RELEASING CONIFERS in the Lake States With Chemicals

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PREFACE

This publication describes the present status of various usable chemical methods for releasing pine and other conifer stands in the Lake States from the competition of undesirable hardwoods and brush. The information presented is based on the firsthand experience and the research results obtained by the authors in northern Minnesota and lower Michigan.

Since most research results and experience on release in the Lake States have been related to planted stands of high value, emphasis is often placed upon the chemical release of conifer plantations. However, the chemical techniques for controlling brush and undesirable hardwoods are equally useful in the release of naturally established conifers.

Each release job requires an individual prescription, depending on the species, density, and the degree of control desired. Moreover, since chemical control of woody vegetation is relatively new, some of the techniques described may be improved or refined from time to time as more research results become available. The techniques outlined here are therefore necessarily general. By giving careful attention to the general prescriptions set forth, each forest manager should be able to adapt them to his local release problem. Until the forest manager has learned the capabilities and limitations of the various herbicides from his own experience, he should of course use caution when applying them to control undesirable hardwoods and brush in conifer stands.

CONTENTS

Note.—A small preliminary edition of essentially the same material was issued in April 1960 under the title, How To Release Conifers in the Lake States With Chemicals.

Releasing Conifers in the Lake States With Chemicals

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INTRODUCTION

Brush and low-value hardwoods are often obstacles to the satisfactory establishment and growth of conifers in both planted and natural stands. Once established, most conifers in the Lake States need full sunlight for best growth. For this reason, brush, undesirable trees, and other competing vegetation must be kept from overtopping these more valuable trees (fig. 1). The job of keeping such competitors from interfering with the satisfactory development of conifers is called release.

This report describes the principal types of release needed in the Lake States region and how they are accomplished with the aid of chemical herbicides. It gives detailed information on the types of herbicides used, and on techniques of application suitable for various kinds and conditions of competition.

FIGURE 1.—This 8-year-old red pine is completely overtopped by brush and in urgent need of light.

TYPES OF RELEASE

The conifer release job in the Lake States falls into two main types, depending on the size of the brush and other competitors to be

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controlled. When these competitors are composed of low shrubs, herbs, and other vegetation, either suppressing or threatening the development of the conifers, the job of removing such vegetation is often called *low release*. Generally the competitors are about as tall as the conifers, or a little taller.

When the competition comes from tall brush and low-value hardwoods that are much larger than and completely overtopping the conifers, the job is known as *high release*. Sometimes the interfering woody growth may form a double overstory or one that is 20 or more feet taller than the conifers (fig. 2). Some high-release jobs are the result of planting conifers under already established stands such as aspen, birch, or oak. Most high-release operations, however, are made necessary by past neglect or poor low release, or by planting in sparsely stocked hardwoods. Since early and adequate low release will reduce both mortality and loss of growth of conifers to a minimum, its importance to the forest manager is obvious; and usually it can be done at a lower cost than high release.

Another important operation that will reduce the size of the release job in plantations or even eliminate it altogether consists of treatments used to control the competing vegetation before the conifers are planted. This is called planting-site preparation, or *preplanting release*.

The control of vegetation crowding conifers that have been planted for Christmas tree production requires special attention in order to promote satisfactory form development as well as growth. This subject is covered in a special section. Nearly complete control of undesirable brush and hardwoods is usually required.

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FIGURE 2.—Red pine overtopped by aspen. Unless the pines are released soon, they will be eliminated by competition.

In conifer stands other than those established for Christmas trees, complete kill of roots and tops of all competing vegetation is seldom needed, nor is it desirable from the site protection standpoint. All that is needed is to set back the brush so that the conifers can get ahead and develop.

CHEMICAL HERBICIDES—THE MODERN RELEASE TOOL

Before World War II, all release operations in conifer stands, whether low release, high release,

preplanting release, or care of Christmas trees, were carried on by laborious and costly handtool methods. Sprout regrowth following such methods was often so great as to require successive operations. Later development of the chemical herbicides has completely changed this situation and the use of handtools alone to release conifers is becoming less common. It still has a place, however, in plantations and natural stands that are too small or scattered to make release with herbicides practical.

Chemical herbicides can be used either alone or in conjunction with cutting to kill the tops of undesirable vegetation and to reduce sprout regrowth. They are usually more effective and less costly than hand cutting.

Various chemicals, available in commercial quantities, can be used as herbicides to kill trees, brush, and other vegetation. However, for control of undesirable hardwoods and brush in conifer stands only the *selective* or "hormone" type herbicides are recommended; those of the *nonselective* type are toxic to both conifers and broadleaf vegetation. The most common of the selective herbicides are 2,4,5-T and 2,4-D. But it must be remembered that the selective properties of these two general herbicides are *relative. Extremely heavy dosages will kill all vegetation; when properly diluted, they will kill some species and not others.*

2,4,5-T Esters
(2,4,5-trichlorophenoxyacetic acid)

The herbicide now most widely used to control brush and undesirable hardwoods is 2,4,5-T. The most effective formulations of this herbicide for brush control contain one of the esters;[2] these are miscible in diesel oil, fuel oil, or kerosene and emulsifiable in water and in oil-water. Such ester formulations are produced by a number of chemical companies in 1-gallon, 5-gallon, and 55-gallon lots. They usually have an acid equivalent (2,4,5-T) of 4.0 pounds per gallon. Formulations with a different acid equivalent are also available, however, particularly in smaller size lots.

The cost of low-volatile ester formulations of 2,4,5-T containing a 4.0-pound acid equivalent varies from about $6 to $12 per gallon, depending on the quantity purchased. Since the price per gallon of this and other herbicides will depend largely on the amount of their acid equivalent, it is important to check the latter figure when purchasing such herbicides.

When properly diluted and applied, ester formulations of 2.4,5-T will kill the tops of most broadleaf brush and hardwood species in the Lake States and reduce sprouting. This herbicide should be used for controlling such species as rose, raspberry, oaks, maples, and other species resistant to some of the other common herbicides. It can also damage conifers if applied in heavy quantities, especially during the period of new growth.

Recent experiments with invert emulsions of 2,4,5-T indicate that they may have some use for controlling unwanted brush with less

[2] These are of two types: the low-volatile esters recognized by the U.S. Department of Agriculture (the propylene glycol butyl ether group, butoxyethanol, iso-octyl, etc.) and the older volatile esters (methyl, ethyl, isopropyl, butyl, pentyl, etc.). The former are somewhat more expensive and are reputedly more effective on brush. They do not vaporize as do the volatile esters and hence are safer to use where conifers may be adjacent to agricultural crops.

drift effect. Dosages for invert emulsions, however, have not been worked out for general field applications.

2,4-D Esters
(2,4-dichlorophenoxyacetic acid)

The first of the hormone herbicides to be used for brush control, 2,4-D, can be used to kill shrubs and hardwood trees such as hazel, alder, sumac, willow, and aspen. Like 2,4,5-T, it is marketed in low-volatile ester formulations which usually have a 4.0-pound acid equivalent per gallon, and in volatile ester formulations ranging from 2.7- to 6.0-pound acid equivalent. The cost of 2,4-D per pound of acid equivalent is only about half that of 2,4,5-T; it will therefore be the preferred choice where shrubs or trees equally sensitive to both herbicides are to be controlled.

Mixtures of 2,4-D and 2,4,5-T Esters

Also available are many different brands of so-called chemical "brush killers." These are mixtures of various esters of 2,4-D and 2,4,5-T, usually 50–50 but occasionally ⅔–⅓. Many of these products are composed of the low-volatile esters of the two herbicides, but others contain only the older volatile esters. "Brush killer" mixtures have been widely used, particularly with the view of reducing costs of brush control on areas containing a mixture of species, some of which are resistant to 2,4-D. However, there is as yet no reliable evidence that the two chemicals combined are any more effective than either alone. For species resistant to 2,4-D, the effectiveness of the 2,4,5-T will probably be the same when used alone or when the equivalent amount is mixed with 2,4-D. In some cases at least, it would be actually less costly and just as effective to apply the equivalent amount of 2,4,5-T alone.

Other Selective Herbicides

Other selective herbicides, notably 2,4,5-TP (2-(2,4,5-trichlorophenoxy) propionic acid) and amitrol (3-amino-1,2,4-triazole), are on the market, but so far these appear to have no advantages over the less expensive herbicides, 2,4-D and 2,4,5-T, for use on the common brush species and weed trees needing control in stands of Lake States conifers. Moreover, amitrol causes injury to some conifers.

The water-soluble amine formulations of 2,4-D and 2,4,5-T have been found to be more effective in minute quantities in killing unwanted hardwoods and reducing sprouting when applied directly to cut surfaces of the tree than are the oil-soluble esters. This herbicide is less expensive than the esters. Oil-soluble amine formulations have been developed, but to date their effectiveness has not been demonstrated.

Nonselective Herbicides

Other herbicides that are very effective for killing both herbaceous and woody vegetation include: Ammate (ammonium sulfamate), monuron, and other urea derivatives. However, these herbicides are nonselective in that they will injure conifers as well as the competing vegetation. They therefore have very limited use in conifer release operations except for careful applications directly on the competing vegetation and not on the conifers.

Selecting the Proper Herbicide

Selection of the type of herbicide to be used should depend entirely

on the composition of the brush and hardwoods to be controlled. If all species are susceptible to 2,4-D, then this herbicide should be used. If a majority of the species are resistant to 2,4-D, then 2,4,5-T alone should be used. A mixture of these herbicides should be used only for areas of brush containing a few scattered stems of species resistant to 2,4-D. A partial list of species sensitive to foliage sprays of 2,4-D and 2,4,5-T is given at the end of this handbook.

METHODS OF APPLICATION

The chemical herbicides described in this report can be applied in several different ways for the release of established conifer stands or the prerelease of conifer plantations. These include foliage spraying, basal cut-bark treatments, and basal bark spraying.

Foliage Spraying

Foliage spraying consists in applying solutions or emulsions (depending on the carrier)[3] of herbicide esters directly on the leaves of the brush or other unwanted plants by means of ground equipment (fig. 3) or from aircraft. For release purposes foliage spraying is limited to the latter part of the growing season when the broadleaf species are still sensitive to the herbicides but the conifers have hardened off. At this stage of growth the conifers

[3] Herbicides of 2,4-D and 2,4,5-T are diluted with either oil, water, or oil and water. The ester formulations are soluble in oil and form an emulsion when mixed with water.

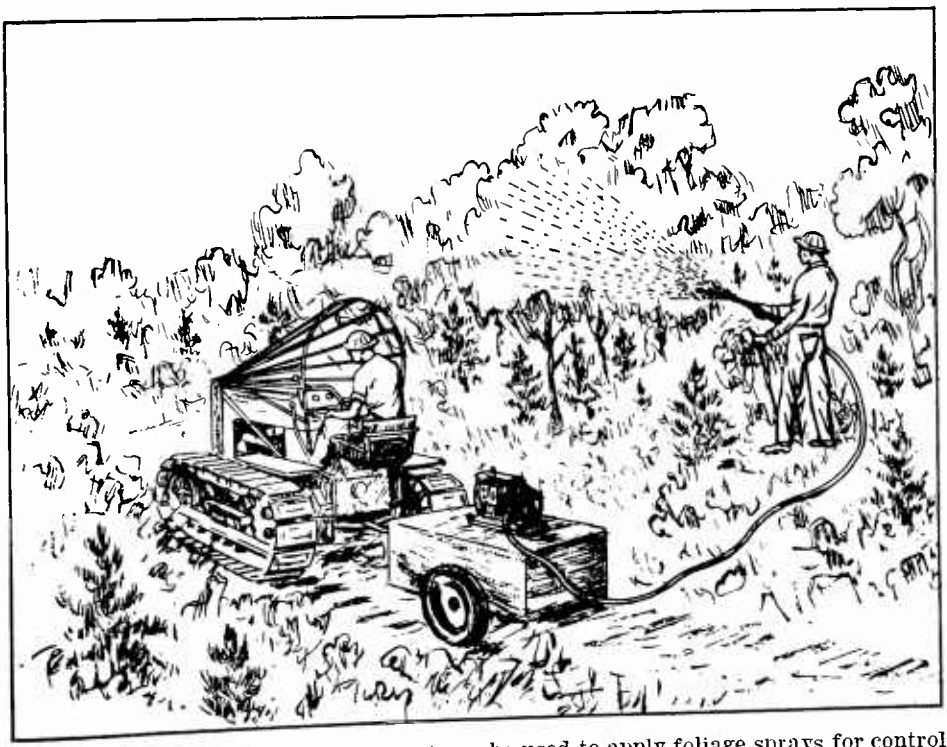

FIGURE 3.—Hydraulic spray equipment can be used to apply foliage sprays for control of brush.

are resistant to light applications of the selective herbicides, whereas the broadleaf species are still sensitive to the same applications.

Even in the latter part of the growing season, foliage sprays must be applied so that only very small quantities will hit the conifers directly. Aerial applications during this time rarely injure the conifers because the total volume used is low. Occasionally, red pines will show a strong recurving of the needles at the end of the new growth as a result of foliage spraying; but this permanent "set" does not seem to affect the future development of the trees.[4] On the other hand, if conifers are sprayed during the active growing season, even with small quantities, the needles will die and the trees may be killed entirely or the current growth malformed.

Of the pines commonly planted in the Lake States, jack pine and Scotch pine are the most susceptible to injury from foliage spraying with herbicides. Somewhat less easily damaged are white pine and red pine. White spruce and black spruce are seldom injured by light applications of selective herbicides after active growth is complete; but Norway spruce is more easily damaged.

Basal Cut-Bark Treatments

Basal cut-bark methods involve the use of hand or power tools to prepare freshly cut surfaces, which are then treated with either 2,4,5,–T ester in oil or the amine of 2,4-D or 2,4,5-T diluted in water. Such treatments are of two general types:

1. Cut-stump treatment, more commonly used for small trees and occasionally for brush.
2. Cut-bark treatments, used on trees larger than 3 to 4 inches in diameter by means of frill girdles or tree injectors.

In the cut-stump treatment, immediately after the stem has been cut with an ax or saw, the tops, sides, and root collar of the stump are thoroughly drenched with 2,4,5-T mixed with oil (12 to 16 pounds AHG). AHG is an abbreviation for acid equivalent per hundred gallons of solution.

Cut-bark treatments are used to kill individual trees larger than 3 to 4 inches in diameter. The diluted herbicide is applied to the sapwood through fresh cuts in the bark. The cut may be a frill girdle, or a tree injector (see p. 17) may be used. A frill girdle is a continuous troughlike incision made completely around a tree, deep enough to penetrate the bark and extend one-fourth to one-half inch into the sapwood. The incision is thus one-half to one and one-half inches deep depending on the thickness of the bark. It is made as close to the base of the tree as is practicable. Frill girdles are made by a series of overlapping downward cutting strokes with an ax; the chips are not removed, hence the name "frill." A solution of either 2,4,5-T in oil or the amine of 2,4-D or 2,4,5-T in water is then applied to insure top kill and reduce sprouting. (See p. 15 for details.)

Basal Spraying

The basal bark spray method—spraying the base of trees with an oil solution of 2,4,5-T—is used mainly for controlling hardwoods and brush that sprout prolifically, such as aspen, red maple, mountain maple, and speckled alder. Ordinarily it is used for stems *less* than 4 inches in diameter. Large trees can also be killed with basal sprays,

[4] This type of injury closely resembles the condition known as needle droop; the latter is apparently due to drought.

but since this requires a large volume of herbicide, it is seldom practical except along roads and in other accessible places where adequate supplies can be transported by truck or jeep.

The chief advantages of basal sprays are that they kill small trees and brush more completely (less sprouting follows) and that they require less labor, as compared with cutting or girdling. The principal disadvantage is the large volume of chemical needed.

2,4,5-T ester mixed with fuel oil or kerosene is the only herbicide that has been effective for *general* basal-spray work in the Lake States. The oil carrier is essential; it enables the chemical to penetrate the bark, whereas water does not.

Basal sprays applied at any season of the year will give good control of most hardwood species with very little resprouting. The most sprouting follows if trees are sprayed before growth starts in the spring; the least, if sprayed immediately after full leaf development when root reserves are low. For example, aspen trees that are basal sprayed immediately after full leaf development seldom sprout; at other seasons of the year sprouts and suckers still develop.

LOW RELEASE BY HERBICIDE TREATMENT

The control of low brush, small weed trees, and herbs that are approximately the same height as the conifers is accomplished mainly by foliage sprays applied with aircraft or occasionally with ground equipment.[5] For certain special low-brush conditions of limited area, the competing vegetation can be controlled by basal spraying, or by cutting and basal spraying the freshly cut stumps.

Foliage Spraying

Foliage spraying for the low release of conifers can be done with either ground equipment or from aircraft, depending on the size of the area to be released, its accessibility, character of the terrain, and the landownership pattern.

The new growth of all vegetation, including conifers, is easily injured during the period of active growth by herbicides applied in light quantities and even by drift. The release job therefore must be delayed until the new growth has hardened off. In tests in Lower Michigan, foliage sprays of 1 and 2 pounds acid equivalent in the form of esters of both 2,4-D and 2,4,5-T in 2½ and 5 gallons per acre were applied directly on conifers at 2-week intervals during one entire growing season. Such applications caused injury to the new growth until July 15 for white spruce, August 1 for red pine, white pine, and Norway spruce, and August 1 for red pine, white pine, and Norway spruce, and August 15 for jack and Scotch pines. But since the factor governing such injury is the stage of development of the plant, these dates will likely vary not only with location but also with season.

With Ground Equipment

The type of ground spraying equipment selected for low-release work depends largely on the condition and character of the local terrain, size of the control operation, and the density and height of the brush and other vegetation to be controlled.

[5] Release from grass and herbaceous plants is a special type of low release for which no satisfactory chemical method has so far been worked out on a practical basis. However, certain new chemicals, such as simazin, may prove useful for controlling such vegetation.

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Backpack sprayers.—To release small conifers from scattered low brush, use backpack-type sprayers of 3- to 5-gallon capacity (fig. 4). With such equipment, foliage sprays can be carefully directed with little waste of materials and damage to the conifers.

Satisfactory top kill of common brush, such as hazel, alder, willow, and sumac, and of many common herbs can be obtained with 40 to 50 gallons per acre of a water emulsion containing 2 to 3 pounds of 2,4-D AHG (this is 2 to 3 quarts of an ester having a 4-pound acid equivalent). For stands of species that are resistant to 2,4-D, substitute 2,4,5-T.

If the brush includes a small proportion of stems of species that are resistant to 2,4-D and a uniform top kill is desired, use a mixture of esters of these two herbicides. Buy such mixtures in the form of the standard brush-killer formulations, composed usually of 2,4-D and 2,4,5-T in 50–50 mixtures (see p. 4), or make them up in the proportions desired. Ester formulations of a single manufacturer are more likely to be readily miscible than those of different manufacturers.

FIGURE 4.—Backpack spray equipment can be used to control patches of low brush by means of foliage sprays.

Wet the foliage thoroughly but avoid drip from the leaves—this wastes herbicide materials. No special effort need be made to spray both sides of the leaves.

For larger tracts of conifers that are readily accessible and are on fairly level, firm terrain, use either (1) power sprayers equipped with 200- to 400-gallon tanks mounted on trucks or trailers pulled by tractors, or (2) mist blowers.

Power sprayers.—Power pumps apply droplets, which can be varied in size from fog to coarse, at pressures ranging from 60 to 400 pounds per square inch; the lower pressures use less herbicide materials and cause fewer mechanical failures (fig. 5).

Power sprayers, because of their higher operating pressure, typically apply larger volumes than do hand pumps. Therefore the concentration of herbicide should be reduced somewhat below that recommended for hand pumps to prevent damage to the conifers, particularly those growing in openings. If the tops of the conifers are exposed, apply not more than 75 to 100 gallons per acre of a water emulsion containing 1.25 to 1.5 pounds AHG; somewhat higher volumes can be used where the trees are completely overtopped.

To reduce loss through drip, spray only when the foliage of the brush is relatively dry. Windy days should be avoided if there are farm crops on neighboring lands that might be injured by drift.

Mist blowers.—The main advantage of mist blowers lies in their ability to apply low volumes of herbicide mixtures per acre fairly uniformly over dense brush, re-

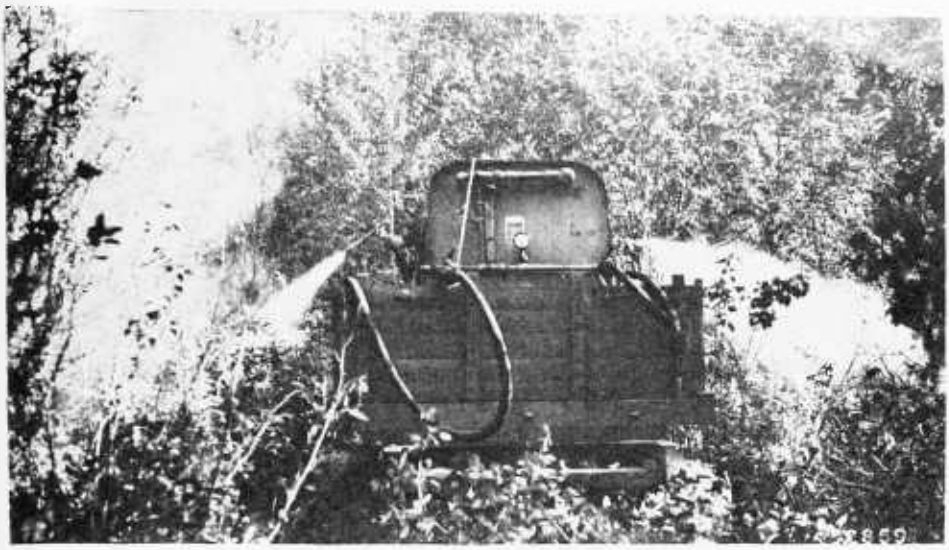

FIGURE 5.—Spraying dense alder brush with 2,4-D prior to planting.

gardless of its size, for distances ranging from 50 to 200 feet (fig. 6). Mist blowers come in a variety of sizes; the largest ones are mounted on trucks or trailers; the smallest one, weighing less than 40 pounds, is of the backpack type.[6]

Mist blowers will not apply small volumes of herbicide as uniformly as aircraft because they cannot be towed or transported at a constant rate of speed over rough terrain. Where the spray is manually directed, however, it can be applied as needed, depending on the density of the brush.

Where the conifers are partly exposed, use 5 gallons per acre of a water-oil emulsion of one of the herbicide esters containing 20 pounds AHG. Where the conifers are completely overtopped, increase the volume to 10 gallons per acre. These volumes are equivalent to 1 or 2 pounds, respectively, of herbicide per acre.[7] Since the high-velocity mist will penetrate the brush and hit the overtopped conifers, do not aim the blower directly at the brush; instead, direct it higher so that the mist falls on the brush. Because the spray can travel a considerable distance, mist blowers must be carefully handled. This is especially true in conifer stands adjacent to farmland. In such areas, do not use mist blowers on days when winds are blowing at more than 2 to 3 miles per hour.

Cost.—Cost of foliage spraying with ground equipment will range from $5 per acre upward depending on the kind and amount of herbicide applied and the type of equip-

[6] For description of some of the mist blowers available, see Potts, S. F., Equipment for pest and disease control. Unasylva 13 (2): 89–101, illus. 1959. (Single copy price 65 cents, available from Columbia Univ. Press, International Documents Serv., 2960 Broadway, New York 27, N.Y.) Another reference: Potts, Samuel Frederick, Concentrated spray equipment, mixtures, and application methods. 598 pp., illus. Durland Books, Caldwell, N.J. 1958.

[7] Follow spray recommendations provided by manufacturer. Spray mixtures used successfully in Lower Michigan have been 1 part chemical, 4 parts No. 2 fuel oil, and 15 parts water.

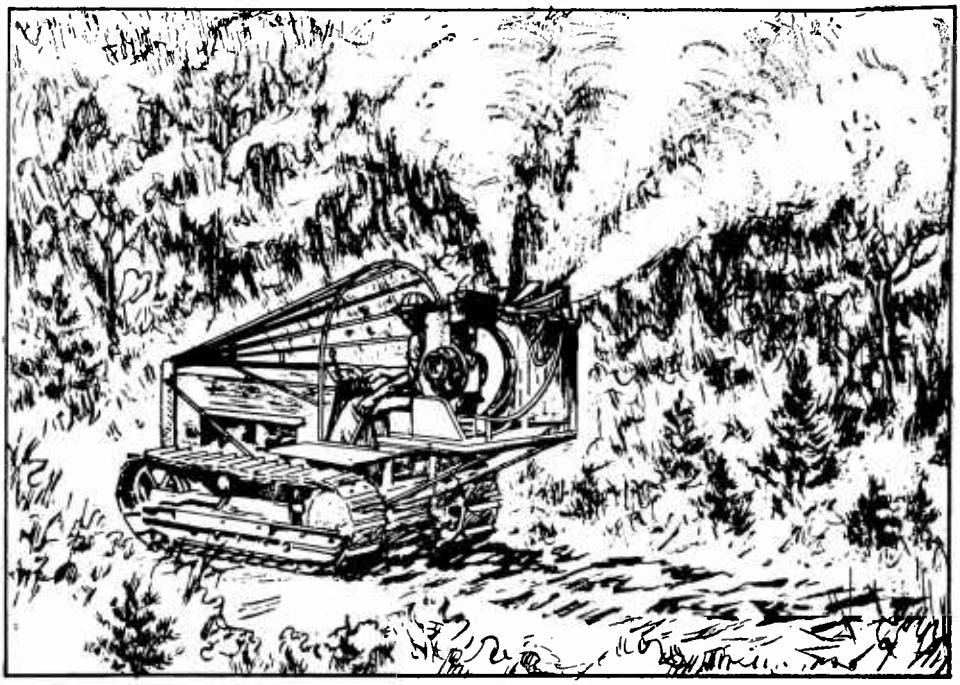

FIGURE 6.—One type of mist blower that can be effectively used to control hardwoods for conifer release. Such a mist blower can be used for both low and high brush and trees.

ment used. Hand applications will naturally cost more than those made with power pumps and mist blowers.

From Aircraft

When the conifers needing low release occupy a tract 5 acres or more in size, rectangular in outline, and so located that there would be no danger of drift damage to adjoining cropland, explore the feasibility of controlling the brush by aerial spraying. Large areas of conifer stands, regardless of their accessibility and the density of their brush competitors, can be released by aerial spraying in just a few hours' time and at a much lower cost than with ground equipment.

In aerial spraying, the same amount of herbicide (acid equivalent) is used per acre as in ground applications, but the total volume applied is low.

The following tabulation will serve as a guide to the amount of herbicide and volume of mixture to apply to brush stands of different degrees of density.

Brush density	*Number of stems per acre*	*Pounds of herbicide per acre*	*Gallons of mixture per acre*
Low	2,000–8,000	1	2
Medium	8,000–25,000	1½	2
Heavy	25,000 and up	2	3

What the best type of carrier is needs further study; water alone has been found to be satisfactory, but good results have also been obtained with mixtures containing small amounts of No. 2 fuel oil or diesel oil.[8] The addition of oils to the carrier should, therefore, be continued until research or experience proves them unnecessary. Typical mixtures used are: 1½ quarts herbicide ester, 1 quart oil, and 5½ quarts water; or 2 quarts herbicide, 2 quarts oil, and 12 quarts water. To avoid trouble, mix the oil and herbicide needed for a planeload and then add this slowly to the water required to complete the load, stirring vigorously all the while. *Do not add the water to the herbicide-oil mixture.*

Carriers composed entirely of fuel or other oils have been used in foliage spraying. In some applications damage to jack pine and even death has been reported. General recommendations cannot be given until further tests have determined the conditions under which oil carriers can be safely used.

Make aerial applications for low release at about the same time of year as ground foliage sprays. Since the volumes applied with aircraft are much lower and are less well distributed, such spraying can, however, begin 1 to 2 weeks earlier than applications made with ground equipment, especially where none of the conifers are exposed. To minimize drift, flying should be done when the general wind velocity is less than 6 miles per hour. Little is known about the effect of temperature conditions; Ray[9] recommends a temperature range of 65° to 80° F. with high humidity. The higher temperature limit is presumably set so that turbulent air conditions will be avoided.

Because the volumes applied aerially are small, it is not important that foliage be dry. This is fortunate because early morning and early evening, both periods tending to have heavy dew, are generally the best times of day for aerial spraying. At these times quiet air and favorable temperature and humidity usually prevail.

Tracts needing low release usually can be marked with simple devices so that they are readily identified from the air. Mark corners or boundaries with flags, with captive orange or yellow balloons 3 to 4 feet in diameter and 15 to 20 feet above the brush, or with reflectors made of aluminum foil, freezer grade. Where oil-water is used as the herbicide carrier, balloons should be of the oil-resistant type. Helium can be used to inflate the balloons; hydrogen, besides having greater buoyancy, is easier to obtain and less expensive. *Hydrogen, however, is dangerously explosive and must be handled with great care.* Tracts fairly regular in outline can of course be sprayed with less ground marking and supervision than those with irregular boundaries. In some areas of irregular shape, it may be more practical to spray certain portions with ground equipment.

Planes commonly used are the lighter craft, such as those em-

[8] No. 1 fuel or diesel oil should never be used. Besides being more expensive than No. 2 oil, it is more injurious to conifers.

[9] Ray, Hurlon C. General information on herbicides and aerial application for hardwood suppression. *In* Chemical Control of Range Weeds, Unnumbered handbook, U.S. Depts. Agr. and Int. Range Seeding Equipment Committee. (96 pp.) Rev. 1959.

ployed for agricultural crop spraying. Helicopters have been used only to a minor extent in the Lake States but will likely be used more in the future. Light conventional aircraft commonly have a 40- to 200-gallon storage tank feeding the nozzles through a wind-driven pump. Most planes are equipped with a series of from 20 to 25 nozzles, evenly spaced along a boom extending the width of the plane and operated at pressures ranging from 25 to 50 p.s.i. More research is needed to determine the best nozzle arrangement.

Where topography and the shape of the tract to be sprayed permit, flying should preferably be done in a grid pattern, alternating the swaths in opposite directions. In rough country, flying gridwise may be impossible. Here it will be safer to fly either along the contours or downslope, making the swaths all in the same direction.[10] Planes usually fly from 25 to 75 feet above the brush canopy; the latter elevation is the minimum height permitted for reasons of human safety, in all U.S. Forest Service aerial brush control operations.

The costs of low release by means of aerial foliage sprays vary with the herbicide used, its concentration, the volume of mixture applied per acre, the size of the area sprayed, and type of aircraft used. For sizable tracts, total costs will range from $3 to $5 per acre for the recommended mixtures of 2,4-D and $4.50 to $7 per acre for the 2,4,5-T mixtures with fixed-wing aircraft. Helicopter costs for herbicide spraying have been reported to range from $7 to $15 per acre.

[10] U.S. Agricultural Research Service. How to spray the aircraft way. U.S. Dept. Agr. Farmers' Bul. 2062, 32 pp., illus. 1954.

Basal Bark Spraying

Although foliage spraying is the chief method of applying herbicides in the low release of conifers, basal bark spraying can be used to control low brush in the dormant season as well as at other seasons of the year. The basal portion of the stems is thoroughly soaked at the ground line and up to a height of about 1 foot with a solution of 2,4,5-T in fuel oil.[11] For general application, use 12 pounds AHG (a 3-percent solution of an ester having a 4-pound acid equivalent) until local experience shows that lower concentrations will provide the desired degree of control. For example, on the Superior National Forest, 4 pounds AHG of this herbicide has been used successfully to control upland alder (*Alnus crispa*) clumps in a jack pine plantation.

HIGH RELEASE BY HERBICIDE TREATMENTS

Natural and planted conifers that have been overtopped by aspen, oaks, or tall brush may be released most efficiently by two principal herbicide methods. These are (1) foliage spraying with either aircraft or mist blowers, and (2) basal cut-bark treatments. Basal bark spraying can also be used for special high release conditions of limited area. Foliage spraying is a blanket treatment, whereas the other two methods permit the selection of the trees to be controlled.

The choice of method depends mainly on the size of job and the time of year selected to do the work. Overtopped conifers on tracts of 5 acres or more and of fairly regu-

[11] Use the cheaper No. 2 oil as the carrier for 2,4,5-T for basal spraying and all basal cut-bark treatments.

lar outline can be released during the latter part of the growing season by spraying the foliage of the competing vegetation with herbicide mixtures applied from aircraft. Smaller or very irregular areas can more feasibly be released by spraying the foliage of the competitors with a mist blower or by one of the two ground methods using hand labor—basal cut-bark treatments and basal bark spraying.

Although basal cut-bark and basal spray methods are generally most effective immediately after full leaf development, they will also give good results during the winter months when labor is relatively easy to hire. These methods, being applied on an individual tree basis, can control composition and density in overtopped plantations where it may not be desirable to remove all of the hardwood competition. In aerial foliage spraying, selectivity is of course not possible.

Foliage Spraying From Aircraft

The same details given for aerial spraying under low release apply to high release with but little modification (fig. 7). Since the competitors are taller, however, somewhat larger amounts of herbicide and greater volumes of mixture per acre will be required.

For alder, paper birch, and willow, use 1½ to 2 pounds of 2,4-D in 4 gallons of oil-water emulsion per acre; for aspen, 3 pounds of 2,4-D in 4 gallons of water emulsion per acre; for oaks, one-half to 1 pound of 2,4,5-T in 2 to 2½ gallons of oil-water emulsion per acre. In Lower Michigan red pine has been successfully released from aspen with an application of 2 pounds of 2,4-D in 4 gallons of No. 2 fuel oil solution per acre, and 15-year-old jack pine from scrub oak competition with one-half to 1 pound of 2,4,5-T in 2 gallons of fuel oil solution per acre, with no apparent damage to the pines. In Maine white pine has been successfully released with 1 to 3 pounds of 2,4,5-T in 2½ gallons of fuel oil. But in northern Minnesota herbicide applications with an oil carrier have damaged or killed jack pine of pulpwood size. Further testing with oil carriers is needed before general conditions for its use can be prescribed.

Marking the boundaries of tracts to be aerially sprayed for high release also needs special consideration. This job must be done in advance of the spraying time so the boundaries will be plainly visible from the air. Mark the corners with either flags or colored balloons that float at least 15 to 20 feet above the general canopy. Or, in oak stands where the trees to be sprayed are 4 inches or more in diameter, selected trees on the boundaries of the tract may be killed by frill girdling (see pp. 6 and 15) 2 or 3 weeks before the aerial spraying. The bright brown foliage of the freshly killed trees can be seen for distances of 2 to 4 miles as the pilot approaches the tract.

It will also help the pilot to mark the boundaries parallel to the line of flight with flags or balloons at about 1,000-foot intervals. Sometimes swath widths are also set off by flagmen as the job progresses. In rough topography, as in the northern part of the Lake States, such extra marking is not feasible, and many pilots do not feel it is necessary.

Pilots on large aerial release jobs should be given good maps with which they can become thoroughly familiar before the work is started. Two-way radio communication between pilots, the loading base, and

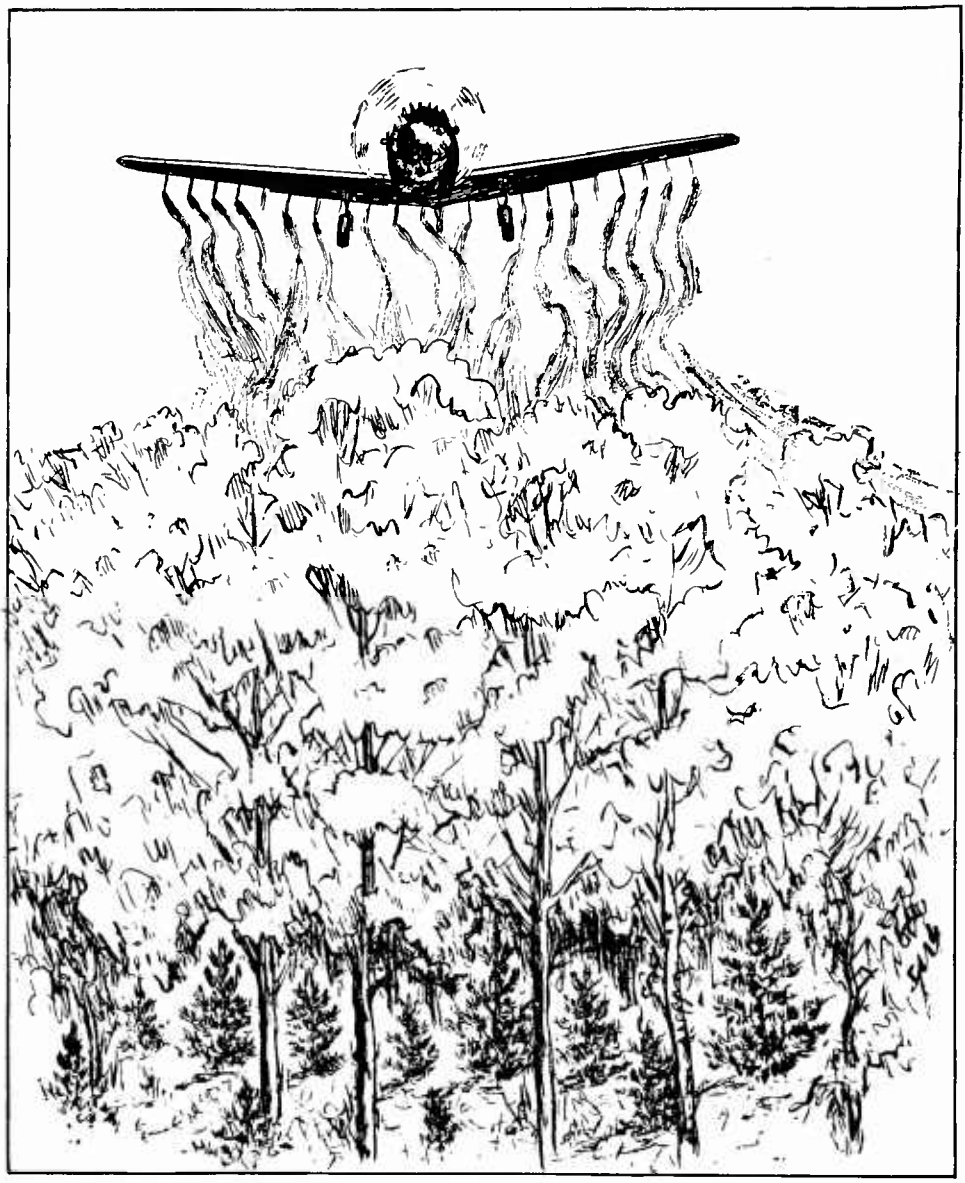

FIGURE 7.—Airplanes can be used to apply foliage sprays to control both high and low brush and trees for conifer release.

ground observers is also of much help.

Since high release generally requires the use of stronger concentrations and larger volumes of herbicide mixtures per acre, costs will be somewhat higher than those given for aerial low release on page 10. However, large areas of red pine plantations are being released from overtopping scrub oaks in Lower Michigan by one aerial spraying costing less than $4 per acre. This moderate cost is due to several favorable factors, mainly the relative ease of controlling oak

and the sizable tracts sprayed, making it feasible to use big, fast planes with large tank capacities. Costs for high-release jobs normally range from $4 to $7 per acre with fixed-wing aircraft, and $7 to $15 per acre with helicopters.

Foliage Sprays With Mist Blowers

Foliage spray applied by ground equipment has limited use for high release. Where ground equipment can operate, mist blowers with manually directed mist streams can be used on tall brush and low-value hardwoods for conifer release. This type equipment will require about 10 gallons of oil-water emulsion per acre, varying with the height and density of the brush. For an application of 10 gallons per acre, the emulsion should contain 2 quarts of herbicide ester—2 pounds acid equivalent. Follow manufacturer's directions for carrier dilution or try 1 part chemical, 4 parts No. 2 fuel oil, and 15 parts water.

Theoretically, mist blowers can apply low spray volumes at a uniform rate like aircraft sprays. But most blowers operate over fairly rough terrain where it is difficult to apply uniform low rates. A uniform rate of application may not be necessary, however—especially in high release work. Instead, the spray should be directed where needed to cover the high brush and undesirable hardwoods. Care should be taken not to blast the conifers directly with mist-blower sprays.

Basal Cut-Bark Treatments

Basal cut-bark treatments have been used extensively in the Lake States to control individual hardwoods for high-release purposes. Several cutting techniques and herbicide mixtures can be used, depending mainly on the size of the hardwoods and personal preferences. These include chemical frill girdles, cut stumps, and chemical tree injectors.

Chemical Frill Girdles

In the Lake States, frill cuts around the base of the tree are commonly treated with an ester of 2,4,5-T at 4 to 8 pounds AHG (1- to 2-percent solution by volume) in No. 2 fuel oil or diesel oil. The chemical is applied to the frill cut preferably within an hour or two after the ax work is completed (fig. 8).

A variety of different containers can be used to apply this herbicide solution to frill girdles. A backpack type sprayer with a built-in pressure pump and a nozzle that sprays a fine straight stream for a distance of only a few inches has proved satisfactory. With this sprayer only a few pounds of pressure should be maintained to avoid waste of the solution. The incision is filled once by walking or reaching around the tree. This will require about a teaspoonful (4 to 6 milliliters) of solution for every 3 inches of tree circumference (approximately 1 inch of diameter). One gallon of mixture will treat 800 to 1,000 inches of tree diameter.

Since the individual ax cuts usually form an irregular line, spraying the herbicide directly into a frill is often difficult and time consuming. A better technique is to spray the chemical-oil mixture on the tree trunk about one-half inch above the girdle, so that it runs down into the cut trough. Not only is this faster, but also it conveniently marks the trees that have been treated, since the oil mark on the tree is visible for several days. An *oil soluble* dye, such as para red or National Oil Red O, can also be used in the solution to stain the frills and identify treated trees.

Another herbicide that can be used for treating frill girdles is the

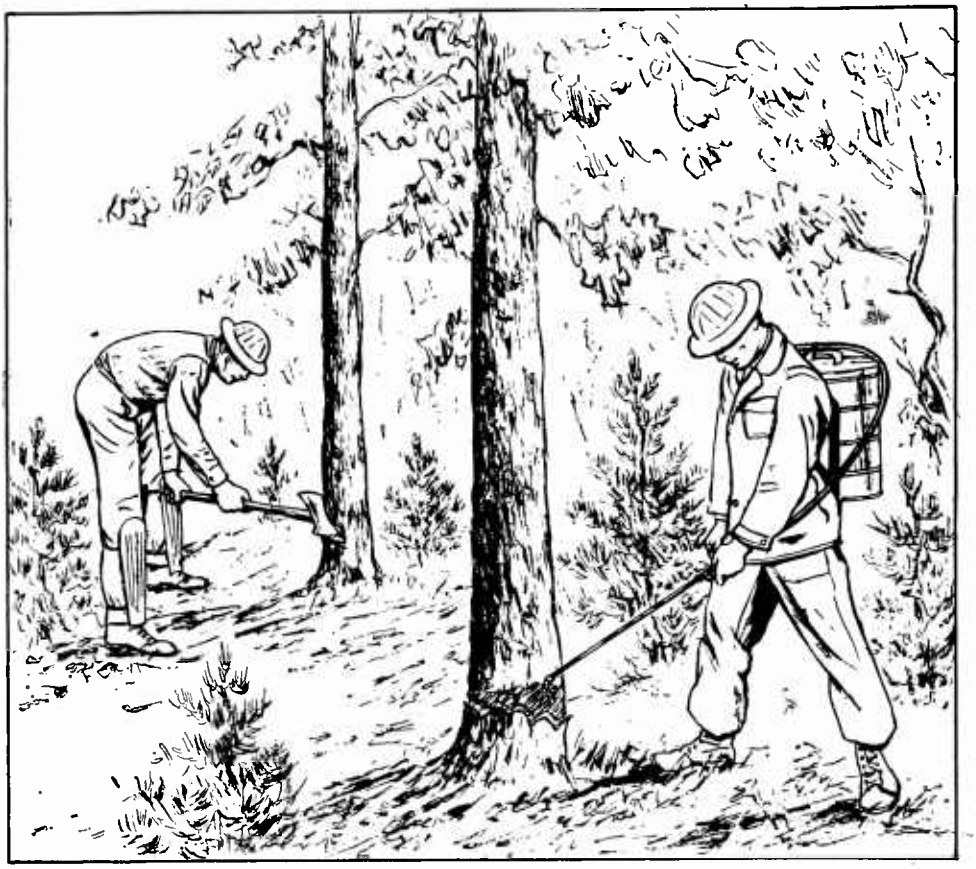

FIGURE 8.—Chemical frill girdling is used to control individual hardwoods for conifer release.

amine salt of 2,4-D and 2,4,5-T. This type of herbicide, applied in very small quantities (1 milliliter of a 50-percent water solution per 1 inch of diameter) to frill girdles, gives both effective top kill and reduced sprouting. One gallon will treat 4,000 inches of diameter or four to five times the coverage given by 2,4,5-T ester in oil. Since the volume of herbicide needed is so small, the amine form can be very useful in basal cut-bark treatments. The amine of 2,4,5-T is effective on most hardwoods. The amine of 2,4-D works equally well on oaks and aspen.

To keep sprouting to a minimum, chemical treatment of frills is most effective when the work is done close to the root collar and immediately after full leaf development, when root reserves are lowest. Unless the conifers being released are less than 3 or 4 feet in height, however, the greater sprouting which follows frilling done at a more convenient and safe working height or during the dormant season will be of little importance.

Cut Stumps

Competing tall brush and hardwoods too small to girdle should be cut right along with the girdling. Where only an occasional small sapling is cut, the stump can be

treated with the same concentration of 2,4,5-T recommended for the frill girdles—4 to 8 pounds AHG. If the cut trees are numerous, use 12 pounds AHG throughout the stand. Thoroughly spray cut stumps with 2,4,5-T and oil around the root collar or ground line to effectively reduce sprouting.

Tree Injectors

Tree injectors [12] may be used to make cuts through the bark into the sapwood around the base of the tree. The herbicide is injected into the tree through the cutting head (either automatically on some models or by a trigger release) before it is withdrawn. These tools apply the herbicide close to the root collar of the tree and are safer to use than an ax. The herbicide mixture generally recommended for tree injectors is 16 to 20 pounds AHG of 2,4,5-T ester in fuel oil. The amine salts of 2,4,5-T diluted with an equal part of water should also be effective for controlling hardwoods when applied by means of tree injectors.

Costs

Costs of high release by basal cut-bark treatments have been found to range as follows:

Labor for frilling and chemical treating—$4.50 to $6 per 1,000 inches of tree diameter treated (3 to 4 man-hours). A satisfactory work unit is a three-man crew, with two men cutting frills and the third man applying the herbicide.

Chemical for frill girdles—$0.25 to $0.50 per 1,000 diameter-inches treated with 8 pounds of 2,4,5-T AHG (2-percent solution by volume) in fuel oil or a 50-percent amine-water solution. For stronger solutions of 2,4,5-T, costs will increase proportionately.

Cut-stump treatment—can be expected to cost more than frill girdling, mainly because of the use of somewhat larger amounts of a slightly stronger solution of 2,4,5-T.

Tree injector—no cost data available but costs are likely to be comparable with chemical frill girdling costs.

Basal Bark Spraying

Basal sprays for high release have possibilities on small jobs and for controlling species that sprout abundantly, such as aspen, red maple, mountain maple, and speckled alder. Bark spraying is especially effective when done in the period just after full leaf development.

Apply basal sprays of fuel oil containing 12 pounds 2,4,5-T AHG so as to drench the bark to a height of 1 to 2 feet completely around the base of the tree (fig. 9). Apply

FIGURE 9.—Basal sprays are an effective method of controlling small brush and trees that are prolific sprouters.

[12] Current manufacturers and dealers include Reuel Little Tree Injection Co., Madill, Okla.; Forestry Suppliers, Jackson, Miss.; and Ben Meadows Co., Atlanta, Ga. Prices currently range from $13 to $53.

just enough spray to wet the bark thoroughly and cause runoff to appear around the root collar. Trees with thick, corky bark require heavier applications than smooth-barked ones such as aspen, beech, and red maple; paper birch, however, is difficult to kill with basal sprays. The larger the tree, the more volume of chemical herbicide needed to kill it.

Basal sprays can be applied with various types of hand-operated equipment. Especially satisfactory is a 3- to 5-gallon sprayer of the backpack type with a pump operated by a side handle and maintaining a low pressure (less than 15 pounds). A nozzle producing a fan-shaped spray is more efficient than one producing a cone-shaped spray.

A 4-gallon backpack sprayer can be emptied in 30 minutes on basal spray work and the delay time to refill it depends on the walking time to source of supply. One cost test in lower Michigan required 2 man-hours per 1,000 inches of diameter to basal spray oaks ranging from 1 to 12 inches d.b.h. This included time spent in refilling the sprayers (delay time) which for a three-man crew amounted to 25 percent of the total time.

The volume of herbicide solution used for basal sprays varies considerably with tree diameter; trees ranging from 1 to 4 inches in diameter will require only about 4 gallons of solution per 1,000 inches of diameter treated compared with about 12 gallons for trees ranging from 1 to 12 inches.

RELEASE OF CHRISTMAS TREE PLANTATIONS

The control of undesirable hardwoods and brush in Christmas tree plantations requires more care than that in plantations for timber production. A high degree of sprout control is needed, and only very slight damage to the conifers can be tolerated. Browned foliage and malformed branches on even a few conifers per acre caused by improper application of herbicides can be extremely costly in Christmas tree plantings.

The safest and most effective release method is to cut the undesirable brush and hardwoods and spray the freshly cut stumps with 2,4,5-T in oil. Use an ester of 2,4,5-T at 8 to 12 pounds AHG (2- to 3-percent solution by volume) in No. 2 fuel oil.

The second most effective method is basal sprays. Drench the bases of the trees to a height of 2 feet with an ester of 2,4,5-T in fuel oil at 12 pounds AHG. On prolifically sprouting species, such as aspen, cherry, and red maple, apply such sprays immediately after full leaf development.

To eliminate large trees, use the basal cut-bark methods described on pages 6 and 15. Since complete sprout control is desired, do this work immediately after full leaf development.

Foliage sprays, at the rates listed under Low Release, can also be used for brush control in Christmas tree plantings. They must, however, be applied late in the growing season and carefully directed so that only very light volumes fall on the conifers.

Backpack pump sprayers are useful for treating low brush or scattered dense patches of low brush. Power sprayers and mist blowers can also be used on dense brush, but their use in Christmas tree plantations is not generally advisable because they are likely to damage the trees.

The larger Christmas tree plantations, like plantations for other products, can be released by aerial

spraying. In fact, this method is favored because herbicide can be more easily applied uniformly by airplane than with ground equipment.

Complete control of all undesirable brush is seldom achieved by one application of foliage sprays. In dense brush one aerial spray treatment will seldom provide more than 90 percent release—especially from the tall brush and trees. The remaining release can be obtained the following year with ground treatments designed for complete control of the undesirable low brush.

PREPLANTING RELEASE

Preplanting release aims at prior control of brush and undesirable hardwoods to reduce the need for release of conifers after they are planted. It is also called planting-site preparation. Formerly this operation was performed only with heavy equipment such as disk plows which uprooted much of the brush and temporarily slowed its growth. Such mechanical treatment, however, is slow and costly and is restricted to firm, fairly even ground without much slope.

In the last few years, foliage spraying of brush in advance of planting has proved an effective and much cheaper substitute for mechanical preplanting release (fig. 10). Through the proper use of this method, the need of subsequent release of plantations on brushy sites can be greatly reduced and in some cases eliminated. Where brush regrowth overtakes the planted conifers, a good job of low release with herbicides should set the unwanted vegetation back so that the trees will be free to grow.

Areas scheduled for preplanting release usually have no conifers present to be injured by the herbicide. Spraying therefore can be done at the ideal time for the prevention of resprouting—immediately following full leaf development, normally after July 1 in the Lake States. In this active growth period, all vegetation is sensitive even to minute amounts of herbicide, so special care must be taken to prevent damage on adjacent areas.

Like foliage spraying for low release and for high release, the job can be done from the ground with hand or power equipment or from aircraft, applying 1 to 2 pounds per acre [13] acid equivalent of 2,4-D or 2,4,5-T, depending on the density and species of trees or brush to be controlled. Detailed prescriptions are given on pages 10 and 13.

The volume of mixture used will vary with the equipment used. Suggested are the following applications and carriers: [14]

Aircraft—2 to 4 gallons per acre of an oil-water emulsion.

Mist blowers—5 to 10 gallons per acre of an oil-water emulsion, depending on density and height of brush.

Backpack pumps—50 gallons per acre of water emulsion.

Power pumps—50 to 200 gallons per acre of water emulsion.

The benefits of prerelease spraying are exemplified by a plantation of red pine and white spruce planted during May 1955 on the Superior National Forest. The site, a 20-acre tract of rough land covered with dense hazel, upland alder, willow, and mountain maple, was sprayed from the air with 2 pounds of combined 2,4-D and 2,4,5-T in 4 gallons of oil-water emulsion per acre in late July 1954, the year before planting. Three growing sea-

[13] Large aspen may require as much as 3 pounds of 2,4-D per acre.

[14] Use oil solutions where oak or large aspen is to be sprayed from aircraft.

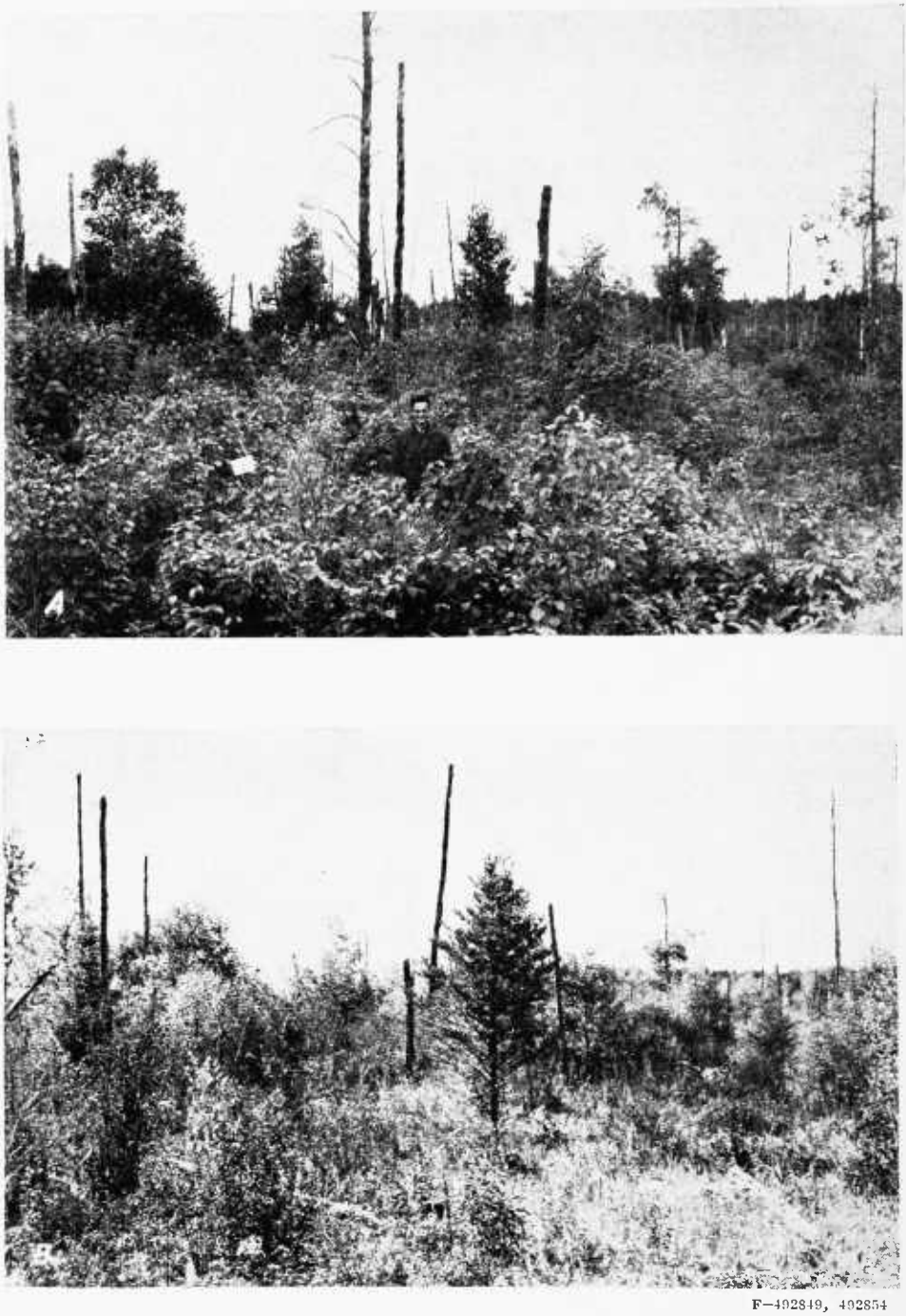

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Figure 10.—Chemical spraying lowers the cost of preplanting treatment. *A*, Dense brush of hazel, willow, and mountain maple on area otherwise suitable for planting. *B*, Same area 5 years after aerial spraying; note the good reduction of brush in foreground.

sons later, only 12 percent of the planted conifers in the sprayed area needed release, compared with 85 percent where the same species were planted on adjacent unsprayed land. Moreover, the trees on the sprayed area were making better growth. These results were obtained by site preparation which cost only $7.50 per acre, whereas $15 to $20 per acre would have been spent had the work been done by disking.

The possibilities of aerial spraying for the preparation of brushy land for planting, both on lowland and upland sites, are therefore promising, not only from the standpoint of cost reduction but also from that of making progress toward restocking the millions of acres of Lake States land now unproductive. Chemical methods other than foliage sprays can also be used, where applicable, for preplanting release. The section on Basal Cut-Bark Treatments gives details on these methods.

SAFETY MEASURES

Chemical release of conifers, except for the special accident hazards associated with aerial spraying, is a relatively safe operation. Both hand and power sprayers should be operated at pressures within safe limits. Hose clamps on hand sprayers are often flimsy and should be replaced by more substantial ones. The oils used to prepare herbicide solutions for cut-surface treatments and basal spraying may cause burns to the body of the operator. Leaky tanks, hose, or shutoff valves should therefore not be used. A tight-fitting gasket of neoprene rubber will prevent leakage from around the filler cap of backpack sprayers. Since the herbicides and oil carriers are toxic to the skin of some persons, gloves and goggles should be worn by crews mixing the spray materials. Manufacturers' recommendations of precautionary measures should be followed in all handling and mixing operations.

The usual precautions taken with handtools—use of hard hats, shinguards, safety shoes, sheaths for axes, etc.—should be taken on high-release operations employing basal cut-bark treatments.

Aerial release jobs, on the other hand, involve considerable hazard. If the balloons used for marking are inflated with hydrogen, which is readily flammable and dangerously explosive, great care must be taken to avoid igniting it. Absolutely no smoking is permissible within a radius of 100 feet while the balloons are being filled or within a distance of 50 feet from tanks of hydrogen at other times.

At least the minimum requirements of the Federal Aviation Agency concerning the safety of pilots should be followed. Other safeguards, such as plane-to-ground radios in the plane and at the base and, if possible, also at the scene of the spraying would be very desirable. The same is true of certain types of weather instruments, such as anemometers. When water-based planes are used, a boat and other lifesaving equipment should be available at the loading dock throughout the flying period of the job.

To avoid possible legal difficulties, all aerial release jobs should be done under a contract that clearly defines the responsibilities of the interested parties. Some States have laws regulating the use of herbicides. These should be thoroughly reviewed and applicable provisions of them made a part of the contract.

SPECIES SENSITIVE TO FOLIAGE SPRAYS

Species killed by both 2,4-D and 2,4,5-T [1]

Alder (*Alnus crispa, A. rugosa*)
Ash, black (*Fraxinus nigra*)
Aspens (*Populus grandidentata, P. tremuloides*)
Birch, paper (*Betula papyrifera*)
Cherry, black (*Prunus serotina*)
Cherry, pin (*P. pensylvanica*)
Chokecherry (*P. virginiana*)
Elm (*Ulmus* spp.)
Grape (*Vitis riparia*)
Hazel (*Corylus americana, C. cornuta*)
Locust, black (*Robinia pseudoacacia*)
Sumacs (*Rhus* spp.)
Willows (*Salix* spp.)

Species resistant to 2,4-D but not to 2,4,5-T

Blackberries (*Rubus* spp.)
Juneberries (*Amelanchier* spp.)
Maples (*Acer* spp.)
Oaks (*Quercus* spp.)
Prickly-ash (*Zanthoxylum americanum*)
Raspberries (*Rubus idaeus, R. occidentalis*)
Rose (*Rosa* spp.)

[1] Kill refers to death of foliage only; many woody plants will resprout at or near the ground line during the season following herbicidal spraying of foliage even though their tops are dead.

Only the two common herbicides are considered in this list. Of course it does not include all plant species in the region that are sensitive to these chemicals.

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