prior to application, while
  Oust and Finale treatments were mixed with nonionic surfactant (0.25%, v/v) prior to
  application.
[b]November 30, 2007 and April 10, 2008 evaluations were made after one herbicide
  application; remaining evaluations were made after two herbicide applications.

2015-2016 Herb Robert in Native Forest Trial

Effects of Herbicide Rate and Timing on Herb Robert (*Geranium robertianum*) and Native Plants in Pacific Northwest Forest Habitat

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Funded by US Forest Service, Pesticide Impact Assessment Program (Shawna Bautista)

Abstract. Herb Robert (*Geranium robertianum*) is spreading exponentially in the Pacific
Northwest, prompting its listing as a noxious weed in Washington and Oregon. Most herb
Robert infestations grow comingled with populations of native perennial plant species, so
herbicides were applied at a dosage previously shown to control seedling/young herb Robert
plants to determine the effect of these low rates on established native plants. Trials were
established in late- and early-seral forests at Olympic National Park (ONP) and North Cascades
National Park (NCNP), respectively, during 2015. The most frequently occurring native species
at ONP were red alder (77% of plots), Pacific blackberry (77%), northern bedstraw (83%), sword

fern (95%), bigleaf maple (55%), foamflower (66%), and salmonberry (55%); most frequent species at NCNP were Pacific blackberry (63%), bracken fern (50%), Oregon grape (45%), sword fern (42%), and salal (42%). The most frequent non-native species was wall lettuce (27% at both sites). Herb Robert occurred in 44% of plots at ONP. Low rates of glyphosate (0.75%), imazapyr (0.5%), sulfometuron (1 oz/a), and aminopyralid (3 fl.oz/a) were applied in early May, mid-July, and late September, and full rates of 20% acetic acid, clove oil (20%), and limonene (12.5%) were applied at all three timings. In late September, herb Robert control was 95% with glyphosate applied in July and 90% with sulfometuron applied in May or limonene applied twice (May and July). Control with imazapyr was 80 and 85% when applied in May and July, respectively. By the following July, herb Robert control was maximized by applications of sulfometuron, with control from July and September applications at 80%. Native species showing greater than 30% injury at two or more evaluations included red alder (from glyphosate and sulfometuron), salmonberry (glyphosate, imazapyr, and sulfometuron), grass/sedge species (glyphosate and imazapyr), spring beauty (glyphosate and aminopyralid), thimbleberry (glyphosate, imazapyr, and aminopyralid), and foamflower (glyphosate). Thimbleberry was also sensitive to acetic acid and clove oil, salmonberry to limonene, and salal to clove oil. Based on these results, sulfometuron applied in summer or fall was the best treatment, providing up to 12 months of herb Robert control while not greatly injuring established nontarget vegetation.

Materials and Methods. Plots were established at Olympic National Park (ONP) April 27, 2015 and at North Cascades National Park (NCNP) April 28, 2015. Plot sites were selected based on vegetation at each location in effort to include many species of established native perennial plants as well as some non-native plant species. Plots measured 8 by 30 ft and were situated at the edge of unimproved access roads at both locations. Synthetic herbicides were scheduled to be applied at three timings, early season, midseason, and late season; because they have little residual activity, nonsynthetic herbicides were scheduled to be applied at all three timings. Herbicides were applied May 1, July 15, and September 30 at ONP and April 28 and July 14 at NCNP. The late season applications at NCNP were not made because a wildfire removed most above-ground vegetation in the plots in late August, 2015. Herbicides were applied using a CO_2-pressurized backpack sprayer equipped with a 5-nozzle boom delivering the equivalent of 31 gallons/acre. Weather data for the application dates are included in Table 2. Because herb Robert was only sparsely present in the plots, a non-replicated set of plots was established in a dense population next to the main trial at ONP. These plots received the same treatments as applied in the main trial. Plots were rated for percent visual foliar injury May 12, June 8, and September 30, 2015 and April 28 and July 30, 2016 at ONP and May 8, June 12, and August 6, 2015 at NCNP. The experimental design was a randomized complete block with 4 replicates. Data were analyzed by ANOVA using SAS 9.3. Means were separated using Tukey's Honestly Significant Difference test statistic (P ≤ 0.05).

Results and Discussion.
Inventory. At least 55 different plant species were represented in plots at both sites, 51 species at ONP (Table 3) and 32 species at NCNP (Table 4). Grasses, sedges, and mosses were identified only to that level and not to genus/species, and so are representative only of those general

classifications. Plants of 33 different species were of sufficient abundance to warrant analysis; an additional 22 species were of too sparse a population for statistical analysis. The most frequently occurring native species at ONP were sword fern (95% of plots), red alder and Pacific blackberry (77% each), northern bedstraw (83%), foamflower (66%), and bigleaf maple and salmonberry (55% each); most frequent species at NCNP were Pacific blackberry (63%), bracken fern (50%), Oregon grape (45%), and sword fern and salal (42% each). Moss species were found in nearly every plot at both sites. The most frequent non-native was wall lettuce (27% at both sites). Herb Robert occurred in 44% of plots at ONP but was not found in the plots at NCNP.

Herbicide Effects, Native Species. Injury to native species are listed individually for each herbicide (Tables 5 through 11). There was considerable variability in plant response within each application timing, even from the same herbicides. This is probably partially due to different conditions at the two sites (ONP and NCNP), and may also be partially due to herbicide interception by foliage growing over the top of other species in the plots.

Native species showing 30% or greater injury from the May herbicide applications include bigleaf maple (imazapyr), false lily-of-the-valley (imazapyr), foamflower (glyphosate, imazapyr), goatsbeard (imazapyr), grass/sedge species (glyphosate), huckleberry (imazapyr), lady fern (sulfometuron, clove oil), Pacific blackberry (aminopyralid, clove oil), red alder (glyphosate, sulfometuron), salal (clove oil), salmonberry (glyphosate, imazapyr, sulfometuron, aminopyralid), spring beauty (glyphosate, aminopyralid), starflower (imazapyr), thimbleberry (imazapyr, aminopyralid), trail plant (glyphosate), twisted stalk (glyphosate, imazapyr, sulfometuron), violet (aminopyralid, acetic acid, clove oil), and western hemlock (aminopyralid).

Native species showing 30% or greater injury from the July herbicide applications include bigleaf maple (imazapyr), bracken fern (glyphosate), foamflower (glyphosate), grass/sedge (glyphosate, imazapyr, limonene), huckleberry (imazapyr, sulfometuron), lady fern (glyphosate), Pacific blackberry (glyphosate, sulfometuron), red alder (glyphosate, imazapyr), salal (clove oil), salmonberry (glyphosate, imazapyr, sulfometuron, aminopyralid, limonene), smilacina (glyphosate), starflower (glyphosate), sweet cicely (imazapyr, aminopyralid), sword fern (glyphosate), thimbleberry (glyphosate, imazapyr, sulfometuron, acetic acid, clove oil), western hemlock (aminopyralid), western red cedar (glyphosate, aminopyralid), and youth-on-age (imazapyr).

Native species showing 30% or greater injury from the September herbicide application include foamflower (glyphosate), geum (aminopyralid), huckleberry (sulfometuron), salmonberry (glyphosate, imazapyr, sulfometuron), sword fern (glyphosate), thimbleberry (glyphosate, aminopyralid), and youth-on-age (glyphosate, imazapyr).

May and July herbicide applications were generally more injurious to native vegetation than the September application. Based on visual ratings the year after treatment, the following herbicide/species combined effects were observed:

Glyphosate. Most species were only slightly injured by May glyphosate applications or had generally recovered by 14 months after treatment (MAT), with only red alder, salmonberry, and trail plant displaying greater than 30% injury. When applied in July, however, glyphosate caused 83% injury to salmonberry, 50% injury to western red cedar, 45% injury to foamflower, 43% injury to sword fern, and 40% injury to thimbleberry and starflower at 12 MAT. Plants treated with glyphosate in September generally showed only slight injury by 10 MAT, except for salmonberry (80% injury) and thimbleberry (100% injury).

Imazapyr. Imazapyr application caused some injury at all three timings, although recovery was generally good. Salmonberry was particularly susceptible to imazapyr, with injury of 65% from May application at 14 MAT, 100% from July application at 12 MAT, and 90% for September application at 10 MAT. Huckleberry was also quite sensitive to imazapyr, with 50% injury at 14 months after May treatment and 73% at 12 months after July treatment. Sweet cicely may also have been killed by imazapyr applied in July, as no plants were observed in treated plots at 12 MAT.

Sulfometuron. When treated with sulfometuron in May, most plant species either did not show more than slight injury or had recovered completely by 14 MAT. Thimbleberry treated with sulfometuron in July was still displaying 50% injury at 12 MAT, and blackberry and salmonberry showed 30% injury at the same evaluation. Only salmonberry (58% injury) and huckleberry (30% injury) had not recovered by 10 months after September treatment.

Aminopyralid. Aminopyralid did not generally cause lasting negative effects to these species, regardless of application timing. Only western red cedar (70% injury) and salmonberry (35% injury) had not generally recovered by 12 months after the July treatment, while no species treated in May or September treatments showed more than 15% injury by summer of the year after treatment. Sweet cicely and western hemlock may also have been killed by aminopyralid applied in July, however, as no plants were observed in treated plots at 12 MAT.

Acetic acid, clove oil, limonene. Slight to moderate foliar damage occurred on certain species shortly after each of three applications, although plants were showing little or no injury by July of the year after applications of these herbicides.

Herbicide Effects, Nonnative Species. Injury to nonnative species (other than herb Robert) are listed individually for each herbicide (Tables 5 through 11). The only nonnative species showing 30% or greater herbicide injury were creeping buttercup from glyphosate applied in May and wall lettuce from sulfometuron applied in July.

Herbicide Effects, Herb Robert. In late September, 2015 herb Robert control was 95% with glyphosate applied in July and 90% with sulfometuron applied in May or limonene applied twice

(May and July) (Table 12). Herb Robert control in September from imazapyr applied in May and July was 80 and 85%, respectively. By April of the year following herbicide treatment, Herb Robert control exceeded 75% with glyphosate applied the previous September or sulfometuron (July or September applications). By July, 2016, only sulfometuron was still providing acceptable weed control, 75% control from the May, 2015 application, and 80% control from both the July and September, 2015 applications. This result was unexpected, as sulfometuron often does not provide long-term control of vegetation. Continued testing of sulfometuron on herb Robert is warranted based on these promising result.

Conclusions. Multiple applications of nonsynthetic herbicides were not effective against herb Robert, although nontarget injury to established perennial species was moderate at worst and always temporary. Herb Robert control was better from applications of glyphosate, imazapyr, sulfometuron, or aminopyralid, although injury to nontarget plants was also greater. The native plant species most sensitive to these synthetic herbicides were salmonberry, thimbleberry, and huckleberry. This may be a relatively arbitrary result, as these species were widespread in the plots so herbicide effects were fairly clear. Also, because a boom sprayer was used for these applications, most of the foliage of these species received herbicide treatment, which no doubt increased the level of injury observed. Still, these plants were rarely killed outright from the herbicides applied at these rates; rather, they were injured and displayed symptomatic foliar growth, but their full recovery is likely.

It should be pointed out that the summer months were remarkably and atypically dry in 2015, with little rainfall occurring at the trial sites from June to September. Consequently, much of what was viewed as potential herbicide injury (dry foliage, shoot die-back, and failure of plants to regrow in spring of 2016) may have resulted as much from water stress as from herbicide response. This was true at ONP, where plots were located on thin soil along the edge of a gravel roadway. The August, 2015 wildfire at NCNP resulted in complete removal of understory plants through July, 2016, so longer term herbicide effects/recovery were not estimable at that site. The percent injury to various species noted in this study tells only of individual plant injury, or their recovery, from application of these herbicides, as herbicidal effects on population dynamics were not directly measured. Annual herbicide applications for up to three years, as will likely be necessary to fully control herb Robert, may be more damaging than the single treatments in these plots. But given the recovery of many species to the lower herbicide rates testing in these trials, widespread loss of established perennial understory species should not be expected to result from targeted herb Robert control efforts.

Based on these results, it appears that sulfometuron applied in summer or fall was the best treatment. The herbicide provided up to 12 months of herb Robert control while not greatly injuring existing nontarget vegetation. Pacific blackberry, thimbleberry, salmonberry, and huckleberry could be expected to show the greatest injury from sulfometuron applied at this rate and at these timings. Although damage could be severe in some cases, most individual plants of these species should survive these applications. Damage to these berry species could be reduced by applying the herbicide as a directed spray to low-growing herb Robert and therefore below the majority of the foliage on these nontarget species.

Table 2. Weather data at the time of herbicide applications (2015).

Location/date	Timing	Time	Temperature	Foliage wetness
North Cascades				
April 28	Early	10:20 to 11:40 a.m.	48 F	Wet
July 14	Mid	11:00 a.m. to 1:00 p.m.	75 F	Dry
Olympic				
May 1	Early	1:15 to 2:45 p.m.	53 F	Dry
July 15	Mid	10:30 a.m. to 12:30 p.m.	70 F	Dry
September 30	Late	10:10 a.m. to 12:10 p.m.	60 F	Dry

All plots had full canopy cover from mature tree overstory, so little direct sunlight made it to
  the level of vegetation on the ground. No wind was present at the time of any application at
  either site.

Table 3. Plant species found in plots at Olympic National Park (ONP).

Common name	Scientific name	Plant family	Nativity	Life cycle	Total plot number[1]	Percent of plots
Alder, red	*Alnus rubra*	Betulaceae	Native	Perennial	49	76.6
Blackberry, Pacific	*Rubus ursinus*	Rosaceae	Native	Perennial	49	76.6
Buttercup, creeping	*Ranunculus repens*	Ranunculaceae	Introduced	Perennial	5	7.8
Cedar, western red	*Thuja plicata*	Cupressaceae	Native	Perennial	15	23.4
Coltsfoot	*Petasites frigidus*	Asteraceae	Native	Perennial	5	7.8
Dock, broadleaf	*Rumex obtusifolius*	Polygonaceae	Introduced	Perennial	2	3.1
Douglas fir	*Pseudotsuga menziesii*	Pinaceae	Native	Perennial	7	10.9
Elderberry, red	*Sambucus racemosa*	Caprifoliaceae	Native	Perennial	7	10.9
False lily-of-the-valley	*Maianthemum dilatatum*	Liliaceae	Native	Perennial	20	31.3
Fern, bracken	*Pteridium aquilinum*	Polypodiaceae	Native	Perennial	12	18.8
Fern, deer	*Blechnum spicant*	Polypodiaceae	Native	Perennial	2	3.1
Fern, lady	*Athyrium filix-femina*	Polypodiaceae	Native	Perennial	21	32.8
Fern, sword	*Polistichum munitum*	Polypodiaceae	Native	Perennial	61	95.3
Fireweed	*Chamerion angustifolium*	Onagraceae	Native	Perennial	4	6.3
Forget-me-not	*Myosotis arvensis*	Boraginaceae	Introduced	Annual	13	20.3
Foamflower	*Tiarella trifoliata*	Saxifragaceae	Native	Perennial	42	65.6
Geum	*Geum macrophyllum*	Rosaceae	Native	Perennial	13	20.3
Goatsbeard	*Aruncus dioicus*	Rosaceae	Native	Perennial	12	18.8
Gooseberry	*Ribes* spp.	Grossulariaceae	Native	Perennial	1	1.6
Grass	Several	Poaceae	?	?	26	40.6
Hemlock, western	*Tsuga heterophylla*	Pinaceae	Native	Perennial	8	12.5
Herb Robert	*Geranium robertianum*	Geraniaceace	Introduced	Annual	28	43.8
Huckleberry, red	*Vaccinium parvifolium*	Ericaceae	Native	Perennial	15	23.4
Lettuce, wall	*Mycelis muralis*	Asteraceae	Introduced	Annual	17	26.6
Maple, bigleaf	*Acer macrophyllum*	Aceraceae	Native	Perennial	35	54.7
Meadow rue	*Thalictrum occidentale*	Ranunculaceae	Native	Perennial	1	1.6
Mint, field	*Mentha arvensis*	Lamiaceae	Native	Perennial	2	3.1
Moss	Several	Several	Native	Perennial	64	100.0
Nemophila	*Nemophila parviflora*	Hydrophyllaceae	Native	Annual	1	1.6
Northern bedstraw	*Galium boreale*	Rubiaceae	Native	Perennial	53	82.8
Oregon grape	*Mahonia nervosa*	Berberidaceae	Native	Perennial	2	3.1
Oxeye daisy	*Leucanthemum vulgare*	Asteraceae	Introduced	Perennial	4	6.3
Pearly everlasting	*Anaphalis margaritacea*	Asteraceae	Native	Perennial	2	3.1
Salal	*Gaultheria shallon*	Ericaceae	Native	Perennial	29	45.3
Salmonberry	*Rubus spectabilis*	Rosaceae	Native	Perennial	35	54.7
Sedge	*Carex* spp.	Cyperaceae	Native (?)	Perennial	25	39.1

Smilacina	*Smilacina racemosa*	Liliaceae	Native	Perennial	14	21.9
Speedwell	*Veronica* spp.	Scrophulariaceae	?	?	6	9.4
Spring beauty	*Claytonia lanceolata*	Portulacaceae	Native	Perennial	14	21.9
Starflower	*Trientalis arctica*	Primulaceae	Native	Perennial	22	34.4
Sweet cicely	*Osmorhiza chilensis*	Apiaceae	Native	Perennial	13	20.3
Sweetpea	*Lathyrus latifolius*	Fabaceae	Introduced	Perennial	1	1.6
Thimbleberry	*Rubus parviflorus*	Rosaceae	Native	Perennial	22	34.4
Thistle, Canada	*Cirsium arvense*	Asteraceae	Introduced	Perennial	3	4.7
Trail plant	*Adenocaulon bicolor*	Asteraceae	Native	Perennial	7	10.9
Trillium	*Trillium ovatum*	Liliaceae	Native	Perennial	6	9.4
Twinflower	*Linnaea borealis*	Caprifoliaceae	Native	Perennial	11	17.2
Twisted stalk	*Streptopus amplexifolius*	Liliaceae	Native	Perennial	13	20.3
Vetch, American	*Vicia americana*	Fabaceae	Native	Perennial	4	6.3
Violet	*Viola glabella*	Violaceae	Native	Perennial	3	4.7
Youth-on-age	*Tolmiea menziesii*	Saxifragiacaee	Native	Perennial	40	62.5

[1]Total number of plots in which the species was recorded as occurring. The sum total of 64 plots were included in the trial (16 treatments x 4 replicates). Each plot measured 240 ft^2 (30 feet long by 8 feet wide).

Table 4. Plant species found in plots at North Cascades National Park (NCNP).

Common name	Scientific name	Plant family	Nativity	Life cycle	Total plot number	Percent of plots
Alder, red	*Alnus rubra*	Betulaceae	Native	Perennial	6	9.4
Blackberry, Pacific	*Rubus ursinus*	Rosaceae	Native	Perennial	40	62.5
Bunchberry	*Cornus canadensis*	Cornaceae	Native	Perennial	4	6.3
Buttercup, creeping	*Ranunculus repens*	Ranunculaceae	Introduced	Perennial	4	6.3
Cedar, western red	*Thuja plicata*	Cupressaceae	Native	Perennial	20	31.3
Elderberry, red	*Sambucus racemosa*	Caprifoliaceae	Native	Perennial	1	1.6
Fern, bracken	*Pteridium aquilinum*	Polypodiaceae	Native	Perennial	32	50.0
Fern, deer	*Blechnum spicant*	Polypodiaceae	Native	Perennial	4	6.3
Fern, lady	*Athyrium filix-femina*	Polypodiaceae	Native	Perennial	6	9.4
Fern, sword	*Polistichum munitum*	Polypodiaceae	Native	Perennial	27	42.2
Gooseberry	*Ribes* spp.	Grossulariaceae	Native	Perennial	3	4.7
Grass	Several	Poaceae	?	?	13	20.3
Hawkweed, white	*Hieracium alba*	Asteraceae	Native	Perennial	1	1.6
Hemlock, western	*Tsuga heterophylla*	Pinaceae	Native	Perennial	10	15.6
Huckleberry, red	*Vaccinium parvifolium*	Ericaceae	Native	Perennial	10	15.6
Lettuce, wall	*Mycelis muralis*	Asteraceae	Introduced	Annual	17	26.6
Maple, bigleaf	*Acer macrophyllum*	Aceraceae	Native	Perennial	28	43.8
Moss	Several	Several	Native	Perennial	64	100.0
Nipplewort	*Lapsana communis*	Asteraceae	Introduced	Annual	3	4.7
Northern bedstraw	*Galium boreale*	Rubiaceae	Native	Perennial	15	23.4
Oregon grape	*Mahonia nervosa*	Berberidaceae	Native	Perennial	29	45.3
Pearly everlasting	*Anaphalis margaritacea*	Asteraceae	Native	Perennial	1	1.6
Rattlesnake plantain	*Goodyeara repens*	Orchidaceae	Native	Perennial	2	3.1
Salal	*Gaultheria shallon*	Ericaceae	Native	Perennial	27	42.2
Salmonberry	*Rubus spectabilis*	Rosaceae	Native	Perennial	2	3.1
Sedge	*Carex* spp.	Cyperaceae	Native (?)	Perennial	23	35.9
Smilacina	*Smilacina racemosa*	Liliaceae	Native	Perennial	3	4.7
Spring beauty	*Claytonia lanceolata*	Portulacaceae	Native	Perennial	20	31.3
Starflower	*Trientalis arctica*	Primulaceae	Native	Perennial	16	25.0
Twinflower	*Linnaea borealis*	Caprifoliaceae	Native	Perennial	10	15.6
Violet	*Viola glabella*	Violaceae	Native	Perennial	12	18.8
Youth-on-age	*Tolmiea menziesii*	Saxifragiacaee	Native	Perennial	11	17.2

[1]Total number of plots in which the species was recorded as occurring. The sum total of 64 plots were included in the trial (16 treatments x 4 replicates). Each plot measured 240 ft^2 (30 feet long by 8 feet wide).

Table 5. Percent plant injury from glyphosate applied in early May, mid-July, or late September, 2015 to established vegetation in Olympic and North Cascades National Parks (ONP and NCNP, respectively).

Species	Glyphosate Early[1]	Glyphosate Mid[2]	Glyphosate Late[3]
	%	%	%
Pacific blackberry	8, 28, 6, 13, 26, 24	3, 18, 32, 38	0, 25
Bracken fern	0, 19, 10, ---, ---, 15	12, ---, 100, 0	---, ---
Sword fern	0, 23, 7, 14, 3, 22	0, 0, 0, 43	0, 43
Red alder	1, 50, 0, 51, 0, 33	0, 63, 0, ---	0, 0
Bigleaf maple	8, 0, 4, 18, 0, 15	0, 25, 0, 0	0, 13
Oregon grape	0, 8, 18, ---, ---, ---	0, ---, ---, ---	---, 0
Salal	1, 9, 11, 5, 0, 0	5, 3, 0, 0	5, 3
Youth-on-age	10, 0, 0, 0, ---, 0	0, 10, 23, 0	60, 0
Sedge	4, 41, 0, 33, 0, 0	0, 0, ---, ---	---, ---
Salmonberry	5, 16, 0, 35, 40, 37	0, 18, 100, 83	10, 80
Starflower	10, 23, 0, 0, 0, ---	0, 22, 25, 40	0, 10
Spring beauty	4, 33, 0, 0, 0, 0	---, ---, 0, 0	0, ---
Grass	5, 27, 0, 60, 0, 0	15, 43, ---, ---	---, ---
Huckleberry	0, 10, 7, 0, ---, 0	20, ---, ---, ---	---, ---
Smilacina	3, 5, 0, 23, 0, 20	0, 10, 0, 40	---, 0
Lady fern	0, 20, 0, 0, 0, 15	0, 0, 30, ---	30, 8
Western hemlock	0, 5, 25, 30, ---, ---	20, ---, ---, ---	---, ---
Western red cedar	5, 9, 16, 15, 0, 0	0, 0, ---, 50	---, ---
Twinflower	---, ---, ---, ---, ---, ---	0, 0, ---, ---	---, ---
Wall lettuce	---, 15, 0, ---, 0, 0	3, 22, ---, 0	---, 0
Northern bedstraw	0, 0, 0, 0, 0, ---	0, 10, 25, 0	0, 0
Creeping buttercup	0, 30, 0, ---, ---, 0	0, 5, ---, ---	---, ---
Red elderberry	---, ---, ---, ---, ---, ---	5, 0, ---, ---	---, ---
Violet	10, 15, 0, ---, 0	---, ---, ---	---, ---
Thimbleberry	8, 25, 0, 21, 22, 13	0, 30, 100, 40	---, 100
False lily-of-the-valley	0, 0, 0, 0, 0, ---	0, 0, 0, ---	0, 0
Geum	10, 0, 0, 0, 0, ---	0, 10, ---, ---	---, ---
Trail plant	0, 0, 0, 0, 0, 30	---, ---, ---, 0	---, 0
Trillium	---, ---, ---, ---, 10, ---	0, 0, 0, 0	0, 0
Foamflower	0, 0, 0, 45, ---, 10	0, 27, 13, 45	35, 25
Sweet cicely	0, 0, 0, 0, 0, ---	0, 60, ---, ---	---, 0
Twisted stalk	0, ---, 0, 30, ---, 20	---, ---, ---, 0	---, 0
Goatsbeard	---, 0, ---, ---, ---, ---	---, ---, ---, ---	0, ---

[1]Evaluations for "Early" were in mid-May, early June, early August, and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[2]Evaluations for "Mid" were early August and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[3]Evaluations for "Late" were late April and late July, 2016 at ONP.

Table 6. Percent plant injury from imazapyr applied in early May, mid-July, or late September, 2015 to established vegetation in Olympic and North Cascades National Parks (ONP and NCNP, respectively).

Species	Imazapyr Early[1]	Imazapyr Mid[2]	Imazapyr Late[3]
	%	%	%
Pacific blackberry	3, 15, 9, 11, 16, 9	0, 19, 20, 10	10, 13
Bracken fern	0, 13, 16, 0, 15	5, ---, 0, ---	---, ---
Sword fern	1, 21, 2, 11, 8, 13	5, 12, 0, 20	0, 30
Red alder	1, 15, 0, 23, 20, 0	0, 8, 10, 35	5, 20
Bigleaf maple	0, 34, 17, 0, 0, 0	20, 32, ---, ---	0, ---
Oregon grape	0, 5, 5, ---, ---, ---	0, ---, 0, 0	---, ---
Salal	0, 5, 13, 0, 0, 0	5, 0, 0, 0	0, 0
Youth-on-age	1, 23, 0, 13, 0, 0	0, 0, 50, 0	38, 20
Sedge	0, 33, 0, 0, 0, 0	0, 0, 100, 0	0, ---
Salmonberry	0, 19, 0, 35, 63, 65	0, 50, 100, 100	15, 90
Starflower	2, 31, 8, 30, 15, ---	0, 0, --, ---	---, 25
Spring beauty	4, 25, 0, 0, 0, 0	25, ---, ---, ---	---, ---
Grass	0, 11, 20, 25, ---, 0	0, 20, 100, 0	---, ---
Huckleberry	0, 3, 15, 40, 50, 50	5, 0, 40, 73	---, ---
Smilacina	0, 13, 8, 15, ---, ---	---, ---, ---, ---	0, ---
Lady fern	0, 5, 0, 10, ---, 0	0, 10, ---, ---	0, 23
Western hemlock	0, 20, 10, ---, ---, ---	---, ---, 0, 0	0, ---
Western red cedar	0, 13, 3, ---, ---, ---	0, 0, ---, 0	0, ---
Twinflower	0, 0, 0, ---, ---, ---	---, ---, ---, ---	---, ---
Wall lettuce	---, 3, 0, 5, ---, 0	0, 5, 0, 0	0, 0
Northern bedstraw	0, 30, 0, 0, 0, 0	0, 5, 0, ---	0, 0
Creeping buttercup	0, 25, 0, ---, ---, ---	0, ---, ---, ---	---, ---
Red elderberry	---, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Violet	0, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Thimbleberry	0, 13, 0, 40, 50, 0	0, 35, ---, ---	---, ---
False lily-of-the-valley	0, 0, 0, 40, 0, 0	0, 0, 0, ---	0, 0
Geum	---, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Trail plant	---, ---, ---, ---, ---, ---	---, ---, ---, ---	0, 0
Trillium	0, ---, ---, ---, 0, ---	---, ---, ---, ---	---, ---
Foamflower	0, 11, 0, 30, 0, 0	0, 20, 25, 0	28, 6
Sweet cicely	0, 0, 0, 0, ---, ---	0, 100, ---, ---	0, 0
Twisted stalk	15, 18, 0, 40, 0, 0	---, ---, ---, ---	---, 0
Goatsbeard	70, 30, 0, 0, ---, ---	---, ---, ---, ---	---, ---

[1]Evaluations for "Early" were in mid-May, early June, early August, and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[2]Evaluations for "Mid" were early August and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[3]Evaluations for "Late" were late April and late July, 2016 at ONP.

Table 7. Percent plant injury from sulfometuron applied in early May, mid-July, or late September, 2015 to established vegetation in Olympic and North Cascades National Parks (ONP and NCNP, respectively).

Species	Sulfometuron Early[1]	Sulfometuron Mid[2]	Sulfometuron Late[3]
	%	%	%
Pacific blackberry	4, 14, 6, 5, 13, 0	3, 16, 25, 30	11, 20
Bracken fern	0, 5, 15, ---, 0, 0	10, ---, ---, ---	---, ---
Sword fern	3, 4, 7, 4, 3, 8	0, 10, 0, 20	0, 20
Red alder	1, 34, 0, 5, 55, 8	0, 8, 0, 13	0, 13
Bigleaf maple	4, 23, 7, 7, 0, ---	0, 15, 0, 0	0, 6
Oregon grape	0, 8, 13, ---, ---, ---	0, ---, ---, ---	---, ---
Salal	0, 11, 3, 5, 0, 0	3, 0, 0, 10	0, 0
Youth-on-age	0, 14, 8, 0, ---, 0	0, 0, 0, 0	---, ---
Sedge	0, 12, 13, 0, ---, ---	0, 0, 0, 0	---, ---
Salmonberry	3, 15, 0, 40, 100, 0	0, 40, 15, 30	100, 58
Starflower	1, 11, 4, 20, ---, ---	23, 0, ---, ---	---, ---
Spring beauty	5, 0, 0, 0, 0, ---	---, ---, 0, ---	---, ---
Grass	0, 0, 5, 0, 0, 0	0, 0, 0, 0	---, ---
Huckleberry	5, 0, 0, 15, 15, 25	5, ---, 40, 0	15, 30
Smilacina	5, 0, 0, 8, ---, 0	---, ---, ---, ---	---, 0
Lady fern	25, 40, 0, ---, ---, ---	0, 13, 0, 0	10, 17
Western hemlock	---, ---, ---, ---, ---, ---	0, ---, ---, ---	---, ---
Western red cedar	0, 8, 0, 0, 10, ---	---, ---, ---, ---	0, 0
Twinflower	0, 0, 0, 0, ---, ---	0, ---, ---, ---	0, ---
Wall lettuce	---, 20, 18, 0, 0, 0	7, 30, 0, 0	0, 0
Northern bedstraw	0, 9, 0, 23, 0, 0	0, 13, 0, 0	0, 0
Creeping buttercup	---, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Red elderberry	---, ---, ---, ---, ---, ---	---, ---, ---, 0	0, ---
Violet	10, 0, 0, 0, ---, ---	---, ---, ---, ---	---, ---
Thimbleberry	5, 10, 0, 0, 20, 0	0, 10, 50, 50	20, ---
False lily-of-the-valley	0, 0, 0, 10, 0, ---	---, 0, 0, ---	0, 0
Geum	---, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Trail plant	---, ---, ---, ---, 0, ---	0, 0, ---, 0	---, ---
Trillium	---, 0, ---, ---, ---, ---	---, ---, ---, ---	0, ---
Foamflower	0, 0, 0, 28, 0, 0	0, 3, 0, 0	10, 5
Sweet cicely	0, 0, 0, 0, ---, ---	---, ---, ---, ---	---, ---
Twisted stalk	0, 50, 0, 5, ---, 0	0, 8, 0, 0	0, 0
Goatsbeard	0, 25, 0, 0, ---, ---	---, ---, ---, ---	---, ---

[1]Evaluations for "Early" were in mid-May, early June, early August, and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[2]Evaluations for "Mid" were early August and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[3]Evaluations for "Late" were late April and late July, 2016 at ONP.

Table 8. Percent plant injury from aminopyralid applied in early May, mid-July, or late September, 2015 to established vegetation in Olympic and North Cascades National Parks (ONP and NCNP, respectively).

Species	Aminopyralid Early[1]	Aminopyralid Mid[2]	Aminopyralid Late[3]
	%	%	%
Pacific blackberry	17, 32, 11, 37, 30, 0	9, 8, 10, 0	0, 10
Bracken fern	9, 6, 14, 0, 0, ---	0, 0, ---, ---	0, ---
Sword fern	1, 0, 1, 8, 3, 11	0, 3, 0, 11	0, 13
Red alder	16, 18, 0, 17, 0, 2	0, 28, 0, 8	0, 18
Bigleaf maple	19, 21, 8, 20, 0, 0	7, 15, 15, 0	0, 6
Oregon grape	3, 25, 10, ---, ---, ---	13, ---, ---, ---	---, ---
Salal	1, 19, 18, 13, 13, 0	0, 0, 0, 10	0, 0
Youth-on-age	10, 0, 0, 0, 0, 0	0, 3, 0, 5	15, 0
Sedge	0, 0, 0, 0, 0, ---	0, ---, 0, 0	0, 0
Salmonberry	22, 17, 0, 12, 100, 13	0, 15, 10, 35	10, ---
Starflower	15, 23, 3, 0, 0, 0	0, 0, 0, ---	0, 0
Spring beauty	25, 45, 0, 0, ---, ---	---, ---, ---, 0	0, 0
Grass	0, 0, 0, 0, 0, ---	0, 0, 0, 0	0, 0
Huckleberry	17, 20, 0, 13, 10, 0	0, 0, 10, 8	---, ---
Smilacina	28, 25, 8, 0, ---, 0	0,0, 0, ---	---, ---
Lady fern	0, 0, 0, 10, 5, 15	0, 5, 0, 0	0, 0
Western hemlock	8, 10, 50, 0, 10, 0	0, 50, 50, ---	---, ---
Western red cedar	3, 13, 18, 0, ---, ---	5, 30, 50, 70	---, 25
Twinflower	6, 0, 0, 13, 0, 0	0, ---, ---, ---	---, ---
Wall lettuce	---, ---, ---, ---, ---, 0	8, 25, ---, 0	0, 0
Northern bedstraw	18, 24, 0, 0, 0, ---	0, 8, 0, ---	---, ---
Creeping buttercup	---, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Red elderberry	---, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Violet	45, 0, 0, ---, ---, ---	---, ---, ---, ---	---, ---
Thimbleberry	32, 29, 0, 25, 10, 8	0, 20, 13, 8	40, 0
False lily-of-the-valley	0, 18, 0, 3, 0, 0	0, 5, 13, 0	0, 0
Geum	0, 0, 0, 0, ---, ---	0, 10, 0, 0	33, 0
Trail plant	---, ---, ---, ---, ---, ---	---, ---, ---, ---	---, ---
Trillium	---, ---, ---, ---, ---, ---	0, ---, 0, ---	---, ---
Foamflower	0, 0, 0, 29, 5, 0	0, 14, 0, 0	5, ---
Sweet cicely	---, ---, ---, ---, ---, ---	0, 100, ---, ---	30, 0
Twisted stalk	0, 12, 0, 20, ---, ---	---, ---, ---, 0	---, 0
Goatsbeard	0, 15, 0, 0, ---, ---	---, ---, ---, ---	---, ---

[1]Evaluations for "Early" were in mid-May, early June, early August, and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[2]Evaluations for "Mid" were early August and late September, 2015 at both sites, and late April and late July, 2016 at ONP.

[3]Evaluations for "Late" were late April and late July, 2016 at ONP.

Table 9. Percent plant injury from acetic acid applied in early May, mid-July, and late September, 2015 to established vegetation in Olympic and North Cascades National Parks (ONP and NCNP, respectively).

Species	Acetic Acid Early[1]	Acetic Acid Early + Mid[2]	Acetic Acid Early + Mid + Late[3]
	%	%	%
Pacific blackberry	23, 4	22, 14	0, 3
Bracken fern	4, 6	6, 5	0, ---
Sword fern	3, 3	0, 8	0, 5
Red alder	11, 1	0, 7	0, 13
Bigleaf maple	5, 2	5, 1	0, 0
Oregon grape	0, 0	0, ---	---, ---
Salal	0, 0	0, 0	---, ---
Youth-on-age	22, 0	10, 0	0, ---
Sedge	6, 1	0, 5	0, 0
Salmonberry	1, 1	0, 0	---, 0
Starflower	1, 0	20, 0	0, 0
Spring beauty	18, 1	0, 0	0, 0
Grass	0, 0	9, 5	0, 0
Huckleberry	0, 5	0, ---	---, ---
Smilacina	10, 0	0, 0	0, ---
Lady fern	0, 0	0, 3	0, 3
Western hemlock	23, 5	0, 10	0, ---
Western red cedar	14, 8	22, 5	10, ---
Twinflower	0, 0	0, 0	0, 0
Wall lettuce	---, 0	3, 3	0, 0
Northern bedstraw	17, 0	8, 0	0, 0
Creeping buttercup	---, ---	---, 0	---, ---
Red elderberry	0, 0	0, 0	0, ---
Violet	43, 0	0, ---	---, ---
Thimbleberry	25, 0	0, 30	0, 0
False lily-of-the-valley	---, ---	---, ---	---, ---
Geum	10, 0	0, 0	---, ---
Trail plant	0, 0	0, 0	---, ---
Trillium	---, ---	---, ---	---, ---
Foamflower	0, 0	0, 3	0, ---
Sweet cicely	0, 0	0, 0	0, 0
Twisted stalk	0, 0	0, 15	---, 0
Goatsbeard	0, 0	0, 0	---, ---

[1]Evaluations for "Early" were in mid-May and early June, 2015 at both sites.

[2]Evaluations for "Early + Mid" were early August and late September, 2015 at both sites.

[3]Evaluations for "Early + Mid + Late" were late April and late July, 2016 at ONP.

Table 10. Percent plant injury from clove oil applied in early May, mid-July, and late September, 2015 to established vegetation in Olympic and North Cascades National Parks (ONP and NCNP, respectively).

Species	Clove Oil Early[1]	Clove Oil Early + Mid[2]	Clove Oil Early + Mid + Late[3]
	%	%	%
Pacific blackberry	40, 4	8, 5	0, 0
Bracken fern	9, 8	3, 10	0, ---
Sword fern	6, 4	0, 0	0, 10
Red alder	17, 7	0, 10	0, 0
Bigleaf maple	16, 7	16, 7	0, 0
Oregon grape	20, 0	0, ---	---, 0
Salal	42, 11	33, 60	0, 0
Youth-on-age	6, 0	0, 5	0, 0
Sedge	20, 17	13, 0	0, 0
Salmonberry	0, 0	0, 20	---, 0
Starflower	0, 0	0, ---	0, ---
Spring beauty	0, 2	10, 0	0, ---
Grass	0, 0	16, 20	0, 0
Huckleberry	---, ---	---, ---	---, ---
Smilacina	---, 0	---, ---	0, ---
Lady fern	35, 40	0, 20	0, 0
Western hemlock	0, 0	0, 0	---, ---
Western red cedar	7, 7	20, 10	0, ---
Twinflower	0, 0	0, ---	---, ---
Wall lettuce	---, 0	20, 15	0, 0
Northern bedstraw	0, 0	5, 0	0, 0
Creeping buttercup	0, 0	0, 0	---, ---
Red elderberry	0, 0	0, 0	---, ---
Violet	75, 0	0, ---	---, ---
Thimbleberry	20, 5	0, 38	0, 0
False lily-of-the-valley	0, 0	0, 0	0, ---
Geum	3, 0	0, 0	---, ---
Trail plant	0, 0	0, 0	---, ---
Trillium	---, ---	---, ---	---, ---
Foamflower	0, 0	0, 3	0, ---
Sweet cicely	0, 0	0, 0	0, 0
Twisted stalk	---, ---	---, ---	---, ---
Goatsbeard	0, 0	0, 0	---, ---

[1]Evaluations for "Early" were in mid-May and early June, 2015 at both sites.

[2]Evaluations for "Early + Mid" were early August and late September, 2015 at both sites.

[3]Evaluations for "Early + Mid + Late" were late April and late July, 2016 at ONP.

Table 11. Percent plant injury from limonene applied in early May, mid-July, and late September, 2015 to established vegetation in Olympic and North Cascades National Parks (ONP and NCNP, respectively).

Species	Limonene Early[1]	Limonene Early + Mid[2]	Limonene Early + Mid + Late[3]
	%	%	%
Pacific blackberry	15, 6	7, 5	0, 5
Bracken fern	3, 7	8, 0	---, ---
Sword fern	4, 4	0, 0	0, 8
Red alder	13, 4	0, 3	0, 5
Bigleaf maple	2, 1	8, 18	0, 0
Oregon grape	0, 3	0, ---	---, ---
Salal	6, 0	3, 0	5, 0
Youth-on-age	0, 0	0, 0	---, ---
Sedge	10, 4	9, 0	---, ---
Salmonberry	9, 4	0, 32	10, 13
Starflower	8, 0	0, 2	0, 0
Spring beauty	10, 0	9, 0	0, ---
Grass	2, 3	5, 40	0, 0
Huckleberry	15, 5	0, 13	0, 0
Smilacina	18, 0	0, 0	---, ---
Lady fern	0, 3	3, 0	0, ---
Western hemlock	1, 0	0, 3	8, 8
Western red cedar	6, 0	0, 0	0, 0
Twinflower	3, 0	0, 0	0, 0
Wall lettuce	---, 0	5, 3	0, 0
Northern bedstraw	3, 0	5, 0	0, 0
Creeping buttercup	---, ---	---, ---	---, ---
Red elderberry	0, 0	---, ---	---, ---
Violet	20, 0	10, 0	---, ---
Thimbleberry	10, 0	0, 0	0, 0
False lily-of-the-valley	0, 0	0, 0	0, ---
Geum	---, ---	---, ---	---, ---
Trail plant	5, 0	0, 0	0, 0
Trillium	---, 0	---, ---	---, ---
Foamflower	0, 0	0, 5	0, ---
Sweet cicely	0, 0	0, 0	---, ---
Twisted stalk	0, 0	0, 0	---, 0
Goatsbeard	0, 0	0, 0	---, ---

[1]Evaluations for "Early" were in mid-May and early June, 2015 at both sites.

[2]Evaluations for "Early + Mid" were early August and late September, 2015 at both sites.

[3]Evaluations for "Early + Mid + Late" were late April and late July, 2016 at ONP.

Table 12. Herb Robert control from application of several herbicides to established vegetation in Olympic National Park (ONP).

Treatment	Rate	Timing[1]	5/12/15	9/30/15	4/28/16	7/30/16
	% or product		%	%	%	%
Glyphosate	0.75%	Early	15	75	0	0
Glyphosate	0.75%	Mid	---	95	30	20
Glyphosate	0.75%	Late	---	---	75	25
Imazapyr	0.5%	Early	5	80	0	0
Imazapyr	0.5%	Mid	---	85	70	65
Imazapyr	0.5%	Late	---	---	60	45
Sulfometuron	1 oz/a	Early	10	90	40	75
Sulfometuron	1 oz/a	Mid	---	60	90	80
Sulfometuron	1 oz/a	Late	---	---	90	80
Aminopyralid	3 fl.oz/a	Early	50	70	50	50
Aminopyralid	3 fl.oz/a	Mid	---	60	30	15
Aminopyralid	3 fl.oz/a	Late	---	---	50	50
Acetic acid	100%	Early + Mid + Late	0	70	20	0
Clove oil	20%	Early + Mid + Late	25	65	0	0
Limonene	12.5%	Early + Mid + Late	5	90	0	0

[1]Herbicides were applied at three timings in 2015: "Early" on May 1, "Mid" on July 15, and "Late" on September 30.

Himalayan Blackberry
2002-2003

Materials and Methods. A trial was designed to test acetic acid and herbicides applied to control Himalayan blackberry (*Rubus armenicus*). Plots were placed in a large infestation next to Edgewater Park in west Mount Vernon, Washington; plots measured 20 by 20 ft. Herbicides tested were Roundup and Crossbow applied as cut-stem treatments, using 33% solution in water (1 part herbicide, 2 parts water) with 0.5% (v/v) nonionic surfactant, applied to 6-inch blackberry cane stubs immediately following removal using a brush hog. A third cut-stem treatment was Blackberry Brush Blocker (acetic acid, BBB), applied full-strength. About 5 ml of herbicide mixture applied per cut stem. Foliar treatments were also included in the trial, including Crossbow, Roundup, and Finale (1.5%), as well as BBB (16 fl.oz/1000 ft^2). Herbicides were applied February 15, 2002, shortly after budbreak of blackberry canes. A second herbicide application was made May 30, 2002, to plots that had been treated by BBB in February. Full-strength product was applied to both cut-stem and foliar treated BBB plots. A second foliar Roundup application (1.5%) was made June 13, 2002 to plots previously treated with foliar or cut-stem Roundup. Blackberry control was evaluated April 3, May 24, June 5, and August 5, 2002, as compared to noncut and cut, but not treated, blackberry plants. The statistical design was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

A second trial was conducted at this site investigating the effectiveness of BBB applied as a drench. An area of Himalayan blackberry canes was cleared using a hand pruner, and three exposed blackberry crowns were each treated with 4, 8 or 16 fl.oz of BBB slowly poured over the crown August 27, 2002. Crowns producing new shoots were noted April 15, 2003. The statistical design was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means. While this trial had three replicates, the number of blackberry plants treated was limited and the duration was short, so results are considered advisory only.

Results. Cut-stem applications were generally superior to foliar herbicide applications (Table 1). Cut-stem Crossbow applications prevented nearly all regrowth until the August, 2002 evaluation, and control was still 91% at one year after treatment. Roundup applied to cut stems provided 98% control at the June, 2002 evaluation, and retreating that blackberry regrowth gave 80% control by April, 2003. BBB did not even provide suppression of cut blackberry canes, with regrowth equivalent to cut-only canes by August, 2002 even after two applications of product. Foliar applications of Crossbow applied in February, 2002 caused blackberry defoliation by May, 2002, and was still controlling 83% of cane regrowth by August, 2002. Control with foliar Crossbow had declined to 50% by April, 2003, however. Two foliar applications of Roundup was resulted in 98% blackberry control by April, 2003. Foliar-applied Finale initially caused 75% defoliation by April 2002, with control falling to about 50% the rest of the year and only 33% by April, 2003. Regrowth following Finale application was similar to regrowth of cut, but nontreated, blackberry canes by June, 2002. Autumn soil drenches with BBB up to 1 pt/crown reduced, but did not eliminate, blackberry regrowth by the following April (Table 2).

Table 1. Control of Himalayan blackberry by various herbicides.

Treatment[a]	Application type	Rate	Himalayan blackberry control				
			4/3/02	5/24/02	6/5/02[b]	8/5/02[c]	4/15/03[c]
		%	%	%	%	%	%
Crossbow	Cut-stem	33	100 a	100 a	100 a	96 a	91 a
Roundup	Cut-stem	33	100 a	98 a	98 a	85 bc	80 a
BBB	Cut-stem	Full-strength	99 a	62 bc	57 c	13 fg	0 d
Nontreated	Cut	---	99 a	63 b	50 c	22 ef	13 cd
Crossbow	Foliar	1.5	12 c	98 a	96 a	83 c	50 b
Roundup	Foliar	1.5	0 d	73 b	77 b	93 ab	98 a
BBB	Foliar	16 fl.oz/a	2 d	0 d	5 d	23 e	15 cd
Finale	Foliar	1.5	75 b	47 c	50 c	53 d	33 bc
Nontreated	None	---	0 d	0 d	0 d	7 g	0 d

Means within a column followed by the same letter are not statistically different.
[a]Treatments were applied February 15, 2002; BBB = Blackberry Brush Blocker; full-strength BBB was reapplied to previously treated cut-stem and foliar plots May 30, 2002; Roundup (1.5%) was reapplied to previously treated cut-stem and foliar plots June 13, 2002.
[b]BBB treatments were reapplied to cut-stem and foliar BBB plots about 1 week prior to this evaluation.
[c]Evaluations reflect two treatments for both cut-stem and foliar-treated plots: February 15 and May 30, 2002 for BBB plots, and February 15 and June 13, 2002 for Roundup plots.

Table 2. Control of cut Himalayan blackberry by Blackberry and Brush Blocker (BBB) drenches.

BBB rate[a]	New blackberry shoots
	April 15, 2003
fl.oz/crown	shoots/crown
4	0.67 c
8	1.00 b
16	0.33 d
---	1.33 a

Means within a column followed by the same letter are not statistically different.
[a]Himalayan blackberry crowns were cut and treated August 27, 2002.

Conclusions. February cutting only controlled blackberry regrowth until April, if no herbicides are used. Dormant-season Crossbow applied to cut stems, and Roundup applied twice in a season either directly to foliage or to cut stems and regrowing foliage provided greater than 80% blackberry control through spring of the following year. Finale effectively defoliated blackberry, although multiple applications will be necessary to fully control blackberry. BBB was not effective for control of Himalayan blackberry in these trials.

Indigobush
2002-2003, 2003-2005

2002-2003 Indigobush Trial

Materials and Methods. A trial was designed to test several herbicides applied to control indigobush (*Amorpha fruticosa*). Plots were placed in a large infestation next to the Columbia River in Beacon Rock State Park near Stevenson, Washington (Lisa Lantz, Washington State Parks, cooperator). Plots were established September 5, 2002, each measuring 8 by 20 ft, and were treated with cut-stem and foliar applications. Cut-stem applications were applied within 5 minutes to the freshly-cut surface of stems clipped at about 6 inches above the soil. Foliar applications were made to all foliage of plants in designated plots using a 1-nozzle wand and a CO_2-pressurized backpack sprayer. Herbicides tested were Roundup and Crossbow, and Transline, applied at 33% as cut-stem treatments (1 part herbicide, 2 parts water), Transline at 16.7% as a cut-stem treatment (1 part herbicide, 5 parts water), or as 2% foliar treatments of product in water. General indigobush control was estimated November 14, 2002 (2 months after treatment, MAT) and percent control was evaluated July 17, 2003 (10 MAT). The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Initial indigobush control from cut-stem treatments was not possible to evaluate at 2 MAT, as there was no regrowth from any clipped plants, including clipped plants not treated with herbicide (data not shown). There was some dieback of foliage on foliar-treated indigobush, with general injury showing most in Crossbow-treated plants, followed by Transline, and lastly by Roundup. At 10 MAT, control exceeded 90% with cut-stem Crossbow and with Transline applied to foliage or to cut stems (Table 1). Cut-stem Roundup resulted in 78% control at 10 MAT, significantly greater than control from cutting alone (50%). Foliar treatment with Crossbow and Roundup at 2% did not provide control of indigobush (7 to 8% control at 10 MAT).

Conclusions. These data indicate that cut-stem treatments can be very effective on indigobush, but that Roundup should be applied at a higher rate than 33%. Foliar treatment with Transline at 2% was excellent, but Crossbow and Roundup rates need to be higher than 2% if control is to be expected from foliar applications.

Table 1. Control of indigobush 10 months after treatment with cut-stem or foliar applications of three herbicides.

Treatment[a]	Type	Rate	Indigobush control[b] 10 MAT
		product in water	%
Roundup	Cut-stem	33%	78 b
Transline	Cut-stem	16.7%	98 a
Crossbow	Cut-stem	33%	93 a
Cut only	Cut-stem	---	50 c
Roundup	Foliar	2%	7 d
Transline	Foliar	2%	98 a
Crossbow	Foliar	2%	8 d
Noncut, nontreated	---	---	0 d

Means within a column followed by the same letter are not statistically different.
[a]Treatments were applied September 5, 2002; cut-stem treatments were applied to freshly-cut indigobush stems about 6 inches long.
[b]Percent indigobush control estimated July 17, 2003 at 10 months after treatment (MAT).

2007-2008 Indigobush Trial

Materials and Methods. A trial was designed to test several herbicides applied to control indigobush (*Amorpha fruticosa*). Plots were placed in a large infestation next to the Columbia River in Beacon Rock State Park near Stevenson, Washington (Lisa Lantz, Washington State Parks, cooperator). Plots were established September 13, 2007, each measuring 8 by 20 ft. All treatments were cut-stem applications applied to the freshly-cut surface of indigobush stems clipped at about 6 inches above the soil. Herbicides tested were Rodeo, Habitat, Renovate, Clearcast, Milestone, and Transline applied as 25% solutions (1 part herbicide, 3 parts water). Percent control was evaluated August 1, 2008 (11 months after treatment, MAT) and September 22, 2008 (12 MAT). The statistical design was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Indigobush control from cut-stem treatments did not differ at 11 MAT, ranging from 60 to 90% (data not shown). Treatment differences were more obvious at 12 MAT, however, as plants began to defoliate as they entered into autumn (Table 2). At that time, control with Milestone, Habitat, Transline, and Clearcast were superior to treatments with Renovate or Rodeo (72 to 97% for the first four products, 42 to 43% for the latter two). No treatment completely killed the indigobush plants, however, so an increased rate from the tested 25% solutions are indicated.

Table 2. Control of indigobush one year after treatment with cut-stem applications of several herbicides.

Treatment[a]	Rate	Indigobush control[b] 12 MAT
	Product in water	%
Rodeo	25%	42 b
Habitat	25%	92 a
Renovate	25%	43 b
Clearcast	25%	72 a
Milestone	25%	97 a
Transline	25%	87 a
Noncut, nontreated	---	0 c

Means within a column followed by the same letter are not statistically
  different.
[a]Treatments were applied September 13, 2007 to freshly-cut indigobush
  stems about 6 inches long.
[b]Percent indigobush control estimated September 22, 2008 at 12 months
  after treatment (MAT).

Italian Arum
2011-2012, 2016

Materials and Methods. A two-iteration trial was conducted in the greenhouse to determine which herbicides might give acceptable control of Italian arum (*Arum italicum*). The first iteration was conducted from 2012-2013 (Yushan Duan, graduate student), while the second was done from 2016-2017 (Wiharti Purba, graduate student).

First iteration. Early in summer, 2011, Italian arum tubers were collected from a field infestation near Olympia, Washington. Tubers were transplanted into small pots and placed in the greenhouse at WSU Northwestern Washington Research and Extension Center in Mount Vernon, Washington. Foliage started to emerge in fall, 2011 and plants were selected for herbicide treatments May 4, 2012. Plants had at least 3 leaves at the time of herbicide treatment. Foliar chlorosis was estimated June 1, 2011 (1 month after treatment, MAT) and foliage was then clipped off at the soil level and discarded. Plants were then allowed to regrow and foliage was removed from these plants November 26, 2012 (7 MAT), and fresh biomass was determined. The statistical design of the first iteration was a Randomized Complete Block with five replicates. A general linear models procedure was used to analyze the data and Tukey's Honestly Significant Difference test was used to separate the means (P ≤ 0.05).

Second iteration. Italian arum shoots were collected from a field infestation near Mount Vernon, Washington in early April, 2016. Shoots were transplanted into small pots and placed in the greenhouse at WSU Northwestern Washington Research and Extension Center. Foliage began to regrow shortly after transplanting, and plants were selected for herbicide treatments May 7, 2016. Plants had at least 3 leaves at the time of herbicide treatment. Foliar chlorosis was estimated May 31, 2016 (1 MAT) and foliage was removed as in the first iteration. Control was assessed September 16, 2016, and plants were clipped at the soil line December 20, 2016 (7 MAT) and biomass was recorded. The statistical design of the second iteration was a Randomized Complete Block with five replicates. Biomass data from the two iterations were combined into a single dataset and were analyzed using a general linear models procedure. Tukey's Honestly Significant Difference test was used to separate the means (P ≤ 0.05).

Results.
First iteration. While causing chlorosis of Italian arum foliage, there were no significant differences among tested herbicides at 1 MAT (Table 1). Chlorosis ranged from 60 to 86%, even in nontreated plants, since this plant generally loses its leaves in early summer.

Second iteration. Foliar chlorosis of Italian arum was statistically similar for each herbicide at 1 MAT, ranging from 7 to 49% (Table 1). Plants treated with Garlon, however, displayed greater chlorosis (49%) than plants treated with either Oust or Method (7 to 8% chlorosis).

Combined biomass data. Following clipping, most plants regrew their foliage over the next 6 months, and fresh biomass differed among herbicide treatments. None of the herbicides gave 100% foliar control of these greenhouse Italian arum plants, as based on biomass measurement (Table 1). Lowest biomass (= greatest control) at 7 MAT was given by Roundup, Escort, Oust,

Habitat, and Method (95 to 99% control) statistically equal to control by Weedmaster (81%). The largest plants (= poorest control) resulted after treatment with Crossbow, Curtail, Milestone, Transline, or Garlon at tested rates (6 to 29% control). At the conclusion of both iterations, however, many pots contained tubers that were white and crisp and did not appear to be dead.

Conclusions. These Italian arum plants were greenhouse-grown, and therefore were smaller and probably more sensitive to the herbicides than field-grown plants, which have much larger root systems. Several products controlled foliar growth, but since this species tends to go dormant anyway, it is unclear how much of the defoliation was due to herbicide and how much due to natural summer senescence. Finally, since no herbicide completely controlled tuber production, it seems that even those products giving good foliar control (poor foliar regrowth) may not result in lasting control of Italian arum. Still, foliar control is better than no foliar control, and loss of foliage can be expected to result in lower tuber production and perhaps lower tuber viability, especially after multiple herbicide application. It would be advisable to further test products that resulted in good foliar control on field populations of Italian arum, and to also test different combinations of those herbicides.

Table 1. Chlorosis and biomass of Italian arum treated with several herbicides in the greenhouse.

Treatment[a]	Rate	Chlorosis at 1 MAT[b]		Biomass[b]
		2012	2016	7 MAT
	product/a or %	%	%	g/plant (% control)
Oust + nis	1.5 oz	79	8 b	0.06 (97) d
Escort + nis	1.5 oz	69	16 ab	0.04 (98) d
Roundup	3%	75	15 ab	0.01 (99) d
Weedmaster	2 qt	76	40 ab	0.45 (81) cd
Curtail	2 qt	71	36 ab	2.08 (14) ab
Crossbow	3%	71	37 ab	1.70 (29) ab
Garlon	3%	60	49 a	2.26 (6) a
Transline	1 pt	65	33 ab	2.16 (10) a
Plateau + mso	1%	86	16 ab	1.14 (52) bc
Habitat + mso	1%	67	26 ab	0.06 (97) d
Method	12 fl.oz	64	7 b	0.11 (95) d
Milestone	5 fl.oz	63	26 ab	1.89 (21) ab
Nontreated	---	83	0 b	2.40 (0) a

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Treatments were applied in early May, 2012 or 2016 to Italian arum plants with at least 3 leaves; "nis" = nonionic surfactant (Dyne-Amic) applied at 0.25% (v/v); "mso" = methylated seed oil (SunIt II) applied at 0.25% (v/v).
[b]MAT = months after treatment; late May for chlorosis, late November or December for biomass.

Invasive Knotweeds
2011-2012, 2016

2000-2001 Vegetative Reproductive Potential of Knotweed Trial

<u>Materials and Methods</u>. A greenhouse trial was conducted in 2000-2001 to estimate the vegetative reproductive potential of Bohemian (*Reynoutria* x *bohemica*) and giant knotweed (*Reynoutria sachalinensis*) at WSU's Northwestern Washington Research and Extension Center. Stems, rhizomes, and crowns of both plant species were collected from field populations near Mount Vernon, Washington in summer, 2000. Stems and rhizomes were cut into sections of various lengths (2, 4, 8, and 16 inches for stems, 2, 4, and 8 inches for rhizomes), intact crowns were also used in the trial. One of five treatments were then imposed on these plant materials, including left on the potting soil surface (S), buried horizontally in potting soil (BH), buried vertically in potting soil (BV), half-buried in potting soil (vertically, HB), and placed in water (W). Material was kept moist in the greenhouse for six weeks, after which resultant shoots were counted, length measured, and biomass determined. The statistical design of the second iteration was a Randomized Complete Block with five replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

<u>Results</u>. Knotweed crowns were practically guaranteed to produce new shoots (2.3 shoots/crown were produced in 2000 and 2001, data not shown). Average shoot length was 3.9 and 6.4 inches in 2000 and 2001, respectively, and total shoot biomass was 11.4 g in both years.

Shoot number from stem sections increased with section length (Table 1). While all stem sections greater than 2 inches long and bearing a node were capable of producing shoots, stem sections needed to be between 8 and 16 inches long for that particular section to produce a single shoot. Rhizome sections, however, only needed to be between 2 and 4 inches long to produce a single shoot. All rhizome sections longer than 2 inches were able to produce shoots. It therefore appears that rhizomes are roughly 1.5 times more likely to produce shoots than stem sections.

Adventitious root production did occur from Bohemian knotweed stem sections, but even 16-inch-long sections did not always produce a shoot (Table 1). Rhizome sections, however, were able to produce nearly two adventitious roots per section regardless of length (2 to 8 inches in length).

Treatment regime did not greatly affect how many shoots were produced by stem sections (Table 2). Between 0.67 and 0.94 shoots were produced among the five tested treatment regimes, all of which were statistically similar. All rhizome sections placed on moist potting soil also produced shoots at roughly equivalent levels (1.4 to 1.7 shoots/section), but rhizome sections placed in water failed to produce shoots. Rhizome sections were about two times more likely to produce shoots than stem sections.

Adventitious rooting from stem sections was markedly different depending on treatment regime (Table 2). If stem sections were fully buried, either horizontally or vertically, they produced an average of 2.6 to 3.3 roots/stem, respectively. Half-buried stems, however, only produced 0.9

shoots, while stem sections in water or on the surface of the potting soil produced only 0.5 and 0.1 roots/stem. Adventitious roots from rhizome sections did not greatly differ among the treatment regimes, with the exception that no roots were produced from rhizome sections in water. Clearly, then, stem sections that are buried in soil are much more likely to produce roots than stem sections only partially or not at all buried.

Conclusions. Based on these data, it appears that intact knotweed stems should be removed from site to prevent vegetative spread. If stems are chipped and left at the site, stem sections should be less than 2 inches long, as half the stem sections 4 inches or longer and bearing a node were able to produce shoots. Stem sections should be spread thinly on the soil surface to encourage desiccation and discourage rooting. Because rhizomes did not sprout when under water, flooding may provide some control of intact knotweed. Unfortunately, there is certainly danger of knotweed spread if rhizomes are washed out and moved downstream during flood events, as rhizomes exposed to light are well able to produce roots from (or between) nodes. When knotweed is being controlled, rhizomes should be left intact in the soil to minimize their sprouting. If knotweed roots are disturbed during control, to the greatest degree possible, rhizome pieces should not be left on site to prevent re-establishment and potential spread of fragments.

Table 1. Number of shoots and roots produced by Bohemain knotweed stem and rhizome sections after six weeks in the greenhouse.

	Shoot number		Root number	
Section length	Section Type		Section Type	
inches	Stem	Rhizome	Stem	Rhizome
2	0.27 c	0.69 c	0.2 b	1.8
4	0.39 c	1.02 b	0.4 b	1.7
8	0.80 b	1.70 a	0.9 a	1.8
16	1.29 a	---	0.8 a	---

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

Table 2. Number of shoots and roots produced by Bohemain knotweed stem and rhizome sections under five treatment regimes after six weeks in the greenhouse.

	Shoot number		Root number	
Treatment	Stem	Rhizome	Stem	Rhizome
Buried horizontally	0.89	1.7 a	2.6 a	1.8 a
Buried vertically	0.67	1.4 a	3.3 a	2.1 a
Half-buried vertically	0.81	1.5 a	0.9 b	2.4 a
On surface	0.81	1.7 a	0.1 b	2.0 a
In water	0.94	0 b	0.5 b	0 b

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

Recap of Several Invasive Knotweed Herbicide Studies
2003-2005

Several herbicide trials were conducted in the early 2000s. Results from those trials (including both greenhouse and field trials) are highlighted below.

1. <u>Foliar applications to greenhouse grown invasive knotweed (2003-2004)</u>. This trial was conducted in greenhouses at WSU's Northwestern Washington Research and Extension Center. The trial focused on foliar-applied glyphosate, triclopyr, and imazapyr on Bohemian (*Reynoutria* x *bohemica*) and Himalayan knotweed (*Koenigia polystachya*) transplants and giant knotweed seedlings (*Reynoutria sachalinensis*). Triclopyr resulted in rapid expression of symptoms on treated knotweed plants, usually within 48 hours, and defoliation occurred within two weeks. Plants treated with glyphosate and imazapyr did not show symptoms until about a week after treatment, and defoliation had only progressed to about 50% by three weeks. At three weeks after treatment, plants were clipped and knotweed re-growth was monitored for the next eight weeks. Relative susceptibility to these products did not differ much by species, although Bohemian transplants were most tolerant to herbicides applied at 0.5 to 1% product in water. It appears that imazapyr is the most active product on knotweed, as knotweed transplants did not re-grow when treated with imazapyr at 0.5% or greater, either applied alone or tank-mixed with glyphosate or triclopyr. Bohemian knotweed control 11 weeks after treatment with 1% glyphosate mix was 90% (compared to re-growth of untreated plants), while triclopyr at 1% gave 96% control. While knotweed in the field will likely require higher dosages of herbicide to achieve similar levels of control, it appears that all three of these herbicides alone or in combination will aid in the control of these species.

An additional fact observed from these trials involved germination success of knotweed seeds. Japanese knotweed seed were collected from two plants growing near Acme and Marblemount, Washington. Seed from the Acme plant was approximately 30% germinable (2003-2004), while seedling emergence from the Marblemount plant was extremely low (<5%) (2003-2004). Seed from six giant knotweed plants growing near Quilcene, Washington was collected in the spring of 2003. These seeds displayed about 60% germination. Therefore, it is known that invasive knotweed is capable of producing seed seed is produced, including Japanese, giant, and Bohemian. Seed germination ranges from 0% to 60% (as high as 100% has been reported) Resultant seedlings appear to be poor competitors with other vegetation and have high seedling mortality, however. In Massachusetts, first-year seedlings needed to achieve five leaves for plants to successfully survive the winter. Hybridization may well result in plants with greater vegetative reproductive vigor or greater aggressivity. If seed is likely to be produced on plants in the field, control of parent plants should be attempted prior to flowering to prevent development of viable pistils and stamens.

2. <u>Injection and wiping of invasive knotweed (2003-2005)</u>. A novel method of knotweed control evaluated in the Pacific Northwest involves injection of herbicide directly into the hollow stem. Certain formulations of glyphosate are registered for this use on supplemental product labels in

selected states. Up to 5 ml of undiluted product (6 ml for Roundup) is injected into knotweed stems using a syringe or injection gun (www.jkinjectiontools.com), within about 6 inches above the ground surface. An awl may be used to first punch a hole into the stem just below a node, or a specially-designed injection gun may be purchased which performs both functions in the same operation. A second method is to cut the stem just below a node and to place 10 ml of 50% solution in the hollow "well" that is created in the stem section. Note that these labels stipulate the maximum number of stems which may be treated per acre using this method.

Results from field tests on giant knotweed (near Quilcene, Washington; Cathy Lucero, Clallam County Noxious Weed Control Board, cooperator) and Bohemian knotweed (near Acme, Washington; Laurel Baldwin, Whatcom County Noxious Weed Coordinator, cooperator) showed that 2.5 or 5 ml of glyphosate, triclopyr, and imazapyr gave 91 to 100% control of stems and crowns by eight weeks after treatment. **Please note that neither triclopyr nor imazapyr are currently registered for knotweed injection (and probably never will be).**

I also tested wiping the lower three feet of knotweed stems with 33% herbicide solutions (mixing 1 part product with 2 parts water and nonionic surfactant at 0.25%, v/v) using a sponge paintbrush. Wiping uncut canes resulted in 63 to 80% stem control by eight weeks after treatment, while wiping canes whose tops had been cut off at a height of three feet resulted in 97 to 100% stem control.

Bohemian and giant knotweed control at one year after treatment was similar for all treatments, however. While knotweed "knockdown" was quicker if herbicides were applied at early flowering compared to post-flowering, there was no difference in control the following season, indicating that knotweed can be adequately controlled over a fairly wide application window. **Note again that only certain glyphosate formulations are registered for injections!**

Herbicide symptoms from these field trials were apparent on knotweed the following season up to four feet away from where the treatments occurred, with the symptoms being more obvious in August than in April. There were no correlations between injury level and type of application (so injection did not result in more symptomolgy than wiping, for example). There were also visible symptoms on other plant species (salmonberry, thimbleberry, snowberry, blackberry, and reed canarygrass) the year after application; in fact, non-target symptomology was apparent in 22 cases out of a possible 144 (15%). Most of these cases involved imazapyr—not surprising given that herbicide's soil activity and longevity. Glyphosate injury on salmonberry was also noted, however, as was triclopyr injury on snowberry. These non-target plant symptoms were also observed in several field locations in western Washington where glyphosate injection was used for knotweed control.

3. Foliar applications to greenhouse grown invasive knotweed (2005). This trial was conducted in greenhouses at WSU's Northwestern Washington Research and Extension Center. The objective was to verify observations of glyphosate uptake by non-target vegetation. Bohemian, giant, and Himalayan knotweed plants were transplanted into gallon-size pots together with either salmonberry or thimbleberry crowns. The substrate in the pots consisted primarily of sand so as to not interfere with the potential soil activity of glyphosate exuding from the roots of

treated plants. Transplants were grown together in the greenhouse for two months. Aquamaster was then sprayed over the entire pot (2% in water, with added nonionic surfactant at 0.25%, v/v), wiped on knotweed leaves (33% in water, with added surfactant), or injected (full strength, as much as possible into a single internode: 2.8 mls).

Injury to knotweed plants from the overspray averaged 81% (98 to 100% control of Himalayan or giant, and 68% control of Bohemian), with berry plants sustaining 68% injury. Leaf wipes resulted in 89% knotweed control (83% control of Bohemian and 98% control of Himalayan and giant) and about 13% berry plant injury. Injection gave 88% knotweed control (88% of Bohemian and 100% of giant). While I was not able to inject Himalayan knotweed (stems were too small), just the drop of glyphosate on the outside of the stem was enough to cause 63% injury of knotweed plants. Thimbleberry and salmonberry injury from knotweed injection was 26%. Therefore, knotweed injection resulted in about twice as much non-target injury as did leaf wipes, but non-target damage was 2.6 to 5.2 times greater using a foliar spray than wiping or injection, respectively.

4. Field invasive knotweed treatments by County Noxious Weed Control Boards (2004-2005).
Results of glyphosate treatments made to southwestern Washington invasive knotweed sites in 2004 (WSDA funded program) was monitored in June, 2005. Six sites, containing either Bohemian or Japanese (*Reynoutria japonica* Houtt.) knotweed, were monitored to determine the relative effectiveness of the herbicide strategies being conducted by the project managers at each location. Sites and treatments are included in Table 3.

Visual knotweed control ranged from 88 to 94% with no significant differences between sites. There was a trend toward better control when imazapyr was used, however. Stem numbers were reduced from 63 to 80%, and estimated 17,000 to 33,500 stems per acre before treatment compared to 4,600 to 10,800 after treatment. Similarly, stem height ranged from 10 to 20 inches tall compared to an expected height 72 inches (72 to 86% reduction). Injury to non-target vegetation among all treatments was <10%, with no apparent correlation between injury and application type or herbicide choice. All new knotweed shoots in treated areas were from rhizomes/crown (no seedlings). It was also obvious that very little plant growth occurred in any plot once the knotweed was killed. This response probably speaks more to the competitive ability of these knotweeds prior to treatment than resulting from herbicides killing other species.

Table 3. Overview of project sites and knotweed control strategies.

Project	Site	Knotweed Type	Treatment
Clark	Upper East Fork Lewis River	Bohemian	Injection, 5 mls Aquamaster per stem
Clark	Lower East Fork Lewis River	Bohemian	Foliar, 1.5% Habitat
Lewis	Upper Cowlitz River	Bohemian	Foliar, 1.5% Aquamaster + 0.75% Habitat
Pacific	Willapa River	Bohemian	Foliar, 2% Aquamaster + 0.5% Habitat
Skamania	Washougal River	Japanese	Injection, 5 mls Aquamaster per stem
State Parks	Beacon Rock	Japanese	Injection, 5 mls Aquamaster per stem

2005-2006 Aminopyralid on Knotweed Trials

Materials and Methods. A trial was conducted to determine the susceptibility of Bohemian knotweed (*Reynoutria* x *bohemica*) to aminopyralid (Milestone) (Vanelle Peterson, formerly with Dow AgriSciences, cooperator). Two sites were included in the trial, one near Burlington, Washington and in Mount Vernon, Washington. Both populations were Bohemian knotweed, but the Riverside population was treated at full flower (stems 8- to 10-ft tall) August 4, 2005 while the Freeway site had been mowed in July, 2005 and stems were approximately 4-ft tall and beginning to produce flower racemes from upper leaf axils at the time of application (August 23, 2005). Plots measured 20 ft by 20 ft and herbicides were applied using a CO_2-pressurized backpack sprayer. Bohemian knotweed control was estimated at 3, 6, and 8 weeks after treatment (WAT) and at 10 months after treatment (MAT).   The statistical design of the trial was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Milestone applied alone did not provide acceptable control of Bohemian knotweed, whether plants were uncut (Table 4) or regrown following mowing (Table 5). Treating regrowth improved control from Milestone, but control at 10 MAT was maximized at 65% by Milestone at 7 fl.oz/a, compared to 33% for this rate on uncut stems. Garlon applied alone or mixed with Milestone accelerated the onset of herbicidal symptoms in treated plants, but did not increase control at 10 MAT. Rodeo (3%) and Habitat (0.75%) treatments ultimately provided the best knotweed control at 10 MAT, 80 and 96% control for Rodeo on uncut stems and regrowth, respectively, and 85 and 99% control for Habitat, respectively.

Table 4. Bohemian knotweed control with Milestone alone and in combination with other herbicides and applied to uncut stems at full flower.

Treatment[a]	Rate	3 WAT[b]	6 WAT[b]	8 WAT[b]	10 MAT[b]
	product/a or %	%	%	%	%
Milestone	3 fl.oz	18 c	23 d	31 d	4 c
Milestone	5 fl.oz	23 bc	31 c	41 c	8 c
Milestone	7 fl.oz	29 b	39 bc	41 c	33 b
Milestone + Garlon	3 fl.oz + 2 qt	44 a	51 b	56 b	1 c
Milestone + Garlon	5 fl.oz + 2 qt	45 a	51 b	55 b	4 c
Milestone + Garlon	7 fl.oz + 2 qt	46 a	58 ab	64 ab	5 c
Garlon	2 qt	40 ab	55 ab	63 ab	3 c
Rodeo	3%	56 a	69 a	71 a	80 a
Habitat	0.75%	35 b	40 bc	71 a	85 a
Krenite	3%	24 bc	30 c	39 cd	0 c

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Treatments were applied to uncut Bohemian knotweed foliage August 4, 2005; all treatments were mixed with nonionic surfactant (R-11) at 0.25% (v/v), prior to application.
[b]Bohemian knotweed control was estimated August 25, September 13, October 3, 2005 and June 11, 2006; WAT = weeks after treatment; MAT = months after treatment.

Table 5. Bohemian knotweed control with Milestone alone and in combination with other herbicides and applied to 3 to 4-ft-tall regrowth approximately one month after mowing.

Treatment[a]	Rate	3 WAT[b]	6 WAT[b]	8 WAT[b]	10 MAT[b]
	product/a or %	%	%	%	%
Milestone	3 fl.oz	28 c	37 c	37 d	45 c
Milestone	5 fl.oz	33 bc	38 c	45 c	53 bc
Milestone	7 fl.oz	35 b	42 bc	45 c	65 b
Milestone + Garlon	3 fl.oz + 2 qt	47 a	53 ab	58 b	38 c
Milestone + Garlon	5 fl.oz + 2 qt	47 a	53 ab	58 b	47 c
Milestone + Garlon	7 fl.oz + 2 qt	48 a	50 ab	57 b	57 bc
Garlon	2 qt	47 a	55 a	57 b	23 d
Rodeo	3%	33 bc	45 bc	58 b	96 a
Habitat	0.75%	27 c	57 a	72 a	99 a

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Treatments were applied to Bohemian knotweed foliage August 23, 2005; all treatments were mixed with nonionic surfactant (R-11) at 0.25% (v/v), prior to application.
[b]Bohemian knotweed control was estimated August 25, September 13, October 3, 2005 and June 11, 2006; WAT = weeks after treatment; MAT = months after treatment.

2007-2008 Aminopyralid on Knotweed Trials

Materials and Methods. A trial was conducted to determine the susceptibility of Bohemian knotweed (*Reynoutria* x *bohemica*) and giant knotweed (*Reynoutria sachalinensis*) to aminopyralid (Milestone) (Vanelle Peterson, formerly with Dow AgriSciences, cooperator). A second objective was to determine the effectiveness of cutting the tops of knotweed stems about a month prior to herbicide application. The Bohemian knotweed site was near Mount Vernon, Washington and the giant knotweed site was near Hamilton, Washington. Knotweed stems were cut to a length of about 3 feet as a pretreatment, July 26 and 27, 2007 (Bohemian and giant knotweed, respectively). An additional treatment (stems bent at 3 feet tall rather than cut) was also tested at the giant knotweed site. Herbicides were applied August 24 (Bohemian) and August 31 (giant), 2007, when regrowth was about four feet tall and uncut plants were flowering. Plots measured 20 ft by 20 ft and herbicides were applied using a CO_2-pressurized backpack sprayer. Bohemian knotweed control was estimated at 1, 2, 11 and 12 months after treatment (MAT).   The statistical design of the trial was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Milestone applied alone to Bohemian knotweed regrowth gave 61 and 69% control at rates of 0.5 and 1%, respectively at 1 MAT, and control increased for both rates at subsequent evaluations (Table 6). By 12 MAT, control was 89 and 98% for the two rates, respectively. Mixing Milestone at 0.5% with Garlon or Rodeo provided a similar level of control as Milestone alone, but control was significantly lower with these mixtures by 12 MAT. Treating uncut

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Bohemian knotweed was not as effective as treating regrowth by 1 MAT, but control was similar whether uncut or regrown foliage was treated by 2 MAT. Control of uncut Bohemian knotweed stems was uniformly excellent at 11 and 12 MAT. Habitat at 0.75% provided 89% control at 11 and 12 MAT.

Giant knotweed responded in a generally similar way as Bohemian knotweed in these trials, except injury generally occurred more quickly in treatments to giant knotweed (Table 7). Milestone alone or in combination with Garlon or Rodeo provided equivalent control of giant knotweed at 2 MAT and beyond, whether stems were cut or bent prior to treatment. Control with Milestone alone, however, was not as good when applied to uncut stems by 12 MAT. Habitat provided excellent control of giant knotweed if applied to uncut stems, but control was reduced at 11 or 12 MAT if regrowth from cut or bent stems were treated.

Overall control did not differ between Bohemian and giant knotweed at 12 MAT (72% for Bohemian and 72% for giant) (data not shown). When control of the two species were averaged together, bending stems did not increase control at 12 MAT compared to not bending, although pre-treatment bending improved control compared to cutting (69%, 75%, and 73% control for cut, bent, at uncut stems, respectively) (data not shown).

Table 6. Bohemian knotweed control with Milestone alone and in combination with other herbicides and applied to 3 to 4-ft-tall regrowth approximately one month after mowing.

Treatment[a]	Rate	Stems	1 MAT[b]	2 MAT[b]	11 MAT[b]	12 MAT[b]
	%		%	%	%	%
Milestone	0.5	Cut	61 ab	81 ab	99 a	89 ab
Milestone	1	Cut	69 a	91 a	100 a	98 a
Milestone + Garlon	0.5 + 0.5	Cut	71 a	86 a	95 a	61 c
Milestone + Rodeo	0.5 + 1	Cut	74 a	75 ab	99 a	79 b
Habitat	0.75	Cut	48 b	69 bc	84 b	56 c
Nontreated	---	Cut	29 c	34 d	0 c	0 d
Milestone	0.5	Uncut	28 c	53 c	100 a	99 a
Milestone	1	Uncut	38 b	78 ab	100 a	100 a
Milestone + Garlon	0.5 + 0.5	Uncut	54 b	78 ab	100 a	100 a
Milestone + Rodeo	0.5 + 1	Uncut	78 a	78 ab	100 a	100 a
Habitat	0.75	Uncut	14 d	49 c	89 b	89 ab

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Bohemian knotweed stems were cut July 26, 2007; herbicides were applied to foliage August 24, 2007; all treatments were mixed with nonionic surfactant (R-11) at 0.25% (v/v), prior to application.
[b]Bohemian knotweed control was estimated August 25, September 13, October 3, 2005 and June 11, 2006; MAT = months after treatment.

Table 7. Giant knotweed control with Milestone alone and in combination with other herbicides and applied to 3 to 4-ft-tall regrowth approximately one month after mowing.

Treatment[a]	Rate	Stems	1 MAT[b]	2 MAT[b]	11 MAT[b]	12 MAT[b]
	%		%	%	%	%
Milestone	0.5	Cut	71 b	100 a	100 a	94 a
Milestone	1	Cut	91 a	100 a	100 a	98 a
Milestone + Garlon	0.5 + 0.5	Cut	76 b	100 a	100 a	96 a
Milestone + Rodeo	0.5 + 1	Cut	88 a	99 a	97 a	96 a
Habitat	0.75	Cut	54 c	99 a	63 b	63 b
Nontreated	---	Cut	40 d	40 c	0 c	0 d
Milestone	0.5	Bent	85 a	99 a	97 a	96 a
Milestone	1	Bent	78 ab	100 a	94 a	99 a
Milestone + Garlon	0.5 + 0.5	Bent	45 cd	95 ab	91 a	95 a
Milestone + Rodeo	0.5 + 1	Bent	74 b	100 a	95 a	95 a
Habitat	0.75	Bent	38 d	78 b	78 b	70 b
Nontreated	---	Bent	29 de	33 c	0 c	0 d
Milestone	0.5	Uncut	19 e	91 ab	85 ab	31 c
Milestone	1	Uncut	45 cd	96 ab	75 b	71 b
Milestone + Garlon	0.5 + 0.5	Uncut	54 c	85 b	93 a	90 a
Milestone + Rodeo	0.5 + 1	Uncut	93 a	99 a	100 a	100 a
Habitat	0.75	Uncut	44 cd	99 a	100 a	100 a

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Treatments were applied to Bohemian knotweed foliage August 23, 2005; all treatments were mixed with nonionic surfactant (R-11) at 0.25% (v/v), prior to application.

[b]Bohemian knotweed control was estimated August 25, September 13, October 3, 2005 and June 11, 2006; MAT = months after treatment.

2008-2010 Symptomatic Knotweed Trial

<u>Materials and Methods</u>. A trial was conducted to determine whether any herbicides would successfully eliminate Bohemian knotweed (*Reynoutria* x *bohemica*) that was exhibiting symptoms from previous herbicide applications. The trial was conducted in Marblemount, Washington, where an extensive Bohemian knotweed population had been treated with glyphosate and glyphosate + imazapyr in the preceding three years (Kris Knight, The Nature Conservancy, cooperator). Herbicides were applied October 1, 2008 using a CO_2-pressurized backpack sprayer. Symptomatic Bohemian knotweed plants were just starting to turn yellow (~5%) in autumn at the time of application. Plots measured 8 ft by 20 ft and counts of symptomatic plants showed that the Bohemian knotweed population was similar in each plot. Bohemian knotweed plants were evaluated for control May 21 and July 13, 2009 (7 and 9 months after treatment, MAT). Herbicides were applied again September 17, 2009 when a few Bohemian knotweed plants were blooming. Resulting control was evaluated October 7, 2009 and July 2, 2010. The statistical design of the trial was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Bohemian knotweed density did not decrease despite herbicide application to symptomatic plants by 12 MAT (Table 8). After two treatments (four treatments total in five years), no herbicide had completely removed Bohemian knotweed from the site by the July following the second application. Roundup and Habitat + Roundup treatments were the most effective, decreasing the Bohemian knotweed population to 1.8 and 2.8 plants/plot compared to 13.8 plants in nontreated plots (recall that "nontreated" plants were treated twice prior to the start of this trial, which is why they were symptomatic). The poorest result was from two applications of Garlon, in which the Bohemian knotweed density increased relative to nontreated plants (24.3 and 13.8 plants/plot, respectively).

Conclusions. Based on these results, it does not appear that additional treatment of symptomatic plants, even at robust rates, are capable of eliminating Bohemian knotweed.

Table 8. Bohemian knotweed population and plant height after treatment of symptomatic plants with several herbicides and herbicide combinations.

Treatment[a]	Rate	Density Pretreat	Density 5/21/09	Density 10/7/09	Density 7/2/10	Height 10/7/09
	product/a or %	no./plot	no./plot	no./plot	no./plot	cm
Milestone	7 fl.oz	10.8	1.5 bc	19.8 ab	6.3 bc	25 ab
Roundup	5%	11.8	1.3 bc	8.8 b	1.8 c	19 b
Habitat	1%	11.0	0.8 c	8.8 b	3.5 bc	16 b
Garlon	3%	13.0	9.8 a	32.0 a	24.3 a	34 a
Milestone + Roundup	7 fl.oz + 5%	9.0	1.5 bc	16.0 ab	3.8 bc	18 b
Habitat + Roundup	1% + 5%	13.8	0 c	14.8 ab	2.8 c	17 b
Garlon + Roundup	3% + 5%	11.0	1.5 bc	18.3 ab	4.0 bc	19 b
Nontreated	---	11.0	5.3 b	12.3 b	13.8 b	32 a

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Treatments were applied to symptomatic Bohemian knotweed foliage October 1, 2008 and September 17, 2009; all treatments were mixed with nonionic surfactant (R-11) at 0.25% (v/v), prior to each application.

2010-2013 Swimming Pool Knotweed Trial

Materials and Methods. A bioassay trial was designed to determine the ability of glyphosate and imazapyr to translocate in Bohemian knotweed (*Reynoutria* x *bohemica*) rhizomes. The study was suggested by Cathy Lucero (Clallam County Noxious Weed Control Board). Wading pools were used as "pots" in order to use large, established Bohemian knotweed plants for the trial. Plant material was prepared from a field infestation of Bohemian knotweed gathered from a municipal park in Mount Vernon, Washington. Single-stem knotweed crowns were dug in early August, trimmed of excess roots/rhizomes, and the stem clipped to a length of about eight inches. Trimmed crowns were then transplanted into gallon-sized pots filled with potting soil, and placed in the greenhouse at the WSU Northwestern Washington Research and Extension Center in Mount Vernon, Washington, for about six weeks or needed for transplanting to the wading

pool "pots". Drain holes were punched in the pools, after which they were buried to within about six inches of the lip in soil at WSU NWREC. Pools were then filled with potting soil, and live crowns were transplanted into the pools in mid-September of 2010. Bohemian knotweed plants were overwintered in the pools, then kept well-watered until treatments were applied.

Herbicides were applied at one of two timings: either at first bloom (when the first flowers appeared on Bohemian knotweed plants; late August, 2011) or post-bloom (when the corollas had dropped off the plants; mid-October 2011). Foliar glyphosate at 1.2 g (2.5 ml Rodeo) or 0.24 g imazapyr (1 ml Habitat) was applied per plant at the appropriate timing. Products were mixed with 0.25 ml nonionic surfactant and sufficient water to make 100 ml, so equivalent application rates were 2.5% Rodeo and 1% Habitat. All living leaves on each plant were treated using a hand-held spray bottle to eliminate chance of drifting to adjacent plants. Nontreated knotweed plants were included in the trial to provide as check plants. At 24 and 72 hours after treatment (HAT), plants were dug from the pools and all rhizomes were removed. Rhizomes were placed on top of moist potting soil in flats in the greenhouse at WSU NWREC. After five weeks, rhizomes were measured, shoots counted, and dry weight of rhizomes and resultant shoots was determined.

The experiment was repeated in 2012-2013, with Bohemian knotweed plants dug from the same infestation at the Mount Vernon municipal park. Plants were transplanted and treatments were as in the first iteration. The statistical design of the trial was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. In the first iteration, nontreated Bohemian knotweed plants from both timings produced 7.9 rhizomes per plant (including secondary rhizomes, or rhizome branches). Total rhizome length averaged 349 cm (11.5 feet) and dry weight was 42.3 g/plant. In the second iteration, Bohemian knotweed plants only produced 4.5 rhizomes per plant, with an average length of 145 cm (4.8 feet) and an average dry weight of 16.2 g/plant.

Shoot number from treated rhizomes was reduced by imazapyr 96 and 87% in the first and second iteration, respectively (Table 9). Shoot number was also reduced by glyphosate, but those reductions were only 66 and 53% for the two iterations, respectively, significantly less than for imazapyr in both years (Table 10). In the same way, shoot weight was reduced by imazapyr by 97% in both years, while glyphosate reduced shoot weight by 90 and 93% in the first and second iterations, respectively, similar to imazapyr in both years.

Application timing played a variable role in shoot production from treated rhizomes. Herbicides were about eight times more effective at suppressing shoot growth when applied post-bloom than at first bloom in the first iteration, although application timing made no difference in the second iteration. It is not clear that this result is due to application timing, however, as nontreated rhizomes in the first iteration produced 66 to 83% fewer shoots when dug in autumn than when

dug from blooming plants, although shoots resulted from rhizomes dug at both timings. It may be that Bohemian knotweed rhizomes are simply physiologically less likely to produce shoots in October than in September which would mask any herbicide suppression under the conditions of this experiment.

Herbicides were similarly effective at suppressing shoot growth at 24 HAT as at 72 HAT. There was a trend towards greater suppression of shoot biomass at 72 HAT than at 24 HAT in the first iteration. This trend was less obvious with shoot number, particularly in the second iteration.

Conclusions. Seasonal growing conditions apparently play a very large role in Bohemian knotweed rhizome production. Plants in the first iteration produced nearly twice the number of rhizomes that were 2.5 times as long and heavy as rhizomes from plants in the second iteration. At tested doses, imazapyr (1% Habitat) reduced knotweed shoot number slightly more than did glyphosate (2.5% Rodeo). Shoot biomass was reduced 97% by imazapyr in both years, while reductions with glyphosate 90 to 93% in the two iterations. Translocation rates of the two herbicides were similar, although knotweed shoot biomass tended to be lower at 72 HAT as compared to biomass at 24 HAT.

Table 9. Bohemian knotweed rhizome number, length, and biomass after foliar treatment with Rodeo (2.5%) or Habitat (1%) at first bloom or after flowering.

Treatment[a]	Rhizome length				Rhizome number				Rhizome biomass			
	First bloom		Post-bloom		First bloom		Post-bloom		First bloom		Post-bloom	
	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013	2011	2013
	cm	cm	cm	cm	no./plant	no./plant	no./plant	no./plant	g	g	g	g
Rodeo	342	123	297	148	8.8	3.4	6.8	5.3	35.0	10.5	34.0	19.9
Habitat	206	78	331	158	5.4	2.5	7.5	4.9	23.4	8.4	40.8	18.5
Nontreated	295	178	309	94	7.3	4.3	8.0	4.4	37.4	14.7	36.5	19.3

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Treatments were applied to Bohemian knotweed foliage at first bloom (late August) or post-bloom (mid-October); 2.5 ml Rodeo or 1 ml Habitat was mixed with 0.25% (v/v) nonionic surfactant (R-11) and sufficient water to make 100 ml total volume; the entire volume was used on each plant.

Table 10. Bohemian knotweed shoots arising from rhizomes from plants treated with Rodeo (2.5%) or Habitat (1%) at first bloom or after flowering.

Treatment[a]	Shoot number[b]				Shoot biomass[b]			
	First bloom		Post-bloom		First bloom		Post-bloom	
	2011	2013	2011	2013	2011	2013	2011	2013
	no./plant	no./plant	no./plant	no./plant	g	g	g	g
Rodeo	9.0 b	5.0 b	0 b	3.0 b	1.4 b	0.1 b	0 b	0.2 b
Habitat	0.8 c	0.5 c	0.3 b	1.8 c	0.3 b	<0.1 b	0.1 b	0.1 b
Nontreated	22.9 a	10.3 a	3.9 a	6.8 c	11.9 a	2.2 a	1.4 a	1.3 a

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Treatments were applied to Bohemian knotweed foliage at first bloom (late August) or post-bloom (mid-October); 2.5 ml Rodeo or 1 ml Habitat was mixed with 0.25% (v/v) nonionic surfactant (R-11) and sufficient water to make 100 ml total volume; the entire volume was used on each plant.

[b]Shoots collected from rhizomes after five weeks in the greenhouse.

2013-2014 Aminocyclopyrachlor in Bohemian Knotweed Trial

Materials and Methods. Aminocyclopyrachlor was tested for its efficacy on Bohemian knotweed (*Reynoutria × bohemica*) (Norman McKinley, DuPont Agricultural Products, cooperator). The trial was conducted at two sites, one on the edge of an agricultural field near Mount Vernon, Washington and the second next to the Skagit River (Lion's Park, city of Mount Vernon). In the first trial, Bohemian knotweed was treated July 19, 2013 with SG or SL formulations of aminocyclopyrachlor using a CO_2-pressurized backpack sprayer. Plants measured 5 to 8 feet tall and were in the bud stage of growth at the time of the application. Two liters of mixed herbicide was applied to each plot (20 by 15 ft, 300 ft^2). Each treatment was mixed with 1% methylated seed oil prior to application. Percent knotweed injury was estimated at 2 and 4 weeks after treatment (WAT), August 5 and August 19, 2013, respectively, and again at 9 and 13 months after treatment (MAT), April 30 and August 11, 2014. The trial was a randomized complete block with 3 replicates.

In the second trial, Bohemian knotweed was treated October 9, 2013 using the same equipment as listed above. Foliage was wet with dew at the time of application and plants were about 25% chlorotic as they senesced in mid-autumn. One liter of mixed herbicide was applied to each plot (10 by 10 ft, 100 ft^2). Plots were clipped at the soil line by the grounds maintenance crew only three or four days after treatment, so this may have impacted ultimate control. Percent knotweed injury was estimated at 6 and 10 months after treatment (MAT), April 30 and August 11, 2014. The trial was a randomized complete block with 4 replicates.

A general linear model was used to analyze the data in both trials, and means were separated using Fisher's Protected LSD ($P < 0.05$).

Results.

Trial 1, bud-stage trial. Bohemian knotweed injury at 2 WAT did not differ by treatment, ranging from 30 to 45% (Table 11). Aminocyclopyrachlor alone or mixed with Telar showed injury primarily at stem tips. Aminocyclopyrachlor mixed with Garlon caused epinasty as well as leaf necrosis. Rodeo + Habitat treatments killed leaf stem tips and caused a general chlorosis in all foliage. Symptoms were similar but intensified by 4 WAT. There was a rate response in most treatments, although the difference in each two comparative rates was not statistically significant. Addition of Telar to aminocyclopyrachlor did not result in quicker onset or severity of symptoms. The high rate of aminocyclopyrachlor + triclopyr caused more severe injury to Bohemian knotweed than did MAT 50 at 3.4 g/gal with or without chlorsulfuron. Injury from Rodeo + Habitat applied at these rates exceeded that from aminocyclopyrachlor applied at 3.4 g/gal alone or in combination with chlorsulfuron, and MAT 50 at 4.3 g/gal applied with chlorsulfuron.

The adjacent field was planted to silage corn in 2013, which the farmer harvested in September, 2013. Most Bohemian knotweed plots were driven through or cut during harvest operations, so additional data from 2013 was not available. Winter wheat was seeded in October and was harvested the following July. By 9 MAT, Bohemian knotweed control exceeded 90% in all plots

(Table 11). The only treatments that differed statistically were aminocyclopyrachlor at 4.3 g/gal
and Rodeo + Habitat (98% control) exceeding control resulting from aminocyclopyrachlor +
chlorsulfuron at the high rate (90% control). Knotweed control at 13 MAT (August, 2014) was
similar across all treatments, ranging from 87 to 93%.

Trial 2, mid-autumn trial. Bohemian knotweed injury did not differ among treatments at either 6
or 10 MAT, respectively; Table 12). Most plants were showing appreciable epinastic growth in
upper leaves at the 6 MAT evaluation, although knotweed stems were typically about 3 ft in
length, approximately the same length as nontreated knotweed. Symptoms were far less
prevalent by 10 MAT, and most knotweed plants appeared normal despite earlier treatment.
Flowering was beginning in all plots, at similar timing as nontreated knotweed.

Conclusions. The results from the bud-stage trial shows that these herbicides can provide
excellent control of Bohemian knotweed. This outstanding level of control may be reflective of
the total amount of product to these plots, however. The poor control resulting from the late-
season applications were probably due to cool weather, the advanced senescence of leaf material
following the application, and, perhaps most importantly, the cutting of treated plants apparently
prior to appreciable translocation of herbicide to rhizomes.

Table 11. Bohemian knotweed control[a] after treatment with aminocyclopyrachlor at pre-bud
stage of growth.

Treatment[b]	Rate	2 WAT	4 WAT	9 MAT	13 MAT
	g/gal or %	%	%		
Aminocyclopyrachlor SG	3.4	33 a	38 bc	93 ab	87 a
Aminocyclopyrachlor SG	4.3	30 a	48 ab	98 a	93 a
Aminocyclopyrachlor SG + chlorsulfuron	3.4 + 0.9	30 a	30 c	92 ab	88 a
Aminocyclopyrachlor SG + chlorsulfuron	4.3 + 1.1	30 a	38 bc	90 b	92 a
Aminocyclopyrachlor SL + triclopyr	0.16% + 0.34%	38 a	47 ab	96 ab	85 a
Aminocyclopyrachlor SL + triclopyr	0.25% + 0.5%	45 a	52 a	93 ab	88 a
Rodeo + Habitat	2.5% + 0.75%	45 a	55 a	98 a	93 a
Nontreated	---	0 b	0 d	0 c	0 b

Means in the same column followed by the same letter, or without a letter, are not significantly
  different.
[a]Control estimated August 5 and 19, 2013 and April 30 and August 11, 2014; WAT = weeks after
  treatment, MAT = months after treatment.
[b]Herbicides were applied July 19, 2013; all products mixed with MSO (1%, v/v) prior to application.

Table 12. Bohemian knotweed control[a] after treatment with aminocyclopyrachlor at 25% chlorotic in the autumn.

Treatment[a]	Rate	6 MAT	10 MAT
	g/gal or %	%	%
Aminocyclopyrachlor SG	3.4	54 a	28 a
Aminocyclopyrachlor SG	4.3	69 a	18 ab
Aminocyclopyrachlor SG + chlorsulfuron	3.4 + 0.9	59 a	18 ab
Aminocyclopyrachlor SL + triclopyr	0.16% + 0.34%	71 a	19 ab
Nontreated	---	0 b	0 b

Means in the same column followed by the same letter, or without a letter, are not significantly different (P < 0.05).
[a]Control estimated April 30 and August 11, 2014; MAT = months after treatment.
[b]Herbicides were applied October 9, 2013; all products mixed with MSO (1%, v/v) prior to application.

2014-2015 Foam Applicator for Knotweed Control Trial

Materials and Methods. A new spray unit under development by a Minnesota company (www.greenshootsonline.com) uses surfactant to create a shaving cream-like foam that may improve contact time and uptake of herbicides. This sprayer was tested in trials on Bohemian Bohemian (*Reynoutria* x *bohemica*) and Himalayan knotweed (*Koenigia polystachya*) (Frances Lucero, King County Noxious Weed Control Board, cooperator). The trials were conducted near Mount Vernon, Washington (Bohemian) and Skykomish, Washington (Himalayan knotweed) on well-established knotweed infestations. Treatments were applied July 28, 2014 for Bohemian, August 5, 2014 for Himalayan knotweed, at bud stage of growth of both species (no flowers yet present) using either the foam applicator or a CO_2-pressurized backpack sprayer. Tested herbicides were Rodeo (glyphosate), Habitat (imazapyr), Perspective (aminocyclopyrachlor + chlorsulfuron), and Milestone (aminopyralid), with the sprays applied at 2 liters per 400 ft^2-plot and foam applied at 1 liter per 400 ft^2-plot. Control was evaluated at 2 and 4 weeks after treatment (WAT) and 10 months after treatment (MAT).

Results. There was no difference in herbicide efficacy at 1 MAT, regardless of herbicide used (Table 13). Bohemian knotweed showed much less injury than Himalayan knotweed at 2 and 4 WAT (35% and 51% at 2 WAT for Bohemian and Himalayan knotweed, respectively, and 49% and 70% control at 4 WAT, respectively). Initial injury did not differ between spray application and foam application (51% and 46% for foam and spray at 2 WAT, respectively, and 69% and 66% at 4 WAT, respectively).

By 10 MAT, all treatments were providing excellent control of Himalayan knotweed (Table 14). Control with Habitat applied with the foam applicator (92%) was statistically lower the the 100% control with Habitat, Perspective, or Milestone applied using the spray applicator or Perspective with the foam applicator. There was no difference in control of Bohemian knotweed among the treatments or application types at 10 MAT.

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Conclusions. Initial trials indicate that the foam applicator was at least as effective at controlling Bohemian and Himalayan knotweed as typical spray applications. There was a trend toward lower control with the foam applicator, but since less product was applied (1 liter/plot for foam vs. 2 liters/plot for spray), this may be offset by lower herbicide costs. The foam unit was not suitable for large-scale applications, however, and the cost of surfactant may be prohibitive.

Table 13. Bohemian and Himalayan knotweed injury at 2 and 4 weeks after treatment (WAT) with several herbicides applied in water or using a foam applicator.

Treatment	Rate	Type	Himalayan knotweed		Bohemian knotweed	
			2 WAT	4 WAT	2 WAT	4 WAT
	product/a or %		%	%	%	%
Rodeo	2%	Spray	37	80	58	72
Habitat	0.75%	Spray	22	28	25	43
Perspective	3.4 + 0.9 g	Spray	75	95	37	53
Milestone	7 fl.oz	Spray	70	100	42	55
Rodeo	2%	Foam	52	85	48	60
Habitat	0.75%	Foam	38	52	30	63
Perspective	3.4 + 0.9 g	Foam	85	95	30	42
Milestone	7 fl.oz	Foam	78	98	45	57

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Treatments were applied to knotweed foliage at bud stage of growth (July 28, 2014 for Bohemian knotweed and August 5, 2014 for Himalayan knotweed; herbicide sprays were mixed withi 0.25% (v/v) nonionic surfactant (R-11) prior to application; a total volume of 1 liter per plot of mix was applied with the foam applicator, while 2 liters per plot were applied with the spray applicator.

Table 14. Bohemian and Himalayan knotweed control at 10 MAT with several herbicides applied in water or using a foam applicator.

Treatment	Rate	Type	Himalayan knotweed	Bohemian knotweed
	product/a or %			
Rodeo	2%	Spray	98 ab	85
Habitat	0.75%	Spray	100 a	100
Perspective	3.4 + 0.9 g	Spray	100 a	95
Milestone	7 fl.oz	Spray	100 a	95
Rodeo	2%	Foam	95 ab	90
Habitat	0.75%	Foam	92 b	95
Perspective	3.4 + 0.9 g	Foam	100 a	95
Milestone	7 fl.oz	Foam	98 ab	95

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Treatments were applied to knotweed foliage at bud stage of growth (July 28, 2014 for Bohemian knotweed and August 5, 2014 for Himalayan knotweed; herbicide sprays were mixed withi 0.25% (v/v) nonionic surfactant (R-11) prior to application; a total volume of 1 liter per plot of mix was applied with the foam applicator, while 2 liters per plot were applied with the spray applicator.

Meadow Knapweed
2001-2002, 2004-2005

See article: Miller, T.W. and C. Lucero. 2014. Meadow knapweed (*Centaurea debeauxii*) response to herbicides and mechanical control. Invasive Plant Science and Management 7:503-511.

Integrated Control of Perennial Weeds

See article: Miller, T.W. 2016. Integrated strategies for management of perennial weeds. Invasive Plant Science and Management 9:148-158.

Poison Hemlock
2004-2005

Materials and Methods. A trial was designed to determine the susceptibility of poison hemlock (*Conium maculatum*) to several herbicides. Plots were established at the edge of a field near Ebey's Landing National Historical Reserve on Whidbey Island, Washington (Leigh Smith, US National Park Service, cooperator); plots measured 8 by 20 ft. Plants were treated April 22, 2004 when second-year poison hemlock plants were from 2 to 3 ft tall and actively growing. The same plots were maintained and half of each plot was retreated with the same herbicides March 23, 2005, when poison hemlock plants were about 1 ft tall. Some plots contained little poison hemlock at the time of the second application, but did contain birdsrape mustard (*Brassica rapa*) plants that were flowering. Poison hemlock control was rated May 5 and July 28, 2004, and April 6, May 25, and July 27, 2005. The experimental design was a split-plot Randomized Complete Block with three replicates. Means were separated using Fisher's Protected LSD (P ≤ 0.05).

Results. All products except Clarity gave excellent control of poison hemlock at the end of July, 2004 (92 to 100% control) (Table 1). It is interesting to note that control in 2004 was very good with 2,4-D products (Weedar, Weedmaster, Curtail, and Crossbow), while control with Weedar and Weedmaster dropped quickly following the 2005 applications. Plants were taller at the time of application in 2004 than they were in 2005, and coupled with warmer temperatures (65 F in 2004 and 55 in 2005), may have improved 2,4-D activity in 2004.

Poison hemlock control from a single application in 2004 was only at an acceptable level with Plateau (87, 83, and 85% in April, May, and July, 2005, respectively) (Table 1). Control was next best with Garlon, although control was only 65% by July, 2005. Two consecutive herbicide applications worked well with most of the tested products. Exceptions were Weedar and Weedmaster (33 and 43% control in July, 2005); control at that time was moderate with Curtail and Escort (72 and 67%, respectively).

Conclusions. The best tested herbicide for poison hemlock control was Plateau, which provided two years of control from a single application. Two annual Plateau applications resulted in 100% poison hemlock control. Two annual spring applications of several other products also gave excellent control, including Roundup, Transline, Garlon, and Crossbow (90% control or more). 2,4-D activity was enhanced when applied to 2- to 3-ft tall poison hemlock in warm temperatures.

Table 1. Control of poison hemlock by various herbicides applied once or twice over two years.

Treatment[a]	Rate	Poison hemlock control				
		5/5/04	7/28/04	4/6/05	5/25/05	7/27/05
	product/a	%	%	%	%	%
Treated once (4/22/04)						
Weedar	2 qt	87 a	100 a	65 ab	58 ab	20 bc
Roundup	2 pt	40 b	100 a	32 bc	32 bc	28 bc
Clarity	1 qt	33 b	55 b	57 ab	7 c	53 ab
Weedmaster	2 qt	88 a	96 a	67 ab	58 ab	33 bc
Curtail	2 qt	83 a	100 a	62 ab	55 ab	55 ab
Transline	1 pt	70 a	92 a	57 ab	17 bc	23 bc
Garlon	1.5 pt	87 a	98 a	77 ab	53 abc	65 ab
Crossbow	3 qt	90 a	100 a	65 ab	60 ab	22 bc
Plateau + mso	12 fl.oz	22 b	100 a	87 a	83 a	85 a
Escort + nis	1 oz	22 b	100 a	0 c	20 bc	0 c
Treated twice (4/22/04 and 3/23/05)						
Weedar	2 qt	---	---	77 a	48 d	33 bc
Roundup	2 pt	---	---	98 a	97 ab	98 a
Clarity	1 qt	---	---	85 a	60 cd	80 ab
Weedmaster	2 qt	---	---	75 a	68 bcd	43 bc
Curtail	2 qt	---	---	90 a	80 abc	72 abc
Transline	1 pt	---	---	93 a	90 ab	97 a
Garlon	1.5 pt	---	---	93 a	95 ab	93 a
Crossbow	3 qt	---	---	98 a	100 a	100 a
Plateau + mso	12 fl.oz	---	---	93 a	100 a	100 a
Escort + nix	1 oz	---	---	43 b	85 abc	67 abc

Means within a column followed by the same letter are not statistically different.
[a]Plateau treatments were mixed with 0.75% (v/v) SunIt II mso (methylated seed oil) prior to application; Escort treatments were mixed with 0.25% (v/v) R-11 nis (nonionic surfactant) prior to application.

Reed Canarygrass
2000-2002, 2003-2007

2000-2002 Skagit County Trial

See article: Miller, T.W., L.P. Martin, and C.B. MacConnell. 2008. Managing Reed Canarygrass (*Phalaris arundinacea*) to Aid in Revegetation of Riparian Buffers. Weed Technology 22:507-513.

2003-2007 Snohomish County Trial

<u>Materials and Methods</u>. A tree re-establishment trial was initiated in a lowland pasture containing a near-monotypic stand of reed canarygrass (*Phalaris arundinacea*). The intent of the trial was to test re-establishment of native broadleaf and conifer trees in a reed canarygrass-dominated lowland, and to determine if a sequential transplanting of western red cedar (*Thuja plicata*) enabled that species to more successfully establish at this site. Two iterations of the trial were conducted on separate portions of the same pasture near Duvall, Washington, in 2003-2006 and in 2004-2007.

Glyphosate was applied to reed canarygrass through the entire experimental area in August and again in September of Year 1 as a site preparation. Plots measured 8 ft by 8 ft, and were planted to one of three tree species in April of Year 2. Three trees of a single species were planted in a triangle pattern in each plot, with about 3 ft spacing between trees and a buffer width of at least 2.5 ft from each tree to the closest plot border. Broadleaf tree species were Hooker willow (*Salix hookerii*) and black cottonwood (*Populus balsamifera* ssp. *trichocarpus*) while the conifer species was western red cedar. Certain plots then were planted with one red cedar in the center of the triangle pattern in April of Year 2, while certain other plots were transplanted with one red cedar in the center of the triangle pattern in April of Year 3. Other plots were not transplanted with the fourth tree.

Four reed canarygrass maintenance programs were then imposed on these plots. Three programs were treated with one of three herbicide programs during Years 2 and 3, including glyphosate (Roundup Pro), or mixes of imazapyr (Habitat) + clethodim (Select) or sulfometuron (Oust) + sethoxydim (Poast). Products were applied using a backpack CO_2 sprayer equipped with a shielded wand to avoid contacting tree stems or leaves with herbicide. Herbicides were applied in April/May of Year 2, August/September of Year 2 (two applications per plot), and April/May of Year 3 (one application per plot; for a total of three applications per plot). The mowing program (check plots) was conducted using a blade trimmer whenever reed canarygrass foliage exceeded 18 inches in height. Mowings were conducted June/July and August/September of Year 2 (two mowings per plot) and April/May, June, and August of Year 3 (three mowings per plot; for a total of five mowings per plot).

Reed canarygrass and broadleaf weed control was estimated in October of Year 2, April and October of Year 3, and April of Year 4. Survival and growth of Hooker willow, black cottonwood, and western red cedar was determined in October of Year 2 and Year 3. The

statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results.

Reed canarygrass control. In Iteration 1, mowing resulted in the poorest reed canarygrass control in April of Years 2 and 3 (48 and 22%, respectively; Table 1). Herbicides gave 87 to 94% control in October of Year 1, while glyphosate provided the best control in October of Year 3 (Table 1). By April of Year 4, herbicides were giving 79 to 88% reed canarygrass control. In Iteration 2, mowing provided the poorest reed canarygrass control in October of Year 2, while glyphosate gave the poorest control at all evaluation dates in Years 3 and 4. Control with Oust + Poast was best at all evaluation dates, although Habitat + Select also gave similar control in October of Year 2. These data indicate that reed canarygrass control with spot applications of glyphosate was erratic, being excellent in the Iteration 1 and poor in Iteration 2. Reed canarygrass control with either Oust + Poast or Habitat + Select was fairly consistent, ranging from 79 to 93% in Iteration 1 and 72 to 94% in Iteration 2.

Broadleaf weed control. Broadleaf species at this site primarily included birdsrape mustard (*Brassica rapa*) and bull thistle (*Cirsium vulgare*), with scattered pale smartweed (*Polygonum lapathifolium*), mayweed chamomile (*Anthemis cotula*), prickly lettuce (*Lactuca seriola*), and spotted jewelweed (*Impatiens capensis*). Control of broadleaf weeds varied by iteration and evaluation date, although all treatments were providing excellent control by April of Year 4 (86 to 97% in Iteration 1 and 90 to 100% in Iteration 2 (Table 2). It appears these herbicides or mowing was successfully controlling the majority of broadleaf weed species.

Effect of maintenance programs on tree performance. Tree survival did not greatly vary by maintenance operation (Table 3). Survival trended downward with time in both iterations, ranging from 74 to 84% in Iteration 1 and 83 to 89% in Iteration 2. The only significant difference in survival occurred in Iteration 1, with mowing resulting in lower survival than spot treatment with Oust + Poast.

Tree height and seasonal growth was maximized by spot treatment with glyphosate at all evaluation times in both iterations (Table 4). By October in Year 3 of both iterations, however, tree height and growth with mowing was similar to spot treatment with glyphosate. Tree response to Oust + Poast spot treatments was intermediate, while Habitat + Select generally reduced tree height and growth in October of both Year 2 and Year 3 in Iteration 1, and in October of Year 3 in Iteration 2.

Effect of species and undertransplant timing of western red cedar on tree performance. When plots were planted to Hooker willow or black cottonwood, tree survival was generally best if red cedar was not underplanted or was transplanted in April of Year 3, rather than when all four trees were transplanted in Year 2 (Table 5). This was particularly evident with Hooker willow in Iteration 1. During Iteration 2, Hooker willow tolerated underplanting during Year 2 better, although survival was still numerically lowest with that transplant timing. Black cottonwood displayed a similar pattern, although differences were rarely significant in Iteration 1. Black

cottonwood survival was typically lower in Iteration 2, although again, the pattern of underplanting red cedar during Year 2 numerically reducing black cottonwood survival was similar as seen with Hooker willow. Red cedar survival was poor in Iteration 1 regardless of whether the 4th tree was transplanted in Year 2 or Year 3, although underplanting was more successful in Year 3 than in Year 2. Red cedar survival did not vary with transplant timing in Iteration 2.

Hooker willow height and seasonal growth was not greatly affected by underplanting of red cedar in either iteration, especially in October of Year 2 (Table 6). Transplanting in Year 2, however, generally reduced ultimate height and slowed growth of Hooker willow by the end of Year 3. It is suspected that transplanting in Year 2 severed enough willow roots to reduce final height of these trees in both iterations, and to slow willow growth in Iteration 1. Black cottonwood responded to red cedar underplanting in a similar manner as Hooker willow, although differences between these treatments was greater. Black cottonwood height by October of Year 3 in both iterations was greatest with no underplanting of red cedar, lower when transplanting occurred in in Year 2, and was lowest when transplanting occurred in Year 3. Seasonal growth of black cottonwood trees differed by iteration, although growth was generally best in plots with no red cedar present. Red cedar height and seasonal growth did not significantly differ regardless of planting date.

When viewed by species performance, black cottonwood trees ranged from 363 to 476 cm (12 to 16 ft) tall after two seasons of growth, with growth averaging 130 cm (4.3 ft) in the first season and 196 cm (6.4 ft) in the second season (Table 6). Hooker willow height ranged from 183 to 243 cm (6 to 8 ft) after two seasons, with growth averaging 57 cm (1.9 ft) in the first season and 108 cm (3.5 ft) in the second season. Red cedar trees were 92 to 120 cm (3 to 4 ft) tall after two growing seasons, with growth averaging 26 cm in the first season (10 inches) and 38 cm (15 inches) in the second season.

Conclusions. Based on these data, black cottonwood would most quickly overtop reed canarygrass, and presumably would be the earliest to suppress reed canarygrass growth due to canopy shading. Hooker willow would be less able to compete directly with reed canarygrass, but could achieve a similar height as reed canarygrass culms after two seasons of growth. Red cedar in this trial would not be capable of competing with reed canarygrass in terms of seasonal growth and height after two seasons. Finally, tree survival was best if red cedar was underplanted the year following transplanting of broadleaf trees. Conversely, tree height was generally best after two growing seasons if red cedar was underplanted at the same time as black cottonwood and Hooker willow. This tradeoff should be considered when broadleaf/conifer mixes are desired at given sites.

Table 1. Reed canarygrass control from mowing or herbicide application after transplanting of tree species.

Maintenance program[a]	1st Iteration (2003-2006)				2nd Iteration (2004-2007)			
	10/5/04	4/20/05	10/4/05	4/17/06	10/4/05	4/17/06	10/5/06	4/26/07
	%	%	%	%	%	%	%	%
Mow	70 c	48 c	75 c	22 c	75 b	17 d	46 d	15 d
Glyphosate	94 a	86 b	92 a	85 a	21 c	28 c	63 c	69 c
Oust + Poast	87 b	91 a	71 c	88 a	81 a	82 a	94 a	93 a
Habitat + Select	90 ab	93 a	80 b	79 b	81 a	72 b	78 b	78 b

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]All plots were initially treated with glyphosate at 2 lb ae/a in September and October the fall prior to tree transplanting (Year 1). Herbicides were applied in April/May of Year 2, August/September of Year 2 (two applications per plot), and April/May of Year 3 (one application per plot; for a total of three applications per plot). The mowing program (check plots) was conducted using a blade trimmer whenever reed canarygrass foliage exceeded 18 inches in height. Mowings were conducted June/July and August/September of Year 2 (two mowings per plot) and April/May, June, and August of Year 3 (three mowings per plot; for a total of five mowings per plot). All treatments were mixed with 0.25% (v/v) R-11 nis (nonionic surfactant) prior to application.

Table 2. Broadleaf weed control from mowing or herbicide application after transplanting of tree species.

Maintenance program[a]	1st Iteration (2003-2006)				2nd Iteration (2004-2007)			
	10/5/04	4/20/05	10/4/05	4/17/06	10/4/05	4/17/06	10/5/06	4/26/07
	%	%	%	%	%	%	%	%
Mow	72 b	88 b	89 a	97 a	92 a	99 a	91 ab	100 a
Glyphosate	84 a	84 c	71 c	86 c	96 a	99 a	88 ab	93 b
Oust + Poast	68 b	93 a	81 b	94 ab	84 b	93 b	93 a	95 b
Habitat + Select	73 b	87 bc	79 b	93 b	85 b	91 b	86 b	90 c

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]All plots were initially treated with glyphosate at 2 lb ae/a in September and October the fall prior to tree transplanting (Year 1). Herbicides were applied in April/May of Year 2, August/September of Year 2 (two applications per plot), and April/May of Year 3 (one application per plot; for a total of three applications per plot). The mowing program (check plots) was conducted using a blade trimmer whenever reed canarygrass foliage exceeded 18 inches in height. Mowings were conducted June/July and August/September of Year 2 (two mowings per plot) and April/May, June, and August of Year 3 (three mowings per plot; for a total of five mowings per plot). All treatments were mixed with 0.25% (v/v) R-11 nis (nonionic surfactant) prior to application.

Table 3. Mean tree species survival with mowing or herbicide application after transplanting[a].

Maintenance program[b]	1st Iteration (2003-2006)				2nd Iteration (2004-2007)			
	10/5/04	4/20/05	10/4/05	4/17/06	10/4/05	4/17/06	10/5/06	4/26/07
	%	%	%	%	%	%	%	%
Mow	89	85	78	74 b	95	96	93	89
Glyphosate	83	85	83	81 ab	98	97	86	83
Oust + Poast	88	86	85	84 a	97	97	87	83
Habitat + Select	87	87	84	81 ab	97	98	91	88

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Trees were transplanted in April of 2004 (1st Iteration) and April of 2005 (2nd Iteration).
[b]All plots were initially treated with glyphosate at 2 lb ae/a in September and October the fall prior to tree transplanting (Year 1). Herbicides were applied in April/May of Year 2, August/September of Year 2 (two applications per plot), and April/May of Year 3 (one application per plot; for a total of three applications per plot). Mowings were conducted June/July and August/September of Year 2 (two mowings per plot) and April/May, June, and August of Year 3 (three mowings per plot; for a total of five mowings per plot). All treatments were mixed with 0.25% (v/v) R-11 nis (nonionic surfactant) prior to application.

Table 4. Mean tree species height and seasonal growth with mowing or herbicide application after transplanting[a].

Maintenance program[b]	1st Iteration (2003-2006)				2nd Iteration (2004-2007)			
	Height		Seasonal growth		Height		Seasonal growth	
	10/5/04	10/4/05	10/5/04	10/4/05	10/4/05	10/5/06	10/4/05	10/5/06
	cm	cm	cm	cm	cm	cm	cm	cm
Mow	109 b	230 b	52 bc	149 a	148 b	255 b	85 b	127 a
Glyphosate	128 a	251 a	72 a	148 a	155 ab	276 a	98 a	135 a
Oust + Poast	120 a	221 b	59 b	123 b	154 b	241 b	93 ab	106 b
Habitat + Select	110 b	191 c	51 c	100 c	168 a	250 b	102 a	99 b

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Trees were transplanted in April of 2004 (1st Iteration) and April of 2005 (2nd Iteration).
[b]All plots were initially treated with glyphosate at 2 lb ae/a in September and October the fall prior to tree transplanting (Year 1). Herbicides were applied in April/May of Year 2, August/September of Year 2 (two applications per plot), and April/May of Year 3 (one application per plot; for a total of three applications per plot). Mowings were conducted June/July and August/September of Year 2 (two mowings per plot) and April/May, June, and August of Year 3 (three mowings per plot; for a total of five mowings per plot). All treatments were mixed with 0.25% (v/v) R-11 nis (nonionic surfactant) prior to application.

Table 5. Tree species survival among tree species with different underplanting dates of western red cedar.

Species/Timing[a]	1st Iteration (2003-2006)				2nd Iteration (2004-2007)			
	10/5/04	4/20/05	10/4/05	4/17/06	10/4/05	4/17/06	10/5/06	4/26/07
	%	%	%	%	%	%	%	%
Hooker willow, no red cedar	98 a	96 a	94 a	94 a	100 a	100 a	100 a	98 a
Hooker willow, red cedar planted in Year 2	83 bc	78 b	78 bc	78 cd	97 ab	95 ab	84 b	88 abc
Hooker willow, red cedar planted in Year 3	98 a	98 a	94 a	92 ab	100 a	100 a	100 a	95 ab
Black cottonwood, no red cedar	98 a	94 a	94 a	92 ab	96 ab	92 b	88 b	83 bc
Black cottonwood, red cedar planted in Year 2	90 ab	89 ab	84 abc	81 bcd	94 ab	94 ab	83 b	81 c
Black cottonwood, red cedar planted in Year 3	92 ab	92 a	89 ab	88 abc	92 b	94 ab	88 b	88 abc
Red cedar, 4th red cedar planted in Year 2	68 d	63 c	58 d	50 e	98 a	98 a	84 b	78 c
Red cedar, 4th red cedar planted in Year 3	73 cd	80 b	77 c	72 d	100 a	100 a	86 b	78 c

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Three trees per plot were transplanted in April of Year 2 (2004, 1st Iteration; 2005, 2nd Iteration). Plots were then not undertransplanted with red cedar, or undertransplanted with a red cedar tree in April of Year 2 or Year 3 (2004 or 2005, 1st Iteration; 2005 or 2006, 2nd Iteration).

Table 6. Tree species height and seasonal growth among tree species with different underplanting dates of western red cedar.

Species/Timing	1st Iteration (2003-2006)				2nd Iteration (2004-2007)			
	Height		Seasonal growth		Height		Seasonal growth	
	10/5/04	10/4/05	10/5/04	10/4/05	10/4/05	10/5/06	10/4/05	10/5/06
	cm	cm	cm	cm	cm	cm	cm	cm
Hooker willow, no red cedar	102 c	204 d	43 b	134 d	141 cd	243 d	72 c	101 c
Hooker willow, red cedar planted in Year 2	96 c	196 de	39 b	127 de	128 d	212 e	67 c	76 d
Hooker willow, red cedar planted in Year 3	105 c	183 e	44 b	116 e	149 c	198 e	78 c	94 cd
Black cottonwood, no red cedar	167 a	381 a	102 a	219 a	249 a	476 a	173 a	222 a
Black cottonwood, red cedar planted in Year 2	154 b	328 b	93 a	188 b	201 b	390 b	138 b	176 b
Black cottonwood, red cedar planted in Year 3	159 ab	274 c	96 a	158 c	251 a	363 c	180 a	211 a
Red cedar, 4th red cedar planted in Year 2	61 d	98 f	16 c	38 f	80 e	120 f	35 d	41 e
Red cedar, 4th red cedar planted in Year 3	54 d	92 f	17 c	34 f	82 e	103 f	36 d	37 e

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Three trees per plot were transplanted in April of Year 2 (2004, 1st Iteration; 2005, 2nd Iteration). Plots were then not undertransplanted with red cedar, or undertransplanted with a red cedar tree in April of Year 2 or Year 3 (2004 or 2005, 1st Iteration; 2005 or 2006, 2nd Iteration).

Rush Skeletonweed
2016

<u>Materials and Methods</u>. A greenhouse trial was conducted to determine the susceptibility of rush skeletonweed (*Chondrilla juncea*) seedlings to several herbicides. Rush skeletonweed seed was obtained from Klickitat County (compliments of Marty Hudson, Klickitat County Noxious Weed Control Board), and germinated plants were transplanted into small pots and grown in the greenhouse at WSU Northwestern Washington Research and Extension Center near Mount Vernon, Washington. Plants were selected for herbicide treatments May 7, 2016. Rosettes were at least 6 inches in diameter at the time of herbicide treatment. Percent control was estimated May 31, 2016 (1 MAT). The statistical design of the trial was a Randomized Complete Block with five replicates. Data were analyzed using a general linear models procedure and Tukey's Honestly Significant Difference test was used to separate the means (P ≤ 0.05).

<u>Results</u>. Nearly all tested herbicides provided 100% control of rush skeletonweed seedlings at 1 MAT (Table 1). Exceptions were with Habitat, Escort, and Oust, with control ranging from 21 to 55%). These products may have eventually provided better control, but the greenhouse trial had to be discontinued due to lack of available bench space. The successful herbicides should be expected to show excellent activity of field populations of rush skeletonweed seedlings, as well as providing a good level of control of established plants. However, since these were greenhouse-grown plants, rates may need to be higher to provide a similar level of control of rush skeletonweed in the field.

Table 1. Control of rush skeletonweed seedlings treated with several herbicides in the greenhouse.

Treatment[a]	Rate	Rush skeletonweed control 5/31/16 (1 MAT)
	product/a or %	%
Oust + nis	1.5 oz	21 cd
Escort + nis	1.5 oz	36 bc
Roundup	3%	87 a
Weedmaster	2 qt	100 a
Curtail	2 qt	100 a
Crossbow	3%	100 a
Garlon	3%	100 a
Transline	1 pt	100 a
Plateau + mso	1%	100 a
Habitat + mso	1%	55 b
Method	12 fl.oz	100 a
Milestone	5 fl.oz	100 a
Nontreated	---	0 d

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Treatments were applied May 7, 2016 to rush skeletonweed seedlings (6-inch diameter); "nis" = nonionic surfactant (Dyne-Amic) applied at 0.25% (v/v); "mso" = methylated seed oil (SunIt II) applied at 0.25% (v/v).

[b]MAT = months after treatment.

Shiny Geranium
2008-2010

Washougal Oaks Trial #1, 2008-2009

<u>Materials and Methods</u>. A field trial was established to determine the susceptibility of shiny geranium (*Geranium lucidum*) to several herbicides (Alison Halpern, Washington State Noxious Weed Control Board and Carlo Abbruzzese, Washington State Department of Natural Resources, cooperators). Plots measuring 8 by 20 feet were established on the edge of a highly infested dirt road in Washougal Oaks Natural Area near Stevenson, Washington. Herbicides were applied October 20, 2008 to shiny geranium plants from the cotyledon-stage to 4 inches wide. Shiny geranium control was estimated January 5, January 26, and June 11, 2009. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

<u>Results</u>. Shiny geranium control in early January statistically similar for eight herbicides, but exceeded 90% with Habitat, Crossbow, and Plateau (Table 1). Control improved with Oust over time, until 95% control was achieved by mid-June. Milestone also gave control from 75 to 83% control over the duration of this trial, while Garlon resulted in 70 to 79% control. The top four treatments by June 11 (about 8 months after treatment) were Habitat, Oust, Crossbow, and Plateau, all resulting in at least 94% control; statistically equal to Milestone at 81% control.

Table 1. Shiny geranium control after treatment with several herbicides.

Treatment[a]	Rate	Shiny geranium control		
		1/5/09	1/26/09	6/11/09
	product/a	%	%	%
Oust	2 oz	80 ab	85 abc	95 ab
Banvel	1 qt	41 cd	38 ef	46 efg
Roundup	1 qt	43 bcd	48 def	64 cde
Weedmaster	1 qt	54 bc	50 cde	29 gh
Curtail	1.6 pt	50 bc	38 ef	35 fgh
Crossbow	4 pt	93 a	93 ab	95 ab
Garlon	1.5 pt	77 abc	70 a-e	79 a-d
Transline	8 fl.oz	50 bc	60 b-e	63 c-f
Plateau	12 fl.oz	94 a	95 ab	94 ab
Habitat	1 pt	96 a	96 a	99 a
Redeem	1 qt	68 abc	66 a-e	69 b-e
Milestone	3 fl.oz	75 abc	83 a-d	81 abc
Finale	2 qt	59 abc	53 cde	53 d-g
Matran EC	15%	54 bc	43 ef	64 cde

Means within a column followed by the same letter are not statistically different.
[a]Herbicides were applied October 20, 2008; Oust, Plateau, and Habitat were mixed with DyneAmic surfactant at 0.25% (v/v) prior to application.

Bayview State Park Trial, 2009

Materials and Methods. A field trial was established to determine the susceptibility of shiny geranium (*Geranium lucidum*) to several herbicides (Alison Halpern, Washington State Noxious Weed Control Board and John Kambrink, Washington State Parks, cooperators). Plots measuring 4 by 20 feet were established at various locations within Bayview State Park near Bayview, Washington. Products tested were low-rate Roundup (0.5, 0.75, and 1% product in water), and nonsynthetic herbicides Scythe (pelargonic acid), Matran EC (clove oil), Interceptor (pine oil), vinegar (5% acetic acid), and All Down (unknown concentration of acetic acid); other plots were flamed using a hand-held propane flamer. Treatments were applied March 5, 2009 to shiny geranium plants from the cotyledon-stage to 4 inches wide. Shiny geranium control was estimated March 6 (24 hours after application), March 16 (11 days after treatment, DAT), and April 28 (53 DAT), 2009. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Nonsynthetic herbicides giving at least 75% shiny geranium control 1 DAT were 10% Scythe, 20% Interceptor, 20% Matran EC, and propane flame (Table 2). Only 10% Scythe was still providing at least 75% shiny geranium control by 11 DAT. Shiny geranium control from all nonsynthetic products and propane flame was 10% or less by 53 DAT. Roundup applied at a minimum concentration of 0.75% was necessary to control shiny geranium greater than 90% by 53 DAT. Since Roundup does not display soil activity, this indicates that the nonsynthetic products and propane flame did not result in death of shiny geranium seedlings, but rather that treated seedlings regrew following initial defoliation.

Table 2. Shiny geranium control after treatment with several herbicides or propane flame.

Treatment[a]	Rate	Shiny geranium control[b]		
		1 DAT	11 DAT	53 DAT
	%	%	%	%
Roundup	0.5	0 f	3 d	70 b
Roundup	0.75	0 f	10 d	95 a
Roundup	1	0 f	8 d	99 a
Scythe	5	65 cde	55 bc	0 c
Scythe	10	88 a	88 a	0 c
Matran EC	15	70 bcd	58 bc	0 c
Matran EC	20	75 a-d	63 abc	0 c
Interceptor	15	53 e	38 c	0 c
Interceptor	20	83 ab	73 ab	10 c
Vinegar (5% acetic acid)	Full strength	8 f	5 d	0 c
All Down (?% acetic acid)	Full strength	60 de	50 bc	0 c
Propane Flame	---	80 abc	70 ab	0 c

Means within a column followed by the same letter are not statistically different.
[a]Treatments were applied March 5, 2009.
[b]Shiny geranium control was estimated March 6 (24 hours after application), March 16 (11 days after treatment, DAT), and April 28 (53 DAT), 2009.

Washougal Oaks Trial #2, 2009-2010

<u>Materials and Methods</u>. A field trial was established to determine the susceptibility of shiny geranium (*Geranium lucidum*) to several herbicides (Alison Halpern, Washington State Noxious Weed Control Board and Carlo Abbruzzese, Washington State Department of Natural Resources, cooperators). Plots measuring 8 by 20 feet were established on the edge of a highly infested dirt road in Washougal Oaks Natural Area near Stevenson, Washington. Herbicides were applied October 6, 2009 to shiny geranium plants from the cotyledon-stage to 4 inches wide. Shiny geranium control was estimated January 5, June 2, and September 27, 2010. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

<u>Results</u>. The shiny geranium population in the plots was quite variable; consequently there were few statistical differences in control through the duration of the trial (Table 3). Initial control was excellent for all products in January and was statistically similar for the top ten treatments by June. By the end of September, control did not differ among 12 treatments, ranging from 60 to 86% control.

Table 3. Shiny geranium control after treatment with several herbicides.

Treatment[a]	Rate	Shiny geranium control		
		1/5/10	6/2/10	9/27/10
	product/a	%	%	%
Roundup	1 qt	97	79 abc	86 a
Oust	2 oz	98	98 a	81 ab
Oust + Roundup	1 oz + 1 qt	100	85 ab	79 abc
Crossbow	4 pt	100	73 abc	61 abc
Crossbow + Roundup	2 pt + 1 qt	99	63 bcd	79 abc
Garlon	1.5 pt	98	79 abc	75 abc
Garlon + Roundup	1.5 pt + 1 qt	98	60 bcd	71 abc
Plateau	6 fl.oz	94	83 ab	65 abc
Plateau	12 fl.oz	100	80 abc	51 bc
Habitat	6 fl.oz	95	51 cd	69 abc
Habitat	1 pt	100	94 a	55 abc
Milestone	3 fl.oz	100	75 abc	60 abc
Milestone + Roundup	3 fl.oz + 1 qt	99	78 abc	61 abc
Finale	2 qt	96	56 bcd	49 c

Means within a column followed by the same letter, or not followed by a letter, are not
   statistically different.
[a]Herbicides were applied October 6, 2009; Oust, Plateau, and Habitat were mixed with
   DyneAmic surfactant at 0.25% (v/v) prior to application.

Smooth Hawkweed
1999-2000

Materials and Methods. An experiment was conducted to test the sensitivity of smooth hawkweed (*Hieracium laevigatum*) to several herbicides (Laurel Baldwin, Whatcom County Noxious Weed Control Board, cooperator). Plots were established along an on-ramp to I-5 north of Bellingham, Washington that was heavily infested with smooth hawkweed. Treatments were applied May 10, 1999 when the hawkweed was 4 to 8 inches tall and actively growing; plots measured 8 by 20 ft. Rain had fallen most of the previous week, but the weeds were dry at the time of application. Smooth hawkweed control was visually estimated June 7 (1 month after treatment, MAT) and July 16 (2 MAT), 1999 and May 23, 2000 (12 MAT). A 0.09 m^2 quadrat was placed within each plot June 18, 1999 and vegetation within the quadrat clipped at the soil line. Grass foliage was then separated from smooth hawkweed foliage, and both components were air-dried inside a greenhouse for 7 days and dry weights recorded. The experimental design was a Randomized Complete Block with four replicates. Means were separated using Fisher's Protected LSD (P ≤ 0.05).

Results. Initial control of smooth hawkweed with Curtail, Transline, Distinct, Weedmaster, and Crossbow provided 80% or greater control of the weed at 1 MAT (Table 1); Clarity also controlled 80% of the smooth hawkweed control by 2 MAT. All herbicide treatments except Escort applied alone reduced hawkweed dry weight compared to the untreated control. Grass dry weight did not differ by herbicide treatment compared to grass in nontreated plots. Hawkweed flowering in 1999 was suppressed by all treatments except Weedar (data not shown). Final control of hawkweed (12 MAT) was optimized with Transline or Curtail (85 and 80%, respectively).

Conclusions. Smooth hawkweed response to herbicides appears to be similar to that of other hawkweed species. Increased rates of auxinic herbicides than were tested here will likely be necessary to kill smooth hawkweed.

Table 1. Control of smooth hawkweed, and grass and smooth hawkweed biomass after treatment with several herbicides.

Treatment[a]	Rate	Smooth hawkweed control[b]			Dry biomass[c]	
		1 MAT	2 MAT	12 MAT	Hawkweed	Grass
	product/a	%	%	%	g/m^2	g/m^2
Distinct	1.3 lb	81 abc	91 a	45 b	13.3 b	58.9 ab
Weedar	3 qt	55 d	65 c	30 bc	63.3 b	61.1 ab
Clarity	2 pt	68 cd	80 abc	26 bcd	65.6 b	71.1 ab
Weedmaster	2 qt	80 abc	83 ab	26 bcd	44.4 b	78.9 a
Curtail	2 qt	89 a	90 ab	80 a	42.2 b	58.9 ab
Crossbow	3 qt	80 abc	83 ab	43 b	28.9 b	52.2 ab
Transline	1 pt	84 ab	94 a	85 a	38.9 b	50.0 ab
Escort	1 oz	34 e	38 d	3 cd	140.0 a	30.0 b
Escort + Clarity + Weedar	1 oz + 2 pt + 3 qt	74 bc	74 bc	6 cd	34.4 b	27.8 b
Nontreated	---	0 f	0 e	0 d	143.3 a	52.2 ab

Means within a column followed by the same letter or not followed by a letter are not statistically different.
[a]Treatments were applied May 10, 1999 and Escort treatments were mixed with 0.2% (v/v) Sylgard silicon surfactant prior to application.
[b]Hawkweed control was estimated June 7 (1 month after treatment, MAT) and July 16 (2 MAT), 1999 and May 23, 2000 (12 MAT).
[c]Hawkweed and grass was clipped inside 0.09 m^2 quadrats in each plot June 18, 1999.

Spurge Laurel
2010-2011

Materials and Methods. A herbicide trial was initiated on a large infestation of spurge laurel (*Daphne laureola*) in a residential area near Olympia, Washington (Rick Johnson, Thurston County Noxious Weed Control Board and Alison Halpern, Washington State Noxious Weed Control Board, cooperators). Individual stems growing in proximity to each other were marked to receive cut-stem or foliar treatments of several herbicides; 5 to 20 stems were treated per replicate. Cut-stem treatments were 75% solution for glyphosate (3 parts herbicide , 1 part water), and 33% solution for the other products (1 part herbicide, 2 parts water) with 0.5% (v/v) nonionic surfactant applied immediately following clipping of the trunk of the plant at 3 to 6 inches above the soil surface. Cut-stem treatments were applied at one of two timings: early (at flowering June 11, 2010) and late (dormant, December 22, 2010). About 5 ml of herbicide mixture applied per cut stem. Foliar treatments were applied to separate plants, also June 11, 2010. See Table 1 for herbicides tested and foliar application rates.

Spurge laurel control was estimated July 12, August 31, December 16, 2010 (1, 2, and 6 months after spring treatment, MAST) and March 22, June 1, and December 15, 2011 (10, 12, and 18 MAST, and 3, 6, and 12 months after winter treatment (MAWT) as compared to noncut and cut, but not treated, spurge laurel plants. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

Results. The cut-stem spring herbicide treatments provided excellent control when applied within one hour of cutting (Table 1). At 18 MAST, tested herbicides were providing 93 to 100% control (statistically superior to 71% control resulting from cutting alone). Foliar treatments in June with Habitat or Crossbow also provided excellent (98%) control, equal to the cut-stem treatments by 18 MAST. Foliar treatments with Milestone at 7 fl.oz/a controlled spurge laurel at a similar level as cutting alone (68 and 71% control, respectively). Foliar treatment with Roundup and Method at tested rates did not adequately control the weed at any time, and control was only 35 and 38%, respectively, by 18 MAST. When applied as cut-stem treatments in December, control at 12 MAWT was 90 to 100% (Table 2), comparable to the June cut-stem treatments at 12 MAST (Table 1).

Conclusions. Cut-stem treatments with these herbicides provided nearly 100% control of spurge laurel, whether applied in the spring or during winter dormancy. Foliar treatments with Habitat and Crossbow were equally effective applied to flowering spurge laurel in June. The cut-stem application method may be preferable to foliar spray if spurge laurel plants are growing among other vegetation, as these treatments were quite selective against the weed during these tests. Applications during dormancy might also be easier to plan, since wind and moist conditions will not be as likely to prevent treatment from occurring or reduce control. Cut-stem treatments take longer to perform, however, and disposal of cut plant material may be required. Consequently, if only a few spurge laurel plants are to be treated in an area, foliar treatments with these two products may be preferable.

Table 1. Spurge laurel control after treatment with several herbicides applied as cut-stem and foliar treatments in June, 2010.

Treatment[a]	Rate	1 MAST[b]	2 MAST[b]	6 MAST[b]	10 MAST[b]	12 MAST[b]	18 MAST[b]
	%	%	%	%	%	%	%
Cut-stem treatments							
Roundup	75	98 a	98 a	98 a	96 ab	97 a	93 a
Habitat	33	82 a	82 bc	98 a	98 a	99 a	99 a
Crossbow	33	97 a	97 a	97 a	96 ab	97 a	96 a
Milestone	33	82 a	85 abc	95 ab	98 a	98 a	100 a
Method	33	85 a	85 abc	90 abc	93 abc	93 ab	98 a
Cut check	---	90 a	84 abc	79 cd	86 bcd	84 b	71 b
Foliar treatments							
Roundup	3.3 qt/a	20 c	27 e	28 f	32 f	23 e	35 c
Habitat	3 pt/a	8 cd	8 f	65 d	83 cd	97 a	98 a
Crossbow	2 gal/a	93 a	95 ab	98 a	97 ab	100 a	98 a
Milestone	7 fl.oz/a	47 b	78 c	82 bc	78 d	63 c	68 b
Method	8 fl.oz/a	42 b	58 d	50 e	52 e	50 d	38 c

Means within a column followed by the same letter are not statistically different.
[a]All treatments were applied June 11, 2010 and were mixed with 0.5% DyneAmic surfactant (v/v) prior to application.
[b]MAST = months after spring treatment.

Table 2. Spurge laurel control after treatment with several herbicides applied as cut-stem treatments in December, 2010.

Treatment[a]	Rate	3 MAWT[b]	6 MAWT[b]	12 MAWT[b]
	%	%	%	%
Roundup	75	93	95	93
Habitat	33	97	98	98
Crossbow	33	93	95	90
Milestone	33	95	97	100
Method	33	95	95	98

Means within a column do not statistically differ.
[a]All treatments were applied December 22, 2010 and were mixed with 0.5% DyneAmic surfactant (v/v) prior to application.
[b]MAWT = months after winter treatment.

Sulfur Cinquefoil
2006-2008

<u>Materials and Methods</u>. A herbicide trial was initiated on a large infestation of sulfur cinquefoil (*Potentilla recta*) in a pasture near Highway 101 between Sequim and Port Angeles, Washington (Cathy Lucero, Clallam County Noxious Weed Control Board, cooperator). Herbicides were applied to bud-stage sulfur cinquefoil plants June 8, 2006 and again May 31, 2007. Control was initially evaluated August 3, 2006, but plants were too dry for reliable control estimates. Sulfur cinquefoil control from the second herbicide application was estimated July 25, 2007, and April 10, May 28, and July 16, 2008. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

<u>Results</u>. Sulfur cinquefoil control July 25, 2007 (2 months after second treatment, MAST) was maximized by Roundup, Crossbow, and Milestone (84 to 94% control, Table 1). The poorest treatments at that evaluation date were Distinct at 4 oz/a and Transline. At 12 MAST, control was best with Roundup, Milestone, Arsenal, Garlon, Crossbow, Plateau, Weedmaster, and Curtail (80 to 100% control). By 14 MAST, the variation in control due to regrowth in certain plots resulted in lack of statistical significance between means. Consequently, no conclusion regarding control can be ascribed at that evaluation date, other than to say that numerical differences generally followed the 12 MAST results. Thus, it appears herbicides to consider for sulfur cinquefoil control should focus on Roundup, Milestone, Arsenal, Garlon, Crossbow, Plateau, Weedmaster, and Curtail. Note that Roundup and Arsenal are nonselective, so grass species were also killed from application of those products.

Table 1. Sulfur cinquefoil control from two applications of herbicides in consecutive years.

Treatment[a]	Active ingredient	Rate	Sulfur cinquefoil control		
			7/25/07	5/28/08	7/16/08
		product/a	%	%	%
Distinct	Dicamba + diflufenzapyr	4 oz	11 ef	37 cde	41
Distinct	Dicamba + diflufenzapyr	8 oz	34 d	39 cd	69
Roundup	Glyphosate	3 qt	94 a	100 a	100
Weedmaster	Dicamba + 2,4-D	2 qt	38 cd	80 ab	83
Curtail	Clopyralid + 2,4-D	2 qt	19 e	65 abc	30
Crossbow	Triclopyr + 2,4-D	6 pt	93 a	88 ab	95
Garlon	Triclopyr	4 pt	76 b	91 a	98
Transline	Clopyralid	1 pt	0 f	15 de	19
Plateau	Imazapic	3 pt	50 c	88 ab	81
Arsenal	Imazapyr	3 pt	76 b	93 a	79
Redeem	Clopyralid + Triclopyr	1 qt	45 cd	51 bcd	41
Milestone	Aminopyralid	7 fl.oz	84 ab	99 a	100

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Herbicides were applied June 8, 2006 and May 31, 2007; Plateau and Arsenal treatments were mixed with methylated seed oil (0.25%, v/v) prior to application.

Wild Chervil
2003-2005

Yellow Archangel
2007-2007, 2008-2009

See article: Miller, T.W., A.D. Halpern, F. Lucero, and S.H. Shaw. 2014. Efficacy of Several Herbicides on Yellow Archangel (*Lamiastrum galeobdolon*). Invasive Plant Science and Management 7:269-277.

Yellow Fieldcress
2015-2016

<u>Materials and Methods</u>. This trial was also conducted at Weyerhaeuser's Aurora Forest Nursery (Aurora, Oregon) at a site densely infested by yellow fieldcress (*Rorippa sylvestris*), and focuses on herbicide efficacy during the fallow year prior to fumigation, when growth of this weed species is extremely rapid. Plots measured 8 feet by 8 feet. Herbicides were applied July 1, 2015 to 3- to 6-inch tall yellow fieldcress. Arsenal (imazapyr) and Oust (sulfometuron) treatments were mixed with methylated seed oil (MSO) at 1%, v/v prior to application. Percent visual fieldcress cover was evaluated at the time of herbicide application and again September 2, 2015. Plots were tilled in fall, 2015 and will be fumigated by the cooperator in spring of 2016. Two beds were then transplanted to Fraser fir seedlings, and the other two beds were transplanted to noble fir seedlings for the 2016 growing season. Fraser and noble fir seedlings were evaluated for injury and plots were rated for common groundsel control in September, 2016. The experimental design was a Randomized Complete Block design with four replicates. Means were separated using Tukey's Honestly Different Significance test ($P \leq 0.05$).

<u>Results</u>. Initial injury to yellow fieldcress was greatest with Arsenal or Arsenal tank mixtures (Table 1). Weed cover by September 9 (2 months after treatment) was reduced from an average of 20% to 2% in plots treated with that herbicide. Yellow fieldcress cover remained similar to the initial infestation level when treated with Oust at 4 oz/a, significantly less than in nontreated plots and similar to plots treated with Arsenal or Arsenal tank mixture. Yellow fieldcress cover after treatment with Oust at 2 oz/a or Garlon 3A (triclopyr) at 2 gal/a increased only slightly, while weed cover increased up to 3-fold after treatment with Roundup (glyphosate) or Garlon 3A at 1 gal/a. Plots were tilled shortly after the September, 2015 evaluation and were essentially weed-free when observed January 20, 2016 (data not shown).

Fraser and noble fir were sensitive to soil residuals of Arsenal at 14 months after treatement (Table 2). Fraser fir was more sensitive (25 to 40% injury) than noble fir (15 to 26% injury), although both species sustained unacceptably high injury. Common groundsel (*Senecio vulgaris*) was found in most plots in September, 2016, although control did not differ among the different treatments. Because all plots were fumigated after herbicide treatments, these control percentages represent combined control of yellow fieldcress.

<u>Conclusions</u>. Based on these data, Oust alone or in combination with glyphosate applied in the summer prior to soil fumigation is recommended for control of yellow fieldcress in forest tree nurseries. While it provided excellent control, Arsenal persisted to injure subsequent fir seedlings. It is not known if other conifer species may be less sensitive to residual Arsenal.

Table 1. Yellow fieldcress and common groundsel control in a forest tree nursery before and after application of several herbicides and prior to fumigation and transplanting Douglas fir.

| Treatment[a] | Trade name | Rate | Creeping yellow fieldcress cover | | Common groundsel control |
			Pre-treat (Jul 1, 2015)	Sep 9, 2015	Sep 7, 2016
		product/a	%	%	%
Glyphosate	Roundup	1 qt	25	70 a	66
Glyphosate	Roundup	2 qt	20	60 ab	75
Glyphosate	Roundup	3 qt	19	64 ab	86
Imazapyr	Arsenal	3 pt	18	3 c	76
Imazapyr	Arsenal	6 pt	20	0 c	85
Sulfometuron	Oust	2 oz	18	23 bc	75
Sulfometuron	Oust	4 oz	15	14 c	74
Glyphosate + imazapyr	Roundup + Arsenal	1 qt + 6 pt	24	4 c	89
Glyphosate + imazapyr	Roundup + Arsenal	2 qt + 3 pt	18	0 c	86
Glyphosate + sulfometuron	Roundup + Oust	2 qt + 2 oz	21	26 bc	70
Triclopyr	Garlon 3A	1 gal	23	39 abc	86
Triclopyr	Garlon 3A	2 gal	25	29 abc	75
Nontreated	---	---	20	58 ab	64

Means within a column followed by the same letter or with no letters are not statistically different (P ≤ 0.05).
[a]Treatments were applied July 1, 2015; Arsenal and Oust treatments were mixed with methylated seed oil (MSO) at 1%, v/v prior to application.

Table 2. Noble and Fraser fir injury in a forest tree nursery 14 months after application of several herbicides applied to control creeping yellow fieldcress.

Treatment[a]	Trade name	Rate	Noble fir injury[b]	Fraser fir injury[b]
		product/a	%	%
Glyphosate	Roundup	1 qt	0 c	0 c
Glyphosate	Roundup	2 qt	0 c	0 c
Glyphosate	Roundup	3 qt	0 c	0 c
Imazapyr	Arsenal	3 pt	19 ab	20 b
Imazapyr	Arsenal	6 pt	15 b	40 a
Sulfometuron	Oust	2 oz	1 c	0 c
Sulfometuron	Oust	4 oz	0 c	0 c
Glyphosate + imazapyr	Roundup + Arsenal	1 qt + 6 pt	26 a	40 a
Glyphosate + imazapyr	Roundup + Arsenal	2 qt + 3 pt	19 ab	25 ab
Glyphosate + sulfometuron	Roundup + Oust	2 qt + 2 oz	0 c	0 c
Triclopyr	Garlon 3A	1 gal	1 c	0 c
Triclopyr	Garlon 3A	2 gal	0 c	0 c
Nontreated	---	---	0 c	0 c

Means within a column followed by the same letter or with no letters are not statistically different (P ≤ 0.05).
[a]Treatments were applied July 1, 2015; Arsenal and Oust treatments were mixed with methylated seed oil (MSO) at 1%, v/v prior to application.
[b]Tree injury evaluated September 7, 2016.

Yellow Flag Iris
2005-2006

<u>Materials and Methods</u>. Yellow flag iris (*Iris pseudacorus*) infesting Buena Creek near Zillah, Washington was tested for sensitivity to herbicides in (Dick Jacobson, Yakima County Noxious Weed Control Board, Greg Haubrich, Washington State Department of Agriculture, and Jenifer Parsons, Washington State Department of Ecology, cooperators). Applications were made at two timings: pre-flowering (May 4, 2005) or post-flowering (September 27, 2005). Yellow flag iris plants were in bud stage at the time of the spring treatment. Few open flowers were present in the infestation at that time, and no open flowers were in the plots. Yellow flag iris seedpods were present on iris plants at the time of the fall treatment, although none had yet shattered seed. Aquatic products tested were glyphosate (Aquamaster at 2.5 and 5%) and imazapyr (Habitat at 1 and 1.5%), and two combination treatments with both products (3% + 0.75% and 2.5% + 1% for Aquamaster and Habitat, respectively). All treatments were mixed with 1% (v/v) surfactant (DyneAmic). Plots measured 10 by 20 feet and were located on the south bank of the creek.

Yellow flag iris in each plot were visually rated for percent control June 15, 2005 (6 weeks after spring treatment, WAST), September 27, 2005 (5 months after spring treatment, MAST), May 5, 2006 (12 MAST, 7 months after fall treatment, MAFT), and October 17 (17 MAST, 12 MAFT). The statistical design was a Randomized Complete Block with three replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD (P ≤ 0.05) was used to separate the means.

<u>Results</u>.
Comparisons between spring and fall treatments. At comparable times after treatment, it appears that fall herbicide applications were slightly more effective than spring treatments (Table 1). This was particularly true at the 5 to 7 month evaluation, where the average yellow flag iris control provided by fall treatments was 8 percentage points greater than from spring applications (97 and 89%, respectively). By 12 months after treatment, fall treatments were still providing an average of 93% yellow flag iris control, compared to 87% from the average spring treatments.

Spring treatments. Defoliation at 6 WAST was maximized by both rates of Aquamaster alone or by Habitat at the high rate (Table 2). By 5 MAST, control was 98% with Habitat + Aquamaster (2.5% + 1%, respectively), similar to Habitat alone at 1.5%. Habitat at 1 or 1.5% resulted in a similar level of control at that evaluation as Aquamaster at 5% or Aquamaster + Habitat (3 + 0.75%, respectively) (from 88 to 93% control). By 12 MAST, all treatments with Habitat alone or in combination with Aquamaster provided better control (from 90 to 95%) than Aquamaster alone (73 to 78%), a situation that was still evident at the 17 MAST evaluation. Importantly, yellow flag iris plants did not appear to flower following any of these treatments. In summary, yellow flag iris generally responded more quickly to Aquamaster than to Habitat. After about five months, yellow flag iris control with Habitat at 1 or 1.5% was generally superior to that of Aquamaster at 3 or 5%, as was control from combination treatments.

Fall treatments. While there was a statistical difference in yellow flag iris re-growth in the spring, the difference was not of great practical significance (93% control for Aquamaster, 97 and 99% for Habitat at 1 and 1.5%, respectively, and 97 and 99% for the combination treatments) (Table 2). Control by 12 MAFT was still excellent for all treatments except the low rate of Aquamater, which had fallen to 72%.

Conclusions. Yellow flag iris was controlled by all these tested treatments up to seven months following application. Aquamaster at 3%, however, does not appear to provide a full year of control of yellow flag iris.

Table 1. Average yellow flag iris control from herbicides applied in fall or spring.

Treatment timing[a]	5 to 7 MAT	12 MAT
	%	%
Spring	89 b	87 b
Fall	97 a	93 a

Means within a column followed by the same letter are not statistically different.
[a]Spring (pre-bloom) treatments were applied May 4, 2005 and fall (post-bloom) treatments were applied September 27, 2005; treatments were mixed with 1% (v/v) nonionic surfactant (DyneAmic) prior to application.
[b]Percent yellow flag iris control was estimated September 27, 2005 (5 months after spring treatment, MAST), May 5, 2006 (12 MAST, 7 months after fall treatment, MAFT), and October 17 (12 MAFT).

Table 2. Yellow flag iris control after treatment with several herbicides.

Treatment[a]	Rate	Spring treatment				Fall treatment	
		6 WAST[b]	5 MAST[b]	12 MAST[b]	17 MAST[b]	7 MAFT[b]	12 MAFT[b]
	% product	%	%	%	%	%	%
Aquamaster	2.5	80 ab	82 d	73 b	62 b	93 b	72 b
Aquamaster	5.0	87 a	83 cd	78 b	60 b	93 b	93 a
Habitat	1.0	65 c	88 bcd	90 a	80 ab	99 a	100 a
Habitat	1.5	78 ab	93 ab	90 a	83 ab	99 a	100 a
Aquamaster + Habitat	3.0 + 0.75	72 bc	90 bc	95 a	88 a	97 ab	98 a
Aquamaster + Habitat	2.5 + 1.0	73 bc	98 a	93 a	91 a	99 a	95 a

Means within a column followed by the same letter are not statistically different.

[a]Spring (pre-bloom) treatments were applied May 4, 2005 and fall (post-bloom) treatments were applied September 27, 2005; treatments were mixed with 1% (v/v) nonionic surfactant (DyneAmic) prior to application.

[b]Percent yellow flag iris control was estimated June 15, 2005 (6 weeks after spring treatment, WAST), September 27, 2005 (5 months after spring treatment, MAST), May 5, 2006 (12 MAST, 7 months after fall treatment, MAFT), and October 17 (17 MAST, 12 MAFT).

Yellow Nutsedge
1999, 2000-2001, 2002, 2005, 2018

From a newsletter article by Tim Miller, 2018

Yellow nutsedge (*Cyperus esculentus*) is a perennial weed species originating in the eastern Mediterranean Region. Normally the plant loves hot weather, but our biotype seems to have made the environmental adjustment and is able to grow and thrive in the maritime climate of northwestern Washington. This species reproduces by rhizomes (underground stems), by seed, and by pea- to grape-sized tubers. Once established, yellow nutsedge is practically impossible to get rid of. It was declared the World's 16th Worst Weed in Holm's 1977 volume of the same name[1].

Astute readers will remember that Harper Lee's Miss Maudie remarked to little Jean Louise (Scout) about nutsedge: "'Why, one sprig of nut grass can ruin a whole yard. Look here. When it comes fall this dries up and the wind blows it all over Maycomb County!' If she found a block of nut grass in her yard, it was like the second Battle of the Marne: she swooped down upon it with a tin tub and subjected it to blasts from beneath with a poisonous substance she said was so powerful it'd kill us all if we didn't stand out of the way."[2] While I don't agree with her method of control, I do agree with Miss Maudie's sentiment about this bad weed. So let's talk a little about how to recognize yellow nutsedge, and what to do if you find it.

Identification of yellow nutsedge is actually fairly easy. Many folks will recall the mnemonic ditty that is usually rendered "Sedges have edges, rushes are round, grasses are hollow from top to the ground." And it is true: vegetative yellow nutsedge can be identified by its foliage.[3] Plants range from 8 inches to 3 feet in height, and stems are triangular in cross-section, and filled with pith. Leaves attach to each of the three sides, giving the plant a three-ranked appearance when viewed from above. Leaves can be 2 feet long and up to 1/3-inch wide, and tend to be V-shaped in cross-section. Foliage is usually a lighter shade of green than surrounding plants, is smooth and hairless, and often described as having a sweet scent.

Plants rarely bloom in northwestern Washington, unless the summer is an unusually warm one, so seeds are generally not produced there. In the Columbia Basin, however, plants generally produce seeds in late summer. For the nonflowering plants, it is best to dig up a plant or two to confirm that you actually have nutsedge and not some other species of sedge (*Carex* spp.). Look for scaly and fleshy (not woody) rhizomes, which are about 1/16 inch thick and up to 3 feet long.

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1 Holm, L.G., D.L. Plucknett, J.V. Pancho, and J.P. Herbeger. 1977. *World's Worst Weeds: Distribution and Biology*. University of Hawaii, Honolulu. You might be interested to know that the World's Worst Weed is the closely related purple nutsedge (*Cyperus rotundus*), which doesn't grow in our region. So I suppose an optimist may say "Cheer up! Things could always be worse."
2 Lee, H. 1960. *To Kill A Mockingbird*. Lippincot, Philadelphia, PA.
3 DeFelice, M.S. 2002. Yellow nutsedge *Cyperus esculentus* L.—Snack Food of the Gods. Weed Technol. 16:901-907.

Rhizomes will either bear a sharp tip that allows it to push upward to the soil surface to form a new plant some distance from the mother plant, or they will remain underground and produce a dark brown to grayish orange tuber at the tip. None of our native sedges (or even the introduced sedges) bear tubers, so if you find them, they are definitive. (NOTE: purple nutsedge, *Cyperus rotundus*) also produces tubers, but has not been found in Washington. Purple nutsedge bears chains of tubers, like beads on a string. If the rhizomes on your plant have one tuber at its end, you have yellow nutsedge.)

Yellow nutsedge tubers are fleshy and edible, and they are eaten by people wherever in the world the species is found. A cultivated type of yellow nutsedge is called chufa, and was first bred in the White Nile region of Egypt in the fifth millennium BC, making this edible plant nearly as old as cultivated wheat and barley. Livestock (hogs and turkeys, mostly) grow fat on yellow nutsedge tubers, and many species of waterfowl are known to forage extensively on both tubers and seeds. Wild-type yellow nutsedge tubers contain water, fiber, oil (10%), carbohydrates (45%) and saccharose (14%).[4] The same source notes that chufas contain considerably more oil (26%) and saccharose (17%) than yellow nutsedge tubers. Chufa tubers reportedly average a caloric density of 4.26 kcal/g, although 45% of the fresh weight each tuber is water[5]. The major components of chufa tubers (by dry weight) are carbohydrates (58%), lipids (10%), protein (7%), and ash (3%). The major fatty acid in tubers is oleic (61% of total fatty acids), while other fatty acids include linoleic (24%), palmitic (12%), and stearic (2%).

Yellow nutsedge also is tolerant to wet soil conditions, and is better able to grow and produce tubers in moist peaty or loamy soils than in sandy soils. Peak rhizome production occurs during long days, while tuber photoperiods production is greatest when day lengths are less than 12 hours. In Oregon State University trials conducted at Ontario, Oregon, weed scientist Corey Ransom and co-workers found that most yellow nutsedge tubers were produced in the top 6 inches of the soil, up to 32 million per acre of infested ground.[6] Still, the deeper tubers were able to produce shoots and additional tubers. Ten tubers buried at 16 inches produced 108 new shoots and 97 new tubers, and tubers buried at 12 inches produced 119 shoots and 272 new tubers. If buried at 24 inches, ten tubers were still able to produce 6 new shoots and 10 new tubers.

This weed is typically more difficult to manage in annually cultivated ground than in perennial cropping systems, primarily because tubers are spread in the field with every cultivation. Solid-seeded crops, such as cereals, and densely growing crops such as pasture, hay, and forages, are able to compete fairly well with the low-growing yellow nutsedge. Tall row crops such as silage

4 De Vries, F.T. 1991. Chufa (*Cyperus esculentus*, Cyperaceae): A Weedy Cultivar or a Cultivated Weed? Econ. Bot. 45: 27-37.
5 Kelley, J.R. Jr. and L.H. Fredrickson. 1991. 13.4.18. Chufa Biology and Management, *Waterfowl Management Handbook*.
http://digitalcommons.unl.edu/icwdmwfm/34?utm_source=digitalcommons.unl.edu%2Ficwdmwfm%2F34&utm_medium=PDF&utm_campaign=PDFCoverPages
6 Ransom, C.V., C.A. Rice, and C.C. Shock. 2009. Yellow nutsedge (*Cyperus esculentus*) growth and reproduction in response to nitrogen and irrigation. Weed Science 57:21-25.

corn also effectively compete with the weed under northwestern Washington growing conditions. Yellow nutsedge foliage often does not emerge until May in cultivated ground, and sometimes not until June in fields in the cooler parts of Washington where soil is left undisturbed.

Horticultural and agricultural growers have suspected that waterfowl grazing on yellow nutsedge in fields may spread the weed into previously noninfested areas. Oregon Wildlife specialists consider that viable tubers are unlikely to survive the grinding action of the gizzard[7], and recent research reinforces their view.[8] Conducted over two years in Missouri, 362 wild ducks harvested during fall hunting seasons had their esophagus/proventriculus, gizzard, and intestine contents removed, rinsed, and then resultant material was germinated in the greenhouse. Researchers found that 1 yellow nutsedge plant emerged when recovered from the birds' esophagus and proventriculus (0.01% of total), 21 plants emerged from gizzards (0.48%), and 25 plants from intestines (4.94%). For geese harvested during the same time frame, they were only able to germinate 1 plant recovered from the gizzards of 163 harvested birds, with no plants resulting from esophagus/proventriculus or intestine material. These birds likely foraged on both tubers and seed in infested fields, so many (most? all?) of these plants probably germinated from ingested yellow nutsedge seed. This conclusion seems warranted, because yellow nutsedge tubers fed to captive mallards resulted in no intact tubers of yellow nutsedge being recovered from their droppings.[6]

The best way to control yellow nutsedge is…not to get it in the first place. It is essential to clean cultivation and harvest equipment when moving from infested fields to noninfested ground. If new infestations are found, it is smart to do what it takes to remove those pioneer plants before they have the opportunity to produce new rhizomes and tubers. Control by hand (digging/hoeing) is possible on small infestations, but herbicides are generally considered necessary on larger infestations. Soil fumigation (such as metam sodium) provide the best control of established yellow nutsedge plants and tubers, although it is often not possible to fumigate perennial cropland except when the crop is removed for renovation.

Selective broadleaf control herbicides offer suppression for yellow nutsedge in certain crops. Dual Magnum, Outlook, and Eptam provide some level of preemergence control. Chateau, Spartan/Zeus, Basagran, and Goal can selectively remove kill yellow nutsedge foliage in labeled crops and Gramoxone can provide nonselective burn down of nutsedge foliage, but these products provide suppression only, and nutsedge will typically rememerge after a few weeks. Permit/Sandea can be applied postemergence to yellow nutsdege in certain crops, and when applied to actively growing nutsedge foliage generally provides the best control of this species. Roundup or other glyphosate product has fair activity when applied to foliage, but few crops allow a grower to use that herbicide during the summer due to concerns with crop safety. Roundup-ready alfalfa or corn do offer growers that option, however. Casoron also provides fair

7 William, R.D. 1985. Ornamentals Northwest Archives 9(2):4-6, Oregon State University.
8 Farmer, J.A., E.B. Webb, R.A. Pierce, and K.W. Bradley. 2017. Evaluating the potential for weed seed dispersal based on waterfowl consumption and seed viability. Pest Manag. Sci. 73:2592-2603.

control of the species, although many crops are sensitive to this herbicide. Grass herbicides and auxinic/growth regulator herbicides are ineffective on yellow nutsedge.

Finally, if you have yellow nutsedge, consider using an integrated strategy using shallow cultivation/mowing/hand weed control, herbicides, and competitive crops where possible. Herbicide combinations and sequential applications may improve chemical control. What is known for certain is that the weed will not go away on its own. Without an active management strategy, yellow nutsedge will continue to increase in your field, and in our region. For further reading, see the online bulletin "Yellow Nutsedge (*Cyperus esculentus*) in Greater Depth" at http://articles.extension.org/pages/65211/yellow-nutsedge-cyperus-esculentus-in-greater-depth

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1999 Yellow Nutsedge in Raspberry Trial

Materials and Methods. A yellow nutsedge (*Cyperus esculentus*) trial was conducted in a red raspberry field near Burlington, Washington in 1999 (Sakuma Brothers Farms, cooperator). Herbicides were applied in the row March 25 (preemergence, PRE) and May 25 (postemergence, POST), 1999. Plots measured 3 by 10 ft, with the long axis centered on one raspberry row. Fifty berries were picked July 22, 1999 for fruit size analysis, and again for yield of ripe fruit August 5, 1999. Yellow nutsedge control was evaluated October 18, 1999. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Yellow nutsedge control from these herbicides was poor (0 to 55) when evaluated following berry harvest (Table 1). Herbicides caused no visible crop injury (data not shown) and berry yield and fruit size were not negatively affected by these treatments.

Conclusions. Based on these data, it appears that either higher herbicide rates or sequential applications will be necessary to gain control of yellow nutsedge.

Table 1. Yellow nutsedge control and raspberry yield after application of several herbicides.

Treatment[a]	Rate	Timing[b]	Yellow nutsedge control[c]	Raspberry yield	Fruit size
	product/a		%	g/m of row	g/berry
Casoron 4G	100 lbs	PRE	55	135 ab	4.1
Dual Magnum	1.3 pt	PRE	45	137 ab	4.1
Frontier	0.8 pt	PRE	46	120 bcd	3.7
Lasso	4 pt	PRE	50	131 a-d	3.8
Topnotch	1.25 pt	PRE	35	122 a-d	3.9
Sinbar	2 lb	PRE	0	139 a	4.0
Kerb	6 lb	PRE	26	127 a-d	3.8
Spartan	5.3 oz	PRE	54	138 a	3.7
Basagran + coc	2 pt	POST	53	134 abc	3.9
Sandea + nis	1 oz	POST	44	131 a-d	4.0
Nontreated	---	---	0	116 d	3.7

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Herbicides were applied March 25 (PRE) and May 25 (POST), 1999; coc = crop oil concentrate (1%, v/v); nis = nonionic surfactant (0.25%, v/v).
[c]Yellow nutsedge control was estimated October 18, 1999.

2000-2001 Yellow Nutsedge in Raspberry Trial

Materials and Methods. A yellow nutsedge (*Cyperus esculentus*) trial was conducted in a red raspberry field near Burlington, Washington in 2000-2001 (Sakuma Brothers Farms, cooperator). Herbicides were applied in the row April 10 (preemergence, PRE) and June 2 (postemergence, POST), 2000 and again on the same plots April and June, 2002. Plots measured 3 by 10 ft, with the long axis centered on one raspberry row. Fifty berries were picked July 22, 1999 for fruit size analysis, and again for yield of ripe fruit August 5, 1999. Yellow nutsedge control was evaluated May 31 and September 12, 2000, and June 8 and October 30, 2001. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Yellow nutsedge control after two years ranged from 18 to 84% (Table 2). The best control was found with Casoron (84%), followed by Sandea, Sinbar, Dual Magnum, and Spartan (83, 66, 61, and 61%, respectively). Herbicides caused no visible crop injury (data not shown) and berry yield and fruit size were not negatively affected by these treatments, except for fruit size following Topnotch (2.2 g/berry), Lasso, or Basagran (2.4 g/berry); all, however, were similar to nontreated raspberry.

Conclusions. Based on these data, two applications of Casoron, Sandea, Sinbar, Spartan, and Dual Magnum were able to gain fair to good control of yellow nutsedge.

Table 2. Yellow nutsedge control and raspberry yield after application of several herbicides.

Treatment[a]	Rate	Timing[b]	Final yellow nutsedge control[c]	Raspberry yield	Fruit size
	product/a		%	kg/m of row	g/berry
Casoron 4G	100 lbs	PRE	84 a	1.63	2.7 a
Dual Magnum	1.3 pt	PRE	61 ab	1.58	2.6 ab
Frontier	0.8 pt	PRE	18 cd	1.40	2.5 ab
Lasso	4 pt	PRE	28 cd	1.44	2.4 bc
Topnotch	1.25 pt	PRE	28 cd	1.18	2.2 c
Spartan	5.3 oz	PRE	61 ab	1.27	2.5 ab
Sinbar	2 lb	PRE	66 ab	1.43	2.6 ab
Basagran + coc	2 pt	POST	45 bc	1.38	2.4 bc
Sandea + nis	1 oz	POST	83 a	1.31	2.6 ab
Nontreated	---	---	0 d	1.18	2.4 a-c

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.

[a]Herbicides were applied March 25 (PRE) and May 25 (POST), 1999; coc = crop oil concentrate (1%, v/v); nis = nonionic surfactant (0.25%, v/v).

[c]Final yellow nutsedge control (after 2 annual applications) was estimated October 30, 2001.

2002 Yellow Nutsedge in Raspberry Trial

Materials and Methods. A yellow nutsedge (*Cyperus esculentus*) trial was conducted in a red raspberry field near Burlington, Washington in 2002 (Sakuma Brothers Farms, cooperator). Herbicides were applied in the row April 15 (PRE) and June 1 (POST), 2002. Plots measured 3 by 10 ft, with the long axis centered on one raspberry row. Berries were picked three times in July, and total yield and 50-berry weights were determined. Yellow nutsedge control was evaluated August 8, 2002. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Yellow nutsedge control from these herbicides was poor (31 to 48%) when evaluated following berry harvest (Table 3). Herbicides caused no visible crop injury (data not shown) and berry yield and fruit size were not negatively affected by these treatments.

Conclusions. Based on these data, single applications of these herbicides provided only suppression of yellow nutsedge.

Table 3. Yellow nutsedge control and raspberry yield after application of several herbicides.

Treatment[a]	Rate	Timing[b]	Yellow nutsedge control[c]	Raspberry yield	Fruit size
	product/a		%	kg/m of row	g/berry
Casoron 4G	100 lbs	PRE	41 a	3.45	2.5
Dual Magnum	1.3 pt	PRE	46 a	3.25	2.6
Outlook	1.7 pt	PRE	31 a	3.49	2.5
Sandea + nis	1 oz	POST	48 a	2.73	2.5
Nontreated	---	---	0 b	3.00	2.7

Means within a column followed by the same letter, or not followed by a letter, are not statistically different.
[a]Herbicides were applied April 15 (PRE) and June 1 (POST), 2002; nis = nonionic surfactant (0.25%, v/v).
[c]Yellow nutsedge control was estimated August 8, 2002.

2005 Yellow Nutsedge in Raspberry Trial

Materials and Methods. A yellow nutsedge (*Cyperus esculentus*) trial was conducted in a red raspberry field near Woodland, WA infested with yellow nutsedge (Tom Peerbolt and Jerry Dobbins, cooperators) in 2005. Herbicides were applied in the row April 18 (PRE) and June 8 (POST), 2005. Plots measured 3 by 10 ft, with the long axis centered on one raspberry row. Yellow nutsedge control was evaluated June 29 and August 24, 2005. The statistical design was a Randomized Complete Block with four replicates. A general linear models procedure was used to analyze the data and Fisher's Protected LSD ($P \leq 0.05$) was used to separate the means.

Results. Yellow nutsedge control in June was best with Casoron or Sandea, giving 97 and 90%, respectively (Table 4). Treatments did not statistically differ at the time of the late-August evaluation, but only Casoron was still providing >80% weed control.

Conclusions. Based on these data, repeat applications will be necessary to fully control yellow nutsedge. Berry yield was not monitored in this trial, but there were no obvious herbicide effects on fruiting of raspberry floricanes during the growing season.

Table 4. Yellow nutsedge control after application of several herbicides.

Treatment[a]	Rate	Timing[b]	Weed control	
			June 29	August 24
	product/a		%	%
Casoron 4G	75 lbs	PRE	97 a	82
Dual Magnum	1.3 pt	PRE	62 abc	68
Outlook	1.7 pt	PRE	77 ab	77
Chateau	3 oz	PRE	67 abc	42
Sinbar	2 lbs	PRE	67 abc	72
Spartan	6.4 oz	PRE	43 c	55
Basagran + coc	2 pt	POST	47 bc	50
Sandea + nis	1 oz	POST	90 a	55

Means within a column followed by the same letter, or not followed by a letter, are not
  statistically different.
[a]Herbicides were applied April 19 (PRE) and June 8 (POST), 2005; coc = crop oil
  concentrate (1% v/v); nis = nonionic surfactant (0.25%, v/v).

2018 Yellow Nutsedge in Blueberry Trial

Materials and Methods. A yellow nutsedge (*Cyperus esculentus*) trial was conducted in an
established 'Reka' blueberry field near Burlington, Washington (Sakuma Brothers Farms,
cooperator). Preemergence (PRE) products (Casoron, Dual Magnum, and Outlook) were applied
to dormant blueberry and yellow nutsedge February 16, 2018. After blueberry flowering and
yellow nutsedge had emerged to about 5 inches tall (May 30, 2018), plots were treated
postemergence (POST) with Sandea + 0.25% nonionic surfactant (v/v). Yellow nutsedge control
was estimated May 11 and 29, July 10, and October 19, 2018. The experimental design was a
randomized complete block with four replicates. Means were separated using Tukey's HSD (P ≤
0.05).

Results. Initial May evaluation was conducted when yellow nutsedge was just emerging, so most
plots did not differ in initial nutsedge infestation, although nutsedge cover in the Dual Magnum
plots was higher than in nontreated plots (Table 5). By May 29, emergence was similar to
nontreated yellow nutsedge. By July, treatments containing Sandea applied in May had
significantly lowered yellow nutsedge, with cover ranging from 29 to 48%, compared to 98%
cover in nontreated plots. Unfortunately, by October yellow nutsedge cover was again similar in
all plots.

Conclusions. Sandea treatment provided suppression of the weed for several months, but not
total control. Additional treatments with Sandea in late summer or in fall prior to yellow
nutsedge dormancy may need to be evaluated to see if multiple treatments in a given year will be
necessary maintain yellow nutsedge control or to reduce the size of the infestation over time.

Table 5. Yellow nutsedge cover in 'Reka' blueberry after treatment with several herbicides (2018).

Treatment[a]	Rate	5/11[b]	5/29[b]	7/10	10/19
	product/a	%	%	%	%
Casoron CS	2.8 gal	6 a	31	63 abc	74
Dual Magnum	1.3 pt	15 ab	55	83 ab	75
Outlook	1.7 pt	9 a	46	86 ab	85
Sandea	1 oz	14 a	49	48 bc	69
Casoron fb Sandea	2.8 gal fb 1 oz	4 a	24	29 c	68
Dual Magnum fb Sandea	1.3 pt fb 1 oz	10 a	49	46 bc	88
Outlook fb Sandea	1.7 pt fb 1 oz	6 a	30	29 c	63
Nontreated	---	30 b	71	98 a	94

Means within a column followed by the same letter or with no letters are not statistically different (P ≤ 0.05).

[a]fb = followed by. Casoron, Dual Magnum, and Outlook were applied February 16, 2018; post-flowering Sandea were applied May 30, 2018; nonionic surfactant (0.25%, v/v) mixed with Sandea treatments prior to application.

[b]Sandea had not yet been applied to plots at these evaluation dates, so May evaluation percentages resulted from PRE treatments alone.