United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

Research Paper NE-614

Release of 7-Year-Old Underplanted White Pine Using Hexazinone Applied with a Spot Gun

G. W. Wendel
J. N. Kochenderfer

Abstract

Hexazinone, Velpar-L®, applied at rates of 1.0, 1.5, and 1.75 ml per spot, controlled competing hardwoods around 7-year-old underplanted white pine. Growth response was more pronounced when hexazinone was applied to release individual pines than when the entire area was treated on a 6 by 6-foot grid. In most cases, hexazinone killed white oak, chestnut oak, American beech, sourwood, red maple, and black gum. Yellow-poplar, red oak, cucumbertree, black cherry, sugar maple, sweet birch, and sassafras showed variable sensitivity to hexazinone. Three years after treatment, resprouting of killed stems and white pine mortality remain low.

The Authors

G. W. WENDEL, research forester (retired), joined the Northeastern Forest Experiment Station's Timber and Watershed Laboratory at Parsons, West Virginia, in 1962. He received a B.S. degree in forestry from Iowa State University in 1951, and a master's degree in forestry from Yale University in 1957.

J. N. KOCHENDERFER, research forester, joined the USDA Forest Service in 1960 and has been stationed at the Northeastern Station's Timber and Watershed Laboratory since 1967. He received a B.S. degree in forestry from West Virginia University and a master's degree in forestry from Duke University.

Manuscript received for publication 16 December 1987

Northeastern Forest Experiment Station
370 Reed Road, Broomall, PA 19008
April 1988

Introduction

Hexazinone, Velpar-L®, is an effective herbicide for controlling a variety of woody and herbaceous vegetation. In this paper we present the results of a study in which three rates of hexazinone were applied to release 7-year-old underplanted eastern white pines growing in a partially cut hardwood stand. Hexazinone was applied as spots around seedlings or on an equally spaced grid over the treatment area.

In this study, hexazinone was applied to the soil and was readily absorbed through roots and translocated primarily through the xylem. Its mode of action is thought to be inhibition of photosynthesis. Hexazinone has a half-life of 1 to 6 months depending on the soil, rainfall, and other factors (Beste 1983). In a Georgia study, Neary et al. 1983 reported that the half-life of hexazinone in a sandy loam soil was 10 to 30 days.

General toxicity of hexazinone to fish and wildlife is considered low. The lethal concentration (LC_{50}) for mallard ducklings and bobwhite quail was greater than 5,000 ppm, and the median tolerance limit for trout was greater than 320 but less than 420 ppm (Beste 1983).

Hexazinone has been tested in many forest situations—to control understory vegetation in Allegheny hardwoods, release pine in southern forests, and control brush on planting sites in the Southwestern United States (Horsley 1981; Dewey 1980; Heidmann 1984).

The Study Area

The study area is 25 acres; it has a southwest aspect and an average slope of 40 percent (Fig. 1). The soil is mapped as a Berks channery silt loam. It is well drained, moderately shallow (average depth 22 inches), and weathered from bedded acid shale, siltstone, and sandstone of the Chemung geologic formation. The soil is moderately low in fertility and moderate in erosion hazard. Fragments of sandstone and shale generally are found throughout the profile.

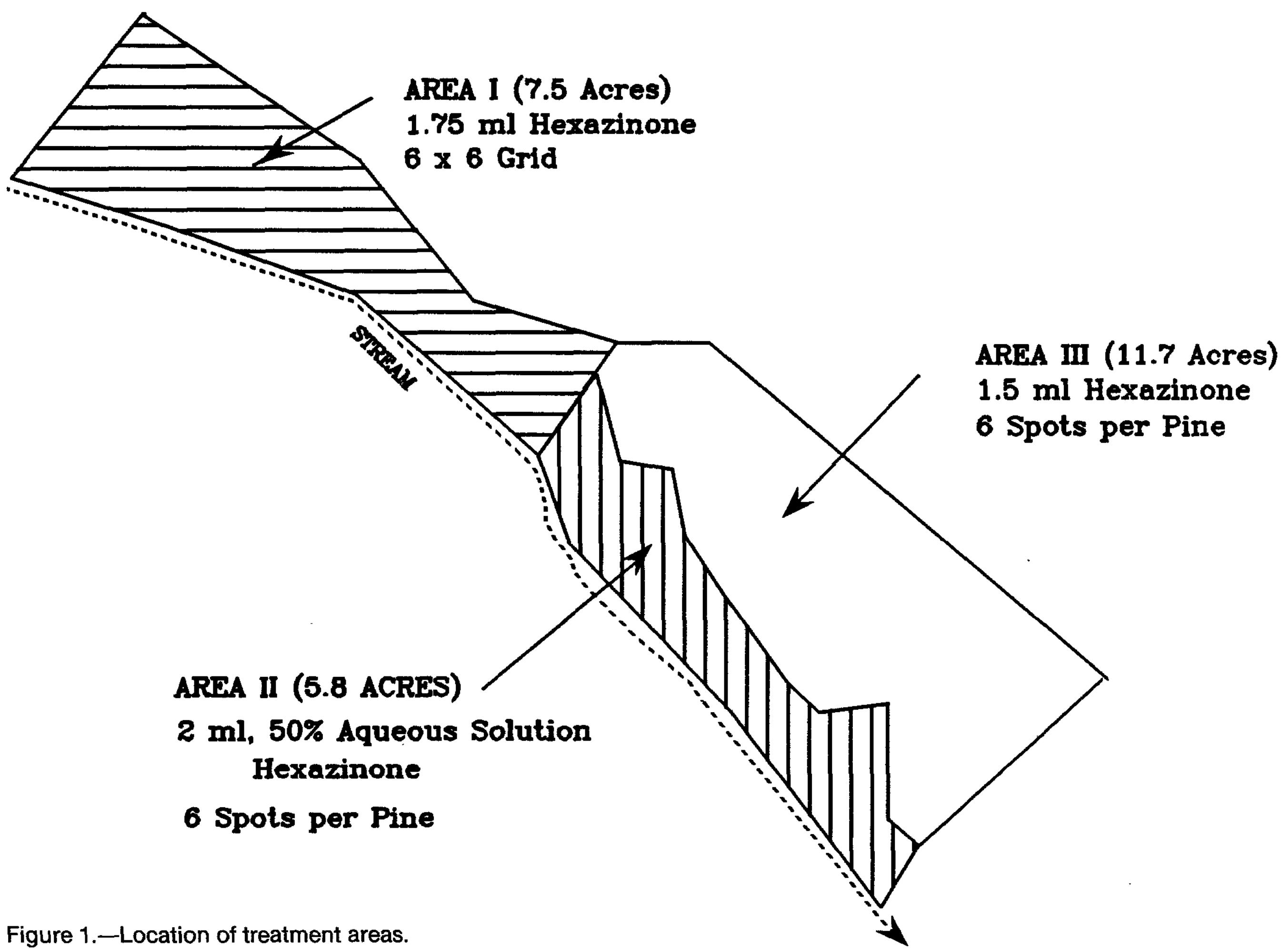

Figure 1.—Location of treatment areas.

Stand History
In the spring of 1977, 2-0 white pine seedlings were underplanted on the study area. During September and October 1977, the area was partially logged with a truck-mounted crane (Kochenderfer and Wendel 1980). Hexazinone treatments were applied during May 1984.

Treatments

The study area was divided into three treatment areas (Fig. 1). Hexazinone was applied to the soil with a spot gun precalibrated with water to deliver the following amounts.

Area I. Undiluted hexazinone (Velpar-L) was applied to the soil at a rate of 1.75 ml per spot on a 6 by 6-foot grid throughout the area.

Area II. Using white pine as a center, 2 ml of 50 percent aqueous solution of Velpar-L was applied to each of six spots around each pine. Spots were not applied closer than 4 feet to a pine on the uphill side nor closer than 3 feet on the downhill side.

Area III. Same as treatment II except that undiluted Velpar-L was applied at a rate of 1.5 ml per spot.

A 50-foot untreated buffer strip was left along the live stream on the lower side of the study area.

Methods

Plot Layout

Fourteen permanent sampling points were established on Areas I and II and 30 points were established on Area III before treatment. Before treatment at each sampling point, a milacre plot was taken to determine the percentage of plot surface area covered by foliage of stems less than 1.0 inch in d.b.h. Species that covered 5 percent or more of the surface area were tallied. Species and d.b.h. (to the nearest 0.1 inch) for all trees larger than 1.0 inch in d.b.h. were tallied on a 1/100-acre plot at the same sampling point. Before treatment, all white pines on the 1/100-acre plot were permanently numbered and measured. Total height to nearest 0.1 foot, crown position, and current-year and previous 2-year height growth were recorded for each pine by measuring internode length.

Plots were retallied at the end of the second and third growing seasons after treatment. The effectiveness of treatments on species was determined by comparing tallies before and after treatment. Pretreatment (1983) height growth for individual white pines in a treatment was compared to height growth in 1986 by a paired "t" test. White pine survival was determined by comparing tallies of numbered seedlings before and after treatment.

At the time of the initial inventory in September 1983, the overstory stand larger than 6 inches in d.b.h. consisted of trees left from earlier logging—low-grade mixed oaks (chestnut, white, and red), red maple, sourwood, American beech, yellow-poplar), and cucumbertree. Volume in trees larger than 6.0 inches in d.b.h. ranged from 841 to 1,247 ft^3/acre and averaged 993 ft^3/acre. Sawtimber volume in trees larger than 11.0 inches in d.b.h. ranged from 1,337 to 3,807 board feet/acre and averaged 2,464 board feet/acre. The total number of trees per acre larger than 1.0 inch in d.b.h. averaged 729 and also included, sassafras, sweet birch, black gum, yellow-poplar, and hickory. Minor amounts of other species also were present.

The initial inventory indicated about 263 white pine per acre; 75 percent of the 1/100-acre plots contained at least three white pine seedlings over all treatment areas. Stocking was 81 percent on Area I, 67 percent on Area II, and 77 percent on Area III. For the entire study area, survival of underplanted pine was about 90 percent during the 7-year period after planting. Thirty-eight percent of the pines were receiving some light and were classed as intermediate in crown class. The remaining pines were classed as overtopped.

Assessment of White Pine Damage
About 1½ months after treatment, we observed that some of the white pines, most of which were in Area III, exhibited various degrees of needle browning. Only a few pines in Areas I and II showed browning; we did not observe pines that we believed might die in these areas. Four needle-browning classes were defined: 1, no browning; 2, slight browning (1 to 25 percent of the needles); 3, moderate browning (26 to 50 percent); 4, heavy browning (51+ percent). For each class, 25 seedlings were chosen and flagged.

Few seedlings had Class 4 browning and those that did were confined to Area III. Final evaluation of the flagged seedlings was made at the end of the second growing season after treatment.

Results

Survival and growth of white pine and effects of hexazinone on competing vegetation in the overstory and understory were assessed at the end of the second and third growing seasons. White pines damaged by hexazinone were evaluated 2 years after treatment.

Survival and Growth

Survival at the end of 3 years averaged 100 percent for intermediate white pines and 96 percent for those classed as overtopped (Table 1). Before treatment, intermediate seedlings were, on average, 1 to 2 feet taller than overtopped seedlings and 2 feet or more taller than overtopped seedlings 3 years after treatment. Average total height of intermediate white pine before treatment was 3.8 feet versus 2.4 feet for overtopped seedlings (Table 1). Three years after treatment, average height of intermediate seedlings was 5.9 feet tall versus 3.5 feet for overtopped seedlings.

In lieu of a conventional control area to gage the effectiveness of treatments, internode lengths were measured 1 and 2 years before treatment. A comparison of 2-year pretreatment growth and 2-year after-treatment growth, 1984-1985, showed no significant differences within a crown class regardless of treatment. This was expected because we had observed in another study that white pines showed little response until 2 or 3 years after release (Wendel and Kochenderfer 1982). Height growth in 1986 was compared to that in 1983 by a paired "t" test. Within a crown class there were no significant differences in height growth at the 0.05 probability level for Areas I and II but there were significant differences in Area III (Table 1).

A comparison of treatments within a crown class using 1986 height growth showed that white pine growth in Area III was significantly higher at the 0.05 probability level than in Areas I or II (Table 1). This was true for both crown classes.

Table 1.—Height growth of white pine

Treatment	Average height		2-year height growth		Average annual height growth		Survival
	Pre-treatment	3 years after treatment	Pre-treatment	Post-treatment	1983	1986	in 1986
	Feet						*Percent*
INTERMEDIATE CROWN CLASS							
I	3.5	5.2	1.3	1.1	0.6	0.5	100
II	4.4	6.5	1.6	1.3	0.7	0.8	100
III	3.4	5.9	1.3	1.3	0.7	1.3	100
Average	3.8	5.9	1.4	1.3	0.7	0.9	100
OVERTOPPED CROWN CLASS							
I	2.5	3.1	0.7	0.5	0.3	0.2	90
II	2.5	3.5	0.7	0.7	0.3	0.3	100
III	2.1	3.9	0.6	0.9	0.3	0.9	100
Average	2.4	3.5	0.6	0.7	0.3	0.5	96

Damage

At the end of 2 years, 11 of the seedlings with heavy needle browning (Class 4) had died (Table 2). Heavy needle browning that was confined to Area III affected less than 1 percent of the white pines. Two years after treatment, no mortality was observed for Classes 1, 2 or 3. An examination of Class 4 seedlings at the end of the third growing season indicated no further mortality. Most of the browned needles had fallen off and seedlings had short "tufted" clusters of green needles.

Cost of Treatment

There was little difference in the cost of treatment for released pine. Cost per tree including chemical and labor averaged about $0.15 for treatments I and II and $0.16 for treatment III (Table 3). In Area III, the number of competing stems larger than 1.0 inch in d.b.h. was reduced by 20 percent and the number of stems larger than 6.0 inches in d.b.h. was reduced by 66 percent at the end of 3 years.

The white pines in Area III had significantly better height growth than those in Areas I and II. We believe that the cost difference of $0.01 per tree is justified by the greater growth.

Table 2.—Damage and mortality of white pine 2 years after spot treatment (damage assessed in Area III)

Damage class	Change in damage class					
	No change	1	2	3	4	Dead
	Percent					
1	93	--	7	0	0	0
2	67	15	--	11	7	0
3	63	6	6	--	25	0
4	55	0	0	0	--	45

Table 3.—Cost of treatment per white pine[a]

Treatment	Area treated	No. pines per acre	Amount of herbicide used	No. hours per acre	Cost per: Acre	Cost per: Released pine
	Acres		*Gallons*		*Dollars*	
I	7.5	286	4.25	2.13	44.04	0.15
II	5.8	221	2.50	1.03	29.68	0.13
III	11.7	283	8.25	1.37	46.44	0.16

[a] Labor cost assumed to be $6.50/hour.

Whether a grid pattern is used or individual pines are treated, each area has to be walked through by the treatment crew, so it makes sense to treat only those areas where there are pine to release. In areas similar in topography, competition, and density of white pine, one person should treat 3 to 4 acres per day using the grid method or 5 to 6 acres per day if treating individual pines. In areas where the density of pines is especially high and stocking is 85 to 90 percent, gridding might be more cost efficient than treating individual trees. However, for the abundance (spacing of approximately 13 by 13 feet) and stocking (75 percent) encountered in this study, treating individual pines might be best.

Species Sensitivity

The data show wide variability among species in sensitivity to hexazinone (Table 4). Much of the variation can be attributed to the distribution, occurrence, and size of the trees on the treatment areas. In theory, an abundance of larger trees with larger root distributions would place more trees in a position to pick up hexazinone from a single spot, whereas a nearly direct hit would be required to kill a small stem such as a newly germinated seedling. In other instances, sensitivity is affected by the concentration used and the method of application.

Overstory hardwoods. White oak, sourwood, American beech, cucumbertree, and red maple exhibited moderate to high sensitivity to hexazinone for all treatments (Table 4). Red oak and chestnut oak were highly sensitive at the two highest rates of application but insensitive at 1 ml per spot. Downy serviceberry and some black gums were susceptible to hexazinone at the higher application rate. Hickory and eastern hemlock were not sensitive. Some species such as black cherry, sugar maple, and sweet birch were found only on Area I and only sugar maple showed some sensitivity to hexazinone.

Ground cover species. In general, spot applications increased the amount of open condition on the treatment areas—nearly fourfold on Area I. On Areas II and III, the amount of open condition increased more than 2.5 times.

Table 4.—Percentage of all hardwood stems larger than 1.0 inch in d.b.h. killed by hexazinone at the end of 2 years

	Treatment		
Species	I	II	III
Yellow-poplar	19	0	15
Red maple	42	23	23
Red oak	50	0	70
Cucumbertree	50	100	37
Black cherry	0	*a*	--
Sugar maple	16	--	--
Sweet birch	0	--	--
Sassafras	14	0	0
Chestnut oak	92	0	73
American beech	31	5	77
Black gum	0	0	29
Sourwood	16	57	27
Hickory	0	--	0
White oak	100	61	73
Hemlock	0	0	0
Downy serviceberry	--	0	100
All	32	21	31
Oaks only	87	44	62

[a] Species not observed in treatment area.

By comparing tallies of ground cover before and after treatment, we observed that seedlings and sprouts of black gum, sugar maple, red maple, American chestnut, sassafras, striped maple, and sourwood showed moderate to high sensitivity to hexazinone. The low concentration used in Area II was least effective in controlling ground cover species. Several shrub species, including mountain laurel, common greenbrier, and witch-hazel, were little affected by any treatment. Least sensitive tree species observed as ground cover were red oak, cucumbertree, sweet birch, and eastern white pine.

Because of the limited root development of the smaller plants observed as ground cover, the mode of action of hexazinone in the soil, and the method of treatment, a species might show increased sensitivity as it becomes larger and develops a more extensive root system.

Overstory Stand Structure

Stand structure was altered considerably by all levels of treatment (Table 5). Three-year net loss of number of stems was 10 percent on Area I, 13 percent on Area II, and 21 percent on Area III. The greatest loss in number of hardwood stems was recorded at the end of the second year after treatment (Table 1). By the end of the third growing season, the number of stems in the 1- to 5-inch d.b.h. class increased and the numbers in the 6- to 10-inch d.b.h. class increased slightly or remained the same. All of the stems larger than 11.0 inches in d.b.h. in Areas I and III were dead at the end of the third year after treatment.

The greatest changes in basal area over the 3-year period were observed in stems larger than 6 inches in d.b.h. in Areas I and III (Table 5), probably because many of the larger trees were the sensitive white and chestnut oak. Also, larger trees have large branching root systems, increasing the chances that several spots might affect the same tree. The reduction in basal area of larger stems is still in effect after 3 years in all treatment areas but less so in Area II, where the lowest concentrations of hexazinone were used. Area III had the largest change in total basal area of all sites and the lowest final basal area. This probably accounts in part for the better growth of white pine on Area III.

Discussion

Application of 1.5 ml of Velpar-L around individual white pines produced the best growth response after 3 years. Growth was most pronounced during the third growing season after treatment, though the reduction in competing vegetation was greatest at the end of the second growing season. Applications of 1.75 ml and 1.5 ml per spot killed all hardwood overstory trees larger than 11.0 inches in d.b.h., whereas the same-size trees that received 1 ml per spot were still alive 3 years after treatment.

The large amount of open area created on Area I probably can be attributed to treatment. Using a grid of 6 by 6 feet, every spot applied created some open area even though no pines were nearby. On the other areas, application was based on pine abundance and distribution which was not uniform over the treatment areas. In Areas II and III, relatively large sections may not have received any Velpar-L. In Area III, control of competing vegetation was best in sections with the greatest pine stocking.

Because the mode of action of Velpar-L is by absorption through the root system, the larger trees are more susceptible to all treatments. High concentrations of smaller stems require that spots be spaced more closely to control competition. Although there is regrowth of many small stems, effects of the treatment are evident after 3 years. The use of 1.5 ml of Velpar-L per spot when treating individual pines is a relatively cheap way to release underplanted white pine. Mortality of pine from the herbicide was minor.

The following procedures for releasing underplanted white pine are recommended:

1. Apply about six spots of undiluted Velpar-L around each pine, no closer than 4 feet to a pine on the uphill side and no closer than 3 feet on the downhill side. When pine stocking is high, the total number of spots can be

Table 5.—Change in number of stems per acre and basal area per acre 2 and 3 years after treatment

Treatment	Diameter class	No. trees/acre 1983	No. trees/acre 1985	No. trees/acre 1986	Basal area/acre 1983	Basal area/acre 1985	Basal area/acre 1986
	Inches				Ft²		
I	1-5	551	386	543	15.5	14.1	18.7
	6-10	115	64	71	36.6	19.9	22.6
	11+	14	14	0	12.9	10.1	0
	All	680	464	614	65.1	44.1	41.3
II	1-5	665	522	586	22.0	17.3	17.7
	6-10	78	56	56	24.9	17.8	17.8
	11+	21	21	21	19.4	19.5	21.5
	All	764	599	663	66.2	54.5	57.0
III	1-5	606	466	547	19.6	12.8	15.0
	6-10	103	39	46	33.0	12.2	16.1
	11+	33	6	0	30.8	5.7	0
	All	742	511	593	83.4	30.7	31.1

reduced since some spots will kill the competition around more than one pine. If pines are taller than 3 feet, increase the distance from pine to spot.

2. Make sure that your spot gun is equipped with a Velpar cylinder and calibrate the gun with water to deliver 1.5 ml per spot.

3. In high rainfall areas such as the central Appalachians, apply Velpar-L in late April or May before active top growth is evident and root growth is in progress. If applied earlier, much of the Velpar-L might be leached through the soil before active root growth of the target species begins.

4. Observe all herbicide precautionary and use information on the label.

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried in a sanitary land-fill dump, or crush or bury them in a level, isolated place.

NOTE: Some states have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Species Mentioned in this Study

Common Name	Scientific Name
American beech	*Fagus grandifolia* Ehrh.
American chestnut	*Castanea dentata* (Marsh.) Borkh.
Black cherry	*Prunus serotina* Ehrh.
Black gum	*Nyssa sylvatica* Marsh.
Chestnut oak	*Quercus prinus* L.
Cucumbertree	*Magnolia acuminata* L.
Downy serviceberry	*Amelanchier arborea* (Michx.f.) Fern.
Eastern hemlock	*Tsuga canadensis* (L.) Carr.
Eastern hophornbeam	*Ostrya virginiana* (Mill.) K.Koch
Eastern white pine	*Pinus strobus* L.
Hickories	*Carya* sp. Nutt.
Red maple	*Acer rubrum* L.
Sugar maple	*Acer saccharum* Marsh.
Northern red oak	*Quercus rubra* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Sourwood	*Oxydendrum arboreum* (L.) DC.
Striped maple	*Acer pensylvanicum* L.
Sweet birch	*Betula lenta* L.
White oak	*Quercus alba* L.
Yellow-poplar	*Liriodendron tulipifera* L.
Greenbrier	*Smilax* L.
Mountain Laurel	*Kalmia latifolia* L.
Witch-hazel	*Hamamelis* L.

Literature Cited

Beste, C. E. 1983. **Herbicide handbook of the Weed Science Society of America.** 5th ed. Champaign, IL: Weed Science Society of America. 515 p.

Dewey, J. B. 1980. **"Gridball pellets"—a new tool for brush control in pines.** Forest Farmer. 15(2): 14-15.

Heidmann, L. J. 1984. **Using herbicides for reforestation in the Southeast.** Gen. Tech. Rep. RM-103. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 11 p.

Horsley, S. B. 1981. **Control of herbaceous weeds in Allegheny hardwood forests with herbicides.** Weed Science. 29: 655-662.

Kochenderfer, J. N.; Wendel, G. W. 1980. **Costs and environmental impacts of harvesting timber in Appalachia with a truck-mounted crane.** Res. Pap. NE-456. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 9 p.

Neary, D. G.; Bush, P. B.; Douglass, J. E. 1983. **Off-site movement of hexazinone in stormflow and baseflow from forest watersheds.** Weed Science. 31: 543-541.

Wendel, G. W.; Kochenderfer, J. N. 1982. **Glyphosate controls hardwoods in West Virginia.** Res. Pap. NE-497. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

☆U. S. GOVERNMENT PRINTING OFFICE: 1988/548-066/60015

Wendel, G. W.; Kochenderfer, J. N. 1987. **Release of 7-year-old underplanted white pine using hexazinone applied with a spot gun.** Res. Pap. NE-614. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

Hexazinone, Velpar-L®, applied at rates of 1.0, 1.5, and 1.75 ml per spot, controlled competing hardwoods around 7-year-old underplanted white pine. Growth response was more pronounced when hexazinone was applied to release individual pines than when the entire area was treated on a 6 by 6-foot grid. In most cases, hexazinone killed white oak, chestnut oak, American beech, sourwood, red maple, and black gum. Yellow-poplar, red oak, cucumbertree, black cherry, sugar maple, sweet birch, and sassafras showed variable sensitivity to hexazinone. Three years after treatment, resprouting of killed stems and white pine mortality remain low.

ODC 414.13:414.27:174.7 *Pinus strobus* L.

Keywords: Spot gun; herbicide; release; white pine

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.