

ent misuse of equipment and its impact on the planting site, such as removal of the organic material. There is also an apparent need for some standardization of terminology for site-preparation equipment. Our survey

provides a beginning of baseline data for improved integration of events between harvesting and establishment of regeneration.



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# Aerial Release of Norway Spruce with Roundup in the Central Appalachians

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**ABSTRACT.** Restrictions on use of 2,4,5-T have created a need for herbicides that can be used for conifer release. Seven-year-old Norway spruce was released from competing vegetation with aerially applied Roundup. A wide spectrum of competing species were controlled and most hardwoods did not resprout during the 2-year evaluation period following treatment. Norway spruce appeared to respond to treatment and suffered negligible damage. Roundup as applied in this study appears to be a safe, effective herbicide that can be used to release Norway spruce.

*North. J. Appl. For.* 2:29-32, June 1984.

Among the many new herbicides being used in forestry is one sold under the trade name Roundup, produced by Monsanto Agricultural Products Company. It is a water-soluble compound that contains 3 pounds per gallon acid equivalent (a.e.) of the isopropylamine salt of glyphosate (N-(phosphonomethyl) glycine). Roundup can be applied as a foliage spray aerially or from the ground, in wipe-on applications, or can be injected into stems of unwanted vegetation. (Mention of a trade name does not constitute an endorsement.)

Some conifers, including Norway spruce, Douglas-fir, grand fir, noble fir, and ponderosa pine, exhibit a tolerance to Roundup (Lund-Hoie 1975, 1976; Newton 1977). A wide spectrum of other species, including many of the hardwoods, ferns, herbaceous plants, grasses, and woody and semi-woody shrubs are sensitive to Roundup (McCormack and Newton 1980, Horsley 1981, Wendel and Kochenderfer 1982, Horsley and Bjorkbom 1983).

As a follow-up to earlier tests with

Roundup, on 6 September 1980, we aerially sprayed a 55-acre watershed planted with Norway spruce. The objective was to release the spruce from heavy regrowth of hay-scented fern, blackberries, and hardwood sprouts. Here we report results obtained 2 years after treatment.

## HISTORY OF STUDY AREA

The treated area is one of the gaged watersheds on the Fernow Experimental Forest near Parsons, West Virginia. It has a south aspect and was clearcut between 1964 and 1968. Intensive herbicide treatments were applied by mistblower to the watershed for 6 years after cutting. The objective of that study was to observe the quantity, regimen, and quality of streamflow from a deforested watershed and to compare hydrologic effects of deforesting upper and lower slopes (Patric and Reinhart 1971). Herbicide spraying ceased in October 1969, and the watershed was allowed to revegetate naturally. In 1973, the area was planted to 2-0 Norway spruce at a spacing of 10 × 10 feet. In August 1975, 2 pounds a.e. per acre of 2,4,5-T were applied aerially to release the spruce. Some control was obtained, but the watershed soon became revegetated with dense stands of hay-scented fern, blackberries, devils-walkingstick, hair-cap moss, and resprouting hardwoods. It was evident that another release would be needed if the spruce were to survive. In the late summer of 1978, we conducted a preliminary study on the watershed. Evaluation after 2 years showed that Roundup applied at rates of 1 to 2 quarts per acre controlled a

wide spectrum of woody and herbaceous vegetation but did not affect the spruce (Wendel and Kochenderfer 1982).

## METHODS

Sixty-five permanent sampling points were established on the watershed. These points were used as the center for (1) milacre plots (2) 1/100-acre plots, and (3) 5-foot radius plots. The percent ground cover was estimated and recorded before spraying for each species that occupied at least 5% of a milacre plot. The average height of vegetation on each milacre was estimated. The diameter and species of all hardwood trees were recorded on a 1/100-acre plot. The total height and crown class of all spruce were also recorded on the 1/100-acre plot. Spruce stocking was determined by recording the occurrence of spruce on a 5-foot-radius plot at each point. All of the spruce on the plot were tagged for future reference. Both plots were remeasured at 1 and 2 years after spraying.

Roundup was applied from a helicopter equipped with a microfoil boom. The desired rate of application per acre was 2 quarts of Roundup in 9½ gallons of water. To assure even coverage of the watershed, half of the solution was applied in a north-south direction and the remainder in an east-west direction. Spraying was done in the early morning hours when there was only slight air movement. Leaves were in a generally green condition with no noticeable yellowing.

## RESULTS

Final evaluation of the herbicide application was made 2 years after treatment.

**Vegetation cover**—Before spraying, an average of 70% of the ground was covered by hay-scented fern, blackberries, and goldenrod (Table 1, Fig. 1). Blackberries accounted for 5% or more of the ground cover on 89% of the milacres. Hay-scented fern covered 5% or more of the ground on 85% of the milacres, goldenrod on 43%, red maple on 34%, and Norway spruce on 19%.

The first summer after spraying,

climbing buckwheat had the highest average percentage of ground cover, 17; this species accounted for 5% or more of the ground cover on 69% of the milacres. Hay-scented fern was reduced to an average ground cover of 8%, blackberry to 1%, goldenrod to 8%. Fern was still well distributed over the area covering 5% or more of the surface area on 51% of the milacres. However, the fern patches were not as dense as they had been. Autumn bentgrass, fireweed, and haircap moss were prominent first-year invaders with average percent ground covers of 11, 8, and 7, respectively. These species accounted for 5% or more of the ground cover on 37, 68, and 20% of the milacres, respectively. Besides spruce, greenbrier was the only species occupying more than 1% of the ground cover before spraying that increased in both the first and second year after spraying—from 5% before spraying to 6 and 9% the first and second year after spraying.

During the second summer after spraying, goldenrod was found on 77% of the milacres, and it had an average ground cover of 19%. Autumn bentgrass had increased to an average ground cover of 23% and was found on 71% of the sample plots. Spruce accounted for 6% of the ground cover the first year after spraying. In the second year, spruce accounted for 10% of the ground cover and occurred on 40% of the milacres (Fig. 2). Most of the ground cover from other woody vegetation was eliminated in 2 years by Roundup.

*Tree and shrub vegetation*—Most of the tree vegetation on the watershed ranged in size from 0.5 to 2.0 inches dbh. Red maple, sugar maple, and striped maple occurred as multiple-sprout clumps whereas most of the other species were single- or double-sprout stems from old root systems. Norway spruce was the most abundant species on the watershed before spraying, followed by red maple, sugar maple, yellow-poplar, black locust, sweet birch, and black cherry (Table 2). Eighty-eight percent of the red maple, 56% of the sugar maple, 73% of the yellow-poplar, 92% of the black locust, and 98% of the sweet birch were killed by the herbicide.

Except for red oak, only 50% of which died, control of the other tree species on the watershed was excellent. The foliage on surviving hardwood trees usually was sparse and deformed 2 years after treatment. Several woody shrubs, including



Fig. 1. Dense stands of blackberries, hay-scented ferns, and sprouting hardwoods completely overtopped many Norway spruce.

striped maple, flame azalea, devils-walkingstick, and mapleleaf viburnum, were controlled adequately with Roundup. Trees that were killed or that had sparse, deformed foliage had not resprouted, indicating that Roundup had been translocated to the roots.

#### Norway Spruce

*Stocking*—The earliest spruce stocking survey made in 1975, 3 years after planting, indicated that 84% of the 5-foot-radius plots taken at 134 points were stocked. In 1980 a similar survey taken at 65 permanent points before spraying Roundup yielded a stocking of 77%. Two years after spraying, stocking taken at the same 65 points also was 77%.

*Survival*—Spruce mortality due to spraying was about 2%. Before dying, these trees had sparse crowns with small yellowish needles, which was attributed to Roundup.

*Growth*—Before spraying, average height of the planted spruce was 3.1 feet. Two years after spraying, the average total height was 4.5 feet. Average annual growth of the spruce in the 2 years after spraying was 0.7 foot. If we assume that average seedling height at planting was 0.5 foot, average annual growth for the 8 years preceding spraying was about 0.3 foot, indicating that release may have benefited spruce growth. Although the growth response of spruce was not measured following the 2,4,5-T treatment in

**Table 1. Average percent ground cover and milacre stocking before aerial spraying and 1 and 2 years after spraying.**

Species	Before spraying		1 year after spraying		2 years after spraying	
	Average ground cover	Milacres stocked	Average ground cover	Milacres stocked	Average ground cover	Milacres stocked
Hay-scented fern	29	85	8	51	15	58
Blackberry	28	89	1	11	4	20
Goldenrod	13	43	8	51	19	77
Greenbrier	5	29	6	28	9	32
Red maple	4	34	<1	3	<1	5
Striped maple	3	11	1	3	<1	5
Sugar maple	2	11	2	5	2	5
Broomsedge	2	5	1	2	0	0
Norway spruce	2	19	6	32	10	40
White ash	1	2	0	0	0	0
Yellow-poplar	1	2	0	0	0	0
Climbing false buckwheat	<1	2	17	69	3	11
Fireweed	0	0	8	68	0	0
White snakeroot	0	0	0	0	4	18
Autumn bentgrass	<1	6	11	37	23	71
Haircap moss	<1	3	7	20	1	8
Deertongue grass	<1	2	<1	6	3	20
Dotted St. John's-wort	0	0	<1	2	1	9
Northern red oak	<1	5	<1	3	<1	3
Black locust	<1	3	<1	3	0	0
Sourwood	<1	2	0	0	0	0
Sassafras	<1	2	0	0	0	0
Chestnut oak	<1	6	0	0	0	0
Black cherry	<1	8	0	0	<1	2
Sweet birch	<1	5	0	0	0	0
Hickory	<1	2	0	0	<1	2
Cucumbertree	<1	3	<1	3	<1	2
Devils-walkingstick	<1	2	0	0	0	0
Bigtooth aspen	<1	2	0	0	0	0

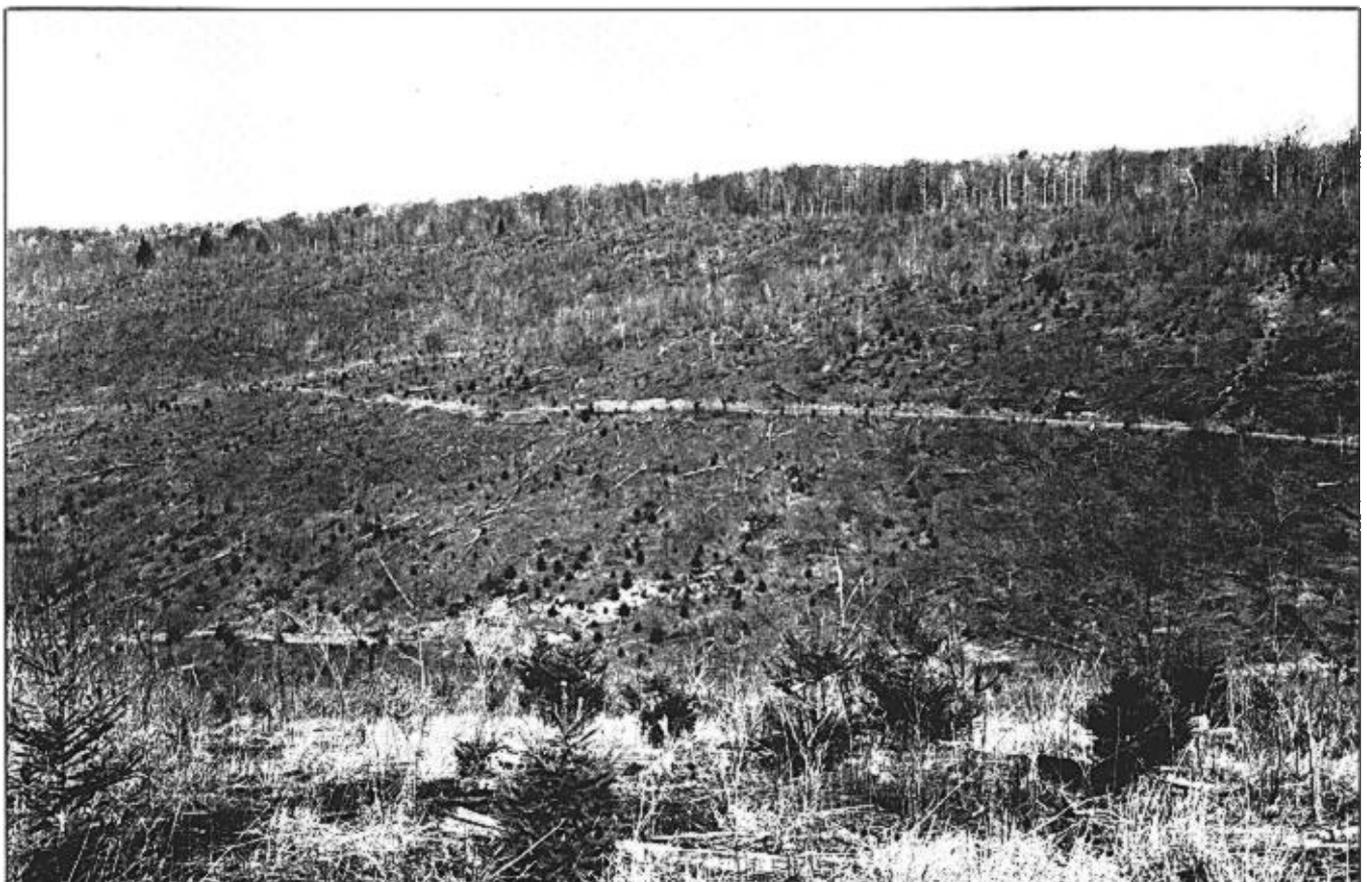
1975, our observations indicated that control of competing vegetation at that time was relatively short-lived. Much of the hardwood brush had resprouted during the ensuing growing season, and control of ferns, blackberries, and other vegetation was minimal.

The distribution of the spruce by size class changed drastically during the 2 years after spraying. Before spraying, 86% of the spruce trees were less than 5.0 feet tall and 14% were more than 5.0 feet tall. Two years after spraying, 68% were less than 5.0 feet tall, 29% were 5.0 to 10.0 feet tall, and 3% were more than 10.0 feet tall.

Before spraying, 38% of the spruce observed were in a "free-to-grow" crown position. Two years after spraying, 62% of the spruce trees observed were in a free-to-grow crown position.

### APPLICATIONS

The application of Roundup by helicopter at a rate of 2 quarts per acre was effective in controlling a wide spectrum of woody and herbaceous vegetation. At this rate, damage to Norway spruce was negligible. In an earlier test (Wendel and Kochenderfer 1982), it was shown that spruce damage was also negligible. These tests also showed that at a rate of 1 quart



**Fig. 2. Two years after spraying with Roundup, control of competing vegetation was nearly complete.**

**Table 2. Number of trees and shrubs per acre ranked according to percent stems dead 2 years after spraying with Roundup.**

Species	No. stems/acre before spraying	% stems killed after 2 yrs.
<i>Trees</i>		
Sourwood	14	100 <sup>a</sup>
White ash	17	100
Bigtooth aspen	3	100
American beech	2	100
American chestnut	2	100
Pin cherry	2	100
Downy serviceberry	29	100
Black cherry	65	98
Sweet birch	69	98
Sassafras	31	95
Black locust	74	92
Red maple	462	88
Cucumbertree	22	79
Chestnut oak	74	73
Yellow-poplar	91	73
Sugar maple	109	56
Northern red oak	25	50
Norway spruce	541	2
Hickory	2	0
Eastern hemlock	2	0
<i>Shrubs</i>		
Willow	2	100
Staghorn sumac	2	100
Blueberry	8	100
Flame azalea	79	100
Devils-walkingstick	89	97
American elder	9	83
Striped maple	111	69
Mapleleaf viburnum	86	57

<sup>a</sup>Percentages for small samples (generally, 25 or fewer) are moderately to extremely imprecise.

per acre, vegetation control was somewhat diminished.

We believe that the total amount of mixture applied per acre and the spraying pattern used is important. At a rate of 5 gallons of 2,4,5-T mixture per acre in an earlier study, the pilot missed several parts of the target area. In this study, we applied 10 gallons of mixture per acre, half in a north-south direction and half in an east-west direction. Virtually no areas were missed and the spraying pattern did not increase costs or create a problem for the pilot.

It is important that Roundup be applied in the latter part of the growing season after the leaves on target species are fully grown and new spruce growth has hardened. On the basis of earlier tests, we contracted for spraying between 15 August and 15 September.

Results published by others, however, suggest that application could have been made as early as 1 August and as late as 30 September (Horsley 1981, Horsley and Bjorkbom 1983). To curtail spruce damage, however, the new spruce growth should be well

hardened before spraying. Similarly, target species should not be under stress from drought, damage, or other factors.

Treated hardwoods generally do not resprout after treatment and those not killed are reduced in vigor. This provides the time needed by Norway spruce to become established and overtop competing vegetation.



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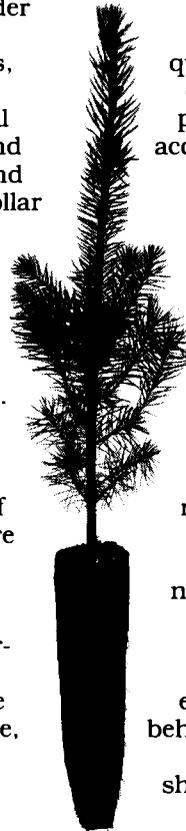
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