THINNING YOUNG, NATURAL HARDWOOD REGENERATION WITH BROADCAST HERBICIDE APPLICATION[1/]

C. H. Pham[2/]

Abstract.--A screening study tested five herbicides in thinning one- to two-year old natural hardwood regeneration established in clearcuts in southeastern West Virginia. Ground foliar broadcast application was examined for (1) density reduction and (2) species tolerance and hence species composition changes.

Velpar L, Tordon 101 Mixture, Garlon 4, Krenite, and Roundup were applied at relatively low to moderate rates. The study used replicated 0.2 acre treatment plots, with milacre plots to monitor density and species composition, and tagged individuals to examine species tolerance.

Stem density was reduced by low to moderate rates of herbicides. Species such as pin cherry, black cherry, sassafras, witch hazel, yellow birch, white ash, beech, and black locust were quite susceptible to a variety of herbicides applied as broadcast sprays. Black cherry's tolerance to Garlon 4 was one notable exception.

In contrast, species like dogwood, striped maple, sugar maple, red maple, northern red oak and perhaps basswood were relatively tolerant to the same herbicides tested.

In terms of changing species composition from unwanted to desired species, because of the variable tolerance of different species, the present results from mixed stands were inevitably mixed. Perhaps herbicides would be best used in stands invaded by one or two unwanted species such as pin cherry or striped maple which can dominate a stand in the first ten years. Stands dominated by northern red oak, sugar maple or red maple can be sprayed to favor these species and to reduce the unwanted beech.

Keywords: thinning, herbicides, natural hardwood regeneration

INTRODUCTION

Most natural hardwood stands on Westvaco property in southeastern West Virginia are being regenerated naturally by clearcutting. Following clearcutting, usually there are adequate stems per acre of a range of species in the young stand. The stem density increases to about age four or five and then declines steadily to rotation age. A maximum of over 60,000 stems per acre containing 40 species has been observed by the author in the area.

During these young ages, thinning may offer a means to select species and control density. Manual thinning of such dense stands, at age 5-10, has reduced density, improved species composition and increased individual tree growth (Pham 1985). However, manual thinning is time consuming in such dense stands and resprouting does occur.

Herbicides may be an alternative to manual thinning of young stands. Preliminary trials in the area, with pellets and foliar spray, have brought out the problem of controlling pellet

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[2/] Research Scientist, Westvaco Corporation, P. O. Box 608 Rupert, WV 25984

placement and spray direction so that leave trees are not affected.

In an operational broadcast application, the herbicide would be applied over the entire stand with no regard to crop trees. If broadcast application is to become an operational practice, we must determine species tolerance to herbicides and appropriate rates.

The purpose of this study was to screen a number of herbicides as broadcast sprays, for controlling stem density and species composition of young hardwood stands.

PROCEDURE

Five herbicides were tested at low to moderate rates in the screening (Table 1).

Velpar L was tested in June 1984 at the Mill Creek Mountain Tract, Greenbrier County. Tordon 101 was tested in September 1984 at the Hominy Creek Tract, Nicholas County. Garlon 4 was tested in August 1985, and Krenite and Roundup in September 1985, both at the Huggins Ridge Tract, Greenbrier County.

Velpar L and Tordon 101 were applied in one-year old clearcuts while Garlon 4, Krenite, and Roundup were applied in two-year old clearcuts. The Velpar L and Tordon 101 stands are on oak-hickory sites at about 3200 and 2500 feet in elevation, respectively. The Garlon 4, Krenite, and Roundup stands are on northern hardwood sites at about 3700 feet.

For each herbicide, treatments were replicated three times in a randomized block design. Square treatment plots of 0.2 acre size were used. Before treatment application, species composition and number of stems of woody species were determined using four circular milacre plots per each treatment plot, at 33 feet on a diagonal from each corner. Four milacre control plots per replication were also established outside the treated plots, also on a diagonal at 33 feet from the corner. These milacre plots were used to monitor the changes in stem density and species composition.

To test the individual species' tolerance to different rates of herbicides, 20-30 stems of each of the dominant species were tagged per treatment before treatment application. A clump of sprouts was considered one tree. Herbicides were applied with a Solo Jetpak-425 Knapsack Sprayer. Dilute spray volume at each location was 15-20 gal/ac.

In May 1985, after budbreak, the Velpar L and Tordon 101 sites were checked for changes in species composition and number of stems per acre. Tagged species were evaluated for their tolerance and identified as: 1) not affected, 2) affected but resprouted, and 3) dead. "Not affected" included all stems looking as normal as control stems. In May 1986, following budbreak, the other three sites were similarly checked.

For each site, reduction in density and species tolerance were analyzed by analysis of variance with treatment means differentiated by Duncan's New Multiple Range Test wherever applicable. Changes in species composition were examined by relative importance value based only on density percentage. Species tolerance was analyzed in terms of percent of "unaffected", "affected but resprouted", and "dead" categories, after transformation of percent values to arcsine values. Arcsine values were then converted back to percent for presentation.

Common and scientific names of species mentioned in this report follow Little (1979): White ash (Fraxinus americana L.), American basswood (Tilia americana L.), American beech (Fagus grandifolia Ehrh.), yellow birch (Betula allegheniensis Britton), black locust (Robinia pseudoacacia L.), blackgum (Nyssa sylvatica Marsh.), black cherry (Prunus serotina Ehrh.), pin cherry (Prunus pensylvanica L.), American chestnut (Castanea dentata [Marsh. L.] Borkh.), flowering dogwood (Cornus florida L.), hickories (Carya Sp.), cucumbertree (Magnolia acuminata L.), Fraser magnolia (Magnolia fraseri Walt.), red maple (Acer rubrum L.), striped maple (Acer pensylvani-

Table 1.--Herbicides evaluated for thinning young hardwood stands in southeastern West Virginia.

Trade Name	Manufacturer	Common Name	Formulation Rates[1/]	Rates Tested
Garlon 4	Dow	Triclopyr (ester)	4 lb ae/gal	1.0, 1.25, 1.5 lb ae/ac
Krenite	DuPont	Fosamine Ammonium	4 lb ai/gal	0.5, 0.75, 1.25 gal/ac
Roundup	Monsanto	Glyphosate	4 lb ai/gal	1.0, 1.5, 2.0 qt/ac
Tordon 101 Mixture	Dow	Picloram and 2,4-D	.54 lb ae and 2 lb ae/gal	0.75, 1.0, 1.25 gal/ac
Velpar L	DuPont	Hexazinone	2 lb ai/gal	0.5, 1.0, 1.5 lb ai/ac

1/ ae = acid equivalent, ai = active ingredient.

cumn L.), sugar maple (Acer saccherum Marsh.), chestnut oak (Quercus prinus L.), northern red oak (Quercus rubra L.), white sassafras (Sassafras albidum [Nutt] Nees), downy serviceberry (Amelanchier arborea [Michx.L.] Fern), yellow-poplar (Liriodendron tulipifera L.), witch hazel (Hamamelis virginiana L.).

RESULTS

Velpar L

Density Reduction.--The reduction in stem density (Table 2) was significant only with the heaviest rate (1.5 lb/ac) (32 percent reduction from 1984). However, when compared to the unsprayed area with 22,139 stems/acre, the percent reduction was close to 41 percent.

Table 2.--The reduction of stem density by Velpar L broadcast spray in a one-year old clearcut.

Treatment	Density[1/] June 1984	Density[1/] May 1985	Reduction from 1984
lb ai/ac	stems/acre		percent
Control	N.A.	22,139 a	-
0.5	16,583 a	17,667 b	0 a
1.0	12,833 a	12,833 b	0 a
1.5	19,083 a	13,000 b	31.9 b

1/ Means in columns followed by the same letter are not significantly different at the 0.05 level. N.A. = not available.

Species Tolerance.--The five main species, which were individually tagged, showed that the effects of Velpar L were heavier (Table 3A) than indicated by the 32 percent reduction in density discussed above. In fact, the intermediate rate of 1.0 lb/ac removed about 65-87 percent of stems of beech, black cherry, pin cherry, and red oak. The only species which seemed relatively tolerant to the herbicide was red maple, with only 43 percent dead with the highest rate (1.5 lb/ac). Based on the range of percentage dead, the order of increasing tolerance was: pin cherry < beech = black cherry < red oak << red maple. There was no interaction between species and rates (Table 3B).

Species Composition.--Given the differential species tolerance discussed above, Table 4 shows the changes in species composition and importance (based on relative density alone) from 1984 to 1985.

Black cherry, beech, and pin cherry as a group dominated in 1984 but their importance was reduced the following year. In 1985, striped maple and red maple became more important. Red oak and chestnut oak held their own or increased somewhat.

Table 3.--Species tolerance to Velpar L broadcast spray in a one-year old clearcut.

A. Species Tolerance:

Species	Treatment	Unaffected	Resprouted	Dead
	lb ai/ac	percent of tagged stems		
Black cherry	0.5	50.0	23.0	27.0
	1.0	19.9	9.7	70.4
	1.5	8.5	19.0	72.5
Beech, American	0.5	26.1	43.7	30.2
	1.0	1.1	33.5	65.4
	1.5	1.2	26.8	72.0
Pin cherry	0.5	63.9	8.8	27.3
	1.0	12.1	1.1	86.8
	1.5	1.6	1.6	96.8
Red maple	0.5	87.1	2.4	10.5
	1.0	43.5	34.8	21.7
	1.5	11.3	46.1	42.6
Red oak	0.5	19.7	44.5	35.8
	1.0	6.1	23.2	70.7
	1.5	0.0	43.5	56.5

B. Analysis of Variance: F-test results.[1/]

Source	DF	Unaffected	Resprouted	Dead
Species	4	**	**	*
Treatment	2	***	NS	***
Block	2	NS	NS	NS
Species X Treat	8	NS	NS	NS
Error	28			
Total	44			

1/ NS = not significant, *, **, and *** = significant at 0.05, 0.01, and 0.001 level, respectively.

Red maple and striped maple have the capacity to resprout. Most oak stems counted were stump sprouts or advance regeneration which resprouted (Table 3A and B). Dogwood and witch hazel also increased slightly.

Two-year results have not been collected, but observations in September 1986 (27 months after treatment) indicated that all species, except beech, did not not show any visible signs of herbicide effects and tree height in the 1.5 lb/ac treatment was noticeably lower than that in the other three treatments.

Table 4.--Species composition changes in a one-year old clearcut sprayed with Velpar L. Ranking is based on relative density as a percent of total.

Treatment	Rank	June 1984		May 1985	
lb ai/ac		Species[1/]	Percent	Species	Percent
Control	1	-	-	BC	32.7
	2			PC	21.5
	3			RM	12.3
	4			WH	5.8
	5			STM	5.4
	6			RO	5.0
	7			WA	4.6
	8			BE	3.8
	9			SB	2.7
	10			YB	2.3
	11-14			Others	3.9
0.5	1	BC	49.7	BC	47.9
	2	PC	15.7	PC	12.3
	3	RO	7.6	STM	7.6
	4	RM	6.1	RM	6.2
	5	BE	6.1	DW	6.2
	6	STM	5.1	BE	4.7
	7	WH	3.1	WH	3.8
	8	DW	2.0	RO	3.3
	9	YP	1.5	YB	3.3
	10	CM	1.0	YP	2.4
	11-14	Others	2.1	Others	2.3
1.0	1	BC	32.5	BC	20.4
	2	BE	25.8	BE	19.7
	3	PC	11.9	WA	11.2
	4	RO	11.3	STM	10.5
	5	RM	5.3	PC	9.2
	6	STM	3.3	WH	7.9
	7	WH	3.3	RM	7.2
	8	SB	2.6	CO	5.3
	9	CO	2.0	RO	5.3
	10	WA	1.3	SB	2.0
	11-12	Others	0.7	Others	1.3
1.5	1	BC	38.4	BE	30.8
	2	BE	18.8	BC	23.1
	3	PC	16.6	RM	19.9
	4	STM	9.2	PC	9.6
	5	RM	8.7	STM	9.6
	6	SB	3.1	WH	2.6
	7	WH	2.6	RO	2.6
	8	RO	1.3	SB	1.3
	9	WA	0.8	WA	0.6
	10	DW	0.4	-	-

1/ Species Code: BC-black cherry, BE-American beech, BG-black gum, BL-black locust, BW-basswood, CH-American chestnut, CM-cucumbertree, CO-chestnut oak, DW-dogwood, FM-Fraser magnolia, HIC-hickories, PC-pin cherry, RM-red maple, RO-northern red oak, SAS-sassafras, SB-serviceberry, SM-sugar maple, STM-striped maple, YB-yellow birch, YP-yellow-poplar, WA-white ash, WH-witch hazel.

Tordon 101 Mixture

Density Reduction.--The lowest rate of Tordon applied (0.75 gal/ac) reduced stem density as well as the highest rate (1.25) (Table 5). About 25 percent average reduction was observed. However, when compared to the unsprayed area with 30,000 stems, the percent reduction was close to 60 percent.

Table 5.--The reduction of stem density by Tordon 101 Mixture broadcast spray in a one-year old clearcut.

Treatment	Density[1/] Sept 1984	May 1985	Reduction from 1984
gal/ac	stems/ac		percent
Control	N.A.	30,000 a	-
0.75	14,083 a	10,333 b	26.6 a
1.0	12,250 a	10,167 b	17.0 a
1.25	16,000 a	11,662 b	27.1 a

1/ Means in columns followed by the same letter are not significantly different at the 0.05 level.

Species Tolerance.--Black cherry, black locust, dogwood, and sassafras were heavily affected by the Tordon 101 Mixture (Table 6A). Only red maple and red oak were relatively tolerant. Based on the range of percentage dead, the order of increasing tolerance was sassafras < black cherry = black locust = dogwood < red maple < red oak. Again there was no significant interaction between species and treatment (Table 6B).

Species Composition.--Sassafras, black locust, dogwood, and black cherry dominated the site in 1984 but in 1985 black locust and black cherry lost out to striped maple and red maple (Table 7). Sassafras remained important, although its number was reduced and dogwood had increased considerably in importance. Chestnut oak and red oak maintained their importance. These results support the relative tolerance rating discussed above, except for dogwood. Dogwood sprouting, layering and seed germination may have played a role in increasing its number. Observations in September 1986 (24 months after treatment) indicated that all species appeared to have healthy leaves.

Table 6.--Species tolerance to Tordon 101 Mixture broadcast spray in a one-year old clearcut.

A. Species Tolerance:

Species	Treatment	Unaffected	Resprouted	Dead
	gal/ac	percent of tagged stems		
Black cherry	0.75	4.5	7.7	87.8
	1.0	1.1	0.0	98.9
	1.25	1.2	2.4	96.4
Black locust	0.75	0.0	1.2	98.8
	1.0	0.0	1.1	98.9
	1.25	0.0	0.0	100.0
Dogwood	0.75	4.8	7.4	87.8
	1.0	0.0	4.5	95.5
	1.25	5.1	0.0	94.9
Red maple	0.75	1.1	41.0	57.9
	1.0	0.0	23.2	76.8
	1.25	3.7	36.7	59.6
Red oak	0.75	1.5	77.7	20.8
	1.0	6.7	57.2	36.1
	1.25	10.8	49.9	39.3
Sassafras	0.75	0.0	1.2	98.8
	1.0	0.0	0.0	100.0
	1.25	0.0	0.0	100.0

B. Analysis of variance: F-test results.1/

Source	DF	Unaffected	Resprouted	Dead
Species	5	NS	***	***
Treatment	2	NS	*	NS
Block	2	NS	NS	**
Species X Treat.	10	NS	NS	NS
Error	34			
Total	53			

1/ NS = not significant, *, **, and *** = significant at 0.05, 0.01, and 0.001 level, respectively.

Garlon 4

Density Reduction.--There were no statistical differences between three different rates of Garlon 4 used, and the density reduction from 1985 values is about 15-45 percent (Table 8). Evidently there was large variation among milacre sample plots.

Species Tolerance.--Analysis of variance (Table 9B) shows that while there were no differences between applied rates of Garlon 4, species responses to the herbicide varied significantly.

Table 7.--Species composition changes in a one-year old clearcut sprayed with Tordon 101 Mixture. Ranking is based on relative density as percent of total.

Treatment	Rank	Sept. 1984		May 1985	
gal/ac		Species1/	Percent	Species	Percent
Control	1	-	-	SAS	40.4
	2			SM	12.2
	3			BC	11.1
	4			DW	8.8
	5			RM	8.0
	6			YP	5.4
	7			RO	4.0
	8			BL	3.7
	9			BG	2.0
	10			CM	1.7
	11-14			Others	2.6
0.75	1	SAS	50.0	SAS	28.2
	2	BL	14.5	STM	16.9
	3	BG	9.0	RM	8.1
	4	BC	8.4	FM	8.1
	5	RO	3.6	RO	6.5
	6	YP	3.0	BL	6.5
	7	HIC	2.4	DW	6.4
	8	DW	2.4	BC	5.6
	9	STM	1.8	HIC	4.0
	10	RM	1.8	BG	2.4
	11-14	Others	3.1	Others	7.3
1.0	1	SAS	29.7	STM	24.8
	2	DW	12.4	DW	16.5
	3	BC	9.6	SAS	13.2
	4	BL	8.3	RO	13.2
	5	RO	7.6	BG	9.9
	6	CO	6.9	CO	5.0
	7	BG	5.5	HIC	4.1
	8	RM	4.8	RM	4.1
	9	SM	4.1	BE	3.3
	10	STM	2.8	BL	2.5
	11-14	Others	8.3	Others	3.3
1.25	1	SAS	48.5	DW	28.1
	2	BC	19.6	SAS	17.3
	3	DW	9.8	BC	17.3
	4	RM	3.1	RM	12.2
	5	YP	3.1	SM	9.4
	6	RO	3.1	HIC	4.3
	7	SM	2.6	RO	2.9
	8	HIC	2.6	STM	2.2
	9	BL	2.1	SB	2.1
	10	FM	1.5	CH	2.1
	11-14	Others	4.1	Others	2.2

1/ Species Code: The same as for Table 4.

Based on the range of percentage dead, the relative species tolerance (Table 9A) was: pin cherry < witch hazel = white ash < red maple = striped maple < sugar maple < black cherry < red oak.

Table 8.--The reduction of stem density by Garlon 4 broadcast spray in a two-year old clearcut.

Treatment	Density[1/] July 1985	Density[1/] May 1986	Reduction from 1985
lb ae/ac	stems/ac		percent
Control	24,667 a	28,500 a	-
1.0	16,583 a	9,667 b	41.7 a
1.25	13,833 a	11,917 b	13.9 a
1.50	15,500 a	8,667 b	44.1 a

1/ Means in columns followed by the same letter are not significantly different at the 0.05 level.

Table 9.--Species tolerance to Garlon 4 broadcast spray in a two-year old clearcut.

A. Species Tolerance:

Species	Treatment	Unaffected	Resprouted	Dead
	lb ae/ac	percent of tagged stems		
Black cherry	1.0	6.7	83.1	10.2
	1.25	6.0	59.6	34.4
	1.50	26.0	39.1	34.8
Pin cherry	1.0	0	0	100.0
	1.25	0	14.8	85.2
	1.50	0.2	33.4	66.4
Red maple	1.0	0.1	48.3	51.6
	1.25	4.8	45.3	49.9
	1.50	5.5	30.6	63.9
Red oak	1.0	0	82.0	18.0
	1.25	0	92.2	7.8
	1.50	0	88.7	11.3
Sugar maple	1.0	0	98.4	1.7
	1.25	0	69.9	30.0
	1.50	0	42.8	57.1
Striped maple	1.0	0	51.7	48.3
	1.25	6.8	75.7	17.5
	1.50	6.3	25.0	68.7
White ash	1.0	0.1	36.5	63.4
	1.25	0	22.5	77.5
	1.50	0	23.8	76.2
Witch hazel	1.0	4.5	46.9	48.6
	1.25	0	22.8	77.1
	1.50	0	36.9	63.1

Table 9.--Continued.

B. Analysis of variance: F-test results.[1/]

Source	DF	Unaffected	Resprouted	Dead
Species	7	NS	***	**
Treatment	2	NS	NS	NS
Block	2	NS	NS	NS
Species X Treat.	14	NS	NS	NS
Error	46			
Total	71			

1/ NS = not significant, *, **, *** = significant at 0.05, 0.01, and 0.001 level, respectively.

Species Composition.--There were noticeable changes in species composition and importance due to Garlon 4 (Table 10). There were fewer species in sprayed plots in 1986. Black cherry increased its importance considerably, followed by sugar maple and red oak, while beech and red maple decreased their importance. After 14 months, there were signs of herbicide effects on leaves of red oak, beech, sugar maple, and red maple but the leaves of black cherry, white ash, striped maple, and cucumbertree appeared healthy. Basswood, black locust, and serviceberry were apparently heavily affected by Garlon 4.

Krenite

Density Reduction.--There were no significant differences between the three rates of Krenite used (Table 11). Reduction from 1985 of about 30 percent was observed.

Table 11.--The reduction of stem density by Krenite broadcast spray in a two-year old clearcut.

Treatment	Density[1/] Sept. 1985	Density[1/] May 1986	Reduction from 1985
gal/ac	stems/ac		percent
Control	5,417 a	5,667 a	-
0.5	6,883 a	4,083 a	40.7 a
0.75	9,333 a	7,000 a	25.0 a
1.25	12,500 a	9,750 a	22.0 a

1/ Means in columns followed by the same letter are not significantly different at the 0.05 level.

Table 10.--Species composition changes in a two-year old clearcut sprayed with Garlon 4. Ranking is based on relative density as percent of total.

Treatment	Rank	Sept. 1985		May 1986	
lb ae/ac		Species[1/]	Percent	Species	Percent
Control	1	RM	29.1	RM	31.3
	2	BC	18.9	BC	19.0
	3	RO	16.9	RO	17.8
	4	BE	14.5	BE	16.4
	5	WH	8.1	WH	5.0
	6	STM	4.4	STM	3.8
	7	WA	2.4	BL	1.2
	8	BL	1.3	WA	0.9
	9	YB	1.3	SB	0.9
	10	SAS	0.4	YB	0.6
	11-14	Others	2.7	Others	3.2
1.0	1	BE	30.2	BC	44.8
	2	BC	25.1	BE	26.7
	3	RM	17.1	RM	12.1
	4	WH	7.0	WA	7.8
	5	WA	4.5	WH	5.2
	6	SM	4.0	PC	1.7
	7	BW	3.0	SB	1.7
	8	FM	2.0		
	9	PC	2.0		
	10	BL	2.0		
	11-13	Others	3.0		
1.25	1	BC	31.9	BC	51.0
	2	WH	19.9	SM	18.2
	3	SM	13.8	WH	8.4
	4	BE	10.2	RO	8.4
	5	SB	7.8	BE	6.3
	6	RO	6.0	STM	5.6
	7	STM	5.4	RM	2.1
	8	BL	1.8		
	9	PC	1.8		
	10	RM	1.2		
1.50	1	BC	26.3	BC	38.5
	2	BE	24.2	RO	31.7
	3	RO	16.7	BE	19.2
	4	WH	13.4	WH	6.7
	5	STM	4.8	PC	2.9
	6	BG	3.8	STM	1.0
	7	SB	3.2		
	8	RM	2.2		
	9	PC	1.6		
	10	SM	1.6		
	11-12	Others	2.1		

1/ Species Code: The same as for Table 4.

Species Tolerance.--There were highly significant differences between species responses (Table 12). Based on the range of percentage dead, the relative tolerance of species was: Pin cherry < black cherry = yellow birch << red maple = striped maple < sugar maple.

Table 12.--Species tolerance to Krenite broadcast spray in a two-year old clearcut.

A. Species Tolerance:

Species	Treatment	Unaffected	Resprouted	Dead
	gals/ac	percent of tagged stems		
Black cherry	0.5	21.9	55.8	22.3
	0.75	0	59.6	40.3
	1.25	8.9	87.4	3.7
Pin cherry	0.5	13.6	79.7	6.7
	0.75	0	34.2	65.8
	1.25	0	92.4	7.4
Red maple	0.5	17.9	82.1	0
	0.75	7.7	88.5	3.8
	1.25	0	93.5	6.5
Sugar maple	0	0.8	98.4	0.8
	0.75	0	100.0	0
	1.25	3.0	97.0	0
Striped maple	0.5	6.7	93.3	0
	0.75	10.4	89.6	0
	1.25	10.0	84.2	5.8
Yellow birch	0.5	91.1	8.9	0
	0.75	8.7	64.3	27.0
	1.25	0	56.3	43.7

B. Analysis of variance: F-test results.[1/]

Source	DF	Unaffected	Resprouted	Dead
Species	5	NS	**	***
Treatment	2	NS	NS	NS
Block	2	*	NS	NS
Species X Treat.	10	NS	NS	NS
Error	33			
Total	52			

1/ NS = not significant at 0.05 level, *, **, *** = significant at 0.05, 0.01, and 0.001 level, respectively.

Species Composition.--Krenite application favored the maples over black cherry, pin cherry, and yellow birch (Table 13). Basswood (a prolific sprouter) appeared strongly in 1986 suggesting that it is also favored by this herbicide. Herbicide effects on red oak, white ash, beech and dogwood were unclear due to insufficient data.

Table 13.--Species composition changes in a two-year old clearcut sprayed with Krenite. Ranking is based on relative density as percent of total.

Treatment	Rank	Sept. 1985		May 1986	
gal/ac		Species[1/]	Percent	Species	Percent
Control	1	SB	21.2	SB	22.1
	2	SM	18.2	SM	20.6
	3	BC	16.7	BC	20.6
	4	YB	15.2	YB	16.2
	5	WH	9.1	WH	7.4
	6	PC	7.6	RM	5.9
	7	RM	4.5	STM	4.4
	8	STM	3.0	PC	2.9
	9	RO	3.0		
	10	BE	3.0		
0.50	1	YB	36.6	RM	38.8
	2	BC	29.3	YB	24.5
	3	RM	24.4	BC	18.4
	4	SM	4.9	SM	14.3
	5	PC	3.6	PC	2.0
	6	RO	1.2	BC	2.0
0.75	1	RM	30.4	RM	41.7
	2	SM	19.6	SM	19.0
	3	BC	18.8	BC	14.3
	4	STM	8.9	STM	9.5
	5	WA	8.9	WA	8.3
	6	YB	4.5	DW	4.8
	7	PC	2.7	WH	1.2
	8	WH	2.7	PC	1.2
	9	DW	2.7		
	10	RO	0.9		
1.25	1	BW	47.2	BW	70.3
	2	BC	12.2	SM	8.8
	3	WH	7.3	BE	4.4
	4	RM	5.7	RM	4.4
	5	PC	4.9	CM	3.3
	6	BE	4.9	STM	2.2
	7	SM	4.0	BC	2.2
	8	STM	4.0	PC	2.2
	9	YB	3.2	YB	1.1
	10	CM	2.4	WH	1.1
	11-12	Others	4.0		

1/ Species Code: The same as for Table 4.

Roundup

Density Reduction.--The lowest rate of 1.0 qt/ac of Roundup reduced density by only 13 percent while the highest rate of 2.0 qt/ac reduced density by as much as 95 percent (Table 14).

Table 14.--Species tolerance to Roundup broadcast spray in a two-year old clearcut.

Treatment	Density[1/] Sept. 1985	Density[1/] May 1986	Reduction from 1985
qt/ac	stems/ac		percent
Control	19,750 a	19,000 a	-
1.0	13,750 a	11,917 a	13.3 a
1.5	16,917 a	9,583 a	43.3 ab
2.0	70,875 a	3,250 b	94.4 b

1/ Means in columns followed by the same letter are not significantly different at the 0.05 level.

Species Tolerance.--There were no significant differences between the three rates of Roundup used for the tagged species except for sugar maple (Table 15). Based on the range of percentage dead, the relative species tolerance to Roundup was: Pin cherry = yellow birch < black cherry < red maple < striped maple = sugar maple.

Species Composition.--The role of Roundup in favoring the maples and discriminating against the cherries and yellow birch is evident when viewing changes in species composition (Table 16). Basswood and beech were also found to be relatively tolerant to Roundup. Both species are prolific sprouters. Red oak seemed to hold its own.

Table 15.--The reduction of stem density by Roundup broadcast spray in a two-year old clearcut.

A. Species Tolerance

Species	Treatment	Unaffected	Resprouted	Dead
	qt/ac	percent of tagged stems		
Black cherry	1.0	0	20.2	79.8
	1.5	0	2.0	98.0
	2.0	0	8.4	91.6
Pin cherry	1.0	0	0	100.0
	1.5	1.7	0	98.3
	2.0	2.1	2.1	95.8
Red maple	1.0	3.3	13.7	83.0
	1.5	5.5	33.9	60.6
	2.0	0	13.5	86.5
Sugar maple	1.0	8.4	77.0	14.6
	1.5	6.0	72.6	11.4
	2.0	0	42.0	58.0
Striped maple	1.0	4.8	31.7	64.5
	1.5	16.5	64.8	18.7
	2.0	0	28.5	71.5
Yellow birch	1.0	0	11.4	88.5
	1.5	0	20.4	89.6
	2.0	0	0	100.0

B. Analysis of variance: F-test results.1/

Source	DF	Unaffected	Resprouted	Dead
Species	5	NS	***	***
Treatment	2	NS	NS	NS
Block	2	NS	NS	NS
Species X Treat.	10	NS	NS	NS
Error	34			
Total	53			

1/ NS = not significant at 0.05 level, *** = significant at 0.001 level.

Table 16.--Species composition changes in a two-year old clearcut sprayed with Roundup. Ranking is based on relative density as percent of total.

Treatment	Rank	Sept. 1985		May 1986	
qt/ac		Species1/	Percent	Species	Percent
Control	1	BE	44.3	BE	47.4
	2	STM	11.4	STM	12.3
	3	PC	9.4	PC	11.8
	4	BC	8.9	BC	10.5
	5	SM	7.2	BW	6.6
	6	YB	6.3	SM	6.1
	7	BW	5.9	SB	3.1
	8	SB	3.0	YB	1.8
	9	YB	2.1	RO	0.4
	10	RM	0.8		
	11	RO	0.4		
1.0	1	STM	33.3	STM	37.1
	2	BC	21.8	BE	28.7
	3	BE	15.8	SM	11.9
	4	SM	10.3	BC	10.5
	5	YB	7.3	RM	5.6
	6	RM	5.4	YB	4.2
	7	PC	4.8	PC	2.1
	8	SB	1.2		
1.5	1	STM	29.1	STM	38.3
	2	PC	21.7	SM	30.4
	3	SM	16.2	PC	15.6
	4	YB	8.9	DW	10.4
	5	DW	7.4	CM	2.6
	6	BC	6.9	RM	0.9
	7	BE	5.9	BE	0.9
	8	CM	2.0	YB	0.9
	9	RM	1.0		
	10	RO	1.0		
2.0	1	BE	43.0	BW	24.0
	2	SB	11.6	BE	21.9
	3	YB	9.4	SB	21.9
	4	BW	9.0	SM	20.8
	5	SM	6.8	STM	5.2
	6	BC	5.4	RM	2.1
	7	WA	4.7	BC	2.1
	8	PC	4.3	PC	1.0
	9	STM	2.9	RO	1.0
	10	RM	1.4		
	11-12	Others	1.4		

1/ Species Code: The same as for Table 4.

DISCUSSION AND CONCLUSIONS

The present study examined broadcast sprays in young stands for the purpose of thinning by using relatively low rates of herbicides. There is virtually no published information with similar application methods and purposes.

It is clear that stem density can be reduced by broadcast sprays with relatively low to moderate rates of herbicides. One can regulate the percentage of reduction by matching species composition with herbicides and rates. In this study, density in mixed stands were reduced by about 50 percent by relatively low rates. However the present results are based on one growing season after treatment, two-year data are desirable because of residual effects of herbicides. And the present results may differ from efficacy data published for other application methods and with higher rates.

For example, for broadcast sprays, Wendel

and Kochenderfer (1982) mistblowed Roundup at 2-3 qt/ac and found that not only pin cherry, black cherry, sweet birch (Betula lenta L.) but also red maple were effectively killed. This is in contrast with the tolerance of red maple, striped maple, and sugar maple to Roundup reported in Table 15. However the discrepancy may be due to their method of collecting the percentage dead. Theirs was not based on tagged stems but on stems found in milacre sample plots.

In an aerial application of Tordon 101 Mixture at 4 gal/ac for brush control, Fears and Dickens (1978) found that white oak, black gum, hickory, and red maple were susceptible while red oak and white ash quite tolerant. This supports the results obtained with Tordon 101 in this study (Table 6). With Garlon 3A at 2 gal/ac (Triclopyr (amine), 3 lb ae/gal) the authors found red maple more tolerant than red oak and black gum. At lower rates used in this study, the maples, red oak, and black cherry were found to be quite tolerant to Garlon 4 (Table 9). Also black cherry was much more tolerant than pin cherry to Garlon 4. This was in contrast with their similar susceptibility observed with Velpar L (Table 3), Krenite (Table 12) and Roundup (Table 15). The reason for this tolerance was unclear and should be studied.

There are more published information on efficacy of herbicides applied by injection and cut-stump treatments in cleaning hardwood stands. For example Campbell (1985) and Kossuth et al (1980) found that by injection many hardwood species are effectly killed except red maple, by Picloram + 2,4D, Fosamine, Glyphosate, and Triclopyr. Wile (1981), in cleaning clearcut areas of residual trees and unwanted new growth, found that red maple was resistant to both Krenite and Velpar L applied by hypo-hatchet injection but striped maple was susceptible to Velpar L. Lewis et al (1985) using cut-stump treatment also found that red maple was more resistant than yellow-poplar and chestnut oak to Glyphosate, Hexazinone, Picloram + 2,4D, and Triclopyr.

In this study, striped maple, red maple and sugar maple were quite tolerant to a variety of herbicides. But striped maple in young stands can be selectively killed by Picloram + 2,4D applied at the base of individuals on the soil surface and by injection (Shipman 1984).

The results of this study indicate that hardwood species in young stands such as pin cherry, black cherry, sassafras, witch hazel, yellow birch, white ash, and black locust were quite susceptible to a variety of herbicides applied as broadcast sprays. Black cherry's tolerance to Garlon 4 was one notable exception.

In contrast, species like dogwood, striped maple, sugar maple, red maple, northern red oak, and perhaps basswood were relatively tolerant to the same variety of herbicides tested.

A species' ability to resprout (e.g. the oaks, the maples, basswood and beech) and/or to reproduce from seed (e.g. dogwood, black cherry) after spray treatment are important factors in influencing species composition following herbicide application. However beech, although a prolific sprouter from stumps and roots, was reduced in importance by Velpar L, Garlon 4, and perhaps by Roundup in the present study. This agrees with results of Ostrofsky and McCormack (1986) who effectively reduced beech advance regeneration by 100% and 93% respectively by mistblowing Roundup and Garlon 3A.

In terms of changing species composition from unwanted to desired species, because of the variable tolerance of different species, the present results from mixed stands were inevitably mixed. Perhaps herbicides would be best used in stands invaded by one or two unwanted species such as pin cherry or striped maple which can dominate a stand in the first ten years. Or stands dominated by northern red oak, sugar maple or red maple can be sprayed to favor these species and to reduce the unwanted beech.

In our area, more work is needed to determine appropriate concentrations of different herbicides and mixture for various species. We wish to release hardwood crop trees in young stands. The timing in terms of stand age and the season of the year when spraying is most effective on different tree species needs to be better defined. The time window provided by bud break phenology can be used. The effects of herbicides on seed germination and root sprouting should be studied further.

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