ECONOMICS OF HERBICIDE APPLICATION METHODS IN HARDWOODS

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Abstract

Forest managers can use the data presented here to determine the least-cost herbicide application method for precommercial thinning treatments in hardwood sapling stands. Herbicides used in managing immature hardwood stands must be applied using individual-tree methods; broadcast applications in hardwoods are not selective and may result in significant damage to preferred crop trees. Individual-tree herbicide application methods include variations of injection, basal spraying, and cut stump treatments after mechanical felling operations. Total costs per acre for these methods and for chain saw felling were compared for a precommercial thinning in a hardwood sapling stand.

Introduction

Numerous safe herbicides and application methods are available for managing hardwood sawtimber in the Northeast. Forestry herbicides can be applied in either broadcast treatments or individual-tree treatments, depending on the silvicultural objective. Broadcast applications, although suitable for site preparation to regenerate new stands, are not used to manage existing hardwood stands. Broadcast herbicide applications are not selective among hardwood species and may damage preferred crop trees. Consequently, herbicides used in managing established hardwood stands must be applied using individual-tree methods— either cut-surface or basal-bark applications.

Forest managers can use the data presented here to estimate costs of individual-tree herbicide treatments in immature hardwood stands. Estimated costs for three variations of injection and four variations of basal spraying are compared for a precommercial thinning in a hardwood sapling stand.

Defining the Treatment Methods

A brief clarification of terms is helpful before discussing the cost of various application methods. Herbicides are applied to individual trees by cut-surface or basal-bark techniques. In cut-surface techniques, herbicides are applied to the tree's cambium layer through a wound in the bark or by treating the entire cambium layer of a stump after felling. In general, herbicide labels recommend that injections should be spaced 1.5 inches apart and receive 1.5 milliliters of herbicide mixture per wound. Tools for applying measured amounts of herbicide mixture include a variety of cylinder models for basal injection or the hypo-hatchet for waist-high injections. A hand ax and a squirt bottle also work (called hack-and-squirt), but applying measured amounts of herbicide mixture is more difficult. Treating cut stumps immediately after felling is another cut-surface technique. Tools for stump treatments include squirt bottles or backpack sprayers. Herbicides used for cut-surface treatments are applied full strength or diluted. Summer or early fall (June-November) applications are most effective, but a moderate degree of control is possible year-round (Kossuth et al. 1980).

In basal-bark techniques, herbicides are not applied directly to the cambium layer as in cut-surface applications. Instead, herbicides are applied at the base of a target tree and reach the cambium layer by penetrating the bark. Application methods vary by herbicide concentration, volume of herbicide mixture applied, and amount of tree surface area treated. Herbicides used for basal-bark treatments are applied full strength or mixed with an oil carrier (diesel or kerosene). Penetrants can be added to improve effectiveness. Dormant season applications are preferred, but effective control is possible year-round (Burch et al. 1987).

In this report, I chose to compare costs for four variations of basal spraying:

Full/conventional basal. Very dilute solutions (<5 percent in oil) are applied to the lower 12 to 24 inches of the stem. Thorough wetting to the point of runoff on all sides of the stem is necessary.

Low-volume basal. A 20 percent solution in oil is applied to the lower 12 to 18 inches of the stem. All sides of the stem are treated, but runoff is not necessary.

Streamline. The herbicide mixture is 20 percent herbicide, 10 percent adjuvant, and 70 percent oil. A narrow band (2 inches wide) of herbicide mixture is applied to one side of the stem approximately 6 inches above groundline. Stems 3 inches dbh and larger are treated on two sides (Williamson and Miller 1986).

Thinline. Undiluted herbicide is applied to all sides of the stem in pencil-thin band about 6 inches above groundline.

Economic/Silvicultural Objectives

Data suggest that precommercial thinning is economical only in stands on good sites that contain relatively high-value species such as black cherry, white ash, or red oak (Miller 1986). Potential growth response due to a single precommercial thinning is limited, perhaps an additional 1 to 2 inches dbh on crop trees at final harvest. Thus, highest returns on precommercial thinning are obtained by minimizing treatment costs per crop tree, and maximizing their value growth response.

Crop tree release is the recommended practice for precommercial thinning in Appalachian hardwood sapling stands (average dbh <5.0 inches). Silvicultural guidelines include selecting 50 to 75 crop trees per acre in stands where codominant trees average at least 25 feet tall, and providing selected crop trees with a full crown-touching release (Smith and Lamson 1986). This approach focuses treatment costs on trees with the greatest potential for earning a profit on the investment. Full crown release maximizes dbh growth response of selected trees, and minimizes costs because only trees that compete with a selected crop tree are removed.

Minimizing Treatment Cost

Two ways to eliminate unwanted trees when releasing young hardwoods are to chemically treat or cut mechanically. Of major concern to the forest manager is applying the desired silvicultural treatment at the lowest possible cost. In an earlier study, chain-saw felling was the least-cost method (Miller 1984).

Sometimes herbicide treatments are more appropriate for achieving stand management objectives in the long run. For example, herbicides can be used to control resprouting.

Costs associated with herbicide application methods have two major components: labor cost and chemical cost. To reduce total treatment costs, one trend is to reduce labor cost by applying less herbicide mixture per tree while increasing the herbicide concentration to maintain effectiveness. Most labels recommend 3-inch spacings for injections, or about one injection per inch of dbh. Research has shown that 5-inch spacings using undiluted herbicides can reduce labor cost (Campbell 1985), but labor cost savings can be offset or exceeded by increases in chemical costs. Other research on injection methods indicates reduced treatment cost by diluting proven herbicides (Wendel and Kochenderfer 1982).

Treatment cost also can be reduced by using more labor-efficient tools. The hypo-hatchet has been shown to be more efficient than the cylinder injectors (Holt et al. 1975). Both tools apply the same volume of herbicide mixture per tree, and they are equally effective on most hardwoods (Cantrell et al. 1985; Holt and Voeller 1972). Hack-and-squirt is also more labor-efficient than cylinder injectors (Wiltrout 1976), but cylinders are more chemical-efficient because they apply metered doses of herbicide mixture.

For basal-bark treatments, we are in the midst of an "application method revolution". Research has shown that hardwood control is satisfactory with full/conventional, low-volume, and streamline basal-bark applications (Hendler et al. 1987). The thinline method using undiluted triclopyr is another effective basal-bark alternative (Melichar and Waggoner 1987). However, the added cost of using undiluted herbicides usually exceeds associated reductions in labor cost.

Backpack and garden sprayers are the main tools used for basal-bark treatments. For streamline and thinline methods, backpack sprayers equipped with handgun applicators, forestry nozzles, and appropriate spray tips are probably most efficient.

Estimating Total Treatment Cost

Total treatment cost includes labor cost and chemical cost. To estimate total cost for a planned operation, it is important to define it in terms of size and number of stems to be treated per acre. Average tree size indicates the appropriate treatment method. Basal-bark methods are practical for stems up to 4 inches dbh. Injection methods are practical for stems 2 to 12 inches dbh. Average tree size is also used to estimate labor and volume of herbicide mixture required per tree for a particular treatment method. Number of stems per acre indicates total labor and total volume of herbicide mixture required per acre. The following sections describe a procedure for computing total treatment cost.

Treatment labor cost.. Labor cost in precommercial thinning operations is determined by treatment method, number of trees treated per acre, average dbh, and wage rate. In 10- to 30-year-old Appalachian hardwoods, crop-tree release requires eliminating 250 to 450 stems per acre. From 4 to 6 trees are treated for each crop tree and treated trees average 2 to 6 inches dbh. Once the treatment has been defined (trees treated per acre and average dbh), production rates for a particular application method can be used to estimate total labor required per acre.

Production rates in Table 1 can be used to estimate labor requirements for several herbicide application methods. Labor requirements are computed by:

$$\underset{\text{(hrs/ac)}}{\text{Total Labor}} = \underset{\text{(no./ac)}}{\text{Stems treated}} \,/\, \underset{\text{(no./hr)}}{\text{Production rate}}$$

For example, if a precommercial thinning operation requires treating 350 4-inch stems per acre, full/conventional basal spraying would require 1.3 hours per acre, while streamline would require 0.9 hours per acre. Cost is determined by the wage rate. At $7.00 per hour, labor costs are $9.10 and $6.30 per acre, respectively.

Treatment chemical cost. Chemical cost is determined by the volume of herbicide mixture used per acre and the unit cost of the mixture. For a given application method, the volume of herbicide mixture (gallons/acre) varies according to the size and number of stems treated per acre. The unit cost of the herbicide mixture ($/gallon) varies according to herbicide cost and dilution rate.

Table 1. Production rates for herbicide application methods used in precommercial thinning in immature Appalachian hardwoods.

General method	Application technique	Production rates, by average dbh		
		1-2 inch	3-4 inch	5-6 inch
			Stems/hour	
Cut surface	Cylinder injection	210	180	140
	Hack-and-squirt	290	220	160
	Hypo-hatchet	370	280	180
Basal bark	Full/conventional	310	270	230
	Low-volume	340	300	260
	Streamline	450	400	375
	Thinline	425	400	375

Sources: Wiltrout 1976; Zedaker 1986, Miller 1984; Holt et al. 1975; Holt and Voeller 1972; Voeller and Holt 1973.

Like labor cost, estimating chemical cost involves a two-step procedure. Information in Table 2 can be used to estimate total volume of herbicide mixture (gallons/acre) for a particular treatment. Volume of herbicide mixture is computed by:

$$\text{Total Herbicide Mixture (gal/ac)} = \frac{\text{Stems treated (no./ac)} \times \text{Mixture usage rate (ml/stem)}}{3785 \text{ (ml/gal)}}$$

Again, if we treat 350 4-inch trees per acre, full/conventional basal spraying would require 6.5 gallons of herbicide mixture per acre, while streamline would require 0.92 gallons per acre.

The second step in determining total chemical cost is computing the unit cost ($/gallon) of the herbicide mixture. If herbicides were used undiluted, the unit cost would simply be the price per gallon of pure herbicide. However, herbicides are often diluted, and the unit cost of the herbicide mixture must be computed from the unit prices of each diluent. An example should clarify the procedure. Table 3 shows cost per gallon for a 2 percent mixture of triclopyr in oil applied by full/conventional basal spraying. Retail prices are $70/gallon for triclopyr and $1/gallon for the oil. Note that the price per gallon for each component (column 3) is multiplied by percentage of the mixture (column 4). The results are then summed (column 5) to determine the average cost of the herbicide mixture, $2.38 per gallon.

Table 2. Volume of herbicide mixture per tree for herbicide application methods in immature Appalachian hardwoods.

General method	Application technique	Application rates, by average dbh 1-2 inch	3-4 inch	5-6 inch
		Milliliters/tree		
Cut surface	Cylinder injection	3	6	9
	Hack-and-squirt	4	8	12
	Hypo-hatchet	3	6	9
Basal bark	Full/conventional	30	70	100
	Low-volume	15	35	50
	Streamline	5	10	15
	Thinline	5	10	15

Sources: Zedaker 1986, Miller 1984, Cantrell et al. 1985, Hendler et al. al. 1987, Kossuth et al. 1980, Wendel and Kochenderfer 1982, Burch et al. 1987.

The unit cost of herbicide mixture is computed by:

Unit Cost of Mixture = (Component price x Percent of mixture)
($/gal) ($/gal) (% v/v)

The cost per gallon of any herbicide mixture can be computed using the methodology in Table 3. If the mixture includes more than one herbicide, or other components, complete the appropriate rows in the table. The procedure simply computes the weighted average cost of all the components.

To determine total treatment chemical cost, multiply the total volume of herbicide mixture (gallons/acre) by the unit cost of herbicide mixture ($/gallon). For 350 4-inch trees per acre, herbicide mixture totals 6.5 gallons per acre using full/conventional basal spraying. At $2.38 per gallon (Table 3), the total chemical cost is $15.47 per acre.

Total treatment cost. In this example, total treatment cost for full/conventional basal spraying was $24.57 per acre, the sum of labor and chemical costs. For other application methods or other herbicide mixtures, the same procedure can be used to estimate total treatment cost. In some treatments, particularly those involving mostly resistant species groups, production rates (Table 1) and herbicide application rates (Table 2) may need to be adjusted. Also, target species will determine the appropriate herbicide mixture to apply. Hamel (1983) and Cantrell and Creighton (1985) provide guidelines for selecting and applying herbicides based on target species.

Table 3. Sample computation of cost per gallon for a 2 percent mixture of triclopyr in oil.

(1) Component	(2) Common name	(3) Retail price of component	(4) Percent of mixture	(5) Cost of component in herbicide mixture
		$/gallon		$/gallon
Herbicide	Triclopyr	70.00	x 2 =	1.40
Herbicide[1/]	-	-	x - =	-
Diluent	Diesel fuel	1.00	x 98 =	0.98
Surfactant[1/]	-	-	x - =	-
Other[1/]	-	-	x - =	-
TOTALS			100	2.38

1/ For herbicide mixtures which include more than one herbicide or other components, insert data in the appropriate row.

A Comparison of Herbicide Treatment Costs

Total treatment costs for several application methods and herbicide mixtures were computed using the procedure outlined. Retail prices of herbicides included in the comparison are listed in Table 4. Total costs were based on treating 350 4-inch hardwood stems per acre. The results of the comparison are presented in Tables 5 and 6. Wages were assumed to be $7.00 per hour.

The least-cost herbicide application method was stem injection using the hypo-hatchet and undiluted 2,4-D amine (Table 5). Using a 20 percent solution of glyphosate increased the cost by about $1 per acre. Among the basal-bark treatments, full/conventional basal spraying using a 4 percent mixture of 2,4-DP and 2,4-D in oil, and streamline using a 20:10:70 mixture of triclopyr (ester):adjuvant:diesel fuel were the least-cost methods (Table 6).

Table 4. Retail prices per gallon of undiluted herbicides used in comparing costs of herbicide application methods.

Herbicide	Active ingredient or acid equivalent	Retail price (1987)
	pounds/gallon	$/gallon
2,4-D (amine)	4	12
2,4-DP + 2,4-D (ester)	2 + 2	22
Glyphosate	4	70
Picloram + 2,4-D (amine)	.25 + 1	18
Picloram + triclopyr (ester)	1 + 2	125
Triclopyr (amine)	3	54
Triclopyr (ester)	4	70

Table 5. Cut surface herbicide application costs per acre based on treating 350 4-inch hardwood stems per acre.

Application method and herbicide mixture[1]	Total[2] labor	Amount of herbicide mixture	Cost of herbicide mixture	Total cost
	Hrs/ac	Gal/ac	$/Gal	$/Ac
Cylinder injection				
2,4-D; undiluted	1.9	.55	12	19.90
Glyphosate; 20%	1.9	.55	14	21.00
Picloram + 2,4-D; undiluted	1.9	.55	18	23.20
Triclopyr (amine); 50%	1.9	.55	27	28.15
Hack-and-squirt				
2,4-D; undiluted	1.6	.74	12	20.08
Glyphosate; 20%	1.6	.74	14	21.56
Picloram + 2,4-D; undiluted	1.6	.74	18	24.52
Triclopyr (amine); 50%	1.6	.74	27	31.18
Hypo-hatchet				
2,4-D; undiluted	1.3	.55	12	15.70
Glyphosate; 20%	1.3	.55	14	16.80
Picloram + 2,4-D; undiluted	1.3	.55	18	19.00
Triclopyr (amine); 50%	1.3	.55	27	23.95

[1]Diluent: tap water.
[2]Wage rate: $7.00/hour.

Labor costs accounted for 58 percent of the least-cost injection treatment, but were only 30 to 40 percent of the least-cost basal-bark treatments. Total costs for injection treatments ranged from $16 to $31 per acre. Computations were based on one injection per inch of dbh, 1.5 ml/injection for basal and hypo-hatchet injections, and 2.0 ml/injection for hack-and-squirt. Injection costs were highest for applications of 50 percent triclopyr followed by undiluted picloram + 2,4-D (Table 5). Unit costs for these herbicide mixtures are relatively high if applied as currently labelled. Costs could be reduced if lower herbicide concentrations or fewer injections per tree are found to be effective.

Total costs for basal-bark treatments ranged from $21 to $71 per acre. However, most basal-bark treatments in the comparison cost less than $32 per acre. Thinline was the most expensive, $71 per acre, because it involved undiluted triclopyr at a unit cost of $70 per gallon (Table 6). Low-volume basal was also relatively expensive at $57 per acre. Both streamline and low-volume basal treatments apply 20 percent triclopyr, but streamline applications required 25 percent less labor and 72 percent less herbicide mixture per acre.

Chain saw Felling Compared to Herbicides

Precommercial thinning in immature hardwood stands can also be applied by felling unwanted trees with a chain saw. Treatment costs associated with chain saw felling are usually lower than herbicide alternatives (Miller 1984). Production rates for chain saw felling are 325, 225, and 125 stems per hour for 2-, 4-, and 6-inch stems, respectively. To account for costs of the chain saw, add about $2.25 per hour to the wage rate when computing total felling cost per acre. For 350 4-inch stems per acre, injection using the hypo-hatchet cost $16 per acre, while chain saw felling cost about $14.50 per acre.

For both felling and herbicide release treatments in young hardwoods, crop trees should be marked prior to the actual release operation. Selecting crop trees during the release operation reduces productivity and increases the risk of removing desirable trees. Also, marking crop trees before treatment allows workers to examine trees and concentrate on "one thing at a time". This assures that the best available crop trees are selected. An experienced worker can mark 45 to 50 crop trees per hour (Smith and Lamson 1983). Marking cost ranges from $10 to $15 per acre.

Table 6. Basal-bark herbicide application costs per acre based on treating 350 4-inch hardwood stems per acre.

Application method and herbicide mixture[1/]	Total[3/] labor	Amount of herbicide mixture	Cost of herbicide mixture	Total cost
	Hrs/ac	Gal/ac	$/Gal	$/Ac
Full/conventional basal				
2,4 DP + 2,4-D; 4%	1.3	6.50	1.84	21.06
Picloram + triclopyr; 2%	1.3	6.50	3.48	31.72
Triclopyr (ester); 2%	1.3	6.50	2.38	24.57
Low-volume basal				
Triclopyr (ester); 20%	1.2	3.25	14.80	56.50
Streamline[2/]				
Triclopyr (ester); 20% (10% adjuvant, 70% oil)	0.9	0.92	16.20	21.20
Picloram + triclopyr; 20% (10% adjuvant, 70% oil)	0.9	0.92	27.20	31.32
Thinline				
Triclopyr; undiluted	0.9	0.92	70.00	70.70

[1/]Diluent: diesel fuel @$1.00/gallon; [2/]Adjuvant: d'limonene @$15/gallon; [3/]Wage rate: $7.00/hr.

Cut Stump Treatments

Sprouting can be controlled by applying herbicides to cut stumps immediately after trees are felled. The herbicide mixture is applied to the cambium layer completely around the outer edge of each stump. A hand-held squirt bottle or backpack sprayer adjusted to apply a straight stream are suitable tools for the job.

Labor for treating stumps, in addition to that required for felling trees, ranges from 5 to 10 seconds per stump. Production rates for 2-, 4-, and 6-inch dbh trees are about 700, 500, and 400 stumps per hour, respectively. Thus, treating stumps during precommercial thinning operations increases labor by about 0.7 hours per acre. At $7.00 per hour, labor cost increases by $4.90 per acre.

Cut stump treatments also require about 0.7 gallons of herbicide mixture per 100 ft^2 of basal area treated (Lewis et al. 1984). For a precommercial thinning operation involving 350 4-inch trees per acre, cut basal area would total 31 ft^2 per acre, and treating stumps would require about 0.25 gallons of herbicide mixture per acre. Using an undiluted mixture of picloram and 2,4-D (Table 5) would cost $4.50 per acre for chemicals. Total treatment cost, including labor and chemical costs, would be $9.40 per acre.

At current herbicide prices and wage rates, treating cut stumps during precommercial thinning operations adds about $10 per acre to the cost of felling alone. For delayed stump treatments, methods and costs are similar to full/conventional basal spraying. Obviously, delayed treatments cost more.

Discussion

In this report, I focused on comparing the cost of using various herbicide application methods for precommercial thinning operations in immature hardwood stands. A simple procedure for estimating total treatment cost was presented. The procedure involves four key steps.

1. Define the treatment in terms of average dbh and number of stems to be treated per acre

2. Estimate labor cost per acre— number of stems per acre divided by production rate for a given application method, then apply an appropriate wage rate.

3. Estimate chemical cost per acre— volume of herbicide mixture (gallons/acre) multiplied by unit cost of the mixture ($/gallon).

4. Estimate total treatment cost per acre— labor cost plus chemical cost.

Total treatment costs were compared for several variations of cut surface and basal-bark application methods. For a hypothetical herbicide treatment involving 350 4-inch stems per acre, injection using the hypo-hatchet was the least-cost application method. Hypo-hatchet is the least-cost herbicide method for stems as small as 2 inches dbh. Stems smaller than 2 inches dbh are too pliable for injection treatments and should be treated using a basal-bark method. Among the basal-bark methods, streamline applications are easiest to apply. Total treatment costs per acre for streamline and full/conventional basal applications are similar. However, streamline treatments require less than 20 percent as much herbicide mixture per acre as full/conventional treatments.

Chain saw felling has several advantages over herbicide treatment alternatives. Herbicides cannot be used to treat sprout clumps that contain crop trees. Movement of chemicals into the root system will kill or damage desirable trees. In young Appalachian hardwood stands, many of the best available crop trees are found growing in sprout clumps. To avoid damaging selected crop trees, undesirable stems in the clump must be felled or girdled. Consequently, field crews applying herbicides must also be equipped with axes or chain saws to complete the release operation. Combined chemical and mechanical operations are more costly than simply felling all target trees. Another advantage to felling is that all unwanted trees are eliminated at the time of treatment. Because herbicide treatments leave competitors standing, trees can be missed or left alive, thus leaving crop trees only partially released. This problem is magnified during the growing season when trees are in full leaf. With chain saw felling, the operator simply continues cutting until light encircles the crop-tree crown, regardless of the season.

Herbicide treatments can be used in visually sensitive areas and in very young stands to control resprouting. Although felling treatments cost less, they leave stands tangled with downed trees for up to 5 years. Herbicide treatments leave dead trees standing, which causes less visual disturbance to the stand and temporarily protects crop trees against excessive ice damage. For cultural treatments in stands where codominant trees are less than 25 feet tall, herbicide methods can be used to control resprouting (Wendel and Lamson 1987). Full/conventional basal spraying, streamline, or hypo-hatchet injection is less costly than felling and treating cut stumps. Control of resprouting is not as important for crop trees taller than 25 feet. Crown closure quickly inhibits height growth of sprouts and crop trees usually maintain a distinct height advantage (Lamson 1983). Thus, chain saw felling should be used to release crop trees whose height averages 25 feet or more. Chain saw felling costs less than herbicide treatments, but the difference in cost is less than $10 per acre. Long-term economic desirability of precommercial thinning is not determined by initial treatment cost alone. Stand value increase due to treatment is equally important. To maximize growth and yield response of individual crop trees, each crop tree should receive a full crown release. Consequently, herbicides used for crop tree release must be nearly 100 percent effective. When planning an herbicide release operation, it is important to identify the target species and to select an appropriate herbicide and application method that are known to control the target species. A "least-cost" method that is only 50 percent effective does not minimize treatment costs. The key is eliminating all crop-tree competitors at the lowest cost.

Safety

Herbicides can be used safely. Always read (and study) the entire product label before using herbicides. Manufacturers periodically update product labels, so make sure you have a current label. New information usually makes the job safer, cheaper, and more effective.

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