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THE USE OF HERBICIDES IN HARDWOOD FORESTRY

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Abstract

Herbicides can play an important role in hardwood management by providing foresters and landowners with a means to eliminate undesirable stand components. Although herbicide technology for hardwood management still needs much development, some methods are available and can be used to enhance the value of the stand. With an emphasis on safety, de&ailed information about the benefits and methods of applying individual stem and broadcast treatments for control of woody and herbaceous components in hardwood forests are presented in this paper.

Introduction

Hardwood forests have an abundance of both woody and herbaceous plant species, and not all are considered of value to the stand manager. Proper use of herbicides allows foresters and forest owners to eliminate undesirable stand components, thereby enhancing the stand's value. Forestry herbicides can be safe and effective tools if used properly, permitting selective removal of undesirable plants that may range from herbaceous weeds to mature hardwoods. Unlike cutting and clearing treatments, herbicides can deaden plants so that resprouting is minimized.

Discussion of herbicides in this paper does not constitute recommendation of their use or imply that uses discussed here are registered. If herbicides are handled, applied, or disposed of improperly, there is a potential for hazards to the applicators, off-site plants, and environment. Herbicides should be used only when needed and should be handled safely. Follow the directions and heed all precautions on the container label.

Use of trade names is for the reader's information and convenience and does not constitute official endorsement or approval by the U.S. Department of Agriculture to the exclusion of any other suitable product.

Both herbicides and application methods are being continuously developed so that more effective treatment options are becoming available. Both tried-and-true treatments and new possibilities for hardwood management are described in this paper. Further details on the broader subject of forestry herbicides can be found in Cantrell's (1985) "A guide to silvicultural herbicide use in the Southern United States." This guide should be studied for details on specific herbicides, personal and environmental safety, prescription writing, Federal and State regulations, and contracting commercial applicators. Herbicide labels should always be read and understood before use and religiously followed.

Herbicide Uses in Hardwood Management

Recent research has identified herbicide treatments that are useful or hold promise for hardwood management:

- Preharvest control of undesirable stems increases the abundance of desirable regeneration (Loftis 1985).

- Postharvest herbicide treatments, applied selectively or using selective herbicides, improves regeneration in some species mixtures (Hurst and Bourland 1980, Pham 1987).

- Selective application of herbicides to small undesirable stems can extend the utility of selection management systems to more stands (Della-Bianca and Beck 1985) and release sapling crop trees (Wendel and Lamson 1987).

- Stump sprouts provide the most productive regeneration in some stands (Zahner and Myers 1984), and by thinning the sprouts, greater yields can be achieved (Lamson 1983). Herbicide thinning using nonsystemic herbicides can be a less expensive treatment than cutting.

- Plantation establishment and early growth of many valuable hardwoods is increased with herbaceous weed control (Bey et al. 1975, Zutter et al. 1986, Bowersox and McCormick 1987, Ponder 1987).

In general, these treatments are aimed at reducing competition and channeling site resources into crop trees. Not only do these treatments appear cost effective, but they appear essential for many management schemes to be usable.

The price of herbicides, which is always considered high by forestry standards, is affected by the overall use picture in agriculture. Forestry herbicides are basically agricultural and industrial herbicides that are labeled for use in forestry. Forestry is a relatlvely minor use that has developed through special research. The high cost per gallon requires that effective application methods be employed and developed, using the lowest rates that are effective, thus reducing the per-acre cost-

Herbicide Terms

An herbicide prescription specifies the herbicide, the rate, and the application method. The rate is the amount of herbicide that is to be applied to an acre or to an individual stem. Rates are either specified as the amount of product per acre or per stem size, such as 2 gal/A or 4 milliliters (ml) per inch of d.b.h., or as the amount of active ingredient. (a.i.) per acre, such as 2 lb a.i./A. . The active ingredient is listed on the herbicide label; its concentration is given as a percentage as well as pounds of actual herbicide in 1 gallon or 1 pound of the product. The remaining portion of the product is made up of inert ingredients, which can consist of solvents, emulsifers, buffers, and stabilizing agents for liquids and dry carriers along with waxes for pellets and granules.

Herbicides are classified as:

Foliar-active - applied as a spray or mist to leaves and twigs of a plant where uptake occurs. Foliar-active herbicides are usually inactivated when they contact the soil.

Soil-active - applied to the soil as a liquid, granule, or pellet; uptake is through the roots. Soil properties, such as percent silt, clay, and organic matter, influence the effectiveness of these herbicides. Soil-active herbicides must have rainfall to be activated; so as to be dissolved and move to the roots. Some herbicides (such as 2,4-D, Tordon™, and Velpar') have both foliar and soil activity.

Systemic (Translocated) - after uptake, either by leaves, roots, or cut surface, the active ingredient moves throughout the plant to sites of activity; here physiological processes are dissrupted, resulting in control. Most forestry herbicides act in a systemic manner.

Contact - mainly kills the plant parts on which it is sprayed; often does not kill the total plant.

Woody control - only effective in controlling woody plants.

Herbaceous control - only effective in controlling broadleaf forbs and grasses. Some herbicides (such as, Velpar, Roundup' and Arsenal-) can control both woody and herbaceous plants.

Forestry herbicides are applied as broadcast or banded treatments over an entire area or to individual stems. Broadcast treatments are applied as sprays or granules, usually by helicopters or tractor-mounted equipment. Banded treatments of sprays and granules are applied in strips over the top of planting rows or next to them by tractor-mounted equipment or handcrews, Individual stem treatments are usually applied by handcrews, are aimed at selected woody plants, and include directed foliar sprays, basal bark sprays, tree injection, stump sprays, and basal soil spots. Individual stem methods have the benefit of selective application, where only undesirable stems are treated.

Remember, foliar-active herbicides should not be applied when rainfall is anticipated within 6 hours of application or during dry periods. Treatment investments can be wasted if rainfall occurs soon after application. Also, effectiveness of all herbicides decreases significantly when treatments are made during severe dry periods.

Vegetation Management Concepts

All systemic herbicides are said to be selective, because they have a spectrum of control over specific species that are killed or injured. When applied at a specified rate, susceptible species are almost all killed, other species are only injured and recover, while some species are tolerant. Selectivity can be very useful if the crop species is tolerant, as with pine-release herbicides. Likewise, in hardwood forestry, selective release treatments may be possible if the selectivity of certain herbicides is well understood and used to control competitors while leaving the crop species free-to-grow.

For a site preparation treatment to be effective, competition must be controlled below a certain level. If only marginally successful, many injured plants will recover and, along with the tolerant species, will rapidly reoccupy the site. Woody and hetbaceous plants will also continue to invade any area at varying rates (Cain and Yaussy 1984). If there is no residual herbicide in the soil, plants will become established from residual or migrating seeds, rootsuckers, and stump sprouts. The seed banks in the forest floor or in old fields make most herbaceous control treatments only temporary, lasting from 1 month up to two growing seasons. Thus the effectiveness of herbicide treatments last only for specific time periods, which are determined by the degree of control, the amount of residual herbicide, site quality, and the number of on-site propagules.

Soil-active herbicides can have longer control periods than foliar-active ones because of residual amounts of herbicide in the soil or decaying plant parts. Fallen leaves and twigs of treated plants can even reinitiate uptake of soil-active herbicides, but after residual concentrations degrade below a phytotoxic level, vegetation will respond. Figure 1 shows that woody regrowth on a Coastal Plain site is more permanently controlled by Tordon, compared to the temporary control of Velpar and windrowing. Tordon controlled a broader spectrum of species and had a longer soil residual than Velpar.

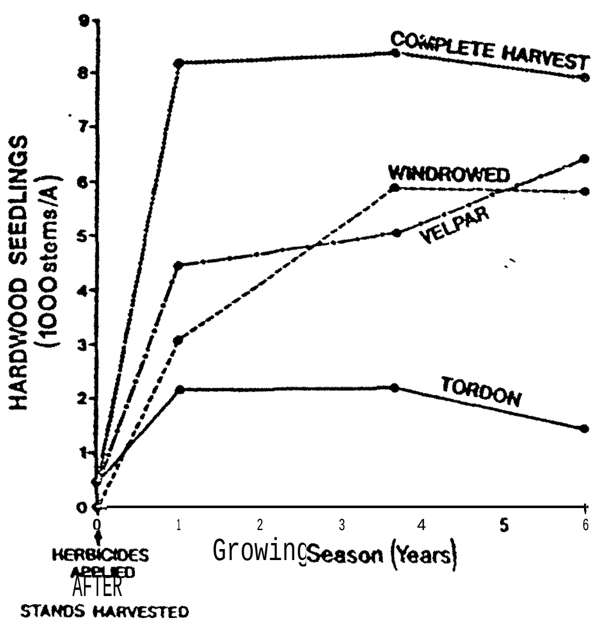


Figure 1. The number of hardwood seedlings that regrew on a Coastal Plain site in Alabama after the following treatments: harvested and no followup treatment, harvested and windrowed, harvested and treated with Velpar or Tordon herbicides.

In a multistoried hardwood forest, if the overstory is controlled, then the midstory will respond, if the midstory is also controlled, the regeneration layer will respond. As canopy control progresses the herbaceous and shrub components will increase in abundance as the amount of sunlight reaching the forest floor increases. The abundance of regrowth depends on Site productivity, numbers of tolerant species, and abundance of propagules able to respond. Thus herbicide applications will not control regrowth for long periods of time unless most perennial plants are controlled and the remaining propagules are few. The hardwood manager must understand these processes and limitations to be able to use herbicide technology most effectively. More information on the herbicides discussed in the following sections are given in Table 1, and scientific names of woody species are given in Appendix Table 1.

Table 1. Herbicide manufacturers, active ingredients, and formulations.

Product	Manufacturer	Active Ingredient(s)	Amount of a.i. in Formulation
AAtrex 4L	Ciba-Geigy	atrazine	4 lb/gal
Arsenal	Amer. Cyanamid	imazapyr	4 lb/gal
Banvel	Sandoz	dlcamba	4 lb/gal
Banvel CST	Sandoz	dicamba	1 lb/gal
Dowpon M	Dow	dalapon	74%
Garlon 3A	Dow	triclopyr amine	3 lb/gal
Garlon 4	Dow	triciopyr ester	4 lb/gal
Krenite	Dupont	fosamine	4 lb/gal
oust	Dupont	sulfometuron methyl	75%
Poast	BASF	sethoxydim	1.5 lb/gal
Princep 4L	Ciba-Geigy	simazine	4 lb/gal
Pronone 10G	Proserve	hexazinone	10%
Roundup	Monsanto	glyphosate	4 lb/gal
Scepter	Amer. Cyanamid	imazaquin	-
Spike 20P	Elanco	tebuthiuron	20%
Tordon 101	Dow	2,4-D + picloram	1/2 + 2 lb/gal
Tordon 101R and RTU	Dow	2,4-D + picloram	1/4 + 1 lb/gal
Velpar L	Dupont	hexazinone	2 lb/gal
Weedone CB	Union Carbide	2,4-DP + 2,4-D esters	.7 + .7 lb/gal
Weedone 2,4-DP	Union Carbide	2,4-DP amine	4 lb/gal
2,4-D ester	several	2,4-D ester	4 lb/gal
2,4-D amine	several	2,4-D amine	4 lb/gal
2,4,5-T	not registered	2,4,5-T	4 lb/gal

Individual Stem Treatments for Woody Plant Control

Individual stem treatments can be applied with the most certainty of success because nonmerchantable species and low-quality trees can be selectively removed without initiating haphazard regrowth.

Tree Injection

Benefits. Injection of undesirable hardwoods has been a successful treatment in promoting desirable regeneration after clearcutting bottomland stands (Hurst and Bourland 1980), as,preharvest treatments (Loftis 1985), as post-harvest treatments after fuelwood harvests (McGee 1986), in selection management (Della-Bianca and Beck 1985), for snag productton to enhance wildlife (McComb and Hurst 1987), and to release crop trees (Wendel and Lamson 1987). Injection is the best method for removing low-quality and noncommercial species 2 inches in d.b.h. or greater. However, experience has shown that injection treatments in mixed stands are usually only 60 to 80 percent successful in controlling stems. Greater success depends on correct application and matching the herbicide with the species to be controlled.

Application. The usual methods of injection use a tubular tree injector (such as Jim-Gem™ and Cranco™), a Hypo-Hatchet-, or the hack-and'squlrt method. With these methods, 1 ml of the herbicide or diluted herbicide is usually applied to each cut. Injection cuts are usually made at 2-inch spacings between cuts around the bole, but Campbell (1985) reported success on many species using Tordon 101 and Garlon™ 3A with S-inch spacings. For multiple stem clumps of red maple, Kossuth et al. (1980) found that multiple injections to each stem were required.

The tubular tree injector is a self-contained unit that uses a chiseltype blade to cut through the tree bark into the vascular system near the base of the tree. The unit is equipped with a handle or wire cord that is then pulled to deliver the herbicide (usually 1 ml) into the cut. The delivery rate of these tools can be adjusted. Campbell (1985) reported a production rate for stems that averaged 4 inches d.b.h. of 193 stems injected per hour, while McLemore and Yeiser (1987) reported 486 stems per hour that averaged 2 inches d.b.h. Production rate depends on tree size and their distributlon as well as worker efficiency.

The Hypo-Hatchet consists of a hatchet that has an internal herbicide delivery system which is connected by a hose to a quart reservoir of herbicide carried on the belt. When the hatchet strikes a tree, the blade penetrates the sapwood and the impact drives a piston forward to deliver 1 ml of the herbicide into the cut. The rate can not be adjusted. Usually the injections are made "waist high" on the trees. Waist-high injections have been shown to be just as effective as basal injections (Holt et al. 1975). Safety glasses should always be worn because when the Hypo-Hatchet strikes a tree, herbicide can splash into the eyes. Holt et al. reported production rates of 290 stems per hour and McLemore and Yeiser reported 456 stems per hour.

Hack-and-squirt is a method that involves only the use of a hatchet and utility spray bottle. A narrow-bit hatchet or ax is used to cut into the sapwood and the spray bottle is then used to apply herbicide into the cut. All commercial spray bottles tested so far are set to deliver 1 ml with each trigger pull. Most applicators prefer a commercial spray bottle such as a l-quart WD-40™ bottle from an automotive parts supplier. Safety glasses should also be worn to be a poor application time in the South (Williamson and Miller 1986) and Midwest (Melichar et al. 1985). McGee (1966) reported that spring injections in North Carolina with 2,4-D and 2,4,5-T were ineffective on oaks, dogwood, and sourwood, while injections in January and July worked best. Species such as red maple should not be treated during the spring sap rise, because the sap washes the herbicide from the cuts. Jackson (1986) reported that in New York, September was more effective than February for injection treatments of Garlon, Also, injection treatments should not be made when the herbicide will freeze in the cut because the herbicide will not be absorbed. Antifreeze can be added to the herbicide to overcome this problem, while Tordon 101R and RTU already contain antifreeze.

Soil Spots

Although not widely used in hardwood forestry, soil spots of Velpar L can be applied to control certain undesirable hardwoods, mainly sweetgum, black cherry, winged elm, and red oaks. Apply 2 to 4 ml of undiluted Velpar L for each 1 inch of d.b.h. On clay soils in the South, the 4-ml rate is advised for effective control (Miller in press). Diluted concentrations can be used if the amount per spot is increased accordingly. Direct the treatment to the soil within 3 ft of the trunk of trees to be controlled. All small hardwoods of susceptible species will also be killed in this 3-ft area. Large trees that are nearby are usually not affected. This method is faster and easier to apply than injection but is about three times more costly when the 4-ml rate is used (Miller in press).

Soil spots are applied in grid patterns to control numerous stems for pine release. Such grid applications may be useful in hardwood management with certain crop trees. To be effective in mixed hardwood stands, the selectivity of Velpar will have to be used. This treatment may be effective in releasing yellow poplar, hickory, and white ash, which are tolerant. But the following competing. species are often poorly controlled: red maple, dogwood, hornbeam, persimmon, sassafras, blackgum, boxelder, and sourwood (Miller 1984, Miller and Burkhardt 1987).

Basal Bark Sprays

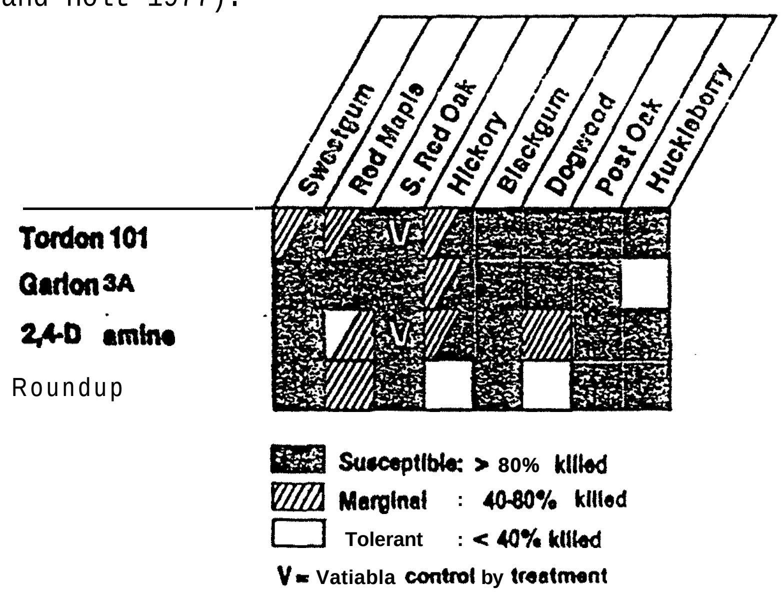
There are two methods of applying basal bark sprays, a low-volume (streamline) and a high-volume (full basal) method. Low-volume application can consistently control stems up to 2 or 3 inches in d.b.h. and the high volume can control stems up to 6 inches in d.b.h.. Larger stems of susceptible species can be controlled. The low-volume method is much quicker to apply and uses less herbicide than the high-volume technique. Both methods should find increasing use in hardwood management for controlling the density and composition of species in the regeneration layer through selective applications (Melichar et al. 1985). There is also a possible use of basal sprays for thinning stump sprouts by selective applications of nonsystemic herbicides.

Low-volume or streamline applications presently use Garlon 4, mixed with Cide-Kick", and diesel fuel. Clde-Kick, manufactured by JLB International Chemical (Vero Beach, FL) is a wetting and penetrating agent. The most commonly used mixture in the South is 20 percent Garlon 4, 10 percent Cide-Kick, and 70 percent diesel fuel (Williamson and Miller 1986). Preliminary results show that single and multiple stems of the following species, that are less than 3 inches in groundline diameter, are controlled at the following levels:

when using tbis method. **Wiltrout** (1976) operationally compared the three injection methods and reported that the hack-and-squirt treatment used the least herbicide. The hack-and-squirt and the Hypo-Hatchet had lower costs per acre than tubular injectors. Workers preferred the hatchet-type equipment, however, the tubular injector worked best on small-diameter stems.

Injection Herbicides. Table 2 shows the selectivity of commonly used injection herbicides. In Tables 2 and 3, a "V" denotes variable control between studies and split boxes denote that the average control was near to the susceptible and tolerant cut-off limits, 80 and 40 percent, respectively. Roundup and Garlon 3A are usually diluted by mixing 1 part herbicide with 1 OK 2 parts water. Tordon RTU and Tordon 101R are used undiluted, which is the same as a 50 percent mixture of Tordon 101 and water. With undiluted Tordon 101, **Shipman** (1984) reported good control of striped maple. Wendel and Kochenderfer (1982) reported that Roundup effectively controlled 14 hardwood species in West Virginia following injections of 20 or 50 percent solutions at a rate of 1.5 ml per incision.

Table 2. Species susceptibility by injection treatments from July-August with commonly used herbicides (from Campbell 1985 and 1980; Kossuth et al. 1980; **Wickham** and Holt 1977).



It should be noted that the use of Tordon products for injection in hardwood stands can cause death or damage to nontarget trees due to a soil active ingredient. The soil-active ingredient can be exuded from roots of treated stems and taken up by nontarget trees. Holt et al. (1975) reported that the movement of herbicide from treated to untreated trees occurred in less than 1 percent of all injected stems. Garlon 3A and Roundup do not have soil-active ingredients, and nontarget control can only result from root grafts, which are common with certain species. Thus the use of Garlon 3A and Roundup may minimize, but not eliminate, the problem.

Injections can be used any time of the year; however, some herbicides work better during certain seasons. Roundup works best in the fall but is consistently ineffective on hickory and dogwood. From December to the middle of January seems

Susceptible (> 70% clumps killed)		Marginal (70-40%)	Tolerant (< 40%)
sweetgum	waxmyrtle	yellow poplar	sourwood
red maple	w. sumac	dogwood	sweetbay
s. red oak	hornbeam	blackgum	titi
water oak	mt. ivy (Kalmia)	rhododendron	hophornbeam
post oak	black locust		loblolly pine
hickory	gallberry		
beech	huckleberry		
black cherry	boxelder		

Control is best on smaller stems of all species. Effectiveness on marginally controlled species can be increased by increasing the percentage of Garlon 4.

The usual method of application is with a backpack sprayer equipped with a straight stream tip, like the Spraying Systems TP 0001 or 0002 tip. Application is usually made in the late dormant season when leaves do not hinder spraying the stem; however, the optimum timing of application has not been fully determined. The herbicide mixture is applied in two back and forth swings across the stem wlthin 20 inches of groundline. Wlthln 1 or 2 hours of application, the wetted area spreads down and encircles the stem. Stems that are beyond the juvenile bark stage, heavy barked, or near 3 inches in diameter may require. treating both sides.

High-volume or full basal treatments can control a wider range of stem sizes up to 6 inches la d.b.h. (and even larger stems of susceptible species like maple, beech, and boxelder). Some herbicide labels do not give limits for the stem diameter. The lower 12 to 24 inches of the stem must be completely wetted with the spray mixture on all sides.

The herbicide mixture is usually applied wlth a backpack sprayer equipped with a spray gun or a spray wand fitted with a narrow-angle flat fan or adjustable spray tip. In the South, the USDA Forest Service uses the Spraying Systems Model 30 Gunjet with a flat spray fan tip (TP 1503). The tip is oriented in the Gunjet with the fan angle parallel to the tree trunk. In other words, the tip should spray a 12- to 24-inch vertical band when aimed directly at the trunk.

The co&only used herbicides in the South, which are applied mixed with diesel fuel, are 2,4-D ester, Garlon 4, and Weedone 2,4-DP. The ready-to-use mixture, Weedone™ CB, is more costly and less frequently used. Coble *et* al. (1969) studied dormant season applications to 3- to 6-ft tall stems and reported that l-percent mixtures of 2,4-D ester in diesel effectively controlled red maple, sassafras, black cherry, white ash, dogwood, yellow poplar, and sourwood. Even the highest rate of 4 percent did not control persimmon, sweetgum, and rhododendron. Basal applications are usually applied during the hardwood dormant season, although some applications are made in the summer. A 6-percent mixture of Garlon 4 in diesel was effective on controlling clumps of 10 hardwood species when applied from February to April in central Alabama (Zutter 1985). A 2-percent mixture of Garlon 4 in diesel and undiluted Weedone CB were effective when applied year-round on southern hardwoods up to 3 inches in d.b.h. (Yeiser and McLemore 1986). The volatility of the oil-mixed combinations may injure nontarget stems when applied on hot summer days.

Stump Treatments

Stump resprouting of many species can be prevented by herbicide treatment. The best control is achieved when treatment occurs within 2 hours of cutting. A backpack sprayer with a straight stream or flat fan tip is used or a utility spray bottle the sawyer can carry. For small diameter stumps a wick applicator is most efficient. The cambial area, the outer 1 inch of the stump, must be thoroughly sprayed with the herbicide. The same herbicides as used for injection are used for stump treatments, although the dilutions of Roundup and Garlon 3A used in injection have not been reported. Lewis et al. (1985) tested five herbicides applied to hardwoods in Virginia at 26 ml/per square foot of basal area and reported that Tordon 101R, Roundup, and Garlon 3A gave an average of 50 percent kill and 80 to 90 percent crown-volume reduction. Tordon was most effective on red maple, hickory, and dogwood; Roundup was most effective on chestnut oak; and all three performed well on sourwood, white oak, and yellow poplar.

From a test of five herbicides on eight species for pine release in Arkansas, Troth et al. (1986) reported that undiluted Garlon 3A and Weedone CB were the most effective. Tordon 101R and Banvel CST caused substantial nontarget pine damage, probably because of their soil-active ingredients. Frequent nontarget pine mortality also occurred on a Garlon 3A treated plot where numerous pine stumps were treated, probably because of root grafts. Thomas et al. (1987) reported complete control and no regeneration damage when treating stumps with Tordon RTU after clearing under sugar maple for hardwood regeneration. Application occurred simultaneously with brush sawing, using a sprayer attachment for the brush saw. As was discussed in the injection section, unacceptable damage or mortality may occur in selective hardwood treatments due to soil-active ingredients in Tordon and Banvel herbicides and root grafts. To minimize these losses, the use of Roundup and Garlon 3A would be preferred because of the absence of soil-active ingredients.

A method for treating stumps up to 5 months after cutting that requires additional testing uses the low-volume basal spray mixture of Garlon 4 (20%), Cide-Kick (10%), and diesel (702) (Williamson and Miller 1986). This mixture is sprayed on the outer l-inch edge of the stump to runoff and on the base of sprouts. Weedone CB may also be useful in delayed stump treatments.

Directed Foliar Sprays

Sprays of foliar-active herbicides in water can be efficiently applied to control unwanted stems that are less than 6 ft tall. Care must be taken to direct the spray away from desirable regeneration. To avoid herbicides with soil-active ingredients, Garlon 3A, Garlon 4, Roundup, and Weedone 2,4-DP are preferred. Always check the label for specific rates, uses, hazards, precautions, and directions.

Current recommended rates and application periods for the' South are:

Herbicide	Percent Mixture in Water	Application Period
Garlon 3A	2 to 5 percent	April - September
Garlon 4	2 to 4 percent	April - September
Roundup	2 to 4 percent	August - October
Weedone 2,4-DP[1]	4 to 5 percent	April - early June

Early season application should be made after the target species' initial flush of leaves are fully expanded, and late season application should be made before fall colors appear. Injury of nontarget plants due to volatility of the herbicide will occur when applying Garlon 4 and Weedooe 2,4-DP on hot summer days. Garlon 4 appears to provide better control than Garlon 3A, especially on red maple, hickory, dogwoods, ash, and some of the waxy leaf brush species. Weedone 2,4-DP does not appear to 'provide good control of red maple, ash, dogwood, blackgum, water and willow oak, hophornbeam, or many waxy-leaf brush species.

Directed spray applications are usually made with a backpack sprayer fitted with a wand and a flat spray tip (TP 2503 by Spraying Systems), full-cone tip, or adjustable tip. To apply, direct the spray onto the target foliage, being sure to cover the growing shoots. Herbicide mixtures of lower concentrations (2X) require heavy foliage wetting, and most of the target foliage must be covered by the spray mixture. Herbicide mixtures of higher concentrations (3-5X) require less wetting and coverage. For instance, when using the less concentrated herbicide mixture, spray the foliage nearly to the point of leaf runoff covering at least 80 percent of the foliage. The more concentrated herbicide mixture needs only about two to three droplets per leaf on about 70 percent of the target foliage. The growing tips should always be thoroughly sprayed. An exception to the above is Weedone 2,4-DP, in which case the foliage should be thoroughly sprayed to just short. of leaf runoff.

Banded Treatments for Woody Plant Control

Woody competition can be controlled by applying soil-active herbicides in bands between, planting rows. Miller and Burkhardt (1987) tested Velpar and Spike 20P pellets (not currently labeled) applied as interrow banded treatments for establishing cherrybark oak in large patches and reported limited success. The banded treatments, applied simultaneously with planting by the planters, were more successful then broadcast applications made 1 year prior to planting. Banded applications of soil-active herbicides between planting rows has shown promise for controlling hardwoods when establishing pine plantations (Griswold and Gonzalez 1981, Hinton 1970, Miller 1985a) and for controlling hardwood brush for range improvement (Merrifield and Ransbrough 1960, Meadors et al. 1956). Application devices can be made to mount on planting machines for banded applications of herbicides for both woody and herbaceous control during plantation establishment on large tracts (Miller et al. 1985, Hinton 1970).

[1]This use may not be labeled in every State.

Broadcast Treatments for Woody Plant Control

Broadcast applications, either by helicopter or tractor-mounted equipment, can provide broad-spectrum control using either spray or pelleted herbicides on clearcut sites before planting hardwoods. High rates and carefully prescribed herbicide mixtures will probably be required to suppress regrowth on highly productive sites with diverse species. It should be remembered that with complete woody competition control, herbaceous competition will become more severe (see section on herbaceous weed control). Information regarding helicopter and ground machine application can be obtained from Cantrell 1985 and Miller 1985c. Table 3 shows some of the selectivity of common herbicides that are broadcast for site preparation prior to pine planting in the South and the amount of herbaceous control as percent bareground. This is unpublished data from fuelwood harvested areas in central Georgia treated from 1 to 7 years after harvest. These area had been treated using a tractor sprayer with a nozzle on a 12-ft high boom and an Omni™ spreader.

Table 3. Second-year assessments of species susceptibility with site preparation rates of herbicides and prescribed burning; the amount of herbaceous control is expressed as percent of bareground.

HERBICIDE(S)	RATE(S)	Sweetgum	Red Maple	S. Red Oak	Hickory	Blackgum	Persimmon	Black Cherry	Dogwood	W. Sumac	Huckleberry	BARE-GROUND IN JUNE
Garlon 4 + Tordon K	0.5+0.5 GPA	M/S	S	M/S	M	S, V	T	S	M	?	?	<10%
Garlon 4	1 GPA	M/S	M, V	M/S	M/S	M	T	M	M, V	T	T	<10%
Pronone 10G	25-35 PPA	S	M	S	T	S, V	T	M	T	T	T	50-80%
Velpar L	1.25-1.75 GPA	M/S	M	S	T	S, V	T	M	M	T	T	50-100%
Roundup	1 GPA	S	M	M/S	T	S, V	M	M	M	M	M	20-50%
Arsenal	1 QPA	S	S/M	S	M	T/M	S	M	T	S	M	10-40%
Banvel + Banvel 720	0.5+2 GPA	M	T	T/M	M	S, V	T	T/M	S, V	?	T	<10%

Susceptible: > 80% of clumps killed   Tolerant : < 40% of dumps killed

Marginal : 4040% of dumps killed   V = Variable control by treatment.

Mistblowing has been used successfully for broadcast applications on a limited number of sites. Ostrofsky and McCormack (1986) reported that beech advance reproduction was completely controlled by mistblowing Roundup, and there was 93-percent control using Garlon 3A. Horsley (1984) was successful in controlling ferns, grasses, and striped maple in Pennsylvania by mistblowing Roundup at 1 qt/A. Earlier results by Tierson (1969) reported successful beech control by mistblowing 2,4,5-T using backpack and tractor equipment. Mistblowing applications under an overstory are limited by interstand access and the effective treatment height. Because mistblown sprays can travel for several miles, mistblowing should only be used on isolated tracts.

It is intriguing to anticipate that broadcast applications of selective herbicides will be used in the future for releasing hardwood regeneration. Pham (1987) has screened five common forestry herbicides, using broadcast sprays at three rates, for release potential on 1- and 2-year-old hardwood clearcuts in West Virginia. Mixed results were reported. Roundup released sugar maple at 1.5 qt/A and effectively controlled yellow birch, pincherry, and black cherry. After application of Tordon 101, the number of northern red oak increased, but red maple competition was also increased; overall densities of all competitors were not changed. With Garlon 4, overall stem reduction ranged from 14 to 44 percent, with best control of pin cherry and white ash. Northern red oak and sugar maple resprouted. Velpar L significantly changed overall density starting at 3 qt/A, with red maple and white ash showing tolerance. Yellow poplar, which is somewhat tolerant of Velpar L, was slightly increased at the 2-qt/A rate. Basswood regrowth from sprouts was increased on Krenite treated plots. Unfortunately, as is often the case, desirable species were not uniformly present in high enough numbers to give a good test of selective release on all plots.

Broadcast herbicide applications can be useful for controlling severe to moderate infestations of vines and noxious weeds that preclude or hinder regeneration. Japanese honeysuckle (Lonicera japonica Thunb.) was successfully controlled on bottomland hardwood sites in North Carolina using broadcast sprays of Roundup (Schcaeckpeper et al. 1987). Raspberry (Rubus strigosus Michx.) in Minnesota was also reportedly controlled by broadcast applications of Velpar L (Alm and Whorton 1985). Kudzu (Pueraria lobata Thund.) infestations in the South are controllable using single or repeated applications of Tordon 101 at 1 to 2 gal/A and Banvel at 2 to 4 gal/A (Miller and True '1986, Miller 1985b).

Considerable effort in research and development will be needed to successfully realize the potential use of herbicides in broadcast release applications hardwood regeneration sites. Even more sophistication in prescribing appropriate mixtures and application uniformity will be required than is currently used in the most developed pine release treatments.

Herbaceous Weed Control

Benefits

The growth benefits certain hardwood species derive from herbaceous weed control during early plantation establishment have been well documented (McCormack 1981, Zutter et al. 1986, Byrnes et al. 1973, Fitzgerald and Sheldon 1975; Ponder 1987, Bowersox and McCormick 1987). Herbaceous weeds strongly compete with hardwood seedlings for all essential resources: moisture, nutrients, and light.' Rodent predation and the hazard of weed fires is also reduced as herbaceous cover is reduced.

Herbaceous control at planting and for at least the first 3 years has been stressed to assure successful plantation establishment (Bey and Williams 1976, Wright and Holt 1985). Weed control is especially necessary when fertilizers are applied (Russell 1977). Hardwood species that show improved survival and increased early growth with 1 or more years of herbaceous control are black walnut, yellow poplar, white and green ash, sweetgum, sycamore, cottonwood, hybrid poplar, and cherrybark oak. Northern red oak has shown variable growth response with herbaceous control. If cultivation is used instead of herbicides for herbaceous control, less growth gains are possible because of soil compaction, erosion, and crop tree damage (Zutter et al. 1986). The long-term growth gains and economic returns from herbicide control have not been established, but improved survival; which assures full stocking, has been demonstrated with many test situations.

Herbicides

Research results have identified the most promising herbicides, in decreasing order of effectiveness, to be Oust'", Roundup, Princep" **4L, AAtrex™ 4L,** 2,4-D ester, Dowpon'" **M, and Poast™.** Not all of these are labeled as yet. Many combinations of these products are being tested. Other products have also shown promise on certain hardwood species.

In the central hardwood region, most trials have been with plantation establishment on old fields usfng preplant sprays. Early research in Iowa found full-season control with April applications of Princep 4L at 1 gal/A applied to plowed and **disked** ground and **AAtrex** 4L at 1 gal/A applied to unprepared ground (Erdmann 1967). The main competition was smooth **brome** grass (Bromus inermis Leyss) and the soils were a silt loam.

More recent trials in Indiana, testing five hardwood species and nine herbicide treatments for two seasons, found that Oust applied at 4 **oz** of product per **acre yielded** the most cost-effective control **with minimal** crop injury (Wright 1985, Wright and Holt 1985). Oust was most effective when applied in April; however, Oust **is** not *yet* labeled for this application. Roundup (3 **pt/A)** in combination with Princep (0.5 to 1 gal/A) provided significantly greater initial control than Oust but was twice as costly. Intermediate in cost and effectiveness was a mixture of Dowpon M, 2-4-D ester, and Princep 4L at 36 lb, 4 pr, and 6 pt respectively, per **acre.** Sam et al, (1985) reported that the forest floor did not have to be removed for Oust to be effective; removal was required for Princep and other products.

In Indiana, Kosinski and Holt (1985) found that black alder could not tolerate the 4 **oz** rate of Oust and that the new herbicide, Arsenal'", at rates as low as 4 fluid **oz/A** severely injured black walnut, red oak, *green* ash, and European black alder. Hall et al. (1986) identified several herbicides and mixtures that could be used safely on black alder **in** Pennsylvania. In Wisconsin, Netzer (1986) tested Oust and Arsenal when establishing hybrid poplars and aspen on abandoned field6 covered with quackgrass. Oust, applied on May 15 at 3 **oz** product per acre, was the most effective.

In Alleghany hardwoods, Horsley (1981) reported that an understory spray of Roundup at 1 **qt/A** was the most effective treatment for controlling fern6 and grasses before a shelterwood cut or-planting. Application was most effective when made between August 1 and September 1. This treatment provided three growing seasons of **control** for **bracken** fern (Pteridium aquilinum (L.) Kuhn), rough goldenrod (Solidago rugosa Mill.), and **flattop** aster (Aster u s Mill.).

In the South, many herbicides and combinations have been tested as **over-the-top** sprays for establishing plantations of sweetgum, **sycamore, and** cottonwood (Metcalfe 1984, Cantrell and Metcalfe 1985, **Knowe** 1984). Oust **is** a promising herbicide for use in sycamore plantations, but causes unacceptable damage to **sweetgum** at certain locations. **Septer™** shows promise for-weed control in cottonwood plantations because of good crop tree tolerance, but only marginal weed control has been obtained at sites tested thus far. Low rates of Arsenal (1 pt/A) yields the best weed control of all the over-the-top sprays tested, but causes about 20 percent severe damage to sycamore, 75 percent to sweetgum, and 100 percent mortality of cottonwood.

In summary, preemergent applications of Oust have provided good control of many forbs and some grasses across many sites. Crop tree tolerances will have to be determined for each commercial hardwood. bate summer sprays of Roundup are effective for preplant and pregermination treatments of a wide spectrum of herbaceous weeds. Other products are less effective but can be used with specific combinations of crop and weeds. Rapid development and testing of new herbicides for herbaceous control is progressing, and new effective products should continue to emerge in the coming years.

Herbaceous Control Applications

Herbaceous herbicides can be applied in three ways: broadcast 'using aerial or ground equipment, in bands over planting rows, and around Individual seedlings as patches. For broadcast applications, Jones et al. (1986) reported that Oust could be tank-mixed with the most commonly used site preparation herbicides without hindering the effectiveness for woody and herbaceous control. Banded and patch applications minimize herbicide costs and concentrate weed control to the area around seedlings. However, application costs may increase. Banded applications are usually made by a tractor or ATV with a boom that treats one to several rows with each pass. When row layout is not precise, sprayer attachments for planting machines permit simultaneous banded applications and planting (Miller et al. 1985). Patch applications around individual seedlings are performed by using a backpack sprayer equipped with a flat fan or cone nozzle (Williamson and Miller 1966). The attachment of a spray shield to the wand permits application of nonselective herbicides (e.g., Roundup) immediately around hardwood seedlings.

Safety Precautions

Many of the uses discussed and suggested in this paper are not as yet labeled. Label instructions must be followed in all situations. You must read and understand the herbicide label before use, or contact a forestry extension specialist or product representative for assistance.

Safety procedures are essential when handling and applying herbicides. Proper clothing and protective gear is essential. for personnel loading and applying herbicides, especially when handling the concentrated product. Proper procedures, with documentation of adherence, are needed. At all times there must be concern and care in keeping herbicides out of surface waters unless the product is labeled for aquatic use, and then, as always, labeled rates must be used.

Thorough and detailed tests by the Environmental Protection Agency of each product have determined that if the label instructions are followed, these herbicides can benefit man and not adversely impact the health of man, wildlife, fish, and the forest ecosystem. Because of the established low human toxicities of forestry herbicides, these products can be used safely and effectively. The necessary ingredients for successful use are: proper prescriptions, technically sound applications, and an acute concern for the environment and the total forest community.

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Appendix Table 1. Common and scientific names of woody plants. (Radford et al. 1968).

Common Name	Scientific Name
American holly	Ilex opaca Ait.
Aspen, hybrid	Populus tremulax, P. tremuloides
Ash, green	Fraxinus pennsylvanica Michx.
Ash, white	F. americana L.
Basswood	Tilia americana L.
Beech	Fagus grandifolia Ehrh.
Black alder	Alder spp.
Black locust	Robinia psuedo-acacia L.
Black walnut	Juglans nigra L.
Blackgum	Nyssa sylvatica Marsh.
Boxelder	Acer negundo L.
Cherry, black	Prunus serotina Ehrh.
Cherry, pin	P. pensylvanica L.
Cottonwood	Populus deltoides Bartr.
Cottonwood, hybrid	Populus spp.
Dogwood	Cornus florida L.
Elm, winged	Ulmus alta Michx.
European black alder	Alnus glutinosa (L.) Gaertn.
Gallberry	Ilex glabra L.
Hickory spp.	Carya spp.
Hophornbeam	Ostrya virginiana L.
Hornbeam	Carpinus caroliniana Walt.
Huckleberry.	Vaccinium spp.
Loblolly pine	Pinus taeda L.
Maple, red	Acer rubrum L.
Maple, sugar	A. saccharum Marsh.
Maple, striped	A. pensylvanicum L.
Mountain ivy	Kalmia latifolia L.
Oak, cherrybark	Quercus falcata var. pagodifolia Ell.
Oak, chestnut	Q. prinus L.
Oak, post	Q. stellata Wang.
Oak, northern red	Q. rubra L.
Oak, southern red	Q. falcata Michx.
Oak, water	Q. nigra L.
Oak, white	Q. alba L.
Persimmon	Diospyros virginiana L.
Poplar hybrid	Populus spp.
Rhododendron spp.	Rhododendron spp.
Sassafras	Sassafras albidum Nutt.

Appendix Table 1 (Cont'd)

Common Name	Scientific Name
Sourwood	Oxydendrus arboreum L.
Sweetbay	Magnolia virginiana L.
Sweetgum	Llquidambar styraciflua L.
Sycamore	Platanus occidentalis L.
Titi	Cyrillaceae racemiflora L.
Waxmyrtle	Myrica cerifera L.
White ash	Fraxinus americana L.
Winged sumac	Rhus copallina L.
Yaupon	Ilex vomitoria Ait.
Yellow birch	Betula lutea Michaux f.
Yellow poplar	Lirlodendron tuliplfera L.