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RESEARCH ARTICLE

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Cutting and Herbicide Treatments for Control of Oriental Bittersweet, Pale Swallow-wort and Morrow's Honeysuckle

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ABSTRACT: Research was conducted on control methods for Oriental bittersweet (*Celastrus orbiculatus*), pale swallow-wort (*Cynanchum rossicum*), and Morrow's honeysuckle (*Lonicera morrowii*) near Long Island Sound in Groton and East Lyme, Connecticut. These nonnative, invasive plants threaten the health of ecosystems at these sites and many other areas throughout the Northeast. For the Oriental bittersweet study, vines were treated at one of three timings (April, August, or November) in 2003 and evaluated in the summer of 2004. Treatments consisted of triclopyr ester formulations applied to the basal bark of uncut vines, or of triclopyr amine or glyphosate formulations applied to the stump surface of cut vines. The experiment was repeated with a different set of vines treated in 2004 and evaluated in 2005. Cut-stump herbicide treatments were generally more effective than basal-bark treatments at killing bittersweet vines. All cut-stump herbicide treatments were effective in reducing vine survival and number and length of sprouts. Pale swallow-wort plots were established in areas of high infestation near the shore. Treatments applied in July 2003, and again in August 2004, included hand pulling, cutting, application of glyphosate or triclopyr amine to cut stems, or foliar sprays of glyphosate or triclopyr amine. By July 2005, glyphosate foliar sprays and cut-stem treatments with glyphosate or triclopyr caused the greatest reduction in the amount of swallow-wort, and the glyphosate treatments were most effective in reducing swallow-wort vigor. Triclopyr foliar sprays injured swallow-wort, but long-term control was not better than that provided by annual hand pulling, cutting, or no treatment. For Morrow's honeysuckle, herbicide treatments were applied to freshly cut stumps in August 2005, and were evaluated in May 2006. Treatments consisted of glyphosate, triclopyr amine, or triclopyr ester, each applied at low or high doses. All triclopyr treatments reduced the number and length of sprouts, and both glyphosate treatments completely prevented sprouting from honeysuckle stumps. Our study provides land managers with effective control methods for three highly invasive plants.

Index terms: bittersweet, *Celastrus orbiculatus*, *Cynanchum rossicum*, glyphosate, herbicides, honeysuckle, invasive plants, *Lonicera morrowii*, swallow-wort, triclopyr

INTRODUCTION

Nonnative invasive plants pose a serious threat to natural ecosystems, including coastal areas such as those adjacent to Long Island Sound. Oriental bittersweet (*Celastrus orbiculatus* Thunb.), pale swallow-wort (*Cynanchum rossicum* (Kleopow) Borhidi; syn. *Vincetoxicum rossicum* (Kleopow) Barbar.), and Morrow's honeysuckle (*Lonicera morrowii* A. Gray) are some of the most problematic invasive plants in Connecticut (IPANE 2009; CIPC 2012; Mervosh and Gumbart, pers. obs.). Oriental bittersweet is a woody vine that wraps around and climbs trees and grows over lower vegetation (McNab and Meeker 1987; Dreyer 1994; IPANE 2009). Bittersweet vines are widespread in forested sections of Bluff Point Coastal Reserve in Groton, Connecticut, and are adversely affecting trees and shrubs (Mervosh and Gumbart, pers. obs.). Pale swallow-wort, and the closely related black swallow-wort (*Cynanchum louiseae* (L.) Kartesz & Gandhi or *Vincetoxicum nigrum* (L.) Moench), are herbaceous perennials that produce dense twining growth (Sheeley and Raynal 1996; Christensen 1998; Lawlor 2002; DiTomasso et al. 2005). Pale swallow-wort has spread rapidly in the Natural Area Preserve at Bluff Point and threatens two endangered native plants (yellow thistle (*Cirsium horridulum* Michx.) and Scotch lovage (*Ligusticum scoticum* L.)) in the cobble beach habitat (CT-DEEP 2010). Various nonnative honeysuckle (*Lonicera*) species are prevalent in natural areas throughout Connecticut (IPANE 2009). Morrow's honeysuckle bushes have invaded a wooded site adjacent to Old Black Point Beach in East Lyme, Connecticut (Mervosh and Gumbart, pers. obs.).

Vines of Oriental bittersweet (staff-tree family (Celastraceae)) can grow to over 12 cm in diameter and 20 m long, and develop a deep and extensive root system that makes physical removal extremely difficult (Dreyer 1994; IPANE 2009). Bittersweet can smother trees and shrubs from the weight of its vines or by blocking sunlight (McNab and Meeker 1987; Dreyer 1994). Larger vines wrap tightly around tree trunks and can constrict vascular tissues and impede sap flow (Dreyer 1994). Bittersweet produces large quantities of orange-red fruits that are a food source for several bird species, and seed dispersal via birds has led to its rapid spread across the Northeast (McNab and Meeker 1987; Niering 1998; IPANE 2009). Bittersweet is a widespread problem in natural and managed landscapes where it invades open woods and fields (McNab and Loftis 2002; Dreyer and Kline 2005; Webster et al. 2006). Control strategies for Oriental bittersweet depend upon whether the vines are growing in open areas or are climbing up trees in woodlands. In open areas, it may be feasible to mow regularly to prevent bittersweet establishment; also, dense stands of low-growing vines can be sprayed with herbicide (Dreyer and Kline 2005). Applied to foliage, triclopyr has generally been more effective than glyphosate in controlling Oriental bittersweet (Ahrens 1987; Dreyer 1988; Dreyer and Kline 2005). Simple cutting of bittersweet vines often leads to multiple sprouts from the base or from root suckers (McNab and Meeker 1987; Dreyer 1994). For climbing vines, herbicide sprays are generally impractical and potentially damaging to trees and other nontarget vegetation (Dreyer and Niering 1986; Gover 2004). Thus, a safer and more effective approach is to cut vines and apply herbicide directly to the cut stumps, or to apply an herbicide that will penetrate through bark directly to the base of vines (Dreyer and Niering 1986; Gover 2004).

The plants commonly known as swallow-worts (dogbane family (Apocynaceae), formerly placed in the milkweed family (Asclepiadaceae)) are native to eastern Europe (DiTommaso et al. 2005; IPANE 2009). Pale and black swallow-wort are assigned to the genus *Cynanchum* by most taxonomists, but some scientists use *Vincetoxicum*, considered a subgenus of *Cynanchum*, as the genus for the swallow-worts (Gleason and Cronquist 1991; Sheeley and Raynal 1996; DiTommaso et al. 2005). The species in our study was pale swallow-wort, an herbaceous perennial that can grow to lengths of 1 to 2 m as its vining stems climb up other vegetation or twine around each other (Christensen 1998; Lawlor 2002; DiTommaso et al. 2005). Pale swallow-wort produces light pink to purple flowers, and its fruits are slender pod-like follicles 4 to 6 cm long (Sheeley and Raynal 1996; Lawlor 2002; IPANE 2009). Mature follicles open to release flattened brown seeds bearing a tuft of silky hairs that aid in seed dispersal via wind (Lawlor 2002; DiTommaso et al. 2005). Although pale swallow-wort dies back to the ground in the fall, the plant regenerates each spring from perennating buds that form on the root crown, thus the root crown expands into a larger clump each year (Sheeley and Raynal 1996; DiTommaso et al. 2005). The fibrous roots are thick and fleshy, and the root system becomes so extensive that plants cannot be pulled easily from the ground (Lawlor 2002). Large, dense patches of swallow-wort can develop within just a few years and crowd out native plants (Lawlor 2002; DiTommaso et al. 2005). Swallow-wort thrives in a wide range of habitats, including calcareous soils, meadows, pastures, wooded edges, and rocky shorelines (Lawlor 2002; IPANE 2009). The New York State Forest Owners' Association stated that swallow-wort is negatively impacting forest regeneration (Lawlor 2003). In New England, pale swallow-wort is currently most prevalent in coastal areas and in the Connecticut River valley (IPANE 2009; Mervosh and Gumbart, pers. obs.). For small swallow-wort infestations, pulling plants is an option to prevent seed production, but removing the below-ground portion of the plant is difficult to accomplish, and re-sprouting will occur (DiTommaso et al. 2005). Digging is a possibility, but it is disruptive to soils. Repeated cutting or mowing prior to follicle formation can be an effective management option (Lawlor 2002; Averill et al. 2008). However, after being cut, swallow-wort sprouts vigorously from the root crown (Lawlor and Raynal 2002; DiTommaso et al. 2005). Cultivation may not kill plants because root crown fragments left on the soil can root even under hot, dry conditions (Lawlor 2002). The systemic herbicides glyphosate and triclopyr have been effective in controlling swallow-wort (Lawlor 2002; Lawlor and Raynal 2002). Herbicide choice for foliar spray treatments will depend on site conditions. In degraded patches with little desirable vegetation, glyphosate may be preferred, but at sites with desirable grasses and other monocots to be preserved, triclopyr amine or triclopyr ester are more selective herbicide options (Lawlor and Raynal 2002; Averill et al. 2008; Mervosh 2009). Follow-up treatments are generally necessary for adequate control.

Native to Japan and South Korea, Morrow's honeysuckle (honeysuckle family (Caprifoliaceae)) has gray-green leaves that are pubescent beneath, white to yellow flowers, and fruits that are red when ripe (Gleason and Cronquist 1991; Batcher and Stiles 2000; IPANE 2009). Several nonnative bush honeysuckle (*Lonicera*) species have escaped cultivation and become common invaders in eastern North America (Batcher and Stiles 2000; IPANE 2009). They are aggressive colonizers in secondary forests and early successional habitats (Luken 1990; Webster et al. 2006). Morrow's honeysuckle occupies a wide range of habitats, including riparian areas and forest edges, and it also invades disturbed sites such as railroad rights-of-way, roadsides, and abandoned farm fields (Batcher and Stiles 2000). Exotic bush honeysuckles can negatively impact forest regeneration and native herb diversity (Collier et al. 2002; Gorchov and Trisel 2003; Hartman and McCarthy 2004). Several methods of controlling bush honeysuckles have been described (Kline 1981; Luken 1990; Nyboer 1992), but few rigorous studies have been conducted that compare different management strategies (Luken and Mattimiro 1991; Hartman and McCarthy 2004; Love and Anderson 2009). Clipping or cutting shrubs is unsuccessful unless done repeatedly (Luken 1990; Luken and Mattimiro 1991; Nyboer 1992). Herbicides are commonly used to control bush honeysuckles (Batcher and Stiles 2000). Foliar applications of glyphosate or triclopyr have been used with varying degrees of success (Nyboer 1992; Love and Anderson 2009). Many land managers use glyphosate as a cut-stump treatment to control bush honeysuckles (Kline 1981; Miller 2003; Love and Anderson 2009).

The objectives of our research were to provide data on the efficacy of the herbicides glyphosate and triclopyr, in conjunction with cutting treatments, for managing infestations of Oriental bittersweet, pale swallow-wort, and Morrow's honeysuckle near the coast of Long Island Sound. Our goal is to develop effective and environmentally sound management plans for these nonnative invasive plants.

METHODS

The Oriental bittersweet study was conducted in forested areas along the western side of Bluff Point Coastal Reserve in the town of Groton, Connecticut. Experimental sites were centered around latitude / longitude coordinates of 41.3271° / -72.0343° (for 2003 treatments) and 41.3232° / -72.0352° (for 2004 treatments) [Google Earth]. The pale swallow-wort experiment was conducted along the cobble beach of the Natural Area Preserve just east of the southern tip of the Bluff Point peninsula (41.3133° / -72.0292°) [Google Earth]. The bittersweet and swallow-wort experiments took place over a 3-yr period (2003 through 2005). The Morrow's honeysuckle experiment was conducted in a wooded area at Pattagansett Marsh, a preserve of The Nature Conservancy, near Old Black Point Beach in East Lyme, Connecticut (41.2937° / -72.2188°) [Google Earth]. Treatments were applied in 2005 and data were collected in 2006.

Oriental Bittersweet

Treatments were applied to vines in two size classes: "small" vines with basal stem diameters of 16 to 25 mm, and "large" vines with basal stem diameters of 26 to 40 mm. In most cases, selected vines were climbing on trees. A numbered aluminum tag was nailed in at the base of each vine, and vine diameters were measured (between 15 and 30 cm above ground) with a caliper and recorded. On each application date, each treatment was applied to five small vines and five large vines. A micropipette was used to precisely measure the volume of herbicide applied to each vine. A basal-bark (BB) treatment consisted of 1.5 ml of herbicide applied uniformly with a small paint brush in a 10 cm wide band around the lower bark of an uncut (intact) vine. For each cut-stump (CS) treatment, a vine was cut off with loppers 15 to 30 cm above ground level and 0.75 ml of herbicide was applied immediately to the cut surface of the stump using a small sponge brush.

The eight treatments in the Oriental bittersweet study were: BB untreated control (uncut / no herbicide); BB triclopyr ester ["Garlon 4"] (61.6% active ingredient (ai)); BB triclopyr ester ['Vine-X'] (13.6% ai); CS untreated control (cut / no herbicide); CS triclopyr amine ["Garlon 3A"] (44.4% ai); CS triclopyr amine ["Brush-B-Gon"] (8% ai); CS glyphosate ["Roundup Pro"] (41% ai); and CS glyphosate ["Roundup Brush Killer"] (25% ai). Herbicide products were applied in undiluted form (full strength). All of these herbicides are classified as "general use" pesticides, but the less concentrated forms of triclopyr and glyphosate are typical of the products available in retail stores that sell to homeowners and small property owners. Each treatment was applied to 10 different vines on three dates in 2003 (April 25, August 21, and November 18), and similarly to a different set of vines on three dates in 2004 (May 7, August 24, and November 16). Each numbered vine was treated only one time during the study. Vines treated in 2003 were evaluated on 29 June 2004, and vines treated in 2004 were evaluated on 7 June 2005. Cut or uncut vines that had new sprouts originating from above or below ground were determined to be alive. The number and length of each new sprout was recorded. If no sprouts were present, a knife was used to remove small sections of bark on opposite sides at the base of each vine. The condition, color, and moisture level of the exposed vascular tissue were factors used to determine if the vine was alive or dead.

Statistical analyses of Oriental bittersweet data included use of Fisher's Exact Test (Mehta et al. 1984) to determine differences between treatments for the total number of vines alive (of a possible 30) each year. Pairwise comparisons were made between vines alive for each basal-bark treatment and between vines alive for each cut-stump treatment. An analysis of variance (ANOVA) of the factorial design was conducted, followed by comparison tests of number of living vines for treatment, application date, and size of vine factors (Statistix 9.0 Analytical Software). To improve homogeneity of variances for the number and length of new sprouts data, these data were transformed as follows prior to analyses of variance procedures: square-root transformation for number of new sprouts, and logarithmic transformation for length of new sprouts. Data were excluded from statistical analyses for treatments in which no new sprouts were produced on any of the 30 vines treated (all zero data, thus zero variance). An F-max test (David 1952) on the ratio of largest variance to smallest variance indicates that the transformed data conforms to the assumption of homogeneity of variances. Treatment means were separated based on Fisher's Protected LSD test ($\alpha = 0.05$).

Pale Swallow-wort

Experimental plots with dimensions of 3.0 × 1.8 m were established in areas of high pale swallow-wort infestation above the high-tide line along the cobble beach. Plots were arranged in randomized complete blocks with three replicate plots per treatment. Treatments consisted of an untreated control, hand pulling of swallow-wort plants, cutting stems just above the level of the rocky surface, cutting followed by application of glyphosate (20.5% ai) ("Roundup Pro", 50% solution) to cut stems, cutting followed by application of triclopyr amine (22.2% ai) ("Garlon 3A", 50% solution) to cut stems, foliar spray of glyphosate (0.82% ai; 2.2 kg ai/ha) ("Roundup Pro", 2% solution), and foliar spray of triclopyr amine (0.89% ae; 1.7 kg ai/ha) ("Garlon 3A", 2% solution). Herbicide treatments were applied to cut-stem surfaces using a paint pad wetted with herbicide solution. For foliar sprays, herbicide treatments were applied with a calibrated CO_2-pressurized sprayer with three nozzles (8003VS tips) spaced 50 cm apart. Spray solutions contained 0.5% nonionic surfactant (Chemsurf 80: Chemorse Ltd., Des Moines, IA) and the volume of spray delivered was 234 L/ha.

Treatments were applied on 15 July 2003, and plots were evaluated on 18 August 2004 for the prevalence of pale swallow-wort plants, swallow-wort vigor, and treatment effects on other plants. Treatments were applied again to the same plots on 25 August 2004, and plots were evaluated as described above on 15 July 2005. Visual evaluations of swallow-wort prevalence or population density (% of plot area covered) and swallow-wort vigor (based on plant height, color, injury symptoms) (10 = most vigorous; 0 = dead) represented the consensus opinion of the two authors and a research assistant. Analyses of variance were conducted on percentage of plot area covered by swallow-wort and on plant vigor ratings collected in 2005 (after two years of treatment applications). Treatment means were separated based on Fisher's Protected LSD test ($\alpha = 0.05$).

Morrow's Honeysuckle

Selected Morrow's honeysuckle shrubs were tagged at the base in early August 2005. Shrubs were cut down with a saw just above the crown level (less than 30 cm above ground) on 17 August 2005. Among treatments, the mean number of cut stems per stump ranged from 3.7 to 5.0, and the mean diameter of the cut stems was between 2.2 and 3.1 cm (data not shown). Within 1 hr of cutting, herbicide treatments were applied to the cut-stem surfaces of the stumps. Each treatment was applied uniformly with a paint brush to three stumps. Treatments consisted of a control (stems cut / no herbicide), glyphosate (4.1% ai) ("Roundup Pro", 10% solution), glyphosate (20.5% ai) ("Roundup Pro", 50% solution), triclopyr amine (4.4% ai) ("Garlon 3A", 10% solution), triclopyr amine (22.2% ai) ("Garlon 3A", 50% solution), triclopyr ester (6.2%) ("Garlon 4", 10% solution), and triclopyr ester (30.8% ai) ("Garlon 4", 50% solution). Stumps were evaluated on 18 May 2006 for the number of new sprouts and lengths of those sprouts. Data for number and length of sprouts were subjected to square-root transformation to improve homogeneity of variances prior to analysis of variance. Treatment means were separated based on Fisher's Protected LSD test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Oriental Bittersweet

In general, cut-stump (CS) treatments were more effective than basal-bark (BB) treatments in reducing the number of living bittersweet vines the year after treatment application (Table 1A). For the same herbicide active ingredient, the formulation containing the higher concentration (% ai) generally provided better control. Vine size ("small" vs. "large" diameters) did not affect treatment response in terms of survival the following year, number of sprouts or sprout length, thus data for small and large vines were combined in Tables 1A, 1B and 1C. Overall, the spring and summer herbicide application timings were more effective than the fall applications; in particular, BB treatments of triclopyr ester products applied in November 2004 were completely ineffective in killing bittersweet (Table 1A). The November 2004 treatments were applied just after an abnormally cold period, which may have reduced absorption and/or translocation of triclopyr ester applied to the bark of vines.

Combined over both years, 5% of untreated vines (BB-Control) and 20% of vines that were cut with no herbicide (CS-Control) were considered dead the following year (Table 1A). However, combining both years for the CS-Control vines, an average of 2.2 new sprouts emerged per cut stump the next year (Table 1B). Although cutting a bittersweet vine prevents seed production and reduces stress on a tree threatened by the vine, the data show that the benefit is temporary because of multiple new shoots that arise from the stump. Sprouting was less extensive when vines were cut in August compared to cutting in spring or fall (Table 1B). The apparent difference in length of new sprouts from CS-Control stumps between the two years (average of 360 cm per vine in 2004 vs. 92 cm per vine in 2005) may be due to differences in evaluation dates (29 June 2004 vs. 7 June 2005) (Table 1C). For data averaged over both years, all CS treatments with either triclopyr or glyphosate were effective in reducing survival of bittersweet vines (77 to 93% mortality) (Table 1A). Application of these herbicide treatments to cut stumps greatly reduced the number of sprouts from stumps or roots (91 to 99% reduction) (Table 1B) and overall length of new sprouts (97 to 100% reduction) (Table 1C).

A very small amount of glyphosate or triclopyr herbicide was needed to prevent re-growth of Oriental bittersweet vines after cutting. Only 0.75 ml of herbicide was applied to the cut surface of the stumps, regardless of the vine diameter. This volume was chosen because it was enough to spread a thin coating across the cut surface of the largest diameter vines, without significant dripping of herbicide down the side of the smallest vines. A gallon consists of 3785 ml, thus when applied as in this experiment, more than 5000 bittersweet vines could be controlled with 1 gallon of herbicide. Excellent results were obtained with this method, and off-target environmental impacts are minimized by carefully applying herbicide directly onto the cut stumps. Ahrens (1987), Dreyer (1988), and Dreyer and Kline (2005) reported more effective control of Oriental bittersweet with foliar sprays of triclopyr compared to spraying with glyphosate. In contrast, our study focused solely on cut-stump rather than foliar applications of these herbicides. As cut-stump treatments, both glyphosate and triclopyr were effective in preventing regrowth of bittersweet vines.

Pale Swallow-wort

Pulling swallow-wort by hand was difficult because the stems tend to break off just above the ground level. In some cases, much of the root system could be removed by pulling, but generally the crown and roots would remain in the coarse rocky soil of the beach. After pulling once per year in July 2003 and August 2004, pale swallow-wort population density (% plot area covered) had been reduced by 43% relative to untreated check plots, but swallow-wort vigor was only slightly lower (Table 2). Cutting the stems just above the rocky surface was slightly less effective than pulling. Pulling and cutting treatments would likely have been more effective if they had been done multiple times per year, although DiTommaso et al. (2013) found that cutting pale swallow-wort twice per year was ineffective.

Application of triclopyr amine or glyphosate to cut stems of swallow-wort was relatively effective in reducing the extent and vigor of swallow-wort growth in subsequent years. After two years of cut-stem treatments, both herbicides reduced the percentage of swallow-wort in plots by about 65%, and glyphosate reduced swallow-wort vigor the most (Table 2). Averill et al. (2008) and DiTommaso et

Table 1A. Control of Oriental bittersweet vines in forested areas of Bluff Point Coastal Reserve in Groton, CT. Treatments were applied to vines in the spring, summer or fall, and vines were evaluated during the summer of the following year.

Treatment[a]	Active ingredient	Number of vines alive in 2004 (of 10 vines per treatment applied on each date below)			Total vines alive in 2004[b]	Number of vines alive in 2005 (of 10 vines per treatment applied on each date below)			Total vines alive in 2005[b]
		Treated 4/25/2003	Treated 8/21/2003	Treated 11/18/2003		Treated 5/7/2004	Treated 8/24/2004	Treated 11/16/2004	
Untreated (uncut / no herbicide): BB-Control	-----	9	9	10	28 a	10	9	10	29 a
BB - Garlon 4	Triclopyr ester, 61.6%	0	2	5	7 bc	0	1	10	11 c
BB - Vine-X	Triclopyr ester, 13.6%	2	2	7	11 b	5	4	10	19 b
Cut only (no herbicide): CS - Control	-----	9	7	9	25 a	8	6	9	23 b
CS - Garlon 3A	Triclopyr amine, 44.4%	1	1	1	3 cd	0	0	1	1 e
CS - Brush-B-Gon	Triclopyr amine, 8%	2	3	3	8 b	2	0	4	6 d
CS - Roundup Pro	Glyphosate, 41%	0	0	1	1 d	1	0	3	4 de
CS - Roundup Brush Killer Concentrate	Glyphosate, 25%	0	0	2	2 d	1	2	2	5 de
Total vines alive per application date (of 80 vines treated)[b]		23 B	24 B	38 A		27 B	22 B	49 A	

[a] For each cut-stump (CS) treatment, a vine was cut off 15 to 30 cm above ground level, and 0.75 ml of herbicide was applied to the cut surface of the stump. For each basal-bark (BB) treatment, 1.5 ml of herbicide was applied to the lower bark of an intact vine in a 10 cm wide band around the vine.

[b] According to Fisher's Protected LSD test ($\alpha = 0.05$), treatment means within each year followed by the same lowercase letter are not significantly different, and application date means within each year followed by the same uppercase letter are not significantly different.

Table 1B. Number of new sprouts from Oriental bittersweet in Bluff Point Coastal Reserve in Groton, Connecticut. Vines treated in spring, summer, or fall of 2003 were evaluated on 29 June 2004. Vines treated in spring, summer, or fall of 2004 were evaluated on 7 June 2005.

Treatment	Active ingredient	Number of new sprouts per vine in 2004 (of 10 vines treated on each date below)			Mean number of new sprouts in 2004[a]	Number of new sprouts per vine in 2005 (of 10 vines treated on each date below)			Mean number of new sprouts in 2005[a]
		Treated 4/25/2003	Treated 8/21/2003	Treated 11/18/2003		Treated 5/7/2004	Treated 8/24/2004	Treated 11/16/2004	
Untreated (uncut / noherbicide):									
BB - Control	-----	0	0.3	0.5	0.27 b	0	0	0	0.00 b
BB - Garlon 4	Triclopyr ester, 61.6%	0	0	0	0.00 b	0	0	0	0.00 b
BB - Vine-X	Triclopyr ester, 13.6%	0	0	0	0.00 b	0	0	0	0.00 b
Cut only (no herbicide):									
CS - Control	-----	3.7	1.2	2.9	2.60 a	1.5	0.7	3.3	1.83 a
CS - Garlon 3A	Triclopyr amine, 44.4%	0.1	0	0	0.03 b	0	0	0.1	0.03 b
CS - Brush-B-Gon	Triclopyr amine, 8%	0.1	0	0.1	0.06 b	0.1	0	0	0.03 b
CS - Roundup Pro	Glyphosate, 41%	0	0	0	0.00 b	0.2	0	0	0.06 b
CS - Roundup Brush Killer Concentrate	Glyphosate, 25%	0	0	0.5	0.17 b	0.4	0.2	0	0.20 b

[a] A square-root transformation of the data was conducted prior to analysis of variance. The actual data are presented in the table. Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test ($\alpha = 0.05$).

al. (2013) both reported significant reductions in pale swallow-wort cover after cutting followed by triclopyr application. Although tedious, this type of cut-stem herbicide application would be appropriate for sites in which native plants, especially if they are rare species, are interspersed among the stand of swallow-wort. For the foliar spray treatments, triclopyr amine was ineffective (Table 2). Within days after triclopyr application each summer, injury symptoms appeared on the swallow-wort leaves and stems, and follicle formation was suppressed. However, swallow-wort recovered the following spring each year and was nearly indistinguishable from untreated plants by July 2005. In contrast, the glyphosate spray treatment had a substantial impact on swallow-wort, and there appeared to be a cumulative effect following the second application in August 2004. By July 2005, swallow-wort population density was reduced by 76% relative to untreated check plots, and the stems were severely stunted and poor in vigor (Table 2).

Repeated applications of 5% glyphosate were necessary to limit regrowth of pale swallow-wort in an Ontario experiment (Christensen 1998). Only those plots receiving applications in June plus early or late August, or in June plus early August and early September, had a reduction in cover greater than 90% the following year. Single applications of glyphosate did not provide satisfactory control of swallow-wort (Christensen 1998). Lawlor and Raynal (2002) compared the efficacy of glyphosate and triclopyr to suppress pale swallow-wort populations in central New York, when applied either as foliar sprays or to cut stems. Foliar spray applications were more effective than cut-stem applications in reducing swallow-wort cover and biomass. Glyphosate foliar spray treatments were applied at the early flowering stage, and triclopyr foliar spray was applied at early fruit formation. Acceptable control using either of these herbicides at recommended doses required repeated applications. Cut-stem applications of glyphosate were found to be significantly more effective than similar treatments with triclopyr (Lawlor and Raynal 2002). In our study, after two applications in consecutive years,

Table 1C. Length of new sprouts from Oriental bittersweet in Bluff Point Coastal Reserve in Groton, Connecticut. Vines treated in spring, summer, or fall of 2003 were evaluated on 29 June 2004. Vines treated in spring, summer, or fall of 2004 were evaluated on 7 June 2005.

Treatment	Active Ingredient	Total length of new sprouts per vine in 2004 (cm)			Mean length of sprouts in 2004 (cm) [a]	Total length of new sprouts per vine in 2005 (cm)			Mean length of sprouts in 2005 (cm) [a]
		Treated 4/25/2003	Treated 8/21/2003	Treated 11/18/2003		Treated 5/7/2004	Treated 8/24/2004	Treated 11/16/2004	
Untreated (uncut / noherbicide):									
BB - Control	----	0	11	27	13 b	0	0	0	0 b
BB - Garlon 4	Triclopyr ester, 61.6%	0	0	0	0 b	0	0	0	0 b
BB - Vine-X	Triclopyr ester, 13.6%	0	0	0	0 b	0	0	0	0 b
Cut only (no herbicide):									
CS - Control	----	585	51	450	360 a	139	20	118	92 a
CS - Garlon 3A	Triclopyr amine, 44.4%	19	0	0	6 b	0	0	16	5 b
CS - Brush-B-Gon	Triclopyr amine, 8%	6	0	32	13 b	7	0	0	2 b
CS - Roundup Pro	Glyphosate, 41%	0	0	0	0 b	2	0	0	1 b
CS - Roundup Brush Killer Concentrate	Glyphosate, 25%	0	0	6	2 b	10	13	0	8 b

[a] A logarithmic transformation of the data was conducted prior to analysis of variance. The actual data are presented in the table. Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test ($\alpha = 0.05$).

cut-stem treatments with either glyphosate or triclopyr reduced swallow-wort cover similarly by about 65%, but swallow-wort shoots in glyphosate-treated plots were less vigorous than those in triclopyr-treated plots (Table 2).

One possible explanation for the lack of control provided by the triclopyr foliar sprays in our study is that the application timings, especially in 2004, were likely later than optimal for this herbicide. Glyphosate generally works best on perennial weeds when applied in late summer, so the application timings in this study were ideal for glyphosate efficacy. Triclopyr tends to be more effective when applied to actively growing weeds, so treatment with triclopyr earlier in the summer may have resulted in better activity. In fact, subsequent experiments (Averill et al. 2008; Mervosh 2009) have shown that triclopyr applied earlier in the growing season was effective in controlling pale swallow-wort. Triclopyr is a useful management tool because of its greater selectivity relative to the nonselective glyphosate (i.e., grasses and sedges are tolerant of triclopyr; Gover 2004). Earlier season treatments would also reduce swallow-wort follicle formation and seed dispersal.

Morrow's Honeysuckle

Prolific sprouting occurred from untreated honeysuckle stumps cut in August 2005. By May 2006, an average of 47.5 sprouts had emerged from these stumps, and the combined length of the new sprouts was estimated at 19.8 m per stump (Table 3). Glyphosate treatments applied to freshly cut stumps were highly effective, completely preventing sprouts the following spring. Triclopyr treatments greatly reduced sprouting, but were not as effective as the glyphosate treatments. Efficacy of the triclopyr treatments improved with higher concentration of active ingredient. At lower triclopyr concentrations, the number of new sprouts was reduced 69 to 75%; at higher triclopyr concentrations, the number of new sprouts was reduced 90 to 98% (Table 3). The triclopyr amine formulation was as effective as the triclopyr ester formulation. The glyphosate product completely prevented any new growth from the cut honeysuckle stumps, even when applied as a 10% solution. This treatment solution

Table 2. Control of pale swallow-wort on a cobble beach site at Bluff Point Natural Area Preserve in Groton, Connecticut. Treatments were applied on 15 July 2003, and plots were evaluated on 18 August 2004. Treatments were applied again to the same plots on 25 August 2004, and plots were evaluated on 15 July 2005[a].

		Pale swallow-wort evaluations			
		18 August 2004		15 July 2005	
Treatment	Active ingredient	% Plot area covered	Swallow-wort vigor (0–10)	% Plot area covered[b]	Swallow-wort vigor (0–10)[b]
Untreated	-----	80	10	76.0 a	10.0 a
Swallow-wort pulled by hand	-----	55	7	43.3 bc	8.3 a
Swallow-wort stems cut	-----	68.3	9	53.3 b	8.7 a
Cut stems: Garlon 3A (50%)	Triclopyr 22.20%	28.3	5.3	27.7 cd	6.0 b
Cut stems: Roundup Pro (50%)	Glyphosate 20.50%	27.7	4	24.0 d	3.7 c
Foliar spray: Garlon 3A (2%)	Triclopyr 0.88%	56.7	9.3	61.7 ab	10.0 a
Foliar spray: Roundup Pro (2%)	Glyphosate 0.82%	35	3.7	18.0 d	2.3 c

[a] For cut-stem treatments, swallow-wort stems were cut just above the ground, and herbicide treatments were applied to freshly cut stem surfaces. For foliar sprays, herbicide treatments included 0.5% nonionic surfactant and were applied in a spray volume of 234 L/ha. Visual evaluations of swallow-wort population density (% of plot area covered) and swallow-wort vigor (10 = most vigorous; 0 = dead) represent the consensus opinion of three people. Numbers are average values for the three plots per treatment.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test ($\alpha = 0.05$).

was much less concentrated than the 50 to 100% concentration typically recommended for cut-stump treatments.

Our results of complete control of Morrow's honeysuckle with stump treatments of glyphosate are even more substantial than those of Kline (1981), who found that a 20% solution of glyphosate applied to Bell's honeysuckle stumps in the fall resulted in 89% mortality. In an experiment with Amur honeysuckle (*Lonicera maackii* (Rupr.) Herder), Hartman and McCarthy (2004) also had excellent results with a 50% solution of glyphosate, which killed ≥94% of treated stems. However, Love and Anderson (2009) reported much lower efficacy of cut-stump glyphosate treatments on Morrow's honeysuckle. In terms of selectivity, application of herbicides to freshly cut honeysuckle stumps did not affect neighboring native plants (Kline 1981), a result consistent with our observations.

SUMMARY

Triclopyr was effective as a cut-stump or cut-stem treatment for controlling all three of these invasive plants, but did not control pale swallow-wort when sprayed on its foliage once a year. Glyphosate provided excellent control when applied to cut stumps of Oriental bittersweet and Morrow's honeysuckle, and as either a foliar spray or cut-stem treatment on pale swallow-wort. The combination of cutting and directed application of glyphosate or triclopyr will provide effective and environmentally sound management options for several invasive plant species.

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Table 3. Control of Morrow's honeysuckle with cut-stump treatments near Old Black Point Beach in East Lyme, Connecticut. Each treatment was applied to three shrubs. Shrubs were cut down just above the crown level on 17 August 2005. An herbicide treatment was painted on all cut surfaces of a given stump. Stumps were evaluated on 18 May 2006 for new sprouts and length of sprouts.

Treatment	Active ingredient	18 May 2006 Number of new sprouts per stump [a]	Mean sprout length (cm) [a]	Total length of sprouts per stump (m) [a]
Untreated (cut only / no herbicide)	-----	47.5 a	42.5 a	19.8 a
Roundup Pro: 10%	Glyphosate 4.10%	0.0 c	0.0 c	0.0 c
Roundup Pro: 50%	Glyphosate 20.50%	0.0 c	0.0 c	0.0 c
Garlon 3A: 10%	Triclopyr amine, 4.4%	12.0 b	11.8 bc	2.3 b
Garlon 3A: 50%	Triclopyr amine, 22.2%	0.8 c	3.8 c	0.1 c
Garlon 4: 10%	Triclopyr ester, 6.2%	14.8 b	17.5 b	2.9 b
Garlon 4: 50%	Triclopyr ester, 30.8%	4.8 bc	6.0 bc	0.6 c

[a] A square-root transformation of the data was conducted prior to analysis of variance. The actual data are presented in the table. Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test ($\alpha = 0.05$).

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