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Effects of Aerially Applied Glyphosate and Hexazinone on Hardwoods and Pines in a Loblolly Pine Plantation

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SUMMARY

Areas in a 4-year-old loblolly pine (*Pinus taeda* L.) plantation were treated with aerially applied Roundup® (glyphosate), Pronone® 10G (hexazinone), and Velpar® L (hexazinone) plus Lo Drift® (a spray additive). All herbicides were applied with appropriate helicopter-mounted equipment. The proportion of free-to-grow pine trees increased over a 2-year period in both the treated and untreated areas, but the increase was slightly greater in the treated areas. Final loblolly pine height, d.b.h., and volume per tree did not differ significantly among the four treatments. About 1,200 hardwood trees and 4,700 shrubs over 3 ft tall per acre were present at the beginning of the study.

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INTRODUCTION

Many species of hardwood trees and shrubs sprout prolifically after clearcut harvesting and site preparation on forest lands where managers are attempting to establish loblolly pine (*Pinus taeda* L.) plantations. Native early successional species also reappear and compete with planted pines on such sites (Swindel and others 1983). To establish and maintain dominant stands of pines and to increase pine productivity, it may be necessary to release pines from competing trees and shrubs (Clason 1984, Glover and Dickens 1985, Haywood 1986).

Herbicides are often used to free or release pine trees from competition with trees and shrubs that overtop or closely surround them (Ford-Robertson 1971). This study tested the effectiveness of three herbicides labeled for broadcast aerial application to release loblolly pines from competition. The herbicides tested were Roundup®, glyphosate (N-[phosphonomethyl]-glycine); Pronone® 10G, hexazinone (3-cyclohexyl-6-[dimethylamino]-1-methyl-1,3,5-triazine-2,4[1H,3H]-dione); and Velpar® L, hexazinone. The objectives were to evaluate and compare the following: (1) brush control efficacy of these products (reduction in number of hardwood stems per acre and shade competition), (2) the tolerance of loblolly pine to these products (injury and survival), and (3) the height, d.b.h., and volume response of pine saplings to release treatments.

STUDY AREA

The study area is on rolling terrain in central Louisiana. The sandy loam topsoil is 10 to 14 inches in thickness. The subsoil is a sandy clay loam and silt loam. In early 1981, the site was machine planted with improved bare-root loblolly pine seedlings on a spacing of approximately 7 by 10 ft. In January 1982, there were 526 living loblolly pine seedlings per acre on the site.

Four growing seasons after planting, it appeared that both hardwood and herbaceous vegetation were affecting pine development. Hardwoods more than 3 ft tall numbered about 5,900 per acre. Of these hardwoods, about 900 per acre were of species considered serious long-term competitors of planted pines (Haywood 1985). Another 300 hardwood trees per acre were probably developing too slowly to be a serious threat to established pine saplings. The other 4,700 stems per acre were shrubs.

Competing hardwoods included shining sumac (*Rhus copallina* L.) (42 percent of stems), American beautyberry (*Callicarpa americana* L.) (15 percent of stems), sweetgum (*Liquidambar styraciflua* L.) (9 percent of stems), southern bayberry (*Myrica cerifera* L.) (8 percent of stems), tree sparkleberry (*Vaccinium arboreum* Marsh.) (5 percent of stems), blackgum (*Nyssa sylvatica* Marsh.) (4 percent of stems), red maple (*Acer rubrum* L.) (3 percent of stems), eastern baccharis (*Baccharis halimifolia* L.) (3 percent of stems), water oak (*Quercus nigra* L.) (2 percent of stems), and common persimmon (*Diospyros virginiana* L.) (2 percent of stems). The remaining 7 percent of hardwood stems were southern red oak (*Q. falcata* var. *falcata* Michx.), post oak (*Q. stellata* Wangenh.), blackjack oak (*Q. marilandica* Muenchh.), white oak (*Q. alba* L.), bluejack oak (*Q. incana* Bartr.), willow oak (*Q. phellos* L.), live oak (*Q. virginiana* Mill.), chinkapin oak (*Q. muehlenbergii* Engelm.), hickory (*Carya* spp.), flowering dogwood (*Cornus florida* L.), black cherry (*Prunus serotina* Ehrh.), green ash (*Fraxinus pennsylvanica* Marsh.), winged elm (*Ulmus alata* Michx.), sassafras (*Sassafras albidum* (Nutt.) Nees), American holly (*Ilex opaca* Ait.), sweetleaf (*Symplocos tinctoria* [L.] L'Her.), witch-hazel (*Hamamelis virginiana* L.), hawthorn (*Crataegus* spp.), devils-walkingstick (*Aralia spinosa* L.), yaupon (*Ilex vomitoria* Ait.), arrowwood (*Viburnum dentatum* L.), fringetree (*Chionanthus virginicus* L.), and plum (*Prunus* spp.).

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METHODS

Experimental Design and Treatments

Effects of three pine-release herbicide treatments were compared to effects in an untreated check in a randomized complete block design experiment. Three blocks were established based on vegetation and slope within different areas of the stand. There were 12 plots (4 treatments by 3 blocks). The treatments were randomly assigned within the blocks.

The plots were established in the field during July and August 1984. Each plot was 850 ft long. The untreated check plots were 150 ft wide. Roundup and Velpar L plots were 200 ft wide (four 50-ft-wide spray swaths). The Pronone 10G plots were 240 ft wide (three 80-ft-wide spray swaths). The different plot widths were necessary because the helicopter-mounted equipment used to apply individual herbicides produced different swath widths.

Three subplots for pine measurement were established along the centerline of each plot. Each subplot was 46.7 ft^2 (0.05 acre). Subplots were not located in drainages and openings. The centers of the subplots were at least 124 ft from the plot ends. They were at least 124 ft apart and at least 50 ft from the plot edge.

Four hardwood assessment sub-subplots with radii of 6.5 ft (0.003 acre) were established within each pine measurement subplot. The sub-subplots were located just inside each of the corners of the pine measurement subplots.

The treatments were: (1) untreated check: no herbicide treatment; (2) Roundup: two qt of liquid product (1.5 lb acid equivalent) in 9.5 gal water per acre; (3) Pronone 10G: 20 lb of granular product (2 lb active ingredient [a.i.]) per acre; and (4) Velpar L: four qt of liquid product (2 lb a.i.) plus 1.2 oz of Lo Drift® (a spray additive) in 9 gal of water per acre.

The Roundup was applied between 10 and 10:30 a.m. on September 13, 1984, at the end of the fourth growing season, with a helicopter-mounted Microfoil® boom with triple-row 0.016 nozzles. The sky was bright and clear, and the ambient temperature was from 80 to 85 °F. Winds were generally calm.

The Pronone 10G was applied between 10 and 10:30 a.m. on May 7, 1985, at the beginning of the fifth growing season, with a bucket-type distributor slung beneath a helicopter. The sky was fair and hazy, and the ambient temperature was 76 °F. Winds were 2 to 3 mi/h.

The Velpar L was applied between 6:30 and 7:15 a.m. on June 24, 1985, at the beginning of the fifth growing season, with a helicopter-mounted Simplex® 4900, series spray system fitted with T-Jet® Straight Through nozzles with D-12 orifices. The sky was sunny and slightly hazy with an ambient temperature of 73 °F. Winds were calm.

More than 2.5 inches of rain fell on the study site within 2 weeks of the Pronone 10G application. About 2 inches of rain fell on the site during the month before application of Velpar L. In both instances, rainfall should have been sufficient to aid in dispersal of the herbicide through the soil.

Measurements and Data Analysis

Before treatments were applied, all pines in the subplots were identified with numbered metal tags. Their total height was measured to the nearest 0.1 ft, and their d.b.h. was measured to the nearest 0.1 inch. For each pine, shade competition was classified before treatment and two growing seasons after treatment. Classifications were as follows:

0: Free-to-grow—competing vegetation shades the pine's crown on less than 30 percent of the crown's circumference.

1: Mild competition—competing vegetation prevents up to 10 percent of overhead light from reaching the pine's foliage on 30 to 70 percent of the crown's circumference.

2: Serious competition—competing vegetation prevents 11 to 60 percent of overhead light from reaching the pine's foliage on 71 to 100 percent of the crown's circumference.

3: Suppressed—less than 11 percent of overhead light is reaching the pine, and the pine is almost completely overtopped.

Sublethal herbicidal injury to pines was assessed annually for two growing seasons after treatments were applied. Injury was classified as follows:

0: No visible injury.

1: 50 percent or less of the crown shows needle discoloration, malformation, and tip burn on the lateral branches.

2: More than 50 percent of the crown shows needle discoloration, malformation, and tip burn on the lateral branches, and 50 percent or less of the branch leaders have been killed.

3: More than 50 percent of the crown shows needle burn or defoliation, and more than 50 percent of the branch leaders have been killed.

4: Crown is severely damaged; tree not expected to survive.

Pine height and d.b.h. were remeasured annually for 3 years after treatment. The final measurements were made in April 1988, while the pines were in their eighth growing season after planting. Total inside-bark stem volumes were calculated with Schmitt and Bower's (1970) formula.

In each sub-subplot, all hardwood stems more than 3 ft tall were identified by species and counted before and for two growing seasons after treatment.

Initial hardwood stocking, initial shade competition, pine survival, and initial pine height and d.b.h. data

were analyzed with analyses of variance. Where treatment differences were found, Duncan's Multiple Range Tests were used to determine mean separations (Probability > F-value = 0.05). Reductions in hardwood stocking, changes in shade competition, and pine d.b.h., height, and volume data were analyzed with analyses of covariance. The covariate in each analysis was the appropriate pretreatment data (Probability > F-value = 0.05). Data on sublethal pine damage caused by herbicide use are presented without analysis.

RESULTS

Competing Vegetation

One growing season after application of pine release treatments, number of hardwoods in the Roundup and Pronone 10G plots decreased by 3,354 and 2,653 stems per acre, respectively (table 1). Hardwood stocking in the Velpar L plots did not decrease initially, but decreased by 858 stems per acre by the end of the second growing season. Two growing seasons after treatments were applied, the Roundup and Pronone 10G plots had 3,191 and 2,580 fewer hardwood stems per acre, respectively. Sub-subplot data on hardwood stocking were highly variable, and thus there were no statistically significant differences in the reduction of hardwood stems per acre two growing seasons after herbicide treatment (Probability > F-value = 0.0783).

Loblolly Pines

Before treatments were applied, an average of 67 percent of the 4-year-old planted loblolly pine trees were considered free-to-grow, and the proportion of free-to-grow pine saplings did not differ significantly among treatments (table 2). The pretreatment proportion of suppressed trees ranged from 1 to 4 percent.

Two years after treatments were applied, the average proportion of free-to-grow pine trees had increased from 67 percent to 92 percent, and there were still no significant by-treatment differences in the proportion of free-to-grow pine saplings (table 2). The proportion

Table 1.—*Per-acre number of hardwood stems more than 3 ft tall before, and for two growing seasons after, pine-release treatment**

Herbicide treatment	Initial	First growing season	Second growing season	2-year change
	Stems/acre			
Roundup®	6,682a	3,328b	3,490a	3,191a
Pronone® 10G	5,406a	2,753b	2,826a	2,580a
Velpar® L	5,588a	5,643a	4,730a	858a
	Probabilities > F-*value*†			
Treatment effects	0.3357	0.0358	0.0783	0.0783

*Columnar values followed by the same letter are not significantly different based on Duncan's Multiple Range Tests (Probability > F-value = 0.05).

†Probabilities are based on analysis of covariance with initial number of stems per acre as the covariate.

Table 2.—*Proportion of loblolly pines assigned to each of four shade classifications before and two growing seasons after pine-release treatment*

	Initial shade classification*				2nd-year shade classification*			
Treatments	0	1	2	3	0	1	2	3
	Percent							
Roundup®	71	21	7	1	92	7	1	0
Pronone® 10G	61	28	7	4	95	2	1	2
Velpar® L	64	24	10	2	93	4	2	1
Untreated check	72	22	4	2	89	8	2	1
	Probabilities > F-*value*†							
Treatment effects	0.5066	0.4913	0.4577	0.6462	0.0789	0.1868	0.6506	0.8578

*Shade classifications: 0: Free-to-grow—competing vegetation shades the pine's crown on less than 30 percent of the crown's circumference, 1: Mild competition—hardwood vegetation prevents up to 10 percent of overhead light from reaching the pine's foliage on 30 to 70 percent of the crown's circumference, 2: Serious competition—hardwood vegetation prevents 11 to 60 percent of overhead light from reaching the pine's foliage on 71 to 100 percent of the crown's circumference, and 3: Suppressed—less than 11 percent of overhead light is reaching the pine, and the pine is almost completely overtopped.

†None of the columnar values were significantly different based on analyses of variance or covariance (Probability > F-value = 0.05).

Table 3.—*Proportion of loblolly pine trees assigned to each of four sublethal damage categories for two growing seasons after pine-release treatment*

Treatments	1-year damage category*				2-year damage category*			
	1	2	3	4	1	2	3	4
	Percent							
Roundup®	8	1	2	0	6	0	0	0
Pronone® 10G	4	2	1	3	2	0	0	0
Velpar® L	1	1	0	0	0	0	0	0

*Damage categories: 1—50 percent or less of the crown shows needle discoloration, malformation, and tip burn on the lateral branches; 2—More than 50 percent of the crown shows needle discoloration, malformation, and tip burn on the lateral branches, and 50 percent or less of the branch leaders have been killed; 3—More than 50 percent of the crown shows needle burn or defoliation, and more than 50 percent of the branch leaders have been killed; and 4—Crown is severely damaged; tree not expected to survive.

Table 4.—*Average initial height and d.b.h. of loblolly pines four growing seasons after planting (measured in September 1984); and survival, height, d.b.h., and inside-bark volume per loblolly pine in their eighth growing season after planting (measured in April 1988)*

Treatments*	Initial data†		Final data†			
	Height	D.b.h.	Survival	Height	D.b.h.	Volume
	Feet	*Inches*	*Percent*	*Ft*	*Inches*	*Ft³/tree*
Roundup®	7.7	0.9	96	16.2	2.9	0.44
Pronone® 10G	8.7	1.1	71	18.5	3.3	0.57
Velpar® L	7.6	0.9	96	17.9	3.1	0.50
Untreated check	7.1	0.8	99	17.4	3.0	0.44
	Probabilities > F-*value*					
Treatment effects	0.1178	0.1086	0.1377	0.2230‡	0.7014‡	0.7814‡

*The pine-release treatments were applied at different times because these products work best when used in specific seasons of the year and because of operational constraints. The Roundup treatment was installed in September 1984. The Pronone 10G and Velpar L treatments were installed in May and June 1985, respectively.

†None of the columnar means were significantly different based on analysis of variance or covariance (Probability > *F*-value = 0.05).

‡Probabilities are based on analysis of covariance with initial height as the covariate. If initial d.b.h. is used as the covariate, the probabilities are 0.1373 (final height), 0.5672 (final d.b.h.), and 0.6412 (final volume per tree).

of suppressed trees ranged from 1 to 2 percent 2 years after application of treatments.

Crown damage to herbicide-treated loblolly pine trees in the first growing season after treatment was minimal (table 3). The percentage of injured trees decreased during the second growing season after treatment. Changes in pine survival after herbicide treatment were not significant, but mortality of pine saplings was greatest in the Pronone 10G treatment (table 4). However, pine survival was poor in only one of the Pronone 10G plots (data not shown). Pine survival in the other two Pronone 10G plots was comparable to that for the other three treatments within each appropriate block.

Final loblolly pine height, d.b.h., and volume per tree did not differ significantly by treatment after results were weighted for initial height and d.b.h. measurements (table 4). The pines on the Roundup plots grew least, however. Cumulative height growth between September 1984 and April 1988 was 8.5, 9.8, 10.3, and 10.3 ft on the Roundup, Pronone 10G, Velpar L, and untreated check treatments, respectively. Over the same period, cumulative d.b.h. growth was 2.0 inches for the Roundup treatment and 2.2 inches for each of the other treatments.

DISCUSSION

Broadcast application of a liquid hexazinone formulation (Velpar L) caused a delayed reduction in hardwood stocking, whereas broadcast application of a granular hexazinone formulation (Pronone 10G) reduced hardwood stocking in the first year after treatment. Broadcast application of a liquid glyphosate formulation (Roundup) reduced hardwood stocking in the first year after treatment. It is unclear why one hexazinone formulation would have greater early efficacy than the

other. However, efficacies of the two hexazinone treatments did not differ significantly after two growing seasons.

The proportion of free-to-grow pines in the untreated check plots increased by 17 percent over a 2-year period. So, although herbicide release treatments may have increased the proportion of free-to-grow pines, most of this perceived benefit might have occurred without management intervention. Herbicide injury apparently did not keep the pines from responding to release, and the few injured trees were evidently recovering.

Growth and yield of loblolly pines did not differ significantly among treatments, but height and d.b.h. growth were somewhat less on the Roundup plots than on the other plots. This was the case even though the Roundup treatment was somewhat more effective than the others in controlling hardwoods. However, Roundup was associated with slightly more crown damage than were the other herbicides; 6 percent of the Roundup-treated pines had needle discoloration, needle malformation, and tip burn on the lateral branches in less than 50 percent of the crown after two growing seasons. Also, the increase in proportion of free-to-grow pines was slightly less for the Roundup treatment than for the other two herbicide treatments. None of the three aerially applied pine-release herbicides increased the growth and yield of planted loblolly pines in competition with about 1,200 hardwood trees and 4,700 shrubs per acre.

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Three herbicide products, Roundup® (glyphosate), Pronone® 10G (hexazinone), and Velpar® L (hexazinone), were applied aerially to release a 4-year-old loblolly pine plantation from hardwood competition. Herbicide damage to pines was not excessive. Post-treatment growth of pines in herbicide-treated plots was not significantly different from growth of pines in untreated check plots.

Keywords: Competition control, pine-hardwood relationships, *Pinus taeda* L., weed control.

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