Effects of Herbicide Concentration and Application Timing on the Control of Beech Root and Stump Sprouts Using the Cut-Stump Treatment

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ABSTRACT

Application costs and efficacy for two concentrations of herbicide and treatment time intervals were determined for cut-stump treatments applied to American beech (*Fagus grandifolia* Ehrh.) to control root and stump sprouts in central West Virginia. Glyphosate as Glypro™ (53.8 percent a.i.) was applied to the outer 2 inches of beech stumps from trees $\geq$6.0 inches in diameter at breast height within 0 to 1 and 3 to 4 hours after cutting. In addition, the effects on efficacy of using two concentrations of Glypro™ (50 and 100 percent) were also evaluated. This study demonstrated that a 50-percent solution of Glypro™ was just as effective as a 100-percent solution and that an applicator could wait up to 4 hours after stems had been cut before applying the herbicide, without reducing efficacy.

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COVER PHOTO: Applying the cut-stump treatment to a freshly cut beech stump using a back pack sprayer. All photos in this publication were taken by J. N. Kochenderfer.

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INTRODUCTION

Root sprouts of American beech (*Fagus grandifolia* Ehrh.) have been shown to interfere with the establishment and development of desirable shade-intolerant reproduction (Horsley 1991, Horsley and Bjorkbom 1983). Studies in central West Virginia indicated that more than 90 percent of advance beech regeneration originated from root sprouts (Kochenderfer et al. 2004, 2006). The development of dense thickets of beech root sprouts is often stimulated in stands affected by beech bark disease and harvesting of older beech trees (Houston 1975, Ostrofsky and McCormack 1986). Untreated plots had nearly twice as many live beech root sprouts after all beech stems larger than 6.0 inches in diameter at breast height (d.b.h.) were cut during September in a cut-stump study in central West Virginia (Kochenderfer et al. 2006). Widespread partial cutting and overstory mortality of beech caused by beech bark disease have led to the development of dense thickets of beech root sprouts in many stands with a beech component in West Virginia. Beech is more competitive under partial cutting regimes than under other cutting regimes and is practically immune to deer browsing (Tubbs and Houston 1990).

The cut-stump herbicide application method using a glyphosate herbicide has proven to be an effective way to control beech stump and root sprouts. Kochenderfer et al. (2006) demonstrated that glyphosate as Glypro™ (53.8 percent a.i.) herbicide was readily translocated from the surfaces of freshly cut beech stumps via parent root systems to attached live root sprouts. Some root sprouts located up to 45 ft away from 16- to 18-in. treated parent stumps were controlled. These researchers achieved complete control of stump sprouts and >90-percent control of beech root sprouts ≥1.0 ft tall to 5.9 in. d.b.h. by applying a 100-percent solution of Glypro™ within 1 hour after severing the beech stems, thereby controlling an average of 93 beech stems around each treated stump. Zedaker et al. (1987) achieved 69- to 98-percent control on various hardwood species after applying the cut-stump treatment to Piedmont hardwoods to control stump sprouting, using a 100-percent solution of glyphosate as Roundup™ that was usually applied immediately after cutting.

However, some issues not addressed in those studies are important to land managers applying the cut-stump treatment to beech. For example, the effects of using lower herbicide concentrations and increasing the time interval between cutting and application of herbicide to the cut-stump surfaces on treatment efficacy have important management implications. The Glypro™ herbicide label recommends applying a 50- to 100-percent solution to freshly cut surfaces immediately after cutting. Application of the cut-stump treatment within 4 hours after cutting, the sooner the better, is recommended to control stump sprouting of many species (U.S. Forest Service 1994). Using lower concentrations of herbicide reduces treatment costs and potential non-target impacts while extending the time between cutting and treatment can increase safety for applicators on active logging operations and simplify treatment applications.

This study was intended as a followup to the earlier cut-stump study by Kochenderfer et al. (2006) to address the effects of reducing herbicide concentrations and extending time intervals between cutting and herbicide application on treatment efficacy. While the cut-stump treatment has been shown to control both beech stump sprouting and root sprouts, the primary objective of this study was to evaluate the effects of two herbicide concentrations and application time intervals on root sprout efficacy.

METHODS

Study Area

The study was located on a northern hardwood site at an elevation of about 3,000 ft in central West Virginia near Kempton, Maryland, on property managed by Western Pocahontas Properties. American beech and red maple (*Acer rubrum* L.) were the most common overstory trees at the study site; beech root sprouts and striped maple (*Acer pensylvanicum* L.) were the most prevalent interfering understory plants.

Past partial harvests (the last one occurring about 20 years ago), beech bark disease, and preferential deer browsing have resulted in the development of a dense understory of beech root sprouts on the study area. Stand-size distribution of stems and basal area are shown in Table 1. Total stand basal area in trees 1.0 in. d.b.h. and larger averaged 86.0 ft^2/ac. Beech represented 41.7 percent of the total stand basal area at the study site. Basal area in the "other" species category (Table 1) averaged 44.3 ft^2/ac; red maple and black cherry (*Prunus serotina* Ehrh.) were the two dominant species in this category.

Design and Treatments

Twenty 0.3-ac treatment plots (114.3 ft by 114.3 ft) were established at the study site. Treatment plots included a 0.05-ac (46.7 by 46.7 ft) measurement plot centered within each treatment plot. This provided a 33.8-ft buffer around the measurement plots. Plots were located where numerous beech sprouts were present and 6 to 8 beech trees $\geq$6.0 in. d.b.h. were located on each measurement plot. Within each 0.05-ac measurement plot, all beech stems $\geq$1.0 ft tall were tagged. D.b.h. and species were recorded for each stem $\geq$1.0 in. diameter. Beech basal area in trees $\geq$6.0 in. d.b.h. ranged from 36.5 to 84.0 ft^2/ac on the measurement plots. Because of this large range in basal area, the 20 plots were divided into four blocks with similar basal areas to ensure a more even distribution of basal area across treatments. Mean block basal area ranged from 41.1 ft^2/ac (block 1) to 69.3 ft^2/ac (block 4). Then each of the five treatments was randomly selected and assigned to each one of the five plots within a block, yielding a randomized complete block design with five treatments replicated in four blocks. The five treatments in each block are listed below:

1) 50-percent solution of Glypro™ sprayed onto the outer 2 in. of cut stumps within 1 hour after the trees were cut.

2) 100-percent solution of Glypro™ sprayed onto the outer 2 in. of cut stumps within 1 hour after the trees were cut.

3) 50-percent solution of Glypro™ sprayed onto the outer 2 in. of cut stumps 3 to 4 hours after the trees were cut.

4) 100-percent solution of Glypro™ sprayed onto the outer 2 in. of cut stumps 3 to 4 hours after the trees were cut.

5) control-no herbicide treatment on cut stumps.

Beech trees $\geq$6.0 in. d.b.h. were also measured and tagged in the buffer area. All beech stems 6.0 in. d.b.h. and larger were felled and the appropriate treatment was applied to the stumps on all the 0.3-ac plots. The boles of trees cut on the plots were harvested after treatment, but care was taken to preserve the integrity of the plots by keeping logging machines off the plots. A laser surveyor set up on plot corners was used to determine the location of each treated stump.

The herbicide used in the treatments was glyphosate (N-(phosphonomethyl)) glycine as Glypro™ 53.8 percent). A plastic spray bottle calibrated to apply 0.9 ml per squirt was used to dispense 3.5 ml (0.12 fl oz) of solution per inch of stump diameter to the stump surfaces of the cut trees on the treated plots. Previous experience indicated that this amount of solution was sufficient to wet the outer 2-in. band around the stump surfaces. Accumulations of sawdust were wiped off the stumps before treatment. The diameter of each stump was recorded to determine the proper dosage of herbicide (number of squirts per stump). Application times for each stump and actual volumes of herbicide used per treatment plot also were recorded. These data were used to compute production rates and application costs. All plots were treated using two applications in mid-June 2003; the same applicator was used on each plot to apply the herbicide.

Efficacy Evaluations

The plots were evaluated in July 2004, about 12 months after treatment. A rating system, based on a visual estimation of crown control ranging from 1 to 7 (0 to 100 percent crown affected), was used to evaluate the efficacy of each treatment on individual trees (Kochenderfer et al. 2001, Memmer and Maass 1979). Two observers rated all trees on each plot. The mean ratings for each plot showed no discernible bias among observers, so the ratings were not adjusted. Trees with an efficacy rating of 5.0 or higher (75 percent crown necrotic) were considered controlled.

Table 1.–Treatment plot data showing average number of stems and basal area at the study site

Size class (in. d.b.h.)		Numbers of stems (no./ac)	Basal area (ft^2/ac)
<1.0			
	Beech	4,059	------
	Other	------	------
1.0-5.9			
	Beech	549	17.8
	Other	136	3.8
6.0-11.0			
	Beech	50	16.5
	Other	27	10.5
>11.0			
	Beech	9	7.4
	Other	22	30.0
Total beech		4,667	41.7
Total others		185	44.3
All species		4,852	86.0

All the tagged beech stems from ≥1.0 ft tall to 5.9 in. d.b.h. in the study were used to determine the efficacy of the cut-stump treatments, and all beech stumps were evaluated to determine the efficacy of these treatments on beech stump sprouting. Stumps with no stump sprouts were considered controlled. Treatment and block were considered fixed effects. The relationship between the different herbicide concentrations, treatment time intervals, and percentage of stems controlled by size class were analyzed using a one-way analysis of variance (Sall et al. 2001).

RESULTS AND DISCUSSION

Application Information and Cost

Average basal area and number of stumps treated per acre were similar for both herbicide concentrations (Table 2). Average stump diameter (10.8 in.) was identical for both herbicide treatments. Treatment time and volume of herbicide solution used were slightly higher for the 100-percent concentration treatment. These differences are probably due to the 100-percent Glypro™ solution being more viscous than the 50-percent solution, which made it harder to spray on the stump surfaces. Most of the cost difference between the two herbicide treatments can be attributed to chemical costs: the 100-percent Glypro™ treatment was approximately twice as expensive as the 50-percent treatment (Table 2). Application costs ($/ac), individual stump cost ($/stump), and basal area cost ($/ft^2) were all about twice as high for the 100-percent Glypro™ treatment as for the 50-percent treatment. The amount of herbicide solution applied per inch of stump diameter was similar, 3.7 ml for the 50- percent treatment and 3.9 ml for the 100-percent treatment.

Costs reported by Kochenderfer et al. (2006) ranged from $33 to $53/ac for applying the cut-stump treatment. The lower average application costs ($11.63 to $21.20 per acre) in this study (Table 2) can be attributed mainly to lower chemical cost resulting from the reduced price of Glypro™ herbicide, less basal area treated, and the lower concentration of herbicide used on about half of the treated stumps. The average application costs in this study compare favorably with the $15 to 20 per acre cost estimate for the least expensive chemicals used in a cut-stump treatment in Piedmont hardwoods (Zedaker et al. 1987).

Efficacy of Treatments

All four cut-stump treatments were effective in controlling beech root sprouts (Fig.1) in all size classes (Table 3). There were no significant differences between any of the herbicide treatments, but all the herbicide-treated plots were significantly different from the untreated plots. Control ranged from 89 to 92 percent for the ≥1.0-ft-tall to 6.0-ft-tall size class across all treatments. Treatment efficacy averaged 84 percent for stems >6.0 ft tall to 0.9 in. d.b.h. In the 1.0-in. d.b.h to 5.9-in. d.b.h. size class, root sprout control ranged from 70 to 88 percent across all treatments. On the untreated plots, control averaged only 1 percent across all size classes (Fig. 2). Nearly all the root sprout mortality on these plots can be attributed to felling damage.

The absence of a difference in efficacy between the two herbicide concentrations used in this study (Table 3) can probably be explained by referring to a dose-response curve like the one shown in Figure 3. The curve remains flat where no response is detectable from zero until a threshold is reached; it then rises sharply, implying that small changes in dosage cause large changes in toxicity. The curve continues to rise before leveling off when the maximum effect range is reached where increases in dosage result in no further increases in toxicity. These study results imply that both of the herbicide concentrations used in this study fell within the maximum effect range of the dosage curve where increased concentrations would not be expected to further increase efficacy.

The lack of a significant difference in efficacy between the two treatment time intervals can probably be attributed to moderate evaporation at the study site and the relatively small difference between treatment time intervals. Efficacy

Table 2.—Treatment plot cut-stump application data and treatment cost (based on $27.82 per gallon for Glypro™ herbicide and $10.00 per hour for labor)

Characteristic	50% Glypro™	100% Glypro™
Average basal area treated (ft^2/ac)	23.8	23.0
Beech stumps treated (number/ac)	53	54
Average stump diameter (in.)	10.8	10.8
Avg. treatment time per stump (sec.)	24	28
Amount of herbicide solution used (gal/ac)	0.58	0.61
Labor cost ($/ac)	3.56	4.23
Chemical cost ($/ac)	8.07	16.97
Application cost ($/ac)	11.63	21.20
Individual stump cost ($/stump)	0.22	0.39
Basal area cost ($/$ft^2$)	0.49	0.92

Figure 1.—Root sprout efficacy (99 percent) on a measurement plot treated with a 100-percent solution of Glypro™ 3 to 4 hours after cutting.

reductions of cut-stump treatments following delays in treatment after cutting of trees are usually attributed to reduced herbicide absorption caused by drying of stump surfaces. Meteorological data collected in the vicinity of the study site indicate that the treatments were applied under only moderate drying conditions. Relative humidity, temperature, and wind speed averaged 79 percent, 64 °F, and 3.6 miles per hour, respectively, between 8 a.m. and 5 p.m. at an exposed site during the 2-day treatment period in mid-June. Although evaporation is normally highest in June and July in the study area, it is typically less in small forest openings (Patric and Goswami 1968). Evaporation at ground level in a partially cut stand would be expected to be even lower and may have prevented stump surfaces from drying out enough in the 3- to 4-hour interval between cutting and treatment to impact efficacy.

We were somewhat concerned about the potential effectiveness of the cut-stump treatment on this study site because several overstory beech trees had already been removed in earlier partial cuts, thus stumps would not be available to treat and control root sprouts that had originated from them. This situation is often encountered in central Appalachian stands because many stands have been cut over at least once within the past 30 to 40 years and partial cutting is widespread. Fajvan et al. (1998) indicated that diameter-limit harvesting had been used on 80 percent of the stands

Table 3.—Initial number of beech stems/acre and percentage of stems controlled by cut-stump treatment, by size class

	Size class*					
	≥1.0-ft tall to 6.0-ft tall		>6.0-ft tall to 0.9-in. d.b.h.		1.0-in. d.b.h. to 5.9-in. d.b.h.	
Treatment	Initial beech stems	Percent of beech stems controlled	Initial beech stems	Percent of beech stems controlled	Initial beech stems	Percent of beech stems controlled
	(no./ac)	-----(%)------	(no./ac)	--------%-----	(no./ac)	-------%-----
1 Hour-100% Glypro™	390	92a	487	87a	165	88a
1 Hour-50% Glypro™	411	90a	457	78a	97	78a
3-4 Hour 100% Glypro™	341	91a	308	87a	98	80a
3-4 Hour 50% Glypro™	560	89a	277	84a	82	70a
Control	471	1b	357	1b	107	1b

*Means within size classes followed by the same letter are not significantly different at the 0.05 level (Experimentwise) using Tukey's HSD.

Figure 2.—An untreated measurement plot showing uncontrolled beech root sprouts and the development of new beech root sprouts at the end of the first growing season after cutting.

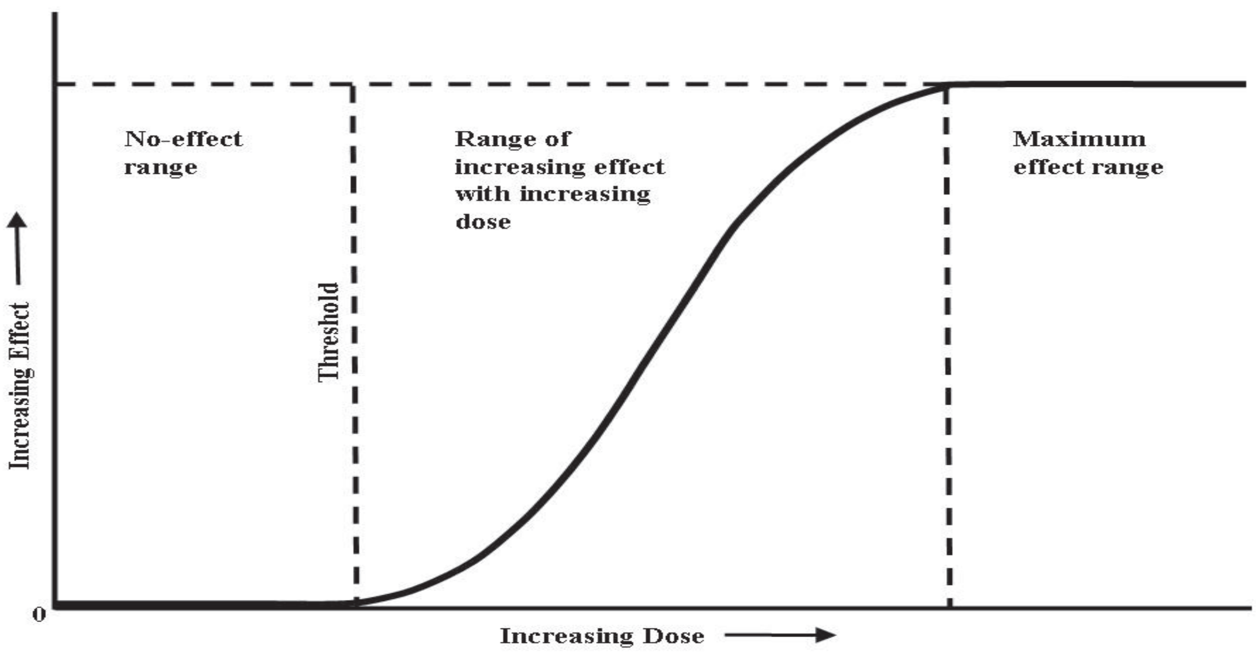

Figure 3.—A dose-response curve showing relationships between chemical toxicity and dosage. (From Ottoboni, 1991, used with permission)

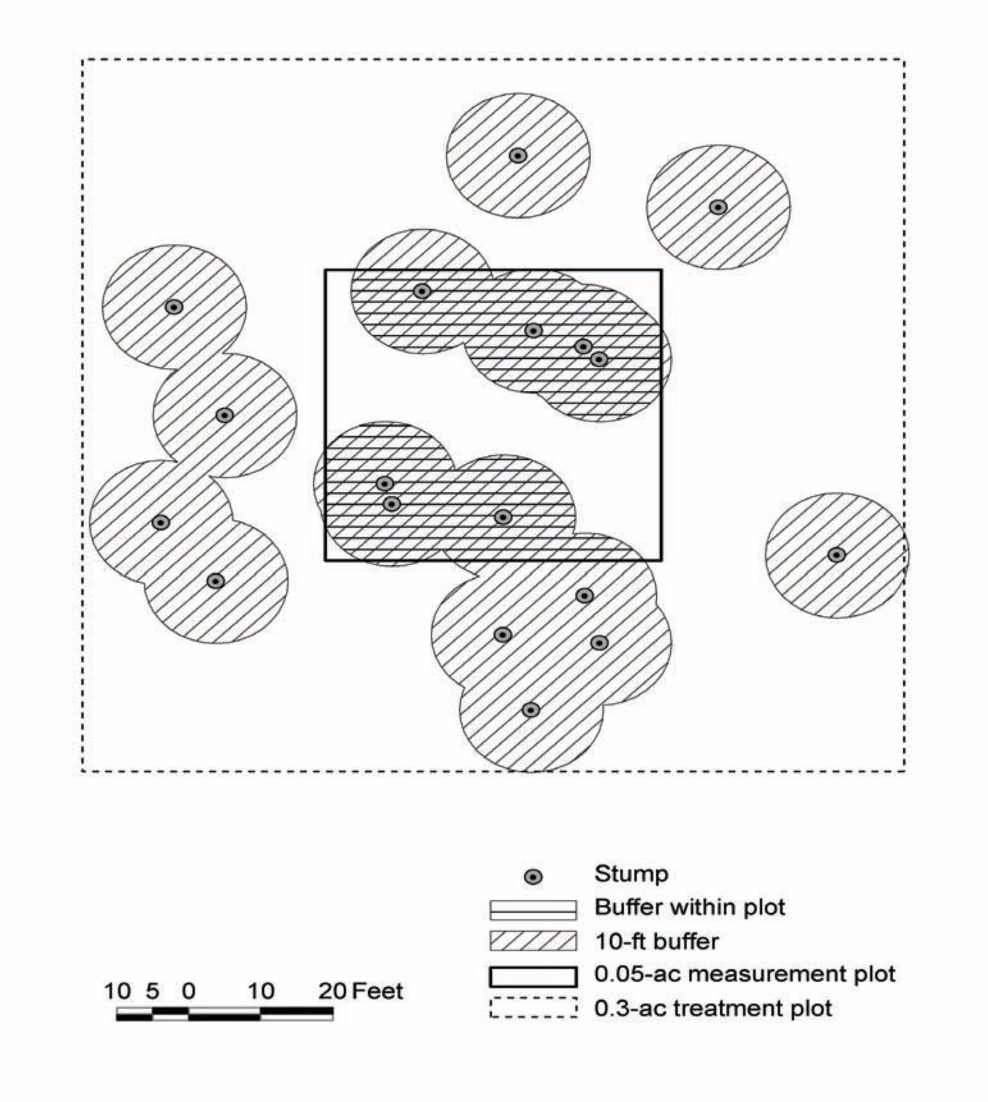

Figure 4.—A 0.3-ac treatment plot showing the distribution of treated beech stumps and the 10-ft-radius buffer zone around each stump. The 0.05-ac measurement plot had seven treated beech trees with an average d.b.h. of 9.4 in. (12.3-in. stump diameter) and an unbuffered area of 38 percent outside the buffer zone around each stump. This plot had an average efficacy of 85 percent across all size classes.

surveyed in West Virginia. All the plots had places where there were usually beech root sprouts but no close treatable stumps.

To explore some relationships between treated stump distribution and efficacy, the percentage of each measurement plot that was buffered was determined by plotting a 10-ft-radius circle around each treated stump (Fig. 4). Previous research by Kochenderfer et al. (2006) indicated that the cut-stump treatment applied to 10-in. beech stumps would have a very high efficacy within a 10-ft-radius zone (buffered area) around each parent stump. The distribution of treated stumps was not uniform on the plots. Treated stumps were often clustered with overlapping buffer areas that resulted in unbuffered areas that ranged from 34 to 66 percent on the measurement plots (Fig. 4). Plots with a low percentage of buffered area did not always have a corresponding lower efficacy. Root sprout efficacy averaged 85 percent across all the treated plots, ranging from 67 to 99 percent. Only two plots had efficacies lower than 75 percent. If unbuffered areas had no root sprouts, efficacy would not be affected. Also, the relatively high efficacy observed on these plots might indicate that the effective treatment range extended beyond 10 ft and that some root sprouts that originated from trees removed in earlier harvests had established root grafts with the treated trees, which made some of them susceptible to these cut-stump treatments. These results indicate that the cut-stump treatments used in this study can be effective in stands that have been subjected to earlier partial cuts if the stumps from at least 120 beech trees/ac with an average minimum d.b.h. of 7.4 in., which buffers at least 50 percent of the stand area, can be treated.

Kochenderfer et al. (2006) achieved greater than 90-percent control on beech root sprouts using a 100-percent solution of Glypro™ (53 percent a.i.). The higher efficacy they found can probably be attributed to treating more stumps per acre, an average of 81 compared to 53 stumps treated per acre in this study. Also, because average stump size was almost 3.0 in. larger in the earlier study, root sprout efficacy around individual stumps would be greater (Kochenderfer et al. 2006) and treatments were applied in September when efficacy of glyphosate herbicide treatments would be expected to be higher (Horsley and Bjorkbom 1983, Kochenderfer and Kochenderfer 2008).

Stump Sprouting

All four of the herbicide treatments eliminated stump sprouting on 100 percent of the treated stumps. Conversely, only 19 percent of the untreated stumps on the control plots failed to sprout. These results are consistent with Kochenderfer et al. (2006) who reported no stump sprouting after treating beech stumps with a 100-percent solution of Glypro™ while more than 90 percent of untreated stumps sprouted.

MANAGEMENT IMPLICATIONS

The cut-stump herbicide treatment is an effective treatment for the control of beech root sprouts. It gives land managers a target-specific, relatively low cost treatment that can be used to manually control beech stump and root sprouts on steep topography, on small ownerships, and in stands where mechanical broadcast spraying might not be feasible or compatible with silvicultural objectives. Using the lowest recommended label rate of 50-percent concentration of Glypro™ reduces chemical costs and potential non-target impacts, and it makes the treatment easier to apply. Increasing the time interval between cutting trees and applying the cut-stump treatment gives applicators greater flexibility and reduces the need for them to work in close proximity to logging crews. Longer time intervals will provide a safer work environment and make treatment applications more efficient. Further extension of the time interval between tree severing and stump treatment, without reducing efficacy, would be highly desirable. Additional herbicide trials are needed to determine if cut-stump treatment time intervals can be extended under conditions encountered in the central Appalachians. This study provides land managers with information that can be used to reduce the costs of applying the cut-stump treatment to control beech stump and root sprouts and increase the time interval between tree cutting and treatment without reducing treatment efficacy.

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Application costs and efficacy for two concentrations of herbicide and treatment time intervals were determined for cut-stump treatments applied to American beech (*Fagus grandifolia* Ehrh.) to control root and stump sprouts in central West Virginia. Glyphosate as Glypro™ (53.8 percent a.i.) was applied to the outer 2 inches of beech stumps from trees ≥6.0 inches in diameter at breast height within 0 to 1 and 3 to 4 hours after cutting. In addition, the effects on efficacy of using two concentrations of Glypro™ (50 and 100 percent) were also evaluated. This study demonstrated that a 50-percent solution of Glypro™ was just as effective as a 100-percent solution and that an applicator could wait up to 4 hours after stems had been cut before applying the herbicide, without reducing efficacy.

Key Words: herbicides, American beech, efficacy, cut-stump treatment, costs, hardwood release, glyphosate, silviculture

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