Controlling Beech Root and Stump Sprouts Using the Cut-Stump Treatment

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ABSTRACT: *Application costs and efficacy 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%) was applied to the outer 2 in. of beech stumps from trees >6.0-in. dbh within 1 hour after cutting. In addition to treatment plots, individual beech stumps were treated to determine mortality patterns. The treatments were applied in early September 2001 and evaluated 12 months after treatment. A rating system ranging from 1 to 7 (0 to 100% crown affected) based on visual estimates of symptoms was used to evaluate the efficacy of the treatments. Trees with a rating of 5 (75% crown control or greater) were considered controlled. After 12 months, more than 90% of beech root sprouts ≥1-ft tall to 5.9-in. dbh on treated plots were controlled. Complete control of stump sprouting also was achieved. An average of 93 beech stems was controlled around each treated stump. Mortality around treated stumps declined as the radial distance from stumps increased and stump size decreased. Average application cost (chemical and labor) ranged from $39.43 to 62.34 per acre depending on the basal area and number of stems treated. After two growing seasons, the number of beech root sprouts on more than 90% of the treated regeneration plots remained below levels considered as interfering according to guidelines for Allegheny hardwoods. This study demonstrated that herbicide is readily translocated from the surfaces of freshly cut beech stumps via parent root systems to attached live beech stems. The cut-stump method can be applied in areas where beech is the primary species interfering with the establishment and development of desirable regeneration. North. J. Appl. For. 23(3):155–165.*

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Large numbers of small American beech (*Fagus grandifolia* Ehrh.) stems often develop near larger beech trees. Although beech reproduces from both seed and root sprouts, reproduction is almost always by root sprouts (Tubbs and Houston 1990). A study in central West Virginia indicated that 97% of advance beech reproduction was of root-sprout origin (Kochenderfer et al. 2004). Held (1983) found that the presence of beech root sprouts varied greatly within the range of beech but that root sprouts were more prevalent in the northern and western limits of its range where climates were severe. A study in New York (Jones and Raynal 1988) indicated that all beech sprouts originated from callus tissue associated with wounds. They suggested that sprouting could be reduced by avoiding spring logging.

Studies have shown that dense understories of shade-tolerant species such as beech can interfere with establishment and development of desirable shade-intolerant reproduction (Horsley and Bjorkbom 1983, Horsley 1991). Beech thickets produce interfering layers of shade that prevent small seedlings of other species from developing on the forest floor. The development of beech reproduction is promoted by partial harvests and preferential deer browsing of other species (Tubbs and Houston 1990). Beech root sprouts also are stimulated by mortality and/or salvage harvesting of trees affected by beech bark disease (BBD), often resulting in the formation of dense thickets of beech sprouts (Houston 1975, Ostrofsky and McCormack 1986). BBD, which results from attack by the beech scale insect (*Cryptococcus fagisuga*) followed by the fungi (*Nectria coccinea* var. faginata), has killed beech trees from Maine to Pennsylvania

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(USDA Forest Service 2003). First detected in West Virginia in 1981, this disease now affects more than 2 million acres in parts of 12 counties (Haynes and Taylor 2002).

Species composition is a key consideration in vegetation management in Appalachian forests. Hardwood species have widely varying value as commercial products and as sources of wildlife food and habitat (Kochenderfer et al. 2001). Because each species contributes to the outputs available from a given stand, it is necessary to maintain species diversity to sustain the production of desired benefits from Appalachian forests (Miller and Kochenderfer 1998).

Herbicides are a versatile tool for manipulating species composition. However, they can be very expensive to apply to large numbers of individual stems. For example, in West Virginia, costs averaged \$253.48/ac for a basal spray treatment to control interfering understory vegetation that averaged 3,666 stems per ac and ranged in size from 2-ft tall to 5.9-in. dbh (Kochenderfer et al. 2004). Zedaker (1986) found that basal sprays were most applicable when the number of stems to be treated was <1,000 ac, and recommended directed foliar sprays when stems are <2.0-in. dbh, <20-ft tall, and exceed 2000 stems/ac. Mechanical foliar spray treatments are effective in controlling understories of interfering vegetation in Allegheny hardwood stands (e.g., Horsley 1991), but this application method has not gained wide acceptance in other regions of the Appalachians. Economic considerations, steep topography, and a reluctance to use broadcast application of herbicides probably have influenced the adoption of this technology.

The cut-stump treatment is an alternative to treating numerous individual stems where larger beech trees will be harvested and control of an existing understory of small beech sprouts is the management objective. This application method is target-specific, applicable to small ownerships, and easy to apply. It entails applying herbicide to the cambium layer of freshly cut stumps. A small spray bottle or a portable sprayer is used. In this article we present information on production rates, application costs, and efficacy of the cut-stump treatment as applied to beech stumps to control sprouting and beech root sprouts <6.0-in. dbh in two Appalachian forest stands.

Methods

Study Area

Treatments were applied in two northern hardwood sites at an elevation of approximately 3,000 ft in central West Virginia. One site is near the community of Webster Springs, on property managed by Pardee & Curtin Lumber Company. The second site is near Bayard, approximately 70 miles to the northeast on property managed by Western Pocahontas Properties. American beech and red maple (*Acer rubrum* L.) were the most common overstory trees whereas beech root sprouts and striped maple (*Acer pennsylvanicum* L.) were the most prevalent interfering understory plants at both study sites.

At Webster Springs, red maple and black cherry (*Prunus serotina* Ehrh.) occupied 26% and 1.0% of stand basal area, respectively. Old stumps indicated that black cherry was more common on this site in the past. Cross sections from large fire cherry (*Prunus pensylvanica* L.f.) indicated a partial harvest in 1950, and other evidence suggests that a high proportion of large beech trees were left in the residual stand. This site is on a well-drained ridge where beech is uniformly distributed.

At Bayard, red maple and black cherry represented 28% and 19% of total stand basal area, respectively. This site was partially harvested in the early 1990s, which included the removal of some beech, and portions of this site are somewhat poorly drained.

Past harvests at both sites have resulted in the development of a dense understory of beech root sprouts. Stand-size distribution of beech stems and basal area are shown in Table 1. More than 95% of the beech stems at both study sites were in the <1.0 in. size class, reflecting the large number of beech root sprouts at both study sites. Total stand beech basal area in trees 1.0-in. dbh and larger averaged 76.8 ft^2/ac and 46.2 ft^2/ac at Webster Springs and Bayard, respectively. Beech represented 62% of the total stand basal area at Webster Springs and 46% at Bayard. A higher proportion of beech basal area (73%) was concentrated in the >11.0-in. dbh class at Webster Springs. Basal area in the other species category (Table 1) averaged 47.2 ft^2/ac at Webster Springs and 54.9 ft^2/ac at Bayard. Red maple was the dominant species in this category at both sites.

Design and Treatments

Two treatments were distributed randomly among eight 0.3-ac plots (114.3 ft × 114.3 ft square) at each study site. All beech stems 6.0-in. dbh and larger were felled on all 0.3-ac plots. Cut trees were left to preserve the integrity of the sites. The two treatments were: 1) control—no herbicide treatment on cut stumps and 2) cut-stump treatment—spraying the outer 2-in. of cut stumps with herbicide. Treatment plots included 0.05-ac (46.7 ft × 46.7 ft) measurement plots centered within each treatment plot. This provided a 33.8-ft buffer around the measurement plots. Plots were

Table 1. Average number of stems and basal area for the study sites.

Size class (in.)	Webster Springs		Bayard	
	Numbers of stems (no./ac)	Basal area (ft^2/ac)	Numbers of stems (no./ac)	Basal area (ft^2/ac)
<1.0				
Beech	5,750		7,940	
Other				
1.0–5.9				
Beech	210	5.2	213	9.9
Other	185	4.5	25	0.5
6.0–11.0				
Beech	35	15.4	50	19.1
Other	25	10.0	28	14.3
>11.0				
Beech	45	56.2	19	17.2
Other	20	32.7	35	40.1
Total beech	6,040	76.8	8,222	46.2
Total others	230	47.2	88	54.9
All species	6,270	124.0	8,310	101.1

located where numerous beech root sprouts were present and at least six beech trees >6.0-in. dbh would be located in each measurement plot. Within each 0.05-ac measurement plot, all beech stems >1.0-ft tall were tagged. Dbh and species were recorded for each stem >1.0-in. dbh. Nine permanent milacre plots were established on each measurement plot to monitor reproduction and changes in ground cover. Stem counts by species were recorded by height class for all stems up to 0.9-in. dbh. Ground cover percentages were estimated to the nearest 5%, initial measurements were taken on all plots before treatment. Milacre plots were remeasured at 1- and 2-year intervals after treatment. Beech regeneration was classified as being of root sprout origin on the basis of appearance. The most common characteristic was the occurrence of multiple stems originating at the same location. Beech root sprouts originating from the same point were counted as one stem.

A 100% solution of glyphosate [*N*-(phosphonomethyl) glycine as Glypro 53.8%] was used in the cut-stump applications. A plastic spray bottle calibrated to apply 0.9 ml per squirt was used to dispense 0.12 fl oz (3.5 ml) of solution per in. of stump diameter. 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 plot also were recorded. These data were used to compute production rates and application costs. All stumps were treated within 1 hour of severing. Sawdust was brushed off the stumps before treatment. All plots were treated in early September 2001; the same applicator was used on each plot to apply the herbicide. Two applicators were used to apply the treatments.

Efficacy Evaluations

The plots were evaluated in late August 2002, 12 months after treatment. A rating system, based on a visual estimation of crown control, ranging from 1 to 7 (0 to 100% crown affected) was used to evaluate the efficacy of each treatment (Memmer and Maass 1979, Kochenderfer et al. 2001). 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% crown necrotic) were considered as controlled.

All of the tagged beech stems from 1.0-ft tall to 5.9-in. dbh 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 as controlled. Treatment effects were analyzed using the nonparametric Wilcoxon rank-sum one-tailed test because of the lack of normality in the distribution of the data (Adler and Roessler 1977).

Individual Stump Treatment

At each study site, three beech stumps of different size located away from the plots were treated to determine mortality patterns and efficacy associated with individual trees. Beech trees in three diameter classes, approximately 6-, 10-, and 14-in. dbh, were cut and treated at each site by the same procedures used on the fixed area plots. All dead beech seedlings and saplings, within a 50-ft radius of each tree were removed before treatment; only live beech stems were left. An 80-ft spacing was maintained between treated stumps to avoid overlap.

One year after treatment, all beech stems at least 1-ft tall were tallied and efficacy was evaluated by two observers. A laser surveyor set up over each treated beech stump was used to determine azimuths and distances of each stem at least 1-ft tall in a circle encompassing all the mortality around each stem. These data were plotted to determine mortality patterns and to compute the average percentage of root sprouts controlled by 5-ft radial increments from treated stumps.

Results and Discussion

Application Information and Cost

Average basal area treated ranged from 81.8 ft^2/ac at Webster Springs to 37.1 ft^2/ac at Bayard (Table 2). The number of stumps treated also was greater at Webster Springs averaging 92/ac as opposed to 70/ac at Bayard. The cost per ft^2 of basal area treated averaged \$0.76/ft^2 at Webster Springs and \$1.06/ft^2 at Bayard (Table 2). Total treatment costs per ac were 58% higher at Webster Springs (\$62.34/ac) than at Bayard (\$39.43/ac). Chemicals accounted for approximately 85% of the application cost at both study sites. The amount of chemical applied per in. of stump diameter was 4.1 ml at Webster Springs and 4.3 ml at Bayard, this was higher than the dosage rate of 3.5 ml per in. of stump diameter intended and can mainly be attributed to applicator error. The primary reason for the higher application cost at Webster Springs was the greater basal area treated at that site. The average stump diameter was 3.1 in. smaller at Bayard. These factors resulted in 60% more chemical being used at Webster Springs (Table 2).

Zedaker et al. (1987) projected costs of \$15 to \$20/ac for applying cut-stump treatments to the cambial area of various hardwoods on the Piedmont of Virginia to control stump sprouts. This projection was based on the use of a variety of herbicides including Roundup, which has the same active ingredient (glyphosate) as Glypro. During growing season treatments in that study, only 0.64 gallon of

Table 2. Cut-stump application data and treatment cost (based on \$33.21 per gallon for Glypro herbicide and \$10.00 per hour for labor).

Characteristic	Webster Springs	Bayard
Basal area treated (ft^2/ac)	81.8	37.1
Beech stumps treated (number/ac)	92	70
Average stump diameter (in.)	15.2	12.1
Avg. treatment time per stump (seconds)	36	32
Amount of herbicide used (gallon/ac)	1.6	1.0
Labor cost (\$/ac)	9.20	6.22
Chemical cost (\$/ac)	53.14	33.21
Application cost(\$/ac)	62.34	39.43
(\$/ft^2 of basal area)	0.76	1.06
(\$/100 stems controlled)	1.08	0.42

herbicide was used per 100 ft^2 of basal area treated compared to 2.20 gallons used in this study. Maximum recommended dosages of herbicide were used in this study because study objectives were to control both stump sprouts and numerous root sprouts that often were a considerable distance from the treated stumps.

The cut-stump treatment is cost-effective because numerous stems can be controlled around each treated stump. An average of 93 beech stems was controlled around each stump treated (Table 3). The cut-stump treatment applied in conjunction with timber harvesting is more cost-effective than basal spraying for controlling numerous small understory beech stems. The cost per 100 stems controlled in this study ranged from $1.08 at Webster Springs to $0.42 at the Bayard (Table 2). By contrast, Kochenderfer et al. (2004) reported a cost of $7.00/100 stems for basal spraying.

Efficacy of Treatments by Size Class

The cut-stump treatment using 100% Glypro was effective in controlling beech root sprouts in all size classes. In the 1.0- to 6.0-ft tall size class, control ranged from 90 to 96% on the treated plots (Table 3). For stems >6.0-ft to 0.9-in. dbh control exceeded 96% at both sites. Treatment efficacy averaged 92% for stems 1.0-in. dbh to 5.9-in. dbh. Efficacy was low on control plots across all size classes, averaging 3% at Webster Springs and <1.0% at Bayard. Nearly all mortality on control plots was attributed to felling damage. The higher efficacy on the control plots at Webster Springs can be attributed to more felling damage because of the increased number of large sawtimber-size beech stems on the plots.

Kochenderfer et al. (2004) achieved 52% control of beech root sprouts when all beech stems >5.9-in. dbh were injected with a 50% solution of glyphosate, as Accord (41.5%). The observed increase in efficacy of the cut-stump treatment on root sprouts probably can be attributed to the removal of a large herbicide sink when trees >6.0-in. dbh were cut, thus making more herbicide available for translocation to attached root sprouts. In the injection treatment, the actively growing parts of the injected trees would have been the primary herbicide sink in the stems >6.0 in., and most of the herbicide probably was held in these larger stems. Control was greater in the cut-stump treatment because, root sprouts <6.0-in. dbh became the site of most activity on the root system after the larger stems were cut. Herbicide tends to go from source to sink, that is the herbicide goes from point of application to site of action, i.e., where herbicides exert toxicity within the plant (Anderson 1996). The site of activity for glyphosate is the most active growing parts of the plant, i.e., cambium and buds. Although the larger beech trees may look like individual stems, they remain connected to roots of parent trees and perhaps by root grafts to other beech stems, forming large connected plant systems. Because all of these individual stems are connected functionally, the herbicide is probably translocated through the xylem to root sprouts or grafted stems once the parent stem is severed because herbicides tend to migrate to the most active regions of plants (Anderson 1996). Bormann (1966) noted that crown death in treated white pine (*Pinus strobus* L.) must have occurred before herbicide was drawn to untreated trees through root grafts. Graham (1959) concluded that the rate at which a dye solution moved from cut stumps through root grafts to intact white pine probably reflected the transpiration rate of the intact trees. The increased light after overstory removal probably stimulated the metabolism and transpiration of the beech root sprouts, further increasing herbicide gradients toward root sprouts. The herbicide treats all connected beech stems as if they were a single plant.

Stump Sprouting

The cut-stump treatment eliminated stump sprouting on 100% of the treated stumps at both sites. Conversely, only 9% of the untreated stumps at Webster Springs and 7% at Bayard failed to sprout on the untreated plots. Although beech does not sprout vigorously from larger stumps (Tubbs and Houston 1990), stump sprouts from beech can become large enough that they interfere with desirable regeneration.

Treatment Effects on Understory Composition

At both study sites there was a significant difference (alpha = 0.05) in the percentage of beech ground cover between treated and untreated plots 2 years after treatment (Figure 1). On the treated plots, the average percentage of beech ground cover decreased from 56 to 1% at Webster Springs and from 51 to 2% at Bayard 2 years after the cut-stump treatment. During the same period, beech ground cover on untreated plots declined by 6% at Webster Springs and by 3% at Bayard.

Table 3. Initial number of beech stems/ac 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. dbh		1.0-in. dbh to 5.9-in. dbh	
Treatment	Initial beech stems (no./ac)	Percent of beech stems controlled (%)	Initial beech stems (no./ac)	Percent of beech stems controlled (%)	Initial beech stems (no./ac)	Percent of beech stems controlled (%)
Webster Springs						
Control	3,675	2	1,785	3	225	3
Treated	4,035	90[a]	2,005	96[a]	200	92[a]
Bayard						
Control	5,830	1	470	0	240	0
Treated	8,890	96[a]	700	98[a]	185	92[a]

[a] Treated significantly different from control at $\alpha = 0.05$ (Wilcoxon rank-sum one-tailed test).

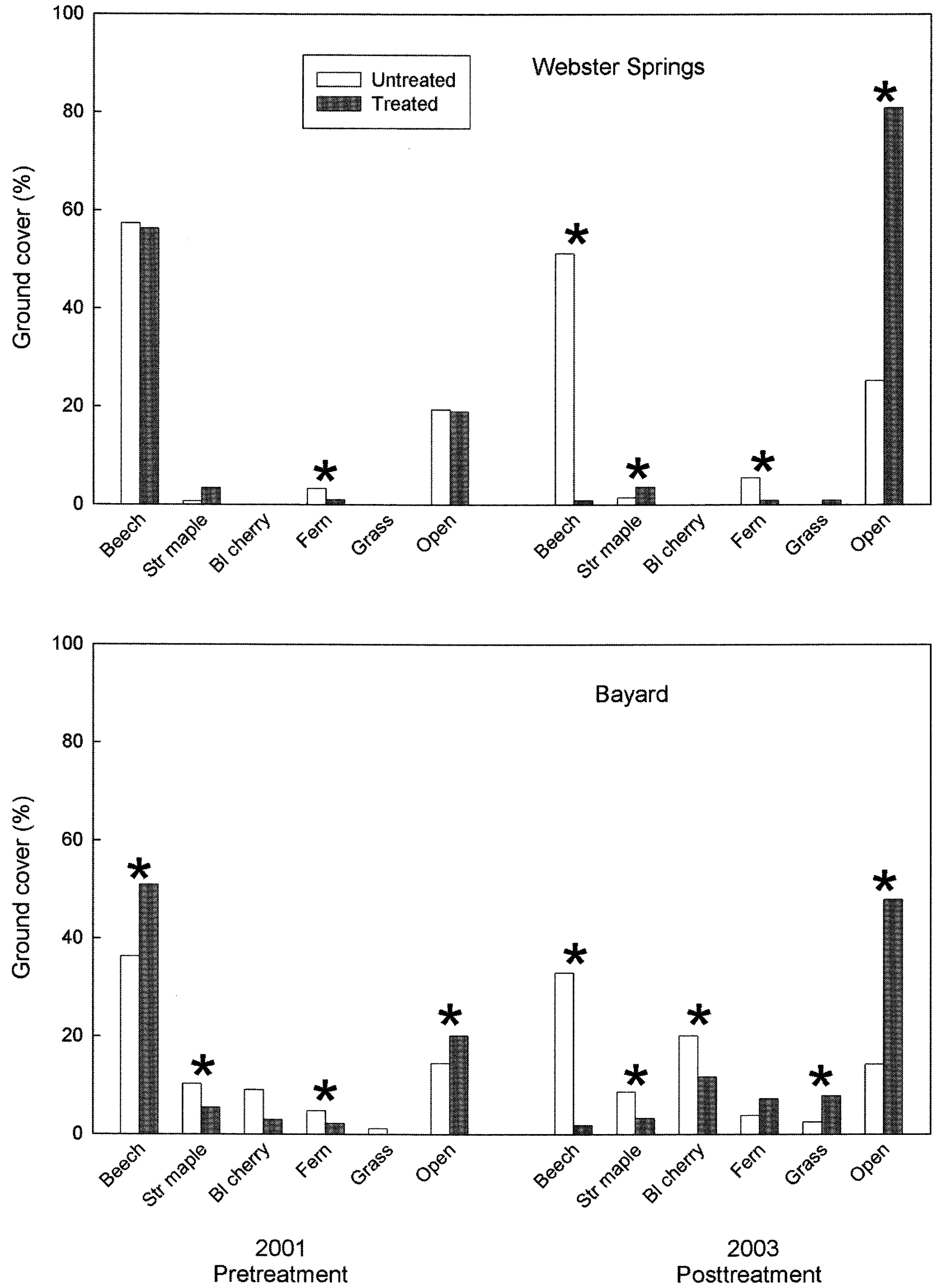

Figure 1. Ground cover mean percentages for selected classes on the untreated and treated plots at Webster Springs and Bayard. *Untreated versus treated significantly different at alpha equal to 0.05 (Wilcoxon rank-sum one-tailed test).

Declines in beech ground cover resulted in significant differences in the amount of open area between treated and untreated plots at both sites. Two years after treatment, the amount of open area increased from 19 to 81% at Webster Springs and from 20 to 48% at Bayard on the treated plots. Groundcover percentages of fern at both sites and striped maple at Bayard were significantly higher on untreated plots, before treatment. Fern and grass cover increased on most of the plots 2 years after treatment. There were substantial increases in grass cover at the somewhat poorly drained Bayard site. Marquis (1979) also found that fern and grass cover both increased after cutting, particularly on poorly drained soils.

Because of a heavy seed crop in the fall of 2000, there were large numbers of small beech seedlings (<0.5-ft tall) on both sites when the study was established in August 2001. Milacre plot data indicated an average of 34,458 and 2,097 beech seedlings/ac present before treatment at Webster Springs and Bayard, respectively (Table 4). The higher number of beech seedlings at Webster Springs probably can be attributed to the higher beech basal area and larger beech trees that produced more seed. Houston (2001) also found a correlation between high beech basal areas and large numbers of beech seedlings. However, the number of beech seedlings decreased substantially within 2 years, declining by 83% on untreated plots and by nearly 91% on treated plots at both sites. This dramatic decline in the number of beech seedlings did not result from the cut-stump treatment because the decrease was observed on both treated and untreated plots. The seedlings could not have been exposed to the herbicide because glyphosate, the active ingredient in Glypro, has no soil activity (Weed Science Society of America 2002). The increased light created by cutting every beech overstory tree >6.0-in. dbh on both the treated and untreated plots and eliminating more than 90% of the understory beech on the treated plots is a more likely explanation for the beech seedling mortality observed in this study. In Maine, Houston (2001) also found that summer clearcutting greatly reduced the number of existing beech seedlings, favoring the development of less shade-tolerant species. This is consistent with the herbicide efficacy data obtained in this study that showed that >90% of the beech >1-ft tall were controlled by the cut-stump treatment, and that most of the advanced beech regeneration was of root sprout origin. Although good beech seed crops are produced at intervals of 2 to 8 years (USDA 1974), these results suggest that beech seedlings fail to develop into advance regeneration and do not play a significant role in beech regeneration on either study site.

The number of beech root sprouts observed on the treated milacre plot declined by 86% at Webster Springs and by 89% at Bayard 2 years after treatment (Table 4). This result reflects the high efficacy of the cut-stump treatment. Ostrofsky and McCormack (1986) recommended waiting more than one growing season after treatment before assessing chemical efficacy because some sprouts developing from roots deeper in the soil might require additional time to emerge. Between years 1 and 2 after treatment, the number of root sprouts on treated plots increased by 3% at Webster Springs and declined by 17% at Bayard. This lack of sprout development on the treated plots indicates that almost complete control of beech root systems was obtained by this treatment. These increases probably resulted from the increased amount of light on adventitious buds and/or root injury incurred when the beech trees were felled.

Table 4. Number of beech seedlings and root sprouts per acre at Webster Springs and Bayard.

Origin	Treatment	Measurement period: Pre-treatment	Year 1	Year 2
Webster Springs				
Seedlings	Control	31,944	7,973[a]	5,583[a]
	Treated	36,972	3,639[a,b]	2,916[a]
Root sprouts	Control	7,251	23,083[a]	16,860[a]
	Treated	7,388	1,029[a,b]	1,056[a,b]
Bayard				
Seedlings	Control	3,000	1,139[a]	500[a]
	Treated	1,194[b]	333	333
Root sprouts	Control	6,000	10,694[a]	11,499[a]
	Treated	10,390	1,444[a,b]	1,194[a,b]

[a] Year 1 or Year 2 significantly different from pretreatment at $\alpha = 0.05$ (Wilcoxon rank-sum one-tailed test).
[b] Treated significantly different from control at $\alpha = 0.05$ by origin and measurement period (Wilcoxon rank-sum one-tailed test).

Cutting all beech stems larger than 6-in. dbh stimulated the development of root sprouts on the untreated plots. Two years after cutting, the number of beech root sprouts more than doubled on the untreated plots at Webster Springs and increased by 92% at Bayard. These results are consistent with those of Ostrofsky and McCormack (1986), who reported a doubling in the number of beech root sprouts on untreated plots 2 years after a shelterwood harvest in Maine. In this study, extra care was taken to avoid disturbing the plots as felled trees were left in place. By contrast, Ostrofsky and McCormack (1986) used cable skidders to remove merchantable beech stems. Houston (2001) concluded harvest treatments that caused the most disturbance generated the most root sprouts. He attributed the root sprout increase to root injury and increased light from tree cutting. Houston suggested that even a minor disturbance for example, stepping on roots, is sufficient to trigger root sprouting in beech.

Guidelines developed by Marquis et al. (1992) were used to evaluate the effectiveness of the cut-stump treatments in controlling woody interfering plants. In these guidelines, stems less than 1-ft tall are counted as one stem whereas larger stems are counted twice. Six-ft radius plots are considered to have interference if they contain ≥12 stems of undesirable species such as beech or striped maple. In addition, if ≥30% of plots have interference, successful desirable regeneration is unlikely. The percentage of 6-ft radius plots that meet these criteria for beech seedlings, beech root sprouts, and striped maple is shown in Table 5.

Stem counts of beech and striped maple were increased to conform to a 6-ft radius plot. Beech seedlings did not interfere at Bayard on the treated or untreated plots 2 years after treatment. At Webster Springs 100% of all plots had ≥12 beech seedlings before cutting, but after 2 years, there were ≥12 seedlings on only 22% of the treated plots and 44% of the untreated plots. The survival trend and size of the beech seedlings, most of which are <0.5-ft tall, indicate that these beech seedlings probably would be a minor factor in interfering with the establishment of desirable regeneration for this type of treatment. The cut-stump treatment reduced the percentage of plots interfered with by beech root sprouts from 78 to 11% at Webster Springs and from 83 to 11% at Bayard within 1 year after treatment. After year 2, the percentage of treated plots interfered with at Webster Springs had dropped to 6 and to 8 at Bayard. The percentage of untreated 6-ft radius plots with ≥12 interfering stems increased at both sites the first year after treatment. After 2 years, 100% of the untreated plots at Webster Springs and

Table 5. Percent of treated and untreated 6-ft radius[a] plots that meet the interference criteria of having at least 12 stems of interfering tree species. Stems larger than 1.0-ft tall count double.

	Beech seedlings			Beech root sprouts			Striped maple			Beech root sprouts and striped maple		
Plot type	2001[b]	2002	2003	2001[b]	2002	2003	2001[b]	2002	2003	2001[b]	2002	2003
Webster Springs												
Treated	100	39[c]	22[c]	78	11[c,d]	6[c,d]	22	22	31	100	58[c,d]	58[c,d]
Control	100	56[c]	44[c]	78	94	100[c]	6	33	31	100	100	100
Bayard												
Treated	6	0	0	83	11[c,d]	8[c,d]	25	31[d]	28	97	44[c,d]	53[d]
Control	19	3	0[c]	75	86	83	36	56	53	92	97	100

[a] Milacre data were adjusted to reflect equivalent counts on 6-ft radius plots.
[b] Pretreatment data.
[c] 2002 or 2003 significantly different from 2001 (pretreatment) at $\alpha = 0.05$ (Wilcoxon rank-sum one-tailed test).
[d] Treated significantly different from control at $\alpha = 0.05$ by plot type and year (Wilcoxon rank-sum one-tailed test).

83% of the untreated plots at Bayard still had interference from beech root sprouts.

Striped maple, which also can interfere with the successful regeneration of desirable hardwoods (Horsely and Bjorkbom 1983), was present at both sites. At Webster Springs, 31% of all plots had >12 striped maple stems 2 years after treatment. At Bayard, 28% of the treated and 53% of the untreated 6-ft radius plots had ≥12 interfering striped maple 2 years after treatment. When the beech root sprouts and striped maple were combined, none of the treatments at either site had <30% of the 6-ft radius plots with <12 interfering stems. However 100% of the untreated plots met the interference criteria compared to approximately half of the treated plots (Table 5).

Treatment Efficacy on Individual Trees

The percentage of root sprouts controlled around individual stumps by 5-ft increments is shown in Figure 2. Control was strongly correlated with stump size; as stump diameter increased, so did the effective range of root sprout control. Beech stumps with a diameter of 5.1- to 5.7-in. controlled beech root sprouts as far as 10 ft from the stump, but root sprout control dropped dramatically to 30% 10 to 15 ft from the treated stump. Nearly every root sprout was controlled within 10 ft of treated stumps 9.9 to 11.6 in. in diameter. The percentage of root sprouts controlled in this size class dropped to 80 between 10 to 15 ft and then declined sharply to 36 at 15 to 20 ft. Control was most effective around the larger 15.7- to 18-in.-diameter treated stumps. Nearly all of the root sprouts were controlled within 15 ft of the stumps. Control dropped to 60% at 15 to 25 ft and nearly 50% of the beech root sprouts were controlled 30 ft from the treated stumps. The percentage of root sprouts controlled decreased sharply after that, but some root sprouts were controlled 40 to 45 ft from the treated stump. These results are consistent with those of Jones and Raynal (1986), who reported that most beech sprouts were within 26.2 ft of parent stems, and that the mean distance of root sprouts from parent stems was greatest for large trees.

Mortality patterns around individual stumps are shown in Figure 3. Mortality was not distributed evenly around individual trees but tended to be irregular. It was concentrated and extended further in some directions than in others from parent stumps. Mortality around the smaller stumps followed a general radial pattern, decreasing as distance from the treated stumps increased. On larger stumps, the same trend was evident but an additional treatment effect was observed where large uncut beech were near treated stumps. Larger uncut beech near individual cut stumps seemed to act as pumps that drew the herbicide to them. As a result, the herbicide not only controlled the large uncut trees but also controlled large numbers of small root spouts around the larger trees and the parent stump. In some areas beech trees up to 16.8-in. dbh growing nearly 30 ft from treated stumps were controlled. This phenomenon may have contributed to the irregular pattern of control observed around the larger stumps, but the irregular distribution of the roots themselves around individual trees and perhaps root grafting probably exerted the most influence on mortality patterns.

The relative importance of root sprouts and grafted trees in stimulating the translocation of herbicide was not evaluated, although root sprouts probably were the dominant agent. True et al. (1955) found that the uptake of solutions through the tops of freshly cut red oak stumps increased with tree size and was higher on stumps united with living transpiring companion sprouts or other live trees by root grafts. Jones and Raynal (1986) found that most beech root sprouts remained attached to the parent system even after the sprouts were 10 years old, and that root grafting of superficial roots was common. Some transmission of herbicide to other beech trees would be expected through root grafts. This mode of transmission would be expected only through self-grafts of individual trees and through intraspecific grafts between roots of the same species. Interspecific grafts between roots of different species are rare (Graham and Bormann 1966).

Management Implications

The cut-stump herbicide treatment is particularly applicable when the goal is to control beech stems, especially root sprouts, that are interfering with the establishment of more desirable regeneration. Land managers can use this flexible tool on a variety of sites regardless of topography or woodlot size. The cut-stump treatment also is effective in controlling stump sprouting for a wide range of species in Appalachia, e.g., red maple, sourwood (*Oxydendrum arboreum* L.), and the oaks (*Quercus spp.*) (Zedaker et al. 1987).

For herbicides with glyphosate formulations it usually is recommended that the cut-stump treatment be applied to the

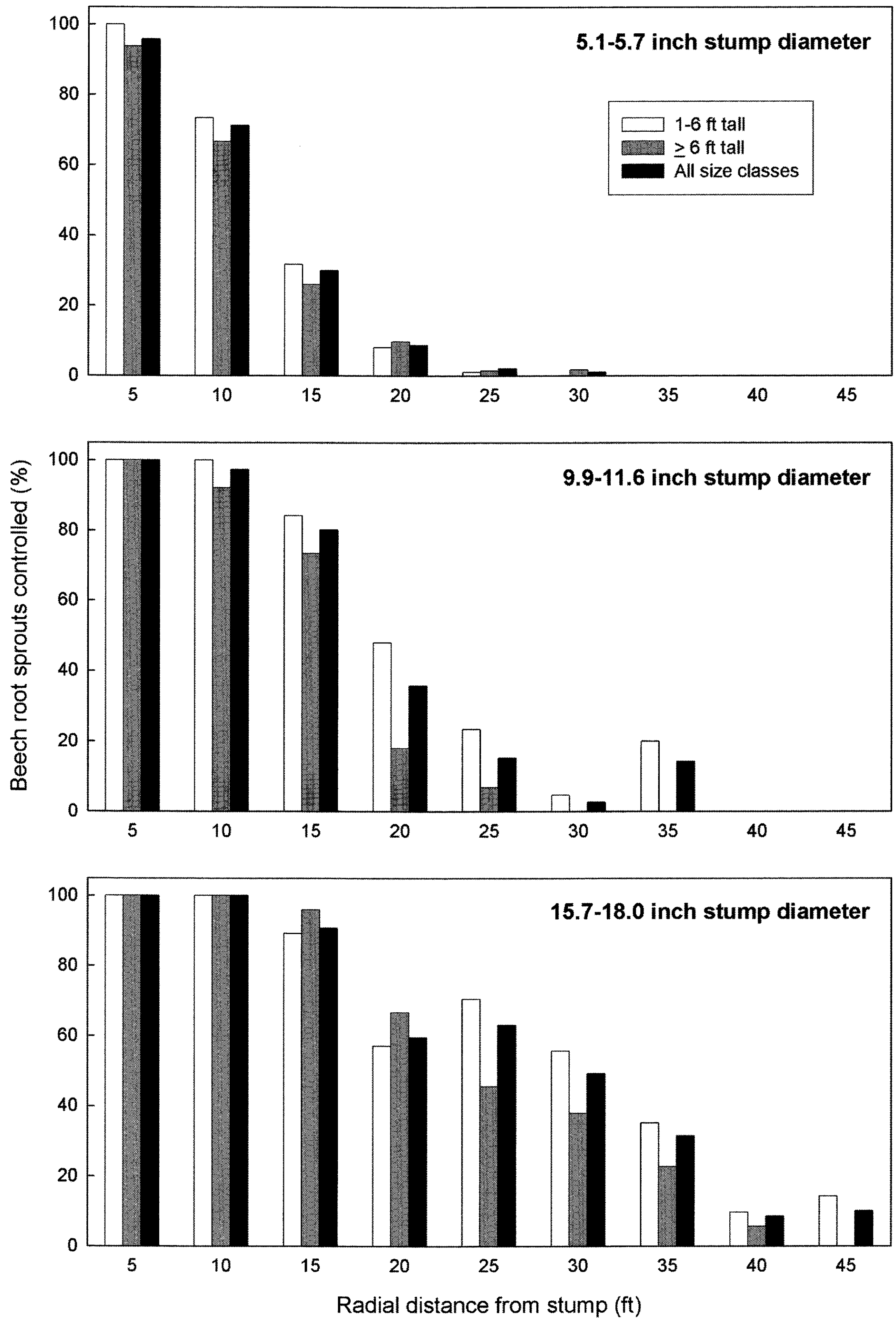

Figure 2. Average percentage of root sprouts controlled at 5-ft-radial increments from treated stumps for three diameter ranges.

surfaces of freshly cut stumps during periods of active growth and full leaf expansion. This treatment probably would be ineffective during periods of sap exudation. Observations indicate that sap flow frequently occurs between November 1 and spring leafout in black birch (*Betula lenta* L.) and the maples (*Acer spp.*) in this region of the Appalachians (Kochenderfer et al. 2004). Although it does not seem to be as prevalent in beech, sap exudation from

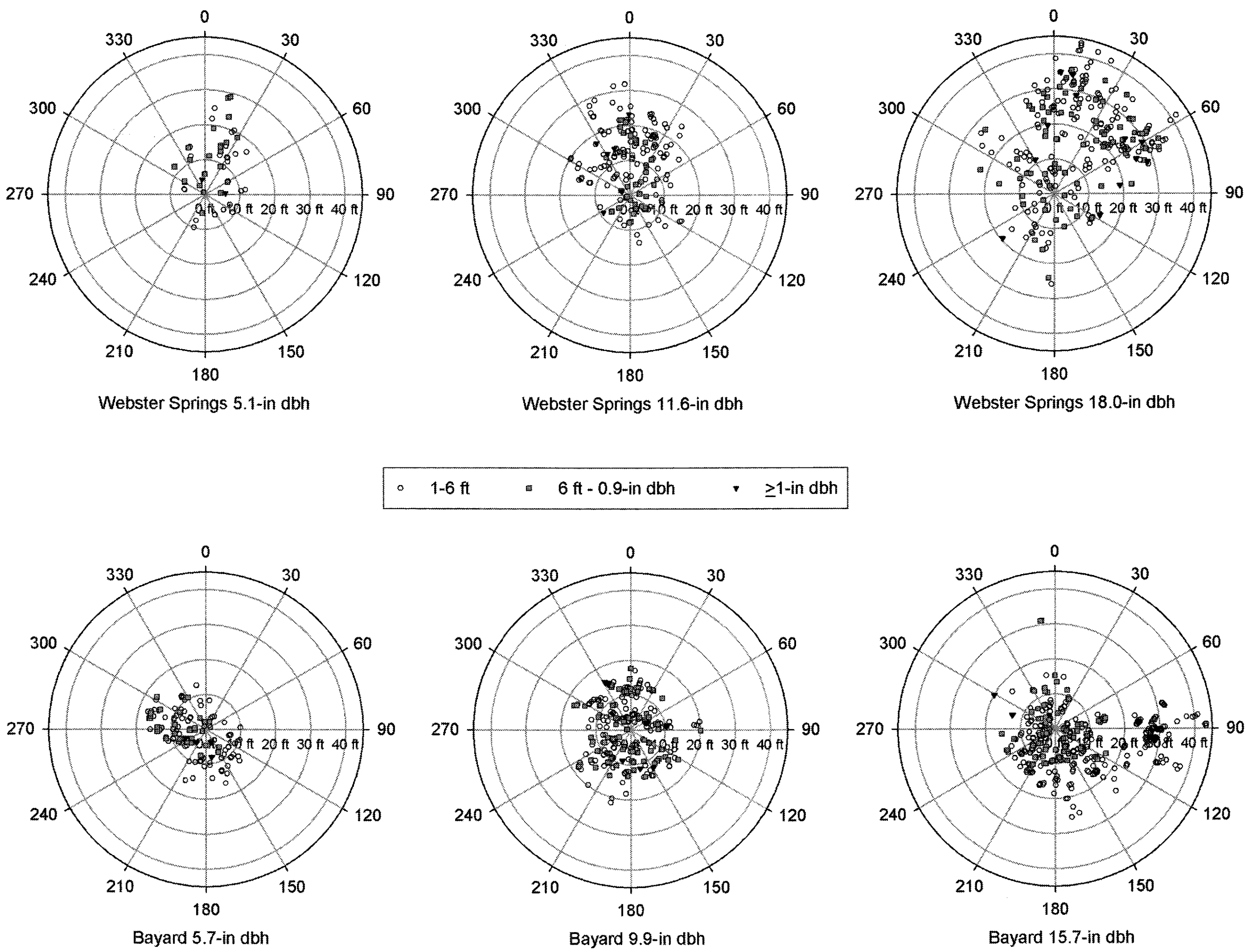

Figure 3. Distribution mortality of beech root sprouts around treated stumps of similar size at Webster Springs and Bayard.

wounded beech trees and stumps has been observed from late February to early May near these study sites; sap flow was especially prevalent during March and April. In January, stumps from some beech trees severed did not exhibit sap flow immediately after the trees were cut. However, these trees exuded sap freely the following April.

Limited herbicide trials near these study areas using the methods described in this study indicated that herbicide can effectively control root sprouts when applied during the dormant season. Two beech trees >6-in. dbh were cut each week and the stumps treated from December until June. Root sprout efficacy generally was good around the stumps treated from December to March. Freshly severed beech stumps rarely exuded sap during this period. Root-sprout efficacy was more erratic around stumps treated during March and April. No root sprout mortality was observed around some stumps treated during heavy sap flow. Although these results are based on a limited data set, they indicate that the cut-stump treatment may be effective during much of the dormant season. In the Virginia Piedmont, Zedaker et al. (1987) found that applying Roundup (glyphosate) in cut-stump treatments in both the dormant and growing season, provided excellent control of stump sprouting. Control was slightly better when the treatment was applied during the growing season.

We have found that no more than 4 hours are required to treat all beech stumps >6.0-in. dbh produced by a typical logging crew in a day. In many situations, the cut-stump treatment is most cost-effective when application is by members of logging crews. This may require licensing a member of the logging crew as a pesticide applicator. Use of the treatment in commercial harvesting operations requires close cooperation among timber purchasers, logging contractors, and landowners to ensure safe and complete coverage. Stumps treated with glyphosate turn yellow several minutes after treatment, so it is easy to determine whether coverage is complete.

In addition to being about twice as effective in controlling beech root sprouts as tree injection, the cut-stump treatment also allows landowners to harvest and sell the treated beech stumpage. Landowners typically receive \$3.00/ton for fiberwood in this region. The biomass of beech trees >6-in. dbh averaged 82.4 tons/ac at Webster Springs and 35.6 tons/ac at Bayard. Receipts from selling the beech fiberwood stumpage would have totaled \$107 to \$247/ac, which is more than enough to cover the cost of the treatment. Thus landowners would probably prefer the cut-stump treatment over injection treatments that usually result in injected trees being left unharvested on the site.

In stands where desirable regeneration has been established but there are large numbers of beech root sprouts, the cut-stump treatment controls beech root sprouts without damaging other species in the overstory and/or existing desirable regeneration. Broadcast spraying, although effective, is not target-specific and would kill most advanced regeneration. Unlike other vegetation management techniques such as burning and broadcast foliar spraying, the cut-stump treatment does not impact existing desirable regeneration. This can be an important consideration on private property where desirable seed sources are often lacking. This is particularly important in oak stands that recently were high graded, because the seed source for desirable regeneration may have been greatly reduced or entirely removed from the site. The cut-stump treatment also might be effective in stands with large proportions of beech in the overstory but few existing beech root sprouts in the understory. This study demonstrated that cutting beech trees and/or a minor disturbance could dramatically increase the development of beech root sprouts. The cut-stump treatment can be applied in stands with a high proportion of beech to ensure that large numbers of beech root sprouts do not result from logging activities.

A disadvantage of the cut-stump treatment is that it is restricted to the control of stump and root sprouts. It does not control other common interfering plants, e.g., grass and ferns. Where these are prevalent, broadcast spraying should be considered (Horsley 1991). It might be feasible to use the cut-stump treatment in combination with other herbicide treatments. For example, a basal spray or injection treatment could be used to control sapling-size striped maple and birch, whereas the cut-stump treatment could be used to control beech. This procedure would reduce total treatment costs by reducing the number of stems treated.

The cut-stump treatment could be used to counteract the effects of BBD by reducing the proportion of susceptible trees. If beech trees can be harvested when they first become infected and the cut-stump treatment is applied, root sprouts, which are clones of susceptible parent trees, would be eliminated. This might be effective in reducing the number of beech stems susceptible to BBD in future stands. Information contained in Figure 2 could be used to establish adequate buffers around resistant trees. It is not known whether the cut-stump treatment would be effective on trees that have been severely affected by BBD and already have serious crown dieback. Use of the cut-stump treatment during earlier stages of the disease when tree boles are still green and conducting water is recommended. It may even be feasible in stands where most of the larger beech trees have already died, to treat a portion of the stumps (e.g., 8 × 8 spacing) of small beech stems throughout the affected stands.

In conclusion, the cut-stump herbicide treatment is applicable throughout a range of conditions and where beech root sprouts are the primary impediment to the development of desirable advance regeneration. Costs depend primarily on the amount of basal area treated, but application costs for this treatment are low compared with those of other herbicide treatments. Research is underway to evaluate the effects of lower herbicide concentrations and extending time intervals between cutting and application on treatment efficacy. Additional research also is needed to quantify the effectiveness of the cut-stump treatment during dormant seasons. Information obtained in this study provides land managers with a relatively low-cost application method that can be used to selectively control beech stump and root sprouts and still permit merchantable beech trees to be harvested.

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