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Directed Foliar Sprays of Forestry Herbicides for Loblolly Pine Release[1]

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ABSTRACT. Six herbicides were compared as directed foliar sprays applied in May, July, and September on seven hardwood species and on loblolly pine. Equal-cost mixtures that met or exceeded minimum labeled rates were tested for Weedone 2,4-DP, Garlon 4, Garlon 3A, Arsenal Applicator Concentrate, Roundup, Escort, and Roundup + Escort. Test hardwoods were sweetgum, southern red oak, water oak, red maple, pignut hickory, dogwood, and yellow poplar. Crown volume reduction and rootstock reduction after one growing season were the main indicators of efficacy. Using directed sprays, yellow poplar was the easiest species to control, and pignut hickory was the most difficult. Control of sweetgum was most effective with Weedone, Arsenal, and Roundup. For control of oaks, the most effective applications were in July with Arsenal, Garlon 4 and 3A, and Roundup; but these and other hardwood species tended to refoliate 2 years after Arsenal treatment. Herbicide safety to loblolly pine was best with Arsenal and Escort, while injury was greatest with Roundup and Garlon 3A, which might have potential use in precommercial thinnings.

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Directed foliar sprays are low cost alternatives to aerial applications of herbicides for releasing pines from competing hardwoods and shrubs (Thomas et al. 1989, Lowery 1981). Directed sprays also could be used in site-preparation treatments, precommercial thinnings, hardwood regeneration management, and cover maintenance of wildlife openings, scenic vistas, and recreational areas. Applications of directed sprays with backpack sprayers are usually made before target stems exceed 6–8 ft in height. A commonly used herbicide for directed sprays has been Weedone 2,4-DP, with the application period restricted to April through June (Williamson and Miller 1988, Gonzalez and Evans 1986). Because of the economical treatment costs associated

with direct sprays, their advantage of selective application and resulting capability to minimize environmental impacts, other effective herbicides need to be identified that will extend the application period and broaden the spectrum of control.

The objective of this study on pine release applications was: (a) to compare the control of equal cost solutions of several forestry herbicides applied as directed sprays at three different timings, and (b) to assess the potential for loblolly pine injury when accidental spraying occurs. Herbicide mixtures of about equal cost—$1.00 to $1.30 per gallon mix—were tested, except for a promising newly labeled product, Escort, which was applied at higher costs ($1.65 per gallon mix). Escort is currently labeled for broadcast applications in established plantations (at least 2 yr old) of loblolly pine (*Pinus taeda* L.).

METHODS

Three study areas were used, one in the Piedmont of east-central Alabama and two in the Great Appalachian Valley of northwest Georgia. All were regeneration areas with 2- to 4-year-old plantations of loblolly pine. Sites had been prepared by shearing and windrowing or by chainsawing alone. Soils were mainly loam to sandy clay loam in surface textures. Test species at the Alabama location were sweetgum (*Liquidambar styraciflua* L.), southern red oak (*Quercus falcata* Michx.), water oak (*Q. nigra* L.), pignut hickory (*Carya glabra* (Mill.) Sweet), and loblolly pine (*Pinus taeda* L.). In Georgia, the test species were red maple (*Acer rubrum* L.), dogwood (*Cornus florida* L.), and yellow poplar (*Liriodendron tulipifera* L.).

Individual hardwood and pine trees—rootstocks with single or multiple stems—were the basic experimental units. For each species and treatment cell, 22 rootstocks were randomly selected, tagged, and measured before treatment. Selected hardwoods were 1.5–6 ft tall, with some yellow poplars up to 8 ft tall. All were seedlings or sprouts from apparently independent root systems, at least 5 ft apart. Large sprouting stumps were avoided, and no rooted downfalls were selected. Test seedlings of loblolly pines were in their third growing season at the time of treatment. Only healthy and relatively open-grown plants were chosen, and woody vegetation was often cut from around the test plants.

Table 1. Description of the test herbicides.

Herbicide	Manufacturer	Formulation[1]
Weedone 2,4-DP	Rhone-Poulenc	4 lb a.e. dichlorprop ester per gal
Garlon 4	Dow	4 lb a.e. triclopyr ester per gal
Garlon 3A	Dow	3 lb a.i. triclopyr amine per gal
Arsenal applicator concentrate	American Cyanamid	4 lb a.i. imazapyr amine per gal
Roundup	Monsanto	4 lb a.i. glyphosate per gal
Escort	DuPont	75% dispersible granule of metsulfuron

[1] a.e = acid equivalent; a.i. = active ingredient.

Test herbicides are described in Table 1 and treatments are listed in Table 2. Rates were selected that were approximately the same cost of the Weedone 2,4-DP at 4–5%, except for the higher costs of Escort and its mixture with Roundup. Rates of Weedone 2,4-DP were increased after the May timing and rates of Roundup were slightly higher in May, to compensate for anticipated periods of lower efficacy. The 5% mixture of Weedone 2,4-DP exceeds the currently labeled rate of 4%. Garlon herbicides are currently labeled for 2–4% mixtures and thus were tested at the lowest labeled rate. Roundup is labeled at 1–2%, which means the 2.5% used in May exceeded this, and the 0.75% with Escort was below label specifications.

Treatments were made in May, July, and September, 1986—a drought year with a record dry spring. The drought was broken with periodic rainfall starting on July 17 in Alabama and on August 10 in Georgia, after the July applications. Thus, these results reflect control of moisture stressed trees. CO_2 gas-pressurized sprayers were used for all applications with 15 psi pressure and a Spraying Systems Company 6501 tip (65° flat fan with 0.1 gpm at 40 psi). A plastic shield, attached over the nozzle, decreased the wind effect and aided in the partial treatment of some test pines. All exposed foliage on the top and sides of every stem comprising a rootstock were sprayed until uniformly covered, without leaf drip. Thus, complete coverage without drip was the criteria set for treatment and very little, if any, herbicide was applied to the soil around plants. Three applicators were trained and supervised in this procedure to assure uniform application. No applications were made when winds exceeded 8 mph or temperatures exceeded 90°F, and no applications were made during periods of excessive morning dew. Herbicides were mixed most often the morning of application or the night before. One water source was used for all mixtures.

To assess the possible injury to

Table 2. Test treatments by timing of application.[1]

Herbicide	May	July	September
Weedone 2,4-DP	4%	5%	5%
Garlon 4	2%	2%	2%
Garlon 3A	2.5%	2.5%	2.5%
Arsenal	0.5%	0.5%	0.5%
Roundup	2.5%	2%	2%
Escort	1/16 oz/gal	1/16 oz/gal	1/16 oz/gal
Escort + Roundup	1/16 oz/gal + 3/4%	1/16 oz/gal + 3/4%	1/16 oz/gal + 3/4%
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[1] A surfactant-penetrant (Cide-Kick II) was added to all herbicide mixtures at 0.5%.

loblolly pine, two different degrees of herbicide coverage were tested. With the first group of pines, only the lower half of the seedlings was sprayed, while complete coverage was used with the second group and is referred to as "all" in the tables.

Each plant was measured before treatment in 1986 and then in August, 1987–11 to 15 months after treatment. This appears to be an appropriate evaluation period for judging control of this size of target stem. Test plants were showing near maximum response to the treatment, and relocation was still possible in the rapidly developing plantations. The measurements were: number of stems in the rootstock, crown height, maximum crown diameter, and right-angle crown diameter. Resprouting was noted in 1987. Measurements were made to normal-sized leaf tips. Arsenal treated trees that were completely defoliated were judged dead, even when the cambium remained green. To determine the amount of recovery, these defoliated individuals were again examined in August, 1988, for the presence of foliage.

As an estimate of complete control, the amount of rootstock reduction (*RR*) was calculated by:

$$RR\ (\%) = \frac{\text{No. treated rootstocks 100\% killed with no resprout}}{\text{Total no. of treated rootstocks} \times \text{Correction factor}} \times 100$$

where

$$\text{Correction factor} = \frac{\text{Number of surviving untreated check rootstocks}}{\text{Number of untreated check rootstocks}}$$

Thus, *RR* is an expression of the percent of treated rootstocks that were completely killed and showed no resprouting during the evaluation period. The amount of crown volume reduction (*CVR*) was calculated using the total height and an average of the crown diameters, for both the treated and untreated trees. *CVR* is a value indicating the degree of topkill. The height and diameter, before and after treatment, were used to calculate the volume of cylinders, which were used to calculate the CVR by:

$$CVR\ (\%) = \frac{(\text{Original crown volume} \times \text{Growth factor}) - \text{Final crown volume}}{\text{Original crown volume} \times \text{Growth factor}} \times 100$$

where:

$$\text{Growth Factor } (GF) = \frac{\text{Final crown volume of untreated check trees}}{\text{Original crown volume of untreated check trees}}$$

Thus, *CVR* takes into account the amount of growth that would have occurred during the period between the initial and the final measurement. A *CVR* equal to zero means that the treated tree grew equally to the average of the untreated trees. A *CVR* of 100 means that the crown was completely deadened and no resprouting occurred.

A completely randomized design was used with the number of replications equaling the number of test plants per treatment. Due to missing observations, analysis of variance with unequal cell sizes was used. Of the 4,752 rootstocks initially tagged, 4,542 were found for final measurements. Arcsine square root transformations were used on all percentage variables to normalize their distribution, while actual values are reported. Tukey's mean separation procedure was calculated for *CVR*'s, but *RR* reduction could not be statistically analyzed since it is an average of all treated rootstocks. When discussing statistically comparable control, a 0.05-level of probability is used.

To provide quick-reference prescription aids, *CVR* and *RR* are presented in figures using three categories of control:

1. Susceptible: greater than 80% control
2. Marginal: 40–80% control
3. Tolerant: less than 40% control

These categories are mainly simplifications of the data for presentation, but do reflect categories of predicted treatment results derived from field and data observations. *CVR* is an integrated value, indicating the average status of all treated plants, which averages in zeros for completely controlled rootstocks. When thinking about these categories for CVR: most rootstocks of a susceptible species are so damaged they will eventually die; marginal species have sustained considerable crown reduction to lessen competition but should recover; and tolerant species will continue to compete at an almost undiminished level. When considering RR and a treatment objective of eliminating competing rootstocks, these categories infer that an excellent level of control can be expected with susceptible species, marginal levels of reduction can be expected on marginal species, and very little competition control can be expected when treating tolerant species. If a reader feels that the divisions are inappropriate, then other cutoffs can be selected and the figures can be modified and shaded accordingly using their own or the tabular information.

RESULTS AND DISCUSSION

The herbicide treatments resulted in a wide variety of control on the test species (Tables 3 and 4), which is indicated by the highly significant treatment effects in the analysis of variance of *CVR* in Table 5. Application timing was least important on overall *CVR* of sweetgum, red maple, and yellow poplar. However, the efficacy of most herbicides on a species, except yellow poplar, changed with timing of application as supported by the significant treatment-timing interactions. Yellow poplar was effectively controlled by most herbicides at all timings. Thus,

Table 3. Crown volume reduction (*CVR*) of hardwoods and loblolly pines less than 8 ft tall after treatment with foliar directed sprays of herbicides at 3 timings.[1]

Herbicide	Swtgum	S. Red Oak	Water Oak	Maple	Hick	Dgwd	Y. Pop	Pine Lower	Pine All
	(%)								
					May				
Weedone	97a	73ab	59a	67b	94a	92a	91	29b	58cd
Garlon 4	75bc	85a	73a	90a	85ab	96a	90	11b	73bc
Garlon 3A	73bc	76ab	72a	97a	83ab	91a	87	29b	87ab
Arsenal	93ab	38bc	53a	89a	68abc	80a	100	18b	37de
Roundup	96a	51bc	81a	96a	65bc	94a	98	69a	94a
Roundup + Escort	68bc	58bc	82a	99a	66ab	84a	81	41b	44de
Escort	60b	49bc	50ab	71b	41cd	77a	83	18b	11e
Untreated	0d	0d	0b	0c	0d	0b	0	0b	0e
					July				
Weedone	75b	64bc	59c	42c	72bcd	85bc	71	17bc	88a
Garlon 4	84b	93a	96ab	79b	95a	93ab	98	8bc	89a
Garlon 3A	83b	94a	88b	85b	86a	96a	86	17c	96a
Arsenal	100a	97a	100a	100a	83ab	99a	100	22c	33b
Roundup	100a	79ab	99a	99a	86a	78c	87	90a	97a
Roundup + Escort	98a	56c	86b	99a	68cd	99a	99	44b	98a
Escort	8c	15d	57c	85b	48d	94ab	51	10bc	17b
Untreated	0c	0d	0d	0c	0e	0d	0	0c	0b
					September				
Weedone	92a	59cd	79b	25b	45bc	79ab	95a	31c	76b
Garlon 4	77ab	86ab	61b	85a	48ab	91a	100a	23c	71b
Garlon 3A	91ab	57cd	28cd	91a	29bc	93a	100a	32c	82ab
Arsenal	97a	99a	95a	81a	62a	93a	92a	11c	21c
Roundup	98a	77abc	99a	98a	26bc	68b	100a	99a	92a
Roundup + Escort	71b	56cd	73b	93a	42bc	85ab	99a	65b	88ab
Escort	26c	24e	43c	92a	37bc	80ab	54b	9c	8c
Untreated	0c	0e	0d	0b	0c	0c	0c	0c	0c

[1] Values in a column followed by the same letter are not significantly different at the a = 0.05-level as determined by Tukey's procedure.
[2] Vandalism of tags prevented exact tree identification and Tukey analyses with the May and July timings.

Table 4. Rootstock reduction (percent that were completely killed) of hardwoods and loblolly pines less than 8 ft tall after treatment with foliar directed sprays of herbicides at 3 timings.

Herbicide	Swtgum	S. Red Oak	Water Oak	Maple	Hick	Dgwd	Y. Pop	Pine Lower	Pine All
	(%)								
					May				
Weedone	91	18	24	4	76	68	78	0	18
Garlon 4	33	48	48	56	67	62	95	0	5
Garlon 3A	24	42	32	80	44	43	90	0	48
Arsenal	50	19	40	70	11	25	100	0	0
Roundup	95	14	40	75	17	64	77	20	43
Roundup + Escort	14	9	48	86	31	50	62	4	0
Escort	10	9	35	15	5	28	95	0	0
Untreated	0	0	0	0	0	0	0	0	0
					July				
Weedone	13	0	5	5	0	36	61	0	48
Garlon 4	36	65	77	10	73	52	91	0	45
Garlon 3A	20	74	32	23	41	76	90	0	76
Arsenal	100	90	100	100	50	85	95	0	0
Roundup	100	18	75	76	14	14	79	41	95
Roundup + Escort	85	0	23	90	0	99	82	4	75
Escort	0	0	4	25	14	62	0	4	0
Untreated	0	0	0	0	0	0	4	0	0
					September				
Weedone	70	4	14	4	9	27	80	5	9
Garlon 4	55	45	36	50	18	74	100	0	33
Garlon 3A	53	9	5	41	9	57	100	0	24
Arsenal	86	90	94	71	60	85	90	0	0
Roundup	75	4	86	65	0	14	100	95	91
Roundup + Escort	9	0	0	78	0	45	91	19	41
Escort	0	0	0	47	0	22	33	0	0
Untreated	0	5	0	4	0	0	0	0	0

Table 5. Results of the analysis of variance of crown volume reduction (*CVR*) showing the probability of a greater *F*.

	SWG	SRO	WO	RM	PH	Dog	YP	PLH	PAL
Treatment	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Date	0.1835	0.0064	0.0001	0.1519	0.0001	0.0006	0.0438	0.0032	0.0001
T × D	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.1920	0.0001	0.0001

each timing must be considered separately when judging the effectiveness of these herbicide solutions.

Table 3 and Figure 1 summarize crown volume reduction, which can be consulted for making prescriptions where partial hardwood control is the objective. The amount of rootstock reduction is presented in Table 4 and then compiled as a quick-reference prescription aid in Figure 2. Figure 2 may be useful for selection of treatments where maximum control is the objective. The degree of pine injury is presented when either the pine is completely sprayed or only the lower half of the crown is sprayed. These results are discussed by species.

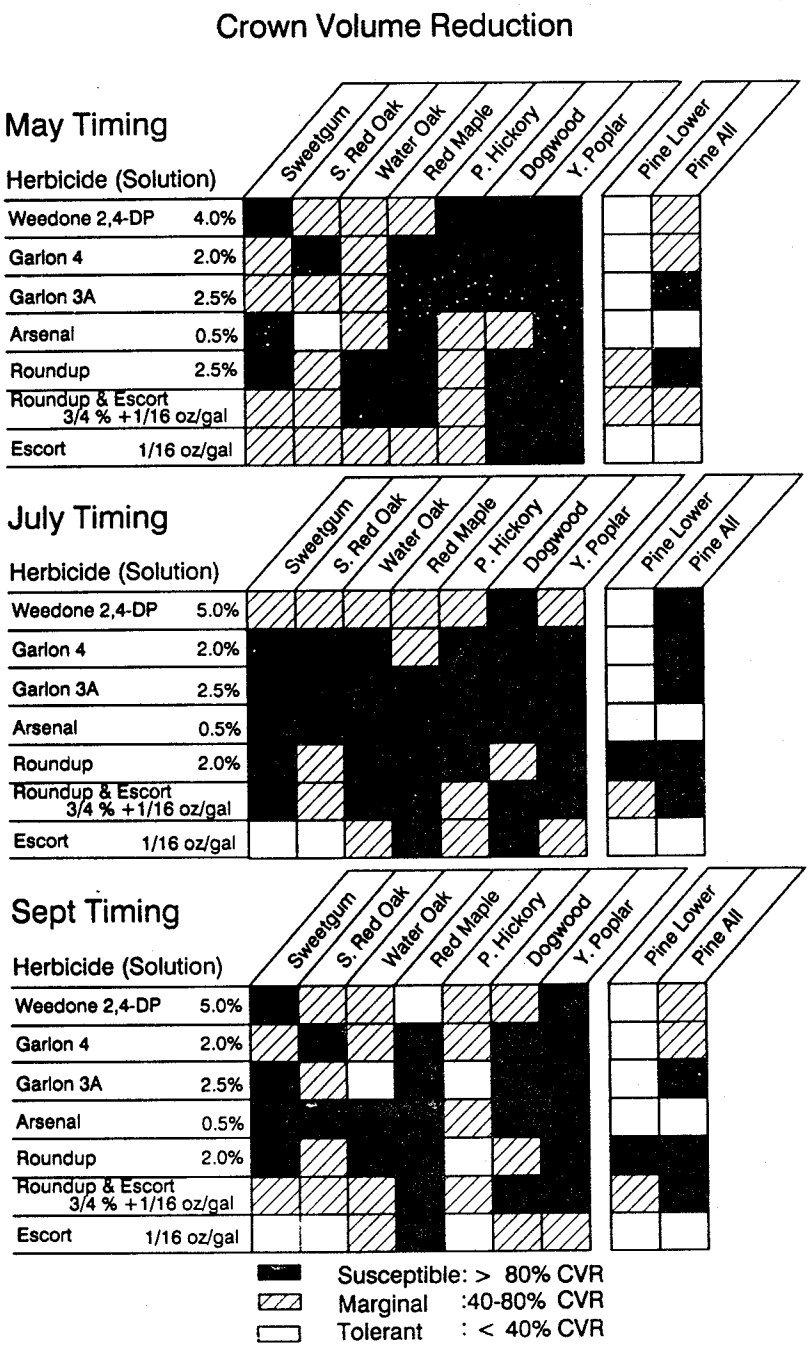

*Figure 1. Crown volume reduction (*CVR*) of hardwoods and loblolly pine less than 8 ft tall after treatment with foliar directed sprays of herbicides at 3 timings.*

Sweetgum

In May, almost complete control was provided by Weedone and Roundup. Arsenal gave comparable *CVR* (crown volume reduction), but resulted in less *RR* (rootstock reduction) and more resprouting was observed. In July, Arsenal and Roundup gave 100% *RR*, while Roundup + Escort gave comparable *CVR*'s but 85% *RR*. Also, both Garlons gave acceptable *CVR*'s of greater than 80%, but less than 40% of the rootstocks were controlled. In September, several herbicides yielded comparable *CVR*'s but some provided marginal *RR;* in descending order of apparent effectiveness was Arsenal, then Roundup, Weedone, Garlon 3A, and Garlon 4.

Southern Red Oak

In May, marginal *RR* was provided by both Garlon formulations, with only Garlon 4 resulting in >80% *CVR*. While red oak was fairly tolerant to Arsenal in May. With July treatments, 90% *RR* was provided by Arsenal. Comparable *CVR*'s, but less *RR*, was yielded by Garlon 3A, Garlon 4, and notably less by Roundup. In September, Arsenal again gave 90% RR, while Garlon 4 sprays yielded only 45% RR but 86% CVR. Roundup provided a 77% CVR which was comparable to Arsenal and Garlon 4.

Water Oak

In May, only 40–48% *RR* was achieved by Garlon 4, Arsenal, Roundup, and Roundup + Escort. Roundup and Roundup + Escort provided the greatest *CVR*, but were not significantly different than the other treatments. In July, Arsenal provided com-

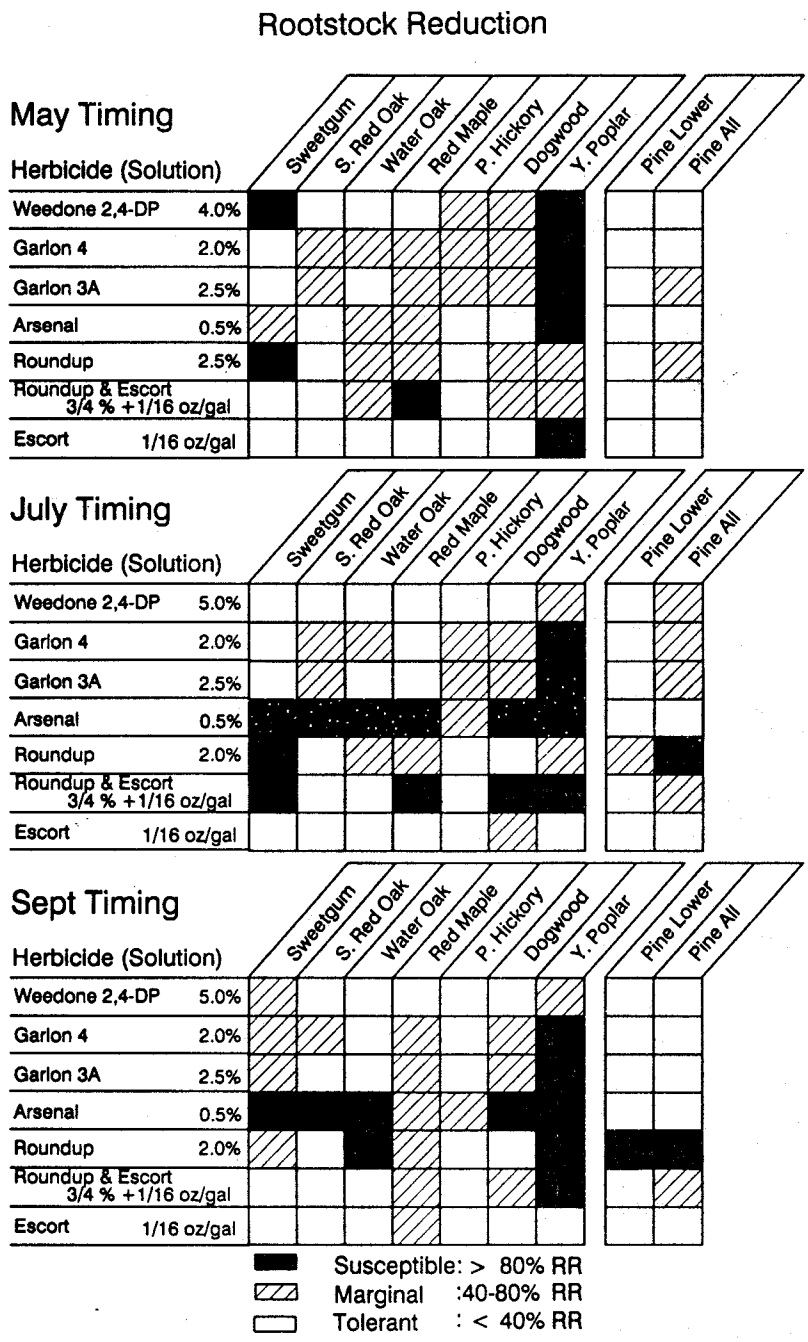

Figure 2. Rootstock reduction (RR) of hardwoods and loblolly pines less than 8 ft tall that were completely topkilled and did not resprout after treatment with foliar directed sprays of herbicides at 3 timings.

plete control of all treated rootstocks, while greater than 95% *CVR* came from Arsenal, Roundup, and Garlon 4. With September applications, Arsenal and Roundup gave comparable *RR* and *CVR*.

Red Maple

In May, only Roundup + Escort and Garlone 3A yielded *RR*'s that were 80% or greater. Five treatments provided comparable *CVR*'s that exceeded 89%: Garlon 4 and 3A, Arsenal, Roundup, and Roundup + Escort. Combining Escort and Roundup yielded comparable *CVR*'s for all timings and tended to increase *RR*'s by 11–15%. For July treatments, complete rootstock control was provided by Arsenal and 90% by Roundup + Escort. In September, all treatments except Weedone gave comparable *CVR* with the most *RR* provided by Roundup + Escort (78%) and Arsenal (71%).

Pignut Hickory

Pignut hickory was one of the most difficult to control species. By judging both *RR* and *CVR*, the best hickory control in May was with Weedone, Garlon 4, and Garlon 3A. Garlon 3A yielded 20–30% less *RR* but comparable *CVR*. In July, four treatments gave comparable *CVR*'s that exceeded 82% (in order of decreasing efficacy): Garlon 4, Arsenal, Garlon 3A, and Roundup. Only Garlon 4 gave *RR* above 50%. For September, poor control was the norm for all treatments with the best being provided by Arsenal (*RR* 60%, *CVR* 62%) and Garlon 4 (*RR* 18%, *CVR* 48%).

Dogwood

Dogwood is often considered to be a difficult-to-control species. Directed sprays with many herbicides yielded excellent *CVR*, but effective rootstock control was the exception. In May, all treatments provided comparable *CVR*'s but Escort was below 80%. Greater than 60% *RR* and 90% *CVR* was provided by Weedone, Garlon 4, and Roundup. In July, nearly complete *RR* was yielded by Roundup + Escort and 85% by Arsenal, with comparable *CVR* by all herbicides except Roundup. For applications in September, Arsenal was most effective by yielding over 85% RR with no resprouting and 93% CVR. When other response variables are considered, the outstanding treatment was Arsenal with 85% *RR* and no resprouting.

Yellow Poplar

Yellow poplar was the easiest species to control with directed foliar sprays. In May, all treatments yielded *CVR* greater than 80%, with Arsenal providing complete control of all treated rootstocks. This is the only species that Escort alone gave greater than 80% *RR*

Table 6. The heights of loblolly pines, before (B) and after (A) treatments, and their difference when the lower-half or the full crown was sprayed.

Herbicide	Lower-half B	Lower-half A	Lower-half Diff.	Full B	Full A	Full Diff.
	(ft)					
May						
Weedone	3.5 a	8.7 a	5.2	4.1 a	6.1 bc	2.0
Garlon 4	3.4 a	8.3 a	4.9	3.9 a	5.4 c	1.5
Garlon 3A	3.3 a	7.8 a	4.5	4.1 a	2.9 d	−1.2
Arsenal	3.5 a	8.5 a	5.0	3.9 a	7.8 ab	3.9
Roundup	3.7 a	5.1 b	1.4	4.1 a	2.2 d	−1.9
Roundup + Escort	3.8 a	7.9 a	4.1	3.9 a	7.8 ab	3.9
Escort	3.5 a	7.8 a	4.3	4.1 a	9.6 a	5.5
Untreated	3.2 a	8.6 a	5.4	3.9 a	9.8 a	5.9
July						
Weedone	3.8 a	7.2 a	3.4	3.5 a	2.3 b	−1.2
Garlon 4	3.6 a	7.2 a	3.6	3.5 a	1.9 bc	−1.6
Garlon 3A	4.0 a	7.3 a	3.3	3.5 a	1.0 bcd	−2.5
Arsenal	4.0 a	7.2 a	3.2	3.7 a	5.9 a	2.2
Roundup	3.7 a	2.4 c	−1.3	3.3 a	0.3 d	−3.0
Roundup + Escort	3.4 a	5.0 b	1.6	3.6 a	0.5 cd	−3.1
Escort	3.6 a	6.8 a	3.2	3.5 a	6.2 a	2.7
Untreated	3.8 a	7.4 a	3.6	3.6 a	6.9 a	3.3
September						
Weedone	3.5 a	5.7 a	2.2	3.9 a	4.2 b	0.3
Garlon 4	3.3 a	6.0 a	2.7	3.8 a	3.2 bc	−0.6
Garlon 3A	3.6 a	5.9 a	2.3	3.8 a	3.3 bc	−0.5
Arsenal	3.8 a	6.8 a	3.0	3.9 a	6.4 a	2.5
Roundup	3.4 a	0.3 c	−3.1	3.9 a	0.8 d	−3.1
Roundup + Escort	3.5 a	3.4 b	−0.1	4.0 a	1.9 cd	−2.1
Escort	3.8 a	6.8 a	3.0	3.9 a	6.9 a	3.0
Untreated	3.4 a	6.4 a	3.0	3.8 a	7.0 a	3.2

[1] Values in a column within an application month followed by the same letter are not significantly different at the 0.05-level as determined by Tukey's procedure.

Table 7. Arsenal-treated hardwoods that were completely defoliated in 1987 and refoliated in 1988.

Species	Timing	Number defoliated 1987	Refoliated 1988 Number	Refoliated 1988 Percent
Sweetgum	May	6	2	33
	July	6	3	50
	Sept	14	7	50
S. red oak	May	4	3	75
	July	14	6	43
	Sept	17	14	82
Water oak	May	6	4	67
	July	11	6	54
	Sept	14	10	71
Hickory	May	1	0	0
	July	6	5	83
	Sept	10	9	90
Dogwood	May	0	0	0
	July	1	0	0
	Sept	0	0	0
Red maple	May	2	2	100
	July	1	1	100
	Sept	0	0	0
Yellow-poplar	May	0	0	0
	July	0	0	0
	Sept	0	0	0

and only with May applications. In July, both *RR* and *CVR* were greatest with Arsenal, Garlon 4 and 3A, Roundup, and Roundup + Escort. For September treatments, complete control of all test rootstocks was provided by Garlon 4 and 3A and Roundup, with near complete control by Weedone, Arsenal, and Roundup + Escort.

Loblolly Pine Injury

Roundup was the most damaging to pines followed by Garlon 3A, for all timings. When the lower-half of pine crowns were sprayed (Table 6), only treatments with Roundup and Roundup + Escort (July and September) resulted in significant height reduction. Damage by Garlon 3A was evident mainly when the growing tip was sprayed. When the complete pine was treated, only Roundup + Escort in May and Escort and Arsenal treatments at the other timings had height growth comparable to untreated pines. However, pine height growth was apparently reduced with Arsenal by 8–20% following applications to the whole pine.

Recovery of Arsenal Treated Hardwoods

The recovery of Arsenal-treated hardwoods during the second growing season after treatment is presented in Table 7. More hardwoods that displayed defoliation in 1987 had recovered by 1988 than were completely controlled by Arsenal. The most pronounced recovery occurred with sweetgum, red and water oak, and hickory that had been treated in September, although it was evident with treatments in May and July as well. Defoliation and recovery was not common with dogwood, red maple, or yellow poplar. The importance of this refoliation to future competition by these hardwoods is unknown. Most had experienced crown volume reduction and been slowed in growth for two years. This would suggest a reduced role in future stand dynamics.

CONCLUSIONS

The following conclusions are apparent from this investigation:

1. There are alternatives to Weedone 2,4-DP directed sprays that are cost-comparable and equally or more effective.

2. There are available herbicides that can be applied as directed foliar sprays throughout the growing season and can provide either effective crown reduction or cause rootstock reduction of common hardwood species. Difficult species to eliminate with all May applications were southern red oak, water oak, pignut hickory, and dogwood. Pignut hickory was also difficult to control in July and September.

3. Arsenal and Escort were safest on loblolly pine, but Escort demonstrated little control of hardwoods except on yellow poplar in May.

4. At all seasons of application, Roundup and Garlon 3A were the most damaging to loblolly pines. This would mean that operational applications of these two herbicides for pine release will require more care and thus require more training of the applicators. These herbicides should have potential for use in precommercial thinning operations of loblolly pine.

5. Sweetgum, southern red and water oak, and pignut hickory treated with Arsenal in September defoliated in the first growing season after treatment but tended to recover in the following year. □

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