TREATING JAPANESE BARBERRY (*BERBERIS THUNBERGII*) DURING THE DORMANT SEASON

Jeffrey S. Ward and Scott C. Williams[1]

Abstract.—Japanese barberry (*Berberis thunbergii*) is an invasive shrub that can suppress forest regeneration and increase the risk of exposure to Lyme disease. In 2008, we began a study in central Connecticut to examine the efficacy of treating barberry infestations during the dormant season (October-March). Techniques included basal spray (triclopyr in oil) and clearing saw cutting with a wet-blade application of triclopyr. Dormant season techniques were compared with a glyphosate foliar spray applied in September. Foliar application resulted in a greater reduction of barberry cover (94 percent) compared to basal spray (84 percent) and wet-blade treatments (74 percent). Treatment effectiveness did not differ among months for either of the dormant season techniques. Labor costs did not differ among techniques, averaging 0.13 hours/acre/percent cover (i.e., 3.9 hours for a 1 acre stand with 30 percent barberry abundance). There was a large difference among treatments in amount of herbicide applied with 0.6 (±0.1), 1.4 (±0.4), and 2.8 (±0.4) ounces/acre/percent cover for wet-blade clearing saw, foliar spray, and basal spray applications, respectively. While not as effective as foliar spraying, wet-blade clearing saw and basal spray applications provide an opportunity to control barberry during the dormant season. Wet-blade clearing saw technique can reduce the amount of applied herbicide.

INTRODUCTION

Controlling invasive species is a challenge for forest managers throughout the central hardwood region (Barton et al. 2004, Bowker and Stringer 2011, McGill et al. 2008, Moser et al. 2008) and the greater United States (Miller et al. 2010, Webster et al. 2006). Japanese barberry (*Berberis thunbergii* DC) is classified as an invasive shrub in 20 states and 4 Canadian provinces. It is also established in another 11 states (Natural Resources Conservation Service 2011). Japanese barberry, or barberry hereafter, is primarily an invader of abandoned agricultural fields (DeGasperis and Motzkin 2007, Mosher et al. 2009). Once established in a forest, it can persist at low light levels (Harrington et al. 2004), and due to the lack of a seed bank (D'Appollonio 1997), spreads primarily by layering (DeGasperis and Motzkin 2007, Ehrenfeld 1999).

Invasive species such as barberry affect multiple trophic levels in forested ecosystems. Tree seedlings and native herbaceous plants can be inhibited by dense thickets of barberry and other invasive shrubs (Collier and Vankat 2002, Gorchov and Trisel 2003, Kourtev et al. 1998, Miller and Gorchov 2004). Barberry can directly alter soil biota and chemistry (Ehrenfeld et al. 2001), as well as soil structure and function (Kourtev et al. 2003). In addition, there can be indirect negative effects. Higher earthworm levels have been associated with barberry (Kourtev et al. 1999, Nuzzo et al. 2009) and honeysuckle (*Lonicera* spp.) (Madritch and Lindroth 2009). Increased earthworm populations have been linked to decreased litter layer depth and sequestered carbon (Bohlen et al. 2004), increased phosphorus leaching (Suarez et al. 2003), and salamander population declines (Maerz et al. 2009).

[1]Chief Scientist (JSW) and Assistant Scientist (SCW), Connecticut Agricultural Experiment Station, Department of Forestry and Horticulture, New Haven, CT 06511. SCW is corresponding author: to contact, email at jeffrey.ward@ct.gov.

Invasive shrub infestations can have indirect, adverse effects on human health by functioning as disease foci. Enhanced levels of blacklegged ticks (*Ixodes scapularis* Say) are associated with Japanese barberry infestations (Elias et al. 2006, Williams and Ward 2010). These ticks can transmit the causal agents of several diseases including Lyme disease (*Borrelia burgdorferi* Johnson, Schmid, Hyde, Steigerwalt, and Brenner), anaplasmosis (*Anaplasma phagocytophilum* Theiler), and human babesiosis (*Babesia microti* Franga) (Magnarelli et al. 2006). Higher densities of lone star ticks (*Amblyomma americanum* L.) infected with the causal agents of human ehrlichiosis (*Ehrlichia chaffeensis)* and *E. ewingii* were found in Amur honeysuckle (*Lonicera maackii* [Rupr.] Herder) infestations in Missouri (Allan et al. 2010). Lone star ticks can also transmit the agent of tularemia (*Francisella tularensis*) (Stafford 2007). Increased awareness of the link between invasive shrubs and diseases that affect humans and their pets should increase public support and funding for controlling invasive shrubs throughout the central hardwood region.

Our earlier research has shown that effective barberry control can be accomplished from late spring through early autumn by a variety of chemical (Ward et al. 2010) and nonchemical methods (Ward and Williams 2011). Because of environmental concerns and potential to damage nontarget species when using broadcast herbicide treatments, we developed a two-step process that reduces the amount of herbicide applied. The first step kills aboveground stems by cutting (clearing saw, mowing) or heat (prescribed fire, propane torches). The second step kills the much smaller new sprouts with herbicide (glyphosate, triclopyr) or directed heat using a propane torch. Two studies were established to compare the effectiveness and costs of different treatments to control invasive species (primarily barberry) from October through March (dormant season), extending the results of earlier studies that found that initial control of barberry can be completed from April through September. The specific objectives were: 1) compare wet-blade and basal spray applications during the dormant season, and 2) determine any restrictions to treating during the dormant season.

STUDY AREAS

In September 2008, the Bicentennial Pond study area was established at Schoolhouse Brook Town Park in Mansfield, CT to compare the effectiveness and costs of treatments to control invasive species (primarily barberry) during autumn and early winter. A second study area, Clover Mill, was established in a different section of the park in November 2008 to examine control alternatives during winter. Upper canopies of both study areas were mixed hardwoods (primarily *Quercus* and *Acer* with some *Fraxinus*, *Betula*, and *Carya*). The areas are managed as nature preserves with no sign of earlier harvesting.

METHODS

Design and Measurements

Autumn/Early Winter Treatments

Ten 66 ft by 66 ft subplots were established at Clover Mill for the autumn/early winter treatment study. Subplots were randomly assigned one of five treatments: foliar spray with glyphosate[2] (Prosecutor®, 1 percent solution) in September; wet-blade application with glyphosate (41 percent solution) in October; wet-blade application with triclopyr (Garlon 4®, 61 percent solution) in

[2]Mention of a product or company is for informational purposes only and does not constitute an endorsement by the Connecticut Agricultural Experiment Station.

October; basal bark application with triclopyr (2 percent solution in oil) in October; and basal bark application with triclopyr (2 percent solution in oil) in December. Two replications of each treatment were established at Clover Mill. Treatment details are given below.

Winter Treatments

The winter treatment study at Bicentennial Pond included two blocks of 12 subplots measuring 66 ft by 50 ft. Within each block, subplots were randomly assigned one of six initial treatments: January, February, or March basal bark application with triclopyr (Garlon 4®, 2 percent solution in oil) or January, February, or March wet-blade application with triclopyr (61 percent solution). Next, subplots within each block were randomly assigned one of two follow-up treatments: foliar spray with glyphosate (1 percent solution) or triclopyr (3 percent solution) in late May. This provided two replications of each initial/follow-up treatment combination at Bicentennial Pond.

Measurements

Within each subplot, percent barberry cover was measured utilizing a 5.4 ft^2 (0.25 m^2) sampling instrument which consisted of a 4 by 4 grid with which percent barberry cover was determined by presence/absence within each cell (Ward and Williams 2011). There were 12 sample points within each subplot for each treatment combination for a total of 504 sample points. Cover was sampled in August 2008 (pretreatment) and June 2009 (post-treatment) at Clover Mill, and in November 2008 (pretreatment), May 2009 (before follow-up treatment), and October 2009 (post-treatment) at Bicentennial Pond. The amount of herbicide applied to each subplot was recorded along with treatment time.

Treatments

Herbicide sprays were diluted per label instructions and were applied until wet to target foliage using hand-pressurized backpack sprayers (Solo® Model LCS-2, Newport News, VA). Only foliage or lower stems of invasive species (primarily barberry) were targeted to minimize impact to native species. A dye was added (1 percent solution) to the tank mixes to identify clumps that had not been treated and to prevent spraying clumps more than once. Basal and foliar applications were made with backpack sprayers. Wet-blade treatments were made using an applicator (Sprout-Less®, Madawaska, NB, Canada) that was attached to the bottom of a clearing saw blade (Model FS 450, Stihl®, Inc., Virginia Beach, VA). The applicator was designed to continually apply a thin film of herbicide to the bottom of the clearing saw blade.

Data analysis

Autumn/Early Winter Treatments

A one-factor (initial treatment) analysis of variance (ANOVA) with initial cover as a covariate was used to compare the influence of initial treatments on barberry cover at Clover Mill. All cover values were arcsine transformed prior to analysis (Zar 1974). Tukey's HSD test was used to test for significant differences among initial treatments. Differences were judged significant at $P < 0.05$.

Winter Treatments

A two-factor (application method, month) ANOVA with initial cover as a covariate was used to compare the influence of initial treatments on barberry cover at Bicentennial Pond. All cover

Table 1.—Mean (standard error) initial (August 2008) and final (June 2009) cover (percent) of Japanese barberry and invasives by treatment method at Clover Mill

			Japanese barberry		All invasives	
Application	Month	Herbicide	Aug08	Jun09	Aug08	Jun09
Foliar	September	glyphosate	16 (6) a†	1 (1) b	28 (13) a	8 (4) a
Wet-blade	October	glyphosate	25 (8) a	1 (0) b	40 (20) a	8 (4) a
Wet-blade	October	triclopyr	19 (4) a	8 (0) a	48 (15) a	14 (2) a
Basal spray	October	triclopyr	28 (26) a	3 (3) b	47 (23) a	17 (13) a
Basal spray	December	triclopyr	20 (13) a	9 (4) a	45 (31) a	12 (5) a

†Column values followed by the same letter were not significantly different at P ≤ 0.05.

Table 2.—Mean (standard error) initial (November 2008) and final (October 2009) cover (percent) of Japanese barberry and invasives by treatment method at Bicentennial Pond

	Japanese barberry			All invasives		
	Nov08	Jun09	Oct09	Nov08	Jun09	Oct09
Application method						
Wetblade	66 (5) a†	14 (3) a	1 (0) a	66 (5) a	18 (3) a	2 (0) a
Basal spray	71 (6) a	9 (3) b	1 (0) a	72 (6) a	10 (3) b	2 (1) a
Time of application						
January	65 (8) a	9 (2) a	1 (0) a	66 (8) a	11 (3) a	1 (0) a
February	64 (5) a	16 (4) b	1 (1) a	64 (5) a	21 (5) b	3 (1) a
March	76 (5) a	9 (3) a	1 (0) a	77 (5) a	9 (3) a	1 (0) a

†Column values followed by the same letter were not significantly different at P ≤ 0.05.

values were arcsine transformed prior to analysis (Zar 1974). Tukey's HSD test was used to test for significant differences among initial treatments. Differences were judged significant at $P < 0.05$.

RESULTS

Autumn/Early Winter Treatments

At Clover Mill, initial barberry cover averaged 22 (±5) percent and total invasive cover averaged 43 (±8) percent (Table 1). While not measured, barberry was 2-3 feet tall prior to treatment. Initial cover of both barberry (F=0.050, df=4, P=0.994) and total invasives (F=0.142, df=4, P=0.959) did not differ among treatments. Triclopyr applications using basal spray in December and wet-blade in October were less effective for controlling barberry than other treatments (F=40.333, df=4, P=0.002), averaging a 57 and 56 percent reduction, respectively. Control of all invasives averaged 72 percent and did not differ among treatments (F=0.360, df=4, P=0.827).

Winter Treatments

At Bicentennial Pond, initial barberry cover averaged 68 (±4) percent and total invasive cover averaged 69 (±4) percent (Table 2). While not measured, barberry was 3-4 feet tall prior to treatment. Initial cover of both barberry and total invasives did not differ between application methods (F=0.539, df=1, P=0.473) or among month of application (F=0.947, df=2, P=0.407). The interaction of application method by month of application was not significant (F=0.223, df=2, P=0.803), and a model without the interaction was used. Although both application methods reduced barberry cover, basal spray was more effective than the wet-blade at 88 vs. 79 percent, respectively (F=12.971, df=1, P=0.002). Effectiveness varied among month of application (F=7.486, df=2, P=0.004). January and March treatments reduced barberry cover more than February treatments at 89, 86, and 74 percent, respectively.

Frequency (the number of points which had at least one barberry or invasive species) averaged 90 percent prior to treatment of both basal spray and wet-blade subplots at Bicentennial Pond. Inevitably, some invasive plants were missed by initial treatments, especially small plants which were easily missed in the dormant, leaf-off conditions of winter and those buried under snow. Frequency of points with barberry averaged 37 and 55 percent after basal spray and wet-blade treatments, respectively.

Follow-up foliar spray applications of both glyphosate and triclopyr in late May after the initial winter treatments were highly effective in reducing barberry cover by 98-99 percent of original cover (Table 2). There was no difference between follow-up herbicides for controlling either barberry (F=0.738, df=1, P=0.401) or total invasive species (F=0.167, df=1, P=0.688). After the follow-up treatments, only 8 percent of points still had live barberry.

Costs

Labor costs (hours/acre) for initial treatments were correlated with pretreatment cover of invasive species, (r^2=0.51, P<0.001), but did not vary among application methods (F=2.005, df=2, P=0.152). Pooling application methods, the estimated time for initial treatment was 1.2 + 0.10 hours/acre/10 percent cover. For example, if the invasive cover was 25 percent, then the treatment time would be 1.2+ 0.1*(25/0.1)=3.7 hours/acre. It should be noted that these estimates do not include time required for travel and preparation time prior to arriving at the field.

The amount of herbicide used varied among application methods (F=25.205, df=2, P<0.001). Basal spraying required approximately 4.4 times more herbicide per acre than wet-blade applications (Fig. 1). Wet-blade application required 6.2 ounces/acre/10 percent cover, while basal and foliar sprays required 27.3 ounces/acre/10 percent cover. Herbicide used (ounces/acre) was correlated with pretreatment cover for both wet-blade (r^2=0.40, chi-square=5.8, df=1, P=0.016) and spray applications (r^2=0.44, chi-square=10.2, df=1, P=0.001).

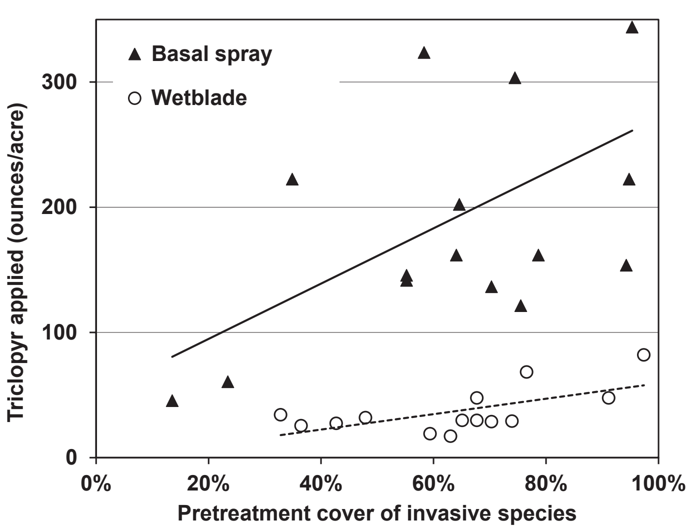

Figure 1.—Amount of herbicide applied (ounces per acre) by pretreatment cover of invasive woody species, primarily Japanese barberry, in central Connecticut.

DISCUSSION

Our results indicated that a program to effectively control Japanese barberry intermingled with other invasive species can be successful when initiated from October through March (Tables 1 and 2). Completing initial control during the dormant season can limit impact to nontarget species, especially herbaceous plants that have lost their leaves.

Combined with earlier work that reported good initial control from April through September (Ward et al. 2010), initial control of barberry can begin throughout the year using a variety of application methods and herbicides, including nonchemical control (Ward and Williams 2011). Therefore, the choice of which application method and herbicide to use as the initial treatment can be tailored to the unique attributes of a site and to the personnel available.

In our study, there was one period when treatment was not as effective. Both wet-blade and basal spray application were less effective in February than in January or March (Table 2). Temperatures were similar during treatment applications in January and February, ranging from 36-40 °F. There was little or no snow on the ground in January and March, but February treatments were applied when there was 6-8 inches of snow on the ground. Because of the snow depth, herbicide application may have been too high on stems to provide for adequate translocation to the root collar and below. In addition, numerous stems offset from vertical were mostly or completely hidden from treatment below the snow. We suggest dormant season treatments should not be attempted if snow depth is more than 1 or 2 inches.

Although effective, we cannot recommend basal spray as a treatment to control barberry for a couple of reasons. First, while basal applications can be an appropriate technique for invasive species with a few large stems (Bowker and Stringer 2011, Lowe et al. 2007, Pergams and Norton 2006), the high number of stems (often 20 or more) in a typical barberry clump (Ward et al. 2009), and the large number of layered stems can require a very high volume of herbicide to be applied on a per acre basis. Our estimate of the amount of herbicide needed (27.3 ounces/acre/10 percent cover) would actually exceed the label maximum (256 ounces per acre) if pretreatment cover exceeded 94 percent. Second, use of an oil (e.g., diesel) as a carrier may be restricted by state/local regulations because of the potential to contaminate groundwater, while commercial basal oils (e.g., methylated seed oils) can be quite expensive on a per acre basis when used in large volumes to treat a species with thousands of stems such as barberry.

Using a clearing saw with a centrifugal herbicide applicator (the wet-blade) was as effective as basal and foliar sprays (Tables 1 and 2) while requiring much less herbicide (Fig. 1), but also has limitations. We noticed that there were strips where all cut stems were dead and other strips where cut stems had new sprouts. We believe that the wet-blade could efficiently transfer herbicide to the blade for 30-45 minutes until the reservoir was about half full. A tank of gas for the clearing saw would last for an hour or more. The period between refilling the gas tank and refilling the wet-blade reservoir was when herbicide was not applied to cut stems. Therefore, until the technology is improved, we recommend pausing at 30 minute intervals to refill the herbicide reservoir and refuel the saw when using wet-blade treatments. Use of the herbicide applicator may be a modification not approved by the manufacture and might invalidate the warranty. In addition, the wet-blade herbicide applicator is quite expensive, costing $490 in 2010.

Other wet-blade studies have had mixed results. Wet-blade applications of diluted triclopyr did not provide effective control of a variety of hardwoods in Pennsylvania (Gover et al. 2002). Mortality of hazelnut (*Corylus cornuta* Marsh.), but not red maple (*Acer rubrum* L.), was increased using wet-blade application of glyphosate in Ontario (Smith et al. 2009). Kirdar and Ertekin (2009) reported wet-blade application of glyphosate provided excellent control of rhododendron (*Rhododendron ponticum* L.) in Turkey.

None of the methods examined in this or earlier studies (Ward and Williams 2011, Ward et al. 2010) provided complete control of invasive species. Eight percent of sample points had live barberry; many were small seedlings that would not survive more than a few years (Ehrenfeld 1999, Ward et al. 2010). While these small plants contribute little to cover, they have the potential to grow and re-infest the site. While it may be unrealistic to achieve complete, multi-year control, a more realistic goal is to provide adequate control to allow the development of desired native herbaceous plants and forest regeneration by periodically retreating the site to maintain invasives at low levels.

Because survival and growth of cut stems did not differ between preleafout and postleafout initial treatments (Ward et al. 2009), we recommend initial treatment during the dormant season when it is easier to see tripping hazards and where barberry is rooted, which would otherwise be hidden by foliage. Cooler temperatures during this period also increase comfort levels of operators wearing thick clothing as protection from barberry spines. Follow-up treatments can be started in late May (Table 2) or delayed until later in summer to minimize over spray (herbicide drift) damage to nontarget native plants (Ward et al. 2010). Biennial monitoring could be used to determine when additional treatments might be required to maintain invasives at levels consistent with management objectives.

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