Control of Butterfly Bush with Postemergence Herbicides[1]

James Altland[2] and Julie Ream[3]
USDA-ARS, Application Technology Research Unit
Ohio Agricultural Research and Development Center
1680 Madison Ave., Wooster, OH 44691

Abstract

Butterfly bush (*Buddleja davidii*) is classified as invasive in several parts of the United States. Two experiments were conducted to evaluate the effectiveness of four herbicides and two application methods on postemergence butterfly bush control. The four herbicides included: Roundup (glyphosate), Aquamaster (glyphosate), Garlon (triclopyr), and Arsenal (imazapyr). Application methods included spraying foliage with a CO_2 backpack sprayer, and applying herbicide concentrate to recently cut stems (cut-stump method). Plants were treated in September with the maximum labeled rate for each herbicide. Cut-stump rates were determined such that the same amount of active ingredient was applied as in the spray treatments. Applications were made to plants several months after planting to simulate control of small recently germinated plants, and again to plants over 1 year old to simulate control of larger and more established plants. Summarizing results over both plant sizes and from two repetitions of the experiment, Roundup and Aquamaster provided higher levels of control compared to Garlon and Arsenal early in the experiment. Cut-stump applications provided more rapid control than spray applications. Despite differences in control when evaluated several weeks after application, all treated plants were dead when evaluated the following spring.

Index words: glyphosate, triclopyr, imazapyr, cut-stump, application method.

Chemicals used in this study: Roundup Ultramax (glyphosate) N-(phosphonomethyl)glycine; Aquamaster (glyphosate); Garlon 3A [(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid; Arsenal (imazapyr) (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid.

Significance to the Nursery Industry

Butterfly bush (*Buddleja davidii*) is classified as invasive in several parts of the United States. In Oregon, invasive populations have been documented along roadsides, abandoned industrial sites, reforestation areas, and riparian areas. Results herein document the effectiveness of Roundup (glyphosate plus surfactant), Aquamaster (glyphosate), Garlon (triclopyr), and Arsenal (imazapyr) for controlling butterfly bush applied as either a spray or cut-stump application. All applications were made in September, and herbicides were applied at the maximum labeled rates. Roundup and Aquamaster, the two products containing glyphosate, generally provided more rapid control than triclopyr or imazapyr. Cut-stump applications also provided more rapid control than spray applications. Despite modest differences in control among herbicide types and application methods, all treatments provided 100% butterfly bush control when plants were evaluated the following spring. Because all treatments were ultimately equally effective, specific site conditions should dictate herbicide selection and application method.

Introduction

Butterfly bush (*Buddleja davidii*) is a popular landscape plant, due primarily to its floral characteristics and butterfly attracting qualities. It is not indigenous to the United States, and is listed as a noxious weed in Oregon and Washington. Butterfly bush is native to shingle banks and river margins in the Hupeh and Szechwan districts of China (4, 7). Horticulturalists first introduced butterfly bush to Britain in 1869 (7) although its date of introduction into the U.S. is not precisely known.

Butterfly bush is reported invasive in the United States and other regions of the world (1). In England, butterfly bush colonizes urban areas such as abandoned buildings, railways, and old industrial sites. Butterfly bush began to colonize wasteland and construction sites in England in the 1930s, and experienced a population boom after World War II with the increased amount of urban rubble resulting from extensive bomb damage (8). In New Zealand, butterfly bush is a weed in forest plantations and riparian areas. It suppresses growth of radiata pine (*Pinus radiata*) seedlings, the dominant tree species in Kiwi forest plantations, by reducing light availability to tree crowns during reforestation (9). Ebeling et al. (5) recently reported that invasive populations of butterfly bush in Germany grew more vigorously and suffered from less herbivory than native populations in China, and suggests these reasons for the plants' invasiveness in Central Europe.

In Oregon, butterfly bush has been documented in riparian areas, reforestation sites, roadsides, and old industrial sites (2, 8). Butterfly bush is replacing native willows (*Salix scouleriana*) and cottonwood (*Populus trichocarpa*) along riparian areas (personal communication, Angie Kimpo, natural resource scientist, City of Portland). Others have noticed butterfly bush spreading along riparian corridors in Oregon, taking up space on cobble bars and floodplains of rivers, and replacing native willows and oaks (*Quercus garryana*) in those ecosystems (personal communication, Kyle Strauss, The Nature Conservancy).

Little research has been conducted on how to control butterfly bush in the United States. Scientists at the New Zealand Forest Research Institute studied the use of a weevil (*Cleopus japonicus*) for biological control. Zheng et al. (11) list two fungal and 13 arthropod species as other natural enemies

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[2]Formerly Assistant Professor of Horticulture, Oregon State University; currently Research Horticulturist for the USDA-ARS in Wooster, OH. James.Altland@ars.usda.gov

[3]Formerly, undergraduate student at Oregon State University.

that might possibly be used for biological control. Clay and Drinkall (4) report that triclopyr and glyphosate are generally used for butterfly bush control in the United Kingdom. They demonstrated that foliar applications of the two herbicides are more effective when applied in late summer, but that neither herbicide provided complete control. They further state (without data) that triclopyr is generally more effective than glyphosate, causing more rapid defoliation.

Butterfly bush is classified as noxious in Oregon, being especially problematic in riparian areas. Yet there is little research based information on safe and efficacious herbicide applications to guide land managers in controlling this plant. The objective of this research was to document which herbicides and application methods were most effective in controlling butterfly bush postemergence.

Materials and Methods

General information. Herbicide efficacy was evaluated on butterfly bush in two separate plantings. The first planting occurred in 2004 (hereafter referred to as crop 1), in which uniform propagated plants in 10 cm (4 in) wide pots of the cultivars 'Black Knight' and 'Ellen's Blue' were planted in a Willamette silt loam soil on July 26. Plants were fertilized individually with 7 g (0.25 oz) 14-14-14 controlled release fertilizer (Osmocote, The Scotts Co., Marysville, OH) to aid establishment. Plants were irrigated overhead with 2.5 cm (1 in) water weekly. A second planting occurred in 2005 (hereafter referred to as crop 2). This crop was planted at the same farm on July 19, 2005, from 5 cm (2 in) pots. Plants were fertilized with 25 g (0.88 oz) 21-5-10 controlled release fertilizer (Apex, J.R. Simplot Co., Lathrop, CA) to aid in establishment and were irrigated similar to crop 1. For both crops, plants were neither irrigated nor fertilized after the year of planting.

Crop 1. The following herbicides and rates were applied September 23, 2004: Roundup Ultramax (glyphosate, Monsanto, St. Louis, MO; hereafter referred to as Roundup) at 2% concentration, Aquamaster (glyphosate, Monsanto) at 2.1% concentration, Garlon 3A (triclopyr, Dow Agrosciences, Indianapolis, IN) at 3% concentration with 0.25% nonionic surfactant, and Arsenal (imazapyr, BASF Corp., Research Triangle Park, NC) at 1.5% concentration with 0.25% nonionic surfactant. Concentrations for each herbicide represent the maximum labeled rate for spot spraying. Concentrations for the glyphosate products differed slightly so that each provided the same amount of acid equivalent. Herbicides were applied when plants were approximately 36 cm (14 in) tall, 46 cm (18 in) wide, and flowering profusely. Herbicides were applied with a CO_2 backpack sprayer equipped with a single 8005 flat fan nozzle (Spraying Systems Co., Wheaton, IL) pressurized to 241 kPa (35 psi). All plants received 100 ml of herbicide solution uniformly applied to the plant canopy. There were eight single plant replications per treatment arranged in a randomized complete block design. Plants were rated for control 1, 4, and 6 weeks after treatment (WAT) using an injury scale from 0 to 10 where 0 = no plant injury and 10 = complete death. Plants were also evaluated the following spring to determine over winter mortality.

Herbicides were applied to a separate group of plants in crop 1 on September 9, 2005, when plants were approximately 2 m (6.6 ft) tall and wide and flowering profusely. Herbicides were applied by either spraying the canopy of intact plants, or painting herbicide concentrate to stumps recently cut to a height of 40 cm (15.7 in) (hereafter referred to as the cut-stump method). Herbicides were sprayed similarly to those in 2004, except that 500 ml (16.9 oz) was used to provide complete canopy coverage. Herbicides were painted to recently cut-stumps using paint brushes. Roundup, Aquamaster, Garlon, and Arsenal were applied undiluted at 10, 10.5, 15, and 7.5 ml (0.34, 0.36, 0.51, and 0.25 oz) per plant, respectively (no surfactants were used for cut-stump treatments). Amount of herbicide active ingredient applied per plant via painting or spraying were the same for a given herbicide. There were eight single plant replications per treatment arranged in a randomized complete block design. Plants were rated 1, 2, 4 and 10 weeks after treatment (WAT) using the same rating scale defined above. Plants were similarly rated the following spring to evaluate over winter mortality.

Crop 2. A group of plants were treated September 9, 2005, when plants were 41 cm (16 in) tall and wide. Applications were sprayed similar to those in 2004. A second group of plants from crop 2 were treated August 22, 2007. Methods were similar to those described for 2005 with the following exceptions. Aquamaster was removed from the treatment list. Plants were treated when they were 1.8 m tall and 1 m wide, and were sprayed with 260 ml (8.8 oz) of herbicide solution and thus cut-stump treatments were applied with 5.2, 7.8, and 3.9 ml (0.18, 0.26, and 0.13 oz) per plant with Roundup, Garlon, and Arsenal, respectively.

Data were subjected to repeated measures analysis of variance. Means were separated with Duncan's multiple range test ($\alpha = 0.05$).

Results and Discussion

Crop 1: Treated same year as planting. One week after herbicide application, Roundup and Aquamaster provided similar and excellent control (Table 1). Plants treated with Garlon were also severely injured, but less than those treated with either glyphosate product. Plants treated with Arsenal appeared relatively unaffected, and were not noticeably different from non-treated controls. Response to herbicide was similar among both cultivars.

By 4 WAT, control was complete with the Roundup and Aquamaster, as all plants sprayed with these herbicides were dead. Plants treated with Garlon were severely injured, however, there was still green tissue near the crown of the plant. Roundup and Aquamaster resulted in higher control ratings than Garlon throughout the experiment with the exception of 'Black Knight' ratings 4 WAT. This contradicts Clay and Drinkall (4) who stated that triclopyr is generally more effective than glyphosate for butterfly bush control. Plants treated with Arsenal began to show signs of injury, but similar to Garlon, plants were not completely dead. Control of 'Ellen's Blue' with Garlon and Arsenal was slightly lower than that observed with 'Black Knight'. 'Ellen's Blue' has foliage that is more pubescent than that of 'Black Knight,' and thus appears more grey in color. This trait is common among some butterfly bush cultivars and wild seedling populations, and the observed difference in control indicates that foliar pubescence might be an important factor governing effectiveness of some herbicides. King and Radosevich (6) reported that pubescence on tanoak (*Lithocarpus densiflorus*) leaves was correlated to reduced triclopyr and glyphosate penetration. When evaluated the following spring on April 10, 2005, all

Table 1. Postemergence control on two cultivars of one-year-old butterfly bush (*Buddleja davidii*) with various herbicides. Plants were rated on a scale from 0 to 10, where 0 = no control and 10 = plant death.

	1 WAT[y]		4 WAT		6 WAT	
Herbicide[z]	**Black Knight**	**Ellen's Blue**	**Black Knight**	**Ellen's Blue**	**Black Knight**	**Ellen's Blue**
Roundup	9.9a[x]	9.0a	10.0a	10.0a	10.0a	10.0a
Aquamaster	9.6a	9.0a	10.0a	10.0a	10.0a	9.9a
Garlon	7.9b	7.9b	9.5a	8.8b	9.1b	7.9d
Arsenal	0.0c	0.1c	8.6b	7.1c	8.4c	7.4e
non-treated control	0.1c	0.0c	0.0d	0.0d	0.0f	0.0f
Main effects			Pr > F			
Cultivar	0.1192		0.0003		0.0001	
Herbicide	0.0001		0.0001		0.0001	
Cultivar × Herbicide	0.4028		0.0002		0.0001	

[z]Herbicides applied September 23, 2004.

[y]Weeks after treatment.

[x]Means within a column with similar letters are not significantly different (LSD, α = 0.05).

herbicide-treated plants were dead while non-treated controls grew vigorously.

Crop 2: treated same year as planting. The experiment was repeated by treating a similar-sized crop planted in 2005. Analysis of variance indicated that results from 2004 and 2005 differed with a significant year by date by treatment interaction ($P < 0.0001$, data not shown). At 1 WAT, there were differences among herbicides (Table 2). Although the relative order of efficacy was similar to results in 2004, control from each herbicide was less than that observed 1 WAT in 2004. By 4 WAT, control was affected by cultivar and herbicide ($P = 0.0016$ for the interaction). Both cultivars were completely controlled with Roundup and Aquamaster. Garlon and Arsenal caused severe injury, but not complete control. Means separation suggests control of 'Black Knight' was greater than 'Ellen's Blue' with Arsenal only. At 6 WAT, all herbicides caused either severe injury or plant death. Similar to the previous study, all herbicide-treated plants were dead when evaluated the following spring while non-treated controls grew vigorously.

Crop 1: Treated one year after planting. Cultivar, herbicide, and method of application affected control 2 WAT (Table 3). With the exception of Garlon, control ratings were higher among 'Black Knight' than 'Ellen's Blue' within each herbicide treatment. Cut-stump treatments collectively provided more effective control than spray treatments ($P = 0.0031$), although within a herbicide there were few significant differences. Similar to smaller plants, Roundup and Aquamaster provided more effective control than Garlon or Arsenal early in the experiment. Clay and Drinkall (4) also reported better control with glyphosate compared to triclopyr when spray applied to butterfly bush plants that were 1 to 3 m (3.3 to 9.8 ft) tall. By 4 WAT, all herbicides cut-stump applied to 'Black Knight' provided effective control (> 9.3). Sprayed Roundup and Aquamaster provided effective control of 'Black Knight' (> 9.8), while sprayed Garlon and Arsenal provided marginal control. Roundup and Aquamaster applied cut-stump to 'Ellen's Blue' provided effective control, while all other treatments provided poor to moderate control. Cut-stump applications with glyphosate-containing herbicides have provided complete control of other woody plants in-

Table 2. Postemergence control two cultivars of one-year-old butterfly bush (*Buddleja davidii*) with various herbicides. Plants were rated on a scale from 0 to 10, where 0 = no control and 10 = plant death.

	1 WAT[y]		4 WAT		6 WAT	
Herbicide[z]	**Black Knight**	**Ellen's Blue**	**Black Knight**	**Ellen's Blue**	**Black Knight**	**Ellen's Blue**
Roundup	5.0a[x]	6.3a	10.0a	10.0a	10.0a	10.0a
Aquamaster	5.5a	5.3a	10.0a	10.0a	10.0a	10.0a
Garlon	3.3b	5.3b	7.4c	7.0c	10.0a	9.8a
Arsenal	0.8c	0.8c	8.9b	6.8c	9.9a	9.1b
non-treated control	0.0c	0.0c	0.0d	0.0d	0.0c	0.0c
Main effects			Pr > F			
Cultivar	0.1254		0.0091		0.0055	
Herbicide	0.0001		0.0001		0.0003	
Cultivar × Herbicide	0.3360		0.0016		0.0099	

[z]Herbicides applied September 9, 2005.

[y]Weeks after treatment.

[x]Means within a column with similar letters are not significantly different (LSD, α = 0.05).

Table 3. Postemergence control of two butterfly bush (*Buddleja davidii*) cultivars using selected herbicides and applied with either a cut-stump treatment or spray. Plants were rated on a scale from 0 to 10, where 0 = no control and 10 = plant death. Plants were treated September 9, 2005, when they were approximately 2 m tall and wide.

Application method	Herbicide	Rate	2 WAT[z]		4 WAT		10 WAT	
			Black Knight	Ellen's Blue	Black Knight	Ellen's Blue	Black Knight	Ellen's Blue
Cut-stump[y]	Roundup	10.0[x]	10.0a[w]	8.0b	10.0a	9.4a	10.0a	9.4abc
	Aquamaster	10.5	10.0a	7.3bc	10.0a	9.0ab	10.0a	9.9ab
	Garlon	15	5.9def	4.8fg	9.5a	7.4cde	9.5abc	8.4cd
	Arsenal	7.5	5.3ef	3.8g	9.3a	6.9de	10.0a	7.9de
	control		0.0h	0.0h	0.0g	0.0g	0.0g	0.0g
Spray	Roundup	2.0[v]	10.0a	6.4cde	10.0a	7.8cd	9.5abc	9.0abcd
	Aquamaster	2.1	9.5a	6.8cd	9.8a	8.1bc	9.0abcd	8.6bcd
	Garlon	3	5.8def	5.1ef	7.6cd	7.3cde	8.5cd	7.0e
	Arsenal	1.5	4.9fg	1.1h	6.5e	2.6f	6.8e	3.5f
	control		0.0h	0.0h	0.0g	0.0g	0.0g	0.0g

Main effects	Pr > F (2 WAT)	Pr > F (4 WAT)	Pr > F (10 WAT)
Cultivar (C)	< 0.0001	< 0.0001	< 0.0001
Herbicide (H)	< 0.0001	< 0.0001	< 0.0001
C × H	0.0060	0.0007	0.0002
Method (M)	0.0031	< 0.0001	< 0.0001
C × M	0.0604	0.1710	0.3229
H × M	0.0803	< 0.0001	< 0.0001
C × H × M	0.0978	0.0043	0.7458

[z]Weeks after treatment.

[y]Herbicide concentrates were painted on recently cut stumps.

[x]The rate for painted plants is expressed as $ml\cdot plant^{-1}$, where rate was applied directly to cut stems of each plant.

[w]Means with different litters within a column are significantly different according to Duncan's multiple range test ($\alpha = 0.05$).

[v]The rate for sprayed plants is expressed as the % concentration in spray solution. All sprays were applied at a rate of 500 $ml\cdot plant^{-1}$.

Table 4. Postemergence control of two butterfly bush (*Buddleja davidii*) cultivars using selected herbicides and applied with either a cut-stump treatment or spray. Plants were rated on a scale from 0 to 10, where 0 = no control and 10 = plant death. Plants were treated August 22, 2007, when they were approximately 1.8 m tall and 1 m wide.

Application method	Herbicide	Rate	2 WAT[z]		4 WAT		10 WAT	
			Black Knight	Ellen's Blue	Black Knight	Ellen's Blue	Black Knight	Ellen's Blue
Cut-stump[y]	Roundup	10.5[x]	8.3ab[w]	8.3ab	8.8a	8.3ab	10.0a	10.0a
	Garlon	15	5.0c	4.8cd	9.5a	9.0a	9.5a	9.0a
	Arsenal	7.5	5.0c	4.0cde	9.3a	9.3a	10.0a	10.0a
	control		0.0f	0.0f	0.0c	0.0c	0.0b	0.0b
Spray	Roundup	2.1[v]	9.0a	8.0ab	9.5a	8.3ab	9.5a	8.5a
	Garlon	3	6.0bc	5.5c	7.8ab	7.5b	8.8a	8.5a
	Arsenal	1.5	1.8ef	2.5de	6.3b	7.5ab	10.0a	9.5a
	control		0.0f	0.0f	0.0c	0.0c	0.0b	0.0b

Main effects	Pr > F (2 WAT)	Pr > F (4 WAT)	Pr > F (10 WAT)
Cultivar (C)	0.4975	0.6252	0.2266
Herbicide (H)	< 0.0001	0.4853	0.0535
C × H	0.9499	0.3482	0.9454
Method (M)	0.3974	0.0073	0.0480
C × M	0.8649	0.7692	0.4985
H × M	0.0237	0.0334	0.6075
C × H × M	0.4975	0.6311	0.7031

[z]Weeks after treatment.

[y]Herbicide concentrates were painted on recently cut stumps.

[x]The rate for painted plants is expressed as $ml\cdot plant^{-1}$, where rate was applied directly to cut stems of each plant.

[w]Means with different litters within a column are significantly different according to Duncan's multiple range test ($\alpha = 0.05$).

[v]The rate for sprayed plants is expressed as the % concentration in spray solution. All sprays were applied at a rate of 500 $ml\cdot plant^{-1}$.

cluding wisteria (*Wisteria sinensis*) (10), gray birch (*Betula populifolia*), pin cherry (*Prunus pensylvanica*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*), and quaking aspen (*Populus tremuloides*) (3). Repeated measures analysis indicated that control changed between 4 and 10 WAT, although relative differences between treatments were similar. Despite treatment differences 10 WAT, all herbicide-treated plants were dead when evaluated the following spring (March 25), while at the same time non-treated controls were growing vigorously.

Crop 2: Treated 2 years after planting. At 2 WAT, analysis of variance indicated a significant herbicide by application method interaction ($P = 0.0237$) (Table 4). Glyphosate and Garlon provided similar control among the two application methods, however, Arsenal provided slightly better control when applied cut-stump compared to spraying. By 4 WAT, the herbicide by application method interaction was still the primary effect governing control of butterfly bush, and again was probably caused by the slightly reduced efficacy of Arsenal in spray applications. By 10 WAT, means separation indicated all herbicides provided similar control; however, there occurred a significant effect from herbicide ($P = 0.0535$) and application method ($P = 0.0480$), but not their interaction ($P = 0.7031$). Across cultivars and application methods, Arsenal provided the highest average control (9.9), while glyphosate (9.5) and Garlon (8.9) provided slightly less control. Across herbicides and cultivars, cut-stump application provided better control than spraying (9.8 vs. 9.1, respectively). Unlike the previous experiment, cultivar did not affect control from herbicides. By spring of 2008, all herbicide-treated plants were dead while non-treated controls were growing vigorously.

Throughout all experiments, Roundup and Aquamaster provided similar control. Aquamaster is a formulation of glyphosate without an adjuvant, making it safer for use near bodies of water. Our research shows that lack of surfactant in a glyphosate formulation will not reduce control, even with spray applications, when applied at rates used in this study. This is important considering many of the most severe invasive butterfly bush populations occur near bodies of water (8).

All herbicides and both application methods provided complete control of butterfly bush, thus efficacy need not be a consideration for deciding which product to use. Spray applications are generally quicker and more efficient for treating large numbers of plants, so long as plants are relatively small. Large butterfly bush are more difficult to spray, especially when trying to avoid drift to nearby desirable vegetation. Because butterfly bush can grow over 2 m (6.6 ft) in a single year, spray applications may not always be feasible. This is particularly true in sensitive riparian areas where herbicidal contact with bodies of water or desirable vegetation can have negative consequences. Due to the effectiveness of all treatments, resources and circumstances should dictate which herbicide and application method is most appropriate to the land manager.

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