

PROGRESS REPORT ON THE CHEMICAL CONTROL OF HARDWOODS AT THE HARVARD FOREST 1/

Mechanical weeding or cleaning to favor selected trees by cutting back others has been used for many years to regulate the composition, form, and growth of young forest stands. The results of this silvicultural technique on hardwoods, however, have been discouraging. The natural sprouting capacity of most of our hardwood trees lowers the feasibility of mechanical weeding because such weeding is costly and must be done repeatedly.

In 1950, as a part of a cooperative research program within the Department of Biology of Harvard University, David P. Hackett 2/ began some chemical weeding experiments at the Harvard Forest. These experiments were designed primarily to investigate the following: the effectiveness of hormone-like chemical compounds for inhibiting the growth of specific local hardwood trees; the effectiveness of different carriers for the compounds; the amount and concentrations of the chemical required; and the method of application.

The information derived from the experiments indicated that it was possible to kill the stems of the common hardwoods of this region with basal sprays of either 2,4,5-T or a mixture of 2,4,5-T and 2,4,-D in solution with kerosene. Furthermore, effective kill could be attained with concentrations as low as 1 and 2 percent 3/ if the basal spray were applied properly.

When Dr. Hackett made his report to the Weed Control Conference in December, 1951, he had seen his experiments through two growing seasons after treatment. Single stems and clumps of sprouts sprayed in the early spring of 1950 had not put out new shoots. Dr. Hackett again checked his original plots in the late summer of 1952, after a third growing season. His figures for kill remained essentially the same as those of his report to the Conference. At the present writing, after a fourth growing season, the percentages are still unchanged, and the sprout clumps sprayed early in the 1950 season still have not resprouted.

With this information at hand or accumulating, further investigations were undertaken at the Harvard Forest in 1952 to determine the feasibility of using a basal spray of 2,4,5-T more extensively and under a variety of forest conditions. These experiments were designed to compare the costs and effectiveness

1/ The present paper was prepared by those members of the staff of the Harvard Forest who were most concerned with follow-up experiments begun in 1952. The layout and conduct of the work were in charge of Mr. Earl P. Stephens, Research Associate, and Dr. Ernest M. Gould, Jr., Forest Economist and Lecturer on Economics. Mr. Herschel G. Abbott assisted with the field work.

2/ Hackett, David P. Experiments on Chemical Control of Hardwoods in Northeastern Forests. (Proceedings of Northeastern Weed Control Conference, New York, N. Y. 1951.)

3/ Total acid equivalent (TAE) by weight.

of mechanical and chemical weedings when both were applied by regular woods workers to similar areas under comparable conditions and with the same objectives. The present paper is a progress report on these experiments.

Equipment

The chemical weedings were done with commercial spraying equipment which consisted of the Myers New Idea Sprayer ^{4/}, capacity 4 gallons, fitted with neoprene spray-resistant washers and hoses. Straight brass extension pipes or wands ^{3/4} inches long were attached to the pump hose. Graduating-type spray nozzles, Myers No. 6690A, were used. A 2.05 percent solution of Esteron ²⁴⁵ ^{5/} and kerosene was the spray applied. This was trucked to the job in a 55-gallon drum and put in a convenient place for refilling the backpack pumps. Three-pound single-bitted axes were used for the mechanical weedings.

Labor

The weedings were applied by three members of the Harvard Forest woods crew. The oldest of these, 62 years of age, had had many years of woods experience. Each of the younger men, age 30, had worked in the woods for three years. All had had experience in mechanical weeding, but none of them had done any chemical weeding. The experiments were explained to the men who then did one day's practice work under supervision. During this time they became familiar with the equipment and learned what was expected of them.

Weeding Procedure

The weedings were conducted from May 5 through May 29, 1952. At the beginning the hardwoods were bare of foliage, the leaf buds just starting to elongate; toward the end, the trees were in full leaf. The chemical weedings were done by basal spraying. The men were instructed to wet thoroughly the entire surface of the lower 8 to 10 inches of each bole so that the spray would run down around the root collar. In the mechanical weeding the trees were cut off completely at a convenient height, usually 2 feet or less above the ground.

Simple instructions, requiring a minimum of interpretation, as to the kinds of trees to be treated were issued for each area. In general, the men moved across the areas three abreast, working at intervals that would give complete coverage. Since there was not available a method for marking the multitude of small trees as they were sprayed, the men used any physical features of the land that would serve for orientation: stone walls, roads, topography, and transect lines which had been established for the purpose of sampling.

^{4/} The F. E. Myers and Bros. Co., Ashland, Ohio. New Idea Knapsack Sprayer (No. 1330AX). Cost in Worcester, Mass. -- \$32.45.

^{5/} Esteron ²⁴⁵, Dow Chemical Co., Midland, Mich. Solution was prepared by mixing 2-1/2 gallons of 2,4,5-T in 50 gallons of kerosene.

Input and Cost Factors

The labor input recorded for each area treated is the number of man-hours actually spent working on each lot. Travel time to and from the area, lunch stops, and work losses due to accidents are not included because these factors will be different for each crew and locality operated. These factors should be allowed for in converting man-hour labor figures to equivalent man-days of work.

The amounts of spray used on each area were measured in two ways. A record was kept of the quantity taken to the job each day and the amount brought back at the end of the day. A running record of the amounts drawn off by each man was also kept as a check against total consumption.

Labor and spray inputs were converted to costs by multiplying these quantities by the current wage rate or the prices paid for spray materials. Labor cost \$1.20 per man-hour, Esteron 245 cost \$12.90 per gallon, and kerosene 15.3 cents per gallon, so that the spray mixture put on the trees cost 76 cents per gallon.

Treatment of the Stands

Three wooded areas including about 33 acres were weeded, 21 chemically and 12 mechanically. One area consisted of a 14-year-old plantation of white pine competing with hardwoods. Another area supported a 9-year-old stand of seedling and sprout hardwoods. The third area was characterized by a 14-year-old mixed stand of natural white pine and hardwood seedlings and sprouts.

Each of the stands was divided into two parts as similar as possible in every respect except acreage. Both parts of each stand were weeded, one chemically and the other mechanically. The silvicultural objectives of the treatments, and the instructions for them, were the same within each stand but different for each of the three stands.

14-year-old White Pine Plantation

On this area of about 7 acres, a 50- to 60-year-old stand of old-field white pine and hardwoods had been clear-cut in 1935. The area was planted in 1938 with white pine at a spacing of 4 x 5 feet. Immediately before planting the most vigorous hardwoods were cut back. By 1944 the pines were being suppressed severely by hardwoods. A mechanical weeding was applied which released all of the pines from overtopping hardwoods.

By 1952, the hardwoods were competing again with the pines and in many instances overtopping them. The principal hardwood species were red maple, black oak, and gray birch. There were approximately 5,700 stems per acre 1/2 inch and larger in diameter at breast height, about 2,000 of which were white pine. About 1,200 of the hardwoods were in sprout clumps, each consisting of three or more stems. There were approximately 280 such clumps per acre. The hardwoods ranged in d.b.h. from 1/2 to 5 inches, the majority being in the 1/2 and 1 inch classes. Their heights were from 5 to 15 feet, with an average of about 8 feet. The pines ranged in d.b.h. from 1/2 to 5 inches, the

2-4 inch classes being the most numerous. Their heights were from 5 to 15 feet with an average of about 12 feet. The plantation was densely stocked and had never been pruned. As a result, it was very difficult to move about in the area, especially with a knapsack pump.

The silvicultural objective on this area was to release the crowns of the pines from the competition of the hardwoods. The men were told to cut or spray all hardwoods 1/2 inch d.b.h. and larger.

The inputs and costs of the weeding per acre were as follows:

Mechanical weeding:

14.32 man-hours input @ \$1.20 \$17.18

Chemical Weeding:

4.88 man-hours input @ \$1.20 \$5.86

8.3 gals. solution input @ \$0.76 6.31

\$12.17

14-year-old Mixed Stand of Natural White Pine and Hardwoods

This stand of about 9 acres had followed the clear-cutting of an 80-year-old mixed stand of old-field white pine and hardwoods that had been severely damaged by the hurricane of 1938. In 1952 the stand had about 2,800 stems per acre of which approximately 800 were white pine. The most common species of hardwoods were red maple, gray birch, red oak, white oak, and fire cherry. The pines were generally distributed over the area with a small group occurring occasionally. Many of them were being overtopped by hardwoods. The hardwoods were from 1 to 6 inches d.b.h., the 1 and 2 inch trees being the most numerous; their heights ranged from 5 to 20 feet, averaging about 10 feet. The white pines were mostly 1 and 2 inches d.b.h. but ranged up to 5 inches, while their heights ran from 5 to 20 feet, with an average of about 8 feet. The stand was open enough to permit the men to move about easily as they chopped or sprayed.

The objective was to release the crowns of the white pines from hardwood competition. The men were instructed to cut or spray those hardwoods that were overtopping the pines and also those that were at least as tall as the pines and in immediate contact with the crowns of the latter. The hardwoods in this class numbered about 860 stems per acre. About three acres were mechanically weeded and almost six acres chemically weeded.

The inputs and costs of the weeding on an acre basis were as follows:

Mechanical weeding:

4.27 man-hours input @ \$1.20 \$5.12

Chemical weeding:

2.21 man-hours input @ \$1.20 \$2.65

3.36 gals. solution input @ \$0.76 2.55

\$5.20

9-year-old Stand of Seedling and Sprout Hardwoods

This area of about 17.5 acres had a stand of seedling and sprout hardwoods which followed the clear-cutting in 1943-44 of a 40- to 50-year-old mixed stand of hardwoods and white pine. This stand had been severely damaged by the hurricane of 1938. The principal species were red maple, red oak, gray birch, and paper birch. There were approximately 5,700 stems per acre ranging in size from 1/2 to 5 inches d.b.h. and 5 to 20 feet tall. Most of the trees were 2 inches and less in d.b.h. Half of the stems were members of sprout clumps of three or more stems each. There were about 500 such clumps per acre. The trees of seedling origin were generally smaller than those of sprout origin. The large number of sprouts in some of the clumps made the latter difficult to treat.

The objective was to up-grade the quality of the stand by eliminating the coarse sprout clumps. The men were told to cut or spray every sprout clump that had three or more stems. Mechanical weeding was applied to about 5.5 acres, and the remainder of the stand, about 12 acres, was weeded chemically.

The inputs and costs of the weedings per acre were as follows:

Mechanical weeding:

4.96 man-hours input @ \$1.20 \$5.95

Chemical weeding:

2.01 man-hours input @ \$1.20 \$2.41
5.49 gals. solution input @ \$0.76 4.17
\$6.58

Table 1. Characteristics of the Stands Treated

| Stand | Area acres | No. of Stems per Acre | | | Basal Area per Acre sq. ft. | | | Area Weeded acres | |
|--|---------------|-----------------------|----------------|-------|--------------------------------|----------------|-------|----------------------|-----------------|
| | | White Pine | Hard- woods | Total | White Pine | Hard- woods | Total | Mechan- ically | Chemi- cally |
| 14-yr.-old white pine plantation | 6.74 | 2,016 | 3,679 | 5,695 | 50 | 21 | 71 | 3.31 | 3.43 |
| 14-yr.-old mixed stand of natural white pine & hardwoods | 9.12 | 815 | 1,991 | 2,806 | 9 | 25 | 34 | 3.16 | 5.96 |
| 9-yr.-old stand of seedling & sprout Hardwoods | 17.42 | ---- | 5,689 | 5,689 | --- | 37 | 37 | 5.59 | 11.83 |

Discussion of Inputs and Costs

With these three cases in mind, what can we say about how the inputs and costs of basal spraying compare with those of mechanical axe weeding? We must agree that these three cases alone do not provide any solid final measures of relative cost. However, we can draw some tentative conclusions or working hypotheses that will serve as a basis for further work.

First, let it be said that the axe weeding, serving here as a datum plane for comparison, was done with somewhat better than average efficiency and dispatch. In our experience it would be very difficult greatly to reduce the amount of labor used per acre. This is not necessarily true of the chemical weeding. It seems likely that fairly substantial savings could be made by improving spray techniques, or greater efficiency could be achieved with about the same input of labor and materials per acre.

With the techniques used, basal spray weeding took about one-third to one-half as much labor per acre as axe weeding. Working time per acre spraying varied from 2 to 5 man-hours. The fact that spraying requires less work may be significant in areas with relatively high wage rates or on lands with a limited amount of labor. It should be possible for the same crew to cover more ground spray weeding than they could in the same time with axe weeding.

From about 3 to 5 gallons of spray mixture were used to weed an acre of the natural stands. About 8 gallons per acre were used in the plantation. At the price paid for Esterone 245, kerosene, and labor, spraying materials made up about half the cost of chemical weeding.

In general, the total dollar cost per acre of chemical weeding was about the same as that of axe weeding. This fact, of course, could be changed through the reduction of inputs by developing a faster spray technique, or lowering the percentage of Esterone 245 used in the spray mixture, or by reducing unit costs with a cheaper carrier, or by less expensive labor or chemicals.

Finally, we must qualify the relative costs per acre of chemical and axe weeding by the effectiveness of each method in reaching the silvicultural objectives.

Discussion of Silvicultural Effectiveness

The extent to which the mechanical and chemical weeding achieved the stated silvicultural objectives can be only partially assessed at this time. The two methods were applied with approximately the same efficiency of coverage. The mechanical weeding on the three acres resulted in 100 percent, 63 percent, and 100 percent coverages, while the chemical counterparts resulted in coverages of 96 percent, 73 percent, and 96 percent.

On the other hand, the effects of the treatments varied greatly. The mechanical weeding brought the immediate release of the crowns of the trees favored. In contrast, the chemical weeding caused a gradual release of the favored trees. This release appeared to be slight during the first growing season. However, many of the smaller trees favored by the mechanical weeding were overtopped by new sprouts during the first and second growing seasons

following treatment. This was especially true on the areas of the 14-year-old natural stand and the 9-year-old hardwood stand. Thus the results of the chemical weedings could not be assessed after the first growing season. After the second season, on the other hand, the crowns of 40 to 60 percent of the trees sprayed were apparently dead, while 8 to 9 percent had one-third live crown remaining, and 30 to 50 percent two-thirds. Even though about 29 percent of these trees had sprouted since being sprayed, the sprouts were extremely low in vigor and did not seem capable of competing seriously for crown space with the selected trees.

In spite of lower percentages of kill than those attained in Dr. Hackett's experiments, our more recent and extensive treatments show results that are very promising indeed. The effectiveness of mechanical weeding, though immediately pronounced, disappears quickly as it has long been known to do in our region. The basal spray treatments, on the other hand, in light of Dr. Hackett's and our more recent work, though a little slower to take effect, bid fair to remain effective for several years -- long enough for the favored trees to get ahead of their undesirable neighbors. We are inclined to credit the lower percentages of kill in our recent experiments not so much to lack of effectiveness in the chemical as to lack of efficiency in its application.

Suggestions for Further Development

One fact seems clear from this second set of experiments with basal sprays at the Harvard Forest. The greatest opportunity for improvement in chemical weeding efficiency and cost seems to be by insuring that each stem is treated properly and completely. This should greatly increase the silvicultural effectiveness of chemical sprays as a tool for weeding. Using the present techniques, we got about as good coverage with sprays as with axes, but only about half of the sprayed stems were completely killed. It seems likely that this kill could be increased by a series of coordinated developments.

Something can be accomplished by better training and instruction for the men, but before this can be effective better spraying equipment and techniques for applying the spray should be developed. The men ran into several problems and difficulties in the field that could be eliminated to make basal spraying easier and more effective. Several improvements could be made in the equipment:

1. Four gallons make too heavy a load for all-day work. A two- or three-gallon load is probably better.
2. The back-pack pump should be tight so that it will not spill over the top when the men duck around through the brush.
3. A more comfortable back-pack carrier would be a great help. The tank could be mounted on a canvas-covered pack board or on an aluminum rucksac frame to prevent its digging into the back.
4. There should be a minimum of protrusions from the tank that can catch on brush and limbs. The pump mechanism was particularly troublesome. A tank that did not

require constant pumping would be desirable. One that could be completely emptied after one charge of compressed air would perhaps be best.

5. A trigger release mechanism that did not clog easily would lead to less dribbling, better maintenance, and a greater economy of spray.
6. A spray nozzle attached to the brass extension pipe at a 90° angle would make it easier to wet the stem all the way around.

With the above equipment changes, a means of coloring the spray so that it would stain the bark some bright color would speed up the work. This would serve several purposes; it would make it easier to tell what had been treated, how thoroughly it had been covered, and would give the men a feeling of accomplishment that is lacking with a simple kerosene spray. After a hard day's work a man cannot see that he has done anything because there is not a mark to show what he has sprayed. If the color lasted, it would also help later in assessing the efficiency of coverage and the thoroughness of the treatment of individual trees.

A closely related need is to find efficient methods for laying out an area for treatment. Strings or painted lines might be used to divide it into convenient work units for individual men or for the crew. This would save time, provide a feeling of accomplishment, and promote better coverage.

The men should be thoroughly trained in the use of these improvements in equipment and technique. It would also help to explain how the sprays work. If woods workers think of these chemicals as "poisons," they are likely to over-rate their effectiveness. They may feel that even a little bit is enough to kill a tree.

With the above developments it seems reasonable to anticipate about as good a coverage by basal spraying as with axe weeding, and a very high percentage of spraying kill. It also seems likely that comparable weeding could be done with about three-fourths as much labor as we experienced in these experiments. However, this saving may be offset by using more spray to get proper treatment, so that the relative costs of chemical and axe weeding would remain unchanged. With a technique that insured proper treatment of each stem, however, it might be feasible to reduce the percentage of Esterone 245 to 1 percent. At present prices this might lead to savings of about 20 percent in the cost of chemical weeding.

The two sets of experiments carried out at the Harvard Forest seem to indicate that basal sprays with 2,4,5,-T or mixtures of this with 2,4,-D in oil form an exceedingly promising silvicultural tool. We have only begun to explore the ways in which this tool can be incorporated into our thinking about forest production. It is difficult to assess the importance of the innovation, but the preliminary results seem well worth following up vigorously.

Table 2.
Comparison of Effectiveness

Hardwood Stems
Acre Basis

| Stand | No. of stems | No. of stems to be treated | 1952 | | | 1953 | | |
|---|--------------|----------------------------|------------------------------|--------------------------------|--|---------------------------------------|--|--------------------------------|
| | | | Mechanical Percent cut | Chemical Percent sprayed | Mechanical Percent of stems sprouting | Chemical Appar- ently dead * | Percent of treated stems 1/3 live crown remaining | 2/3 live crown remaining |
| 14 yr.-old white pine plantation | 5,695 | 3,679 | 100 | 96 | 100 | 60 | 8 | 32 |
| 14 yr.-old natural white pine and hard- woods | 2,806 | 860 | 63 | 73 | 100 | 60 | 8 | 32 |
| 9 yr.-old hardwoods | 5,689 | 2,850 | 100 | 96 | 100 | 44 | 9 | 47 |