# CONTROL OF UNDESIRABLE TREES BY APPLICATION OF HERBICIDES DURING THE DORMANT SEASON

by

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# CONTROL OF UNDESIRABLE TREES BY APPLICATION OF HERBICIDES DURING THE DORMANT SEASON

## INTRODUCTION

### THE BRUSH PROBLEM

Throughout the entire nation undesirable woody plants retard the development of valuable forests, increase the cost of maintenance of highways, and rights-of-way for power and transmission lines, and reduce the value of millions of acres of pasture and range. In the Great Coastal Plain and Piedmont areas of the South, (3, p. 2) professional foresters say that a third to one-half of the forests are now producing at only a fraction of their potential, owing to the competition of brush and weed hardwoods, a situation which is steadily growing worse. In the Lake States, weed species such as alder, hazel and willow in pastures present a serious problem. In the Southwest, extensive areas of range lands have been over-run with woody plants which severely affect grazing in this area. In the Pacific Northwest, west of the foothills of the Cascades, and in particular along the coasts of Oregon and Washington where some of the most productive forest land in the country is located, undesirable species such as alder, salal, and vine maple have usurped thousands of acres of cutover land. In this area, if these weed species have as much as a three-year start over Douglas-fir reproduction it is almost impossible for the seedlings of the latter to survive the competition. Many burned-over tracts in Washington and Oregon are so densely covered with brush that planting would be a profitless venture unless the brush cover were first removed.

In brush competition studies on the Cascade Head Experimental Forest (9, p.12) where alder presents a problem, it has been shown that Douglas-fir seedlings do not long survive beneath the closed alder canopy. That the more valuable species has been eliminated in this case was shown by the fact that soils capable of producing up to 300 cubic feet per acre when well stocked with Douglas-fir, are now well stocked with alder and producing a mean annual increment of one-third this amount or less.

## OBJECTIVES OF STUDY

The purpose of this study was to determine the best methods of eliminating undesirable cover offering competition to the establishment of coniferous reproduction.

The first part of the thesis consists of a review of the literature concerning the most common methods of brush control. With the presentation of this background material, it is not difficult to understand why the chemical weed-killers or herbicides have proved cheaper, more effective, and less dangerous than former methods of control.

The second part of the thesis has attempted to compare, from data collected from field experiments, the efficacy of various herbicides and methods of application during the dormant season of the year.

Dormant treatment of undesirable trees has the following advantages:

1. The danger to valuable crops which are particularly susceptible to the herbicides of the 2.4-D type during the growing season is eliminated.

2. Labor is more easily obtained.

3. As a spray, herbicides can more easily penetrate thick clumps of brush where in summer the dense foliage would prevent a good kill.

4. Certain genera such as the ashes, maples, and hickories are resistant to foliage sprays during the summer but are susceptible to basal sprays while dormant.

PRESENT METHODS OF CONTROL

The principal methods which have been used to eradicate woody weeds are: burning, cutting, and the application of chemicals. Under certain conditions the use of any or all of these methods might be justified.

The problem is to decide where and how each method can be used to the greatest advantage.

Burning. Fire has been used successfully in the Southwest to eliminate sagebrush from grazing areas. In the South, it has been used to maintain Longleaf Pine against the competition of woody shrubs and to control the needle blight. In the Pacific Northwest, Isaac (5, p.56) believes burning influences the rate of development and distribution of woody plants and in general retards their growth. However, he contends that repeated fires, though they eliminate shrubby growth, may encourage herbaceous growth which in turn is in competition with conifer seedlings. In general, coniferous reproduction is more successful on the unburned ground than on ground which has been repeatedly burned.

Cutting. Where the use of fire is hazardous or otherwise unsuitable, the woody weeds have often been removed by cutting. Cutting is an expensive operation and does not give lasting control because of the subsequent sprouting from the stumps, but it often gives the regeneration of the desirable species sufficient advantage to form a closed canopy under which brush cannot survive for long.

Where small brush less than ten feet high is being eradicated, half-severing and bending the stems to the ground has been found to reduce sprouting to some extent.

Girdling. In older coniferous stands large hardwood wolf trees can be killed by girdling. This method is cheaper and less damaging to surrounding crop trees than is cutting. The girdling may consist of a series of overlapping axe cuts extending well into the sapwood of the tree and encircling the trunk. Ordinarily it takes about three years for a girdled tree to die.

Girdling by the Rasmussen Tool, an instrument consisting of a few links of the chain of a power saw alternately arranged, and equipped on either end with wooden handles, has proved very effective. Two encircling cuts are made with this tool, about two inches apart, through the cambium but not into the sapwood. This results in arresting the action of the phloem, thus cutting off the supply of manufactured food to the roots, while the food supply already in the roots is being depleted through the xylem. In this way a slower killing results but later sprouting from the bole is very much reduced.

One advantage of using the axe in girdling is that poison can be injected very easily into the overlapping axe cuts, where it is held until it is absorbed, thus hastening the killing of the trees. Poison is not so easily applied to the grooves formed by the Rasmussen Tool.

An important consideration in girdling or otherwise killing a large number of mature trees is the fire hazard created by the dead snags. This distinct disadvantage should be weighed carefully against the many advantages which accrue.

Chemicals. Along power line rights-of-way where high brush frequently causes outages, it is sometimes possible by cutting and by using a knowledge of ecology, to establish a ground cover of low brush, harmless in itself, which by competition will keep out the higher brush such as alder and maple. However, where high brush is already established, it may be necessary to cut it repeatedly, which is a very expensive control measure. In this case and wherever an area is to be permanently freed from woody weeds, cutting should be followed by treating the stumps with chemicals to prevent sprouting. An alternative is to use chemicals as foliage sprays, although several sprayings may be necessary.

On the whole, the use of chemicals is no more expensive and much more efficient than most other methods of brush control.

Equipment now used in applying chemicals includes:

pack-sack pumps, tank trucks, tractor-towed spray tanks, aeroplanes and helicopters.

More efficient and less costly chemicals are gradually being developed by the research workers. In this search for ideal chemicals to kill weeds the following questions should be answered, according to Melander (6, p.27).

a. Are they readily absorbed by the plant?
b. Are they selective from the standpoint desired?
c. Are they highly toxic so that small quantities will kill the plant?
d. Are they slowly toxic so that small quantities will not kill the plant tissues before penetration takes place through most of the tissues?
e. Are they harmless to man and animals?
f. Are they harmless to the soil?
g. Are these chemicals cheap and available in large quantities?
h. Can the chemicals be applied cheaply and with available equipment?
i. Is the availability of water supply going to be an important factor in their use?

Melander believes the perfecting of chemicals and the means of applying them should ultimately give complete control in a single treatment.

## HERBICIDES

1. General. Chemical weed-killers or herbicides which have been used in woody brush control are divided into two groups - selective and non-selective. Selective herbicides control specific undesirable plants without

damage to others. A selective herbicide functions by acting upon some specific characteristic of the weed, which is not common to its associates.

Non-selective herbicides kill by contact. Since killing doses for different plants may vary considerably, it is often possible to make a non-selective herbicide selective, by carefully adjusting the dosage.

The earlier herbicides were strong acids, bases, or salts. The acids and bases kill plants by their direct toxicity or by overcoming the buffering action of the protoplasm and altering the hydrogen ion concentration. The salts, such as sulfates of iron or copper, hydrolyze to produce active hydrogen ions which vary the pH of the cells of the plant enough to cause injury. The newer herbicides act like enzymes and hormones and easily penetrate the plant tissues.

2. Choice of Herbicides in Forestry. In deciding what herbicides to use, the following considerations are important:

a. Degree of control desired. Sometimes where complete eradication is desired, three or more sprayings may be necessary.

b. Terrain. In inaccessible areas it may be more economical to use pack-sack pumps rather than tank trucks; or aerial spraying may be more practical if a large area is to be covered.

c. Character of Cover. The height, density, and species of cover to be eradicated should be considered in selecting the chemicals, the dosages, the spray density and the equipment to be used.

d. The Season. Although twelve-month spray programs are planned for the future, summer foliage sprays appear to be the best for releasing young growth from an overstory of undesirable species. Coniferous species have shown more resistance to 2,4-D during the latter part of the growing season. Consequently, where conifers are to be protected and 2,4-D used, late July and August may be the best season for spraying.

e. The Cost. Since the cost of eradication must be added to the cost of the protected crop, it should be in proportion to the value of the crop. Good sites on north slopes can carry the cost of removal of a heavy brush cover; poor sites on south slopes may barely support the removal of a much lighter brush cover.

The cost of the herbicides is variable. When first developed, 2,4-D cost between $5.00 and $12.00 per pound. Later, when production increased, the cost dropped to the point where the expenditure for chemicals was less than the expense incurred in applying them. Considerations of initial cost has often delayed or prohibited the use of many herbicides when wider use together with their increased efficiency would have eventually lowered the cost.

3. Use of Herbicides in Forestry. Herbicides are used in Forestry in the following situations:

a. To eliminate brush cover before planting, direct seeding or establishment of natural reproduction.

b. To release young growth overtopped by inferior species.

c. To remove worthless trees from a stand of valuable trees.

d. To kill seed trees of undesirable species prior to logging.

4. Herbicides Used in Forestry. For general forestry improvement work those herbicides which have proved very effective are: sodium chlorate, sodium arsenite, ammonium sulfamate, 2,4-D and 2,4,5-T.

Sodium Chlorate. This is a contact poison when used in concentrations of around two per cent. In the South, it has been effectively used in preventing sprouting from stumps and girdled trees. Girdled trees treated with sodium chlorate usually succumb within two years.

As a foliage spray it is successful only if complete coverage is achieved. It will translocate to the roots and kill them. It can also be absorbed from the soil and so kill roots and tops of plants.

The chief disadvantage of sodium chlorate is its high inflammability. For this reason it should not be used in very hot weather. The Dupont Company has put on the market a preparation containing sodium chlorate which has proved less dangerous than former preparations and which has been used successfully to control poison ivy, sumac, and thornapple.

Sodium Arsenite. Probably the most

powerful of the contact herbicides is sodium arsenite. Oaks, elms, maples, black locusts, and ash are very susceptible to it, but persimmon, hickory, and cottonwood are less liable to be killed.

Sodium arsenite can be used to poison standing trees or stumps. Standing trees may be girdled and the poison injected in solution. In one experiment in the South (1, p.13) 95 per cent of a group of 222 oaks girdled and poisoned were killed within nine months.

Standing trees may also be notched. In notching, a series of pockets about 4 inches or 5 inches apart are cut close to the ground, around the trunk, by using a special axe-punch tool. This instrument is made with an oval opening 1 3/4 inches by 1/2 inches, with a cutting edge 1/2 inch shorter on one side. The device is welded to an axe head so the short side is uppermost. A single stroke removes a core about 1/2 inch in diameter and 1 inch long. These cavities are filled with poison solution. In one experiment in the South, this treatment destroyed 128 out of 175 scrub oaks to which it was applied.

On stumps, the poison may be applied by a brush, swab or sprayer. It is usually best to poison stumps as soon as possible after felling the tree. If the stump has sprouted before the poison is applied, the sprouts must be broken off and the freshly exposed tissues of the sprouts treated with poison.

This poison penetrates the plant by its hydrolyzing effect on the cuticle, after which it destroys the protoplasm. Because it is a deadly poison to man and animals, its use is very much restricted.

Ammonium Sulfamate. This has proved to be an efficient herbicide in the South where successful control of blackjack oak, sweet gum, black gum, elm, ash, cypress, bay, ironwood, and willow has been achieved by it. In the Douglas-fir region it has been used against alder brush.

The herbicide can be used as a spray or in crystal form. The application can be made during any season, but foliage sprays are best when used from late spring to early fall.

Girdling followed by poisoning is the most effective way of treating large trees. Small trees less than 3 inches in diameter at breast height should be cut and the stumps treated with the ammate crystals.

For girdling, two pounds of ammate per gallon of water should be used. For foliage spraying, one pound of ammate per gallon of water makes a sufficiently strong solution.

Ammate solutions kill plants by direct

contact. They are non-poisonous to man and animals but very corrosive to metals. When applied to plants, they may translocate into the crown or roots, or they may be absorbed from the soil and destroy the plants.

## The 2,4-D Compounds

1. General Remarks. Of all the herbicides used in Forestry, 2,4-D and its derivatives hold the greatest promise because they offer selective action and excellent control at very low cost. One serious drawback is the damage which sometimes occurs to farm crops in the vicinity of the treated areas, by drifting spray or dust. However, this danger can be lessened by using those 2,4-D compounds which are least dangerous to specific crops.

2. Different Forms of 2,4-D. Many different forms of 2,4-D are used as herbicides, including the acid itself, and the esters, amines, and sodium salts derived from the acids. These are available in liquid or dust form. The acid is one of the most active forms. Applied at the rate of 1 1/2 pounds of acid to 80 gallons of water per acre, it successfully controls hazel, willow, and alder.

Water soluble forms of 2,4-D are the sodium salt and the amine salt. The sodium salt is not very soluble and tends to clog sprayers, but at the rate of 4.1 pounds of salt to 100 gallons of water per acre it has proved 95 per cent effective against alder in the Northwest. The amine salts are very soluble in water. They are low in cost, can be used with hard water, and are less dangerous to crops than are esters. However, they are not so effective against woody plants as the esters, because the water in which the amine is suspended does not penetrate into the plant so well.

The high volatility of the esters which were first developed, made them dangerous to surrounding crops. This fault has been overcome in the newer esters which have no dangerous volatility and are not hazardous to formerly susceptible crops such as cotton, tomatoes and beans.

The oil soluble forms of 2,4-D are ideal for brush control, stump killing and mesquite control. Frequently used preparations are:

a. Esters, at the rate of 3/4 pound of the acid in 3 gallons of oil per acre or 3/4 pound of the acid in 4 gallons of water and 1 gallon of miscible oil per acre.

b. Amines, at the rate of 1 pound of the acid in 1 gallon of oil and 4 gallons of water per acre.

c. Sodium salts, at the rate of 1 pound of the salt per acre in 1 gallon of oil and 4 gallons of water.

Commercial spray preparations such as Weedone, containing the ethyl ester of 2,4-D; Dow A510, containing the sodium salt of 2,4-D; and Esteron, containing the iso-propyl ester of 2,4-D are very effective against alder and willow, although the sodium salt is less effective than the esters.

3. Methods of Applying Sprays. There are four principal methods of using 2,4-D as a spray:

a. As an over-all spray, high volume, using water as a carrier.

b. As an over-all spray, low volume, using oil as a carrier.

c. Treatment of cut stumps.

d. Basal treatment with water or oil as a carrier.

High volume sprays with water as the carrier are best for many jobs. When coarse sprays are used, the herbicide is concentrated in a few drops on each leaf, and much of the leaf continues to function while the poison, due to the high surface tension of the water, passes slowly into the translocation system. Where leaves are killed at once, the herbicide may not penetrate enough of the plant to insure a complete killing. Thus small doses of more slowly toxic sodium salts in water may have a greater killing power than the more rapid acting esters in oil as a carrier, principally because the translocation is more complete, and the killing effect is extended into the root system.

For quick contact killing, fine sprays with low surface tension are most effective. Esters in oil have low surface tensions and consequently penetrate the cuticle of plants rapidly and are very effective as fine sprays.

During the dormant season, or any season for that matter, spraying cut stumps with 2,4-D in oil has prevented sprouting from the stumps. Care should be taken in this treatment to cover all sides of the stump uniformly to the ground level.

Spraying the bases of trees up to a height of 18 inches, using 2,4-D in either oil or water as a carrier, has been very successful and is particularly effective during the dormant season.

4. Effects of 2,4-D. Crafts and Harvey (2, p.39) mention three outstanding effects this herbicide has upon plants. First, it causes a twisting and bending of stems and leaves due to differential growth rates in petioles, pulvini and elongating regions of the stem. The second effect is the cessation of growth from meristems. The third effect is the death of the cells which is accompanied by color changes.

At high concentrations, 2,4-D may kill any vegetation. At low concentrations, it will kill many plants of low tolerance. Susceptible species are destroyed at concentrations as low as 500 parts per million.

Temperature and soil moisture play an important part in the reaction of 2,4-D. High temperatures and drought conditions on sandy soils greatly increase the effectiveness of 2,4-D in killing weed trees.

In small quantities 2,4-D produces a mild stimulation of growth. This and the fact that it may be leached from the soil reduces the danger of its accumulating in toxic quantities in the soil.

5. 2,4,5-T. (2,4,5-Trichlorophenoxyacetic Acid). This herbicide is similar to 2,4-D but is more expensive to produce and consequently has not been used so extensively. It is effective against woody plants which are resistant to 2,4-D, among which are red maple, wild rose, wild blackberry, and wild raspberry. It is less active than 2,4-D against buckbrush, sumac, black locust and sagebrush. In general, 2,4,5-T is reported to act more consistently and to be less subject to influence of weather than is 2,4-D.

The amines and esters of 2,4,5-T are good weed eradicators. The amines are best when used as foliage sprays where rapid translocation is desired or where the risk of volatile fumes killing desirable growth exists. The esters are best for dormant applications where the chemical must penetrate bark.

6. M.C.P.A. (Methylchlorophenoxyacetic Acid). This is a growth regulating hormone like 2,4-D. It tends to be more water-soluble than 2,4-D but its esters strongly resemble the esters of 2,4-D. M.C.P.A. is more effective on many plants, especially Canada thistle, than is 2,4-D. Mixtures of M.C.P.A. and 2,4,5-T are very effective in controlling blackberry and other brushy plants.

CONTROL MEASURES USED IN OREGON

Some interesting experiments in stand improvement measures were carried out by the Forest Service on the Siuslaw National Forest in an attempt to find the best and cheapest way to eliminate the red alder which was retarding the regeneration of Douglas-fir, Port Orford White Cedar and Sitka Spruce.

In partially stocked stands it was found practical to fell small alder and girdle the large ones. The Rasmussen Tool already mentioned was used in girdling and proved more effective than the axe. In some areas spraying with a tank truck was tried, but this proved too costly owing to the terrain.

On the whole, aeroplane spraying was found to be the cheapest and most practical of all methods of control. The 2,4-D ester was used at the rate of 1 gallon of ester to 8 gallons of diesel oil and was very effective, but owing to the high concentration used, the herbicide scorched the tips of exposed conifers. The 2,4-D dust at 20 pounds per acre was also used. It did not scorch the conifers and was almost as effective as the ester. However, it drifted 1 1/2 miles and could have damaged the crops of adjacent farms.

The results in release of conifers were good. Douglas-fir seedlings grew twice as rapidly after release from the alder. Sitka Spruce showed a 50 per cent increase in height growth. However, Port Orford White Cedar showed little response. Further results of the trials were as follows:

a. The sodium salt of 2,4-D at the rate of 4.1 pounds of salt to 100 gallons of water was 95 per cent effective.

b. Liquid salt amine containing 40 per cent acid equivalent was used at the rate of 3 quarts of the amine to 100 gallons of water per acre and gave a top killing only.

c. The ester dust of 2,4-D containing 5 per cent acid equivalent was used at the rate of 10 pounds per acre and gave a top killing only.

d. The ester of 2,4-D containing 3.34 pounds of acid equivalent per gallon, was used at the rate of 3 1/2 quarts to 100 gallons of water per acre and was 95 per cent effective on trees below 5 inches in diameter at breast height.

e. The sodium salt of 2,4-D containing 60 per cent acid was used at the rate of 4.8 pounds of salt and 1/3 pint of spreader sticker per 100 gallons of water per acre and was 80 per cent effective.

The best solution tried in the experiments was the sodium salt, but almost equal results were obtained with the ester of 2,4-D.

An analysis of the cost of some of the methods outlined above is as follows:

a. Slashing and girdling cost $7.50 per acre where the alder was scattered and $15.50 per acre where the alder was dense.

b. Spraying from tank truck along the road cost $22.40 per acre.

c. Aerial spraying of 18 acres using 3.34 pounds of acid equivalent per gallon mixed with 8 gallons of diesel oil cost $6.00 per acre.

d. Aerial dusting on 50 acres using 20 pounds of 2 pound acid equivalent dust, cost $4.50 per acre.

e. Aerial dusting on 33 acres using 30 pounds of 3 pound acid equivalent dust, cost $6.00 per acre.

CONTROL MEASURES USED IN THE SOUTH

In experiments carried out at the Southern Forest Experiment Station (10,pp.1-4) in May, 1950, eight formulations of 2,4-D and 2,4,5-T (using 4 per cent acid equivalent in diesel oil) were used on blackjack oak from 2 inches to 10 inches diameter at breast height.

The most outstanding results recorded by September, 1950 were:

a. Isopropyl ester was used in notches made by two axe cuts close to the ground. Notches were spaced about 6 inches apart around the bole. Of the notched trees, 92 per cent of the crowns were killed without sprouting.

b. The amine salt of 2,4-D and the isopropyl ester of 2,4-D when used in frills gave 100 per cent crown kill with no subsequent sprouting. However, these were more expensive to use than a 19.3 per cent ammonium sulfamate solution which gave 85 per cent crown kill with some subsequent sprouting.

c. Ammate, butyl ether ester of 2,4-D, and a mixture equal parts of butoxy esters of 2,4-D and 2,4,5-T all gave complete control of stump sprouting.

d. The Cornell Tool[1] was used to make injections 4 inches apart around the trees. Butyl ether ester of 2,4-D or 2,4,5-T was used and killed all trees so treated without subsequent

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[1] The Cornell Tool was developed by Cope and Spaeth, professors at Cornell University, New York. The instrument is about 3 feet long and has a cutting edge at one end. At each blow of the tool a valve opens with a water-hammer effect and a small quantity of poison stored in the body of the instrument enters the cut.

sprouting. Isopropyl ester of 2,4-D when similarly injected gave a 95 per cent crown kill with no sprouting. The cost was estimated at 1.5 cents per tree of 5 inches diameter breast height.

e. Where the lower 18 inches of the trunk were barely saturated with a spray of butyl ether ester, 96 per cent to 100 per cent of the crowns of the trees treated were killed with no subsequent basal sprouting. The cost was 3 cents per tree of 5 inches diameter at breast height.

f. In general isopropyl ester of 2,4-D gave the most effective results.

# EXPERIMENTAL TRIALS ON LOCAL WEED SPECIES

## INTRODUCTION

Much knowledge has been accumulated during recent years about the effectiveness of herbicides in controlling the weeds competitive with agricultural crops. Relatively little is known about their effectiveness in controlling undesirable competitors for space in forest stands, especially so with respect to local conditions. Problems of this nature are frequently of great concern to forest managers throughout the Douglas-fir region, and are encountered by the School of Forestry in management of the McDonald Forest. In the latter instance brushy hardwood shrubs, and weed trees such as bigleaf maple, scrub oak and alder, sometimes become established to such an extent as to almost exclude desirable coniferous species.

The second part of this thesis is therefore an attempt to explain the effectiveness of a few of the more promising herbicides in killing the standing plant, and in preventing the sprouting of cut-stumps on the McDonald Forest. Since the term of residence of the writer was restricted to the fall, winter and spring quarters it was necessary to confine the experiments to dormant season treatments. Five experiments were established in the vicinity of Oak Creek on the McDonald Forest, between November 23, 1950 and March 31, 1951. Results of the treatments were evaluated in early July of 1951.

The herbicides chosen for trial, together with their formulation and methods of application were as follows:

1. Ammonium sulfamate was used in the crystal state on the stumps of chopped and sawed trees and in water solution on girdled trees.

2. Two, four, dichlorophenoxyacetic acid (2,4-D) and 2,4,5 trichlorophenoxyacetic acid (2,4,5-T) were used in combination in different formulations as an emulsion in diesel oil and as an emulsion in water on the stumps of cut and sawed trees and on the base of trees.

3. Two, four, five trichlorophenoxyacetic acid and methylchlorophenoxyacetic acid (M.C.P.A.) were used in combination in the same way as the combination of 2,4-D and 2,4,5-T.

The objectives of the experiments were to determine the relative effectiveness of the chosen herbicides with respect to:

1. Date of treatment

2. Methods of application

3. Strength of formulation

4. Carrier of formulation (oil versus water)

5. Species of weed plants

It must be emphasized that the experiments conducted were merely of an exploratory nature intended to expose the most promising leads for more detailed experiments in the future. Very little information was available on efficient designs for the experiments or on the sizes necessary to provide comparisons of statistical significance. It seemed, however, that arrangements suitable for chi-square, (8, pp.188-213) analysis might be most appropriate. The following experiments were set up therefore on this basis:

Equipment. A Hudson sprayer of the type that can be carried from a shoulder-strap was used in applying the spray formulation. It had a capacity of 3 1/4 gallons and was provided with a rubber hose 18 inches long with a shut-off valve which could be locked open. A spray nozzle 24 inches in length was attached. Pressure was maintained by a piston pump. The medium spray adjustment with which the nozzle was fitted gave an even coverage as long as pressure was maintained in the tank, and was used for all spraying.

A pulpwood bow-saw was used at first in the sawing operations but was replaced later by a power saw which proved much more efficient.

EXPERIMENT NO. 1

The purpose of this experiment was to test the relative effectiveness of different concentrations of the 1:1 combination of 2,4-D and 2,4,5-T, and of 2,4,5-T and M.C.P.A. with diesel oil as the carrier; in controlling sprouting from cut-stumps of bigleaf maple.

The area chosen for the experiment was a rough south slope, which had been logged some twenty years ago, and is now over-run with broadleaved trees and shrubs. Twenty-one plots of seven trees each were established, and the six treatments tabulated below were then assigned at random to the trees of a plot, one tree of a plot was left untreated to serve as a control. All the trees were then felled by axe, leaving a stump about one foot in height, and the stumps were treated according to plan between February 8 and 23, 1951. The formulations used are summarized below, one gallon of diesel oil being the carrier for each.

| Herbicides | Amount | Proportion | Designation |
|---|---|---|---|
| 2,4-D ... 2,4,5-T | 80 c.c. | 5,000 | 2A |
| " " | 160 c.c. | 10,000 | 2B |
| " " | 240 c.c. | 15,000 | 2C |
| 2,4,5-T... M.C.P.A. | 80 c.c. | 5,000 | 3A |
| " " | 160 c.c. | 10,000 | 3B |
| " " | 240 c.c. | 15,000 | 3C |

Results. Final observations of the effects of the treatments were made on June 23. A record being made as to whether each stump had sprouted, or had not sprouted, the results are summarized below:

| Observed Attribute | Treatments 2A, | 2B, | 2C, | 3A, | 3B, | 3C | Control | Totals |
|---|---|---|---|---|---|---|---|---|
| | | | | Number | | | | |
| Sprouts present | 17 | 11 | 12 | 16 | 14 | 8 | 21 | 99 |
| Sprouts absent | 4 | 10 | 9 | 5 | 7 | 13 | 0 | 48 |
| Totals | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 147 |

A chi-square analysis of the data indicates that real differences exist among the treatments at the one per cent level of significance, the observed chi-square is 19.05, while the tabular value is 16.81 at the one per cent level for 6 degrees of freedom.

In order to determine if either one of the mixtures was superior to the other in controlling sprouts, the data were re-summarized by character of mixture, as follows:

| Observed Attribute | Treatments 2A, 2B, & 2C | 3A, 3B, & 3C | Totals |
|---|---|---|---|
| | Number | | |
| Sprouts present | 40 | 38 | 78 |
| Sprouts absent | 23 | 25 | 48 |
| Totals | 63 | 63 | 126 |

A chi-square test applied to these data is not significant at the five per cent level, indicating that the data are insufficient to show that one mixture is superior to another.

Summarizing the data over both mixtures according to degree of concentration yields the results hereunder:

| Observed Attribute | Concentration 2A & 3A | 2B & 3B | 2C & 3C | Totals |
|---|---|---|---|---|
| | | Number | | |
| Sprouts present | 33 | 25 | 20 | 78 |
| Sprouts absent | 9 | 17 | 22 | 48 |
| Totals | 42 | 42 | 42 | 126 |

The observed chi-square for these data is 9.03 which exceeds the tabular value of 7.81 for 3 degrees of freedom at the 5 per cent level. This indicates that there are significant differences in effectiveness among the various concentrations used. Since in general the higher the concentration the better the control, it may be concluded that the evidence is strong enough to support the conclusion.

EXPERIMENT NO. 2

The purpose of this experiment was to determine the relative effectiveness of the (2,4-D + 2,4,5-T) combination and the (2,4,5-T + M.C.P.A.) combination in controlling the sprouting of red alder stumps during the dormant season.

The 2,4-D and 2,4,5-T were used in a 1:1 combination as an emulsion consisting of 47.4 c.c. of the mixture in 1 gallon of diesel oil. The second combination of 2,4,5-T and M.C.P.A. was also a 1:1 mixture as an emulsion of 63.2 c.c. in 1 gallon of diesel oil. Hereafter these two formulations shall be designated as treatments 2 and 3, respectively.

Seventy-two trees were selected for the study on a low boggy area along Oak Creek. The trees were felled over a period from January 13 to February 6, and the treatments were applied at random upon felling the tree. Twenty-four stumps were thus treated with each prescription and a like number remained untreated to serve as control.

Results. The final examination was conducted by the writer on July 4, 1951, a record being made as to whether a stump did or did not sprout. The data for the individual trees are summarized below:

| Condition of Stump | Treatments 2 | 3 | Control |
| --- | --- | --- | --- |
| | Number | | |
| Sprouts present | 2 | 2 | 22 |
| Sprouts absent | 22 | 22 | 2 |
| Totals | 24 | 24 | 24 |

Since both chemical treatments had the same percentage (8.3 per cent) of unsuccessful treatments, no conclusions as to their relative merits could be drawn. However, since only 8.3 per cent of the control stumps failed to sprout and 91.7 per cent of the treated stumps failed to sprout, the effectiveness of both chemical combinations in controlling sprouting when applied during the dormant season was outstanding.

If treatments number 2 and 3 are combined and these compared with the controls, a chi-square test indicates that the treatments as a whole are significantly effective at the one per cent level. The observed chi-square of 145.45 is greatly in excess of the tabular value 6.635 at the one per cent level for one degree of freedom.

EXPERIMENT NO. 3

As described in the introductory part of the thesis, one of the promising methods of using ammonium sulfamate during the dormant season is by depositing the chemical in frills encircling the standing tree. The 2,4-D + 2,4,5-T and the 2,4,5-T + M.C.P.A. treatments, already defined in Experiment 2, as treatments 2 and 3 are also recommended for use in the dormant season as basal sprays. The purpose of this experiment was to compare the effectiveness of such treatments during the dormant season.

The frilling applications consisted of making a series of overlapping axe cuts around the trunk of each selected tree, about three feet above the ground. A solution consisting of two pounds of the ammonium sulfamate (ammate) in one gallon of water was injected into the axe cuts by means of an oil-can. The basal treatments 2 and 3 were sprayed on the lower 18 inches of the trunks of the selected trees by use of the Hudson sprayer.

The three separate treatments described above were each applied to 15 alder trees selected at random from the total number of 75 trees required in the experiment. Fifteen of them were left untreated to serve as control for the basal spray applications, and another 15 trees were frilled, but the ammate was not deposited. The latter served as control for the ammate treatment.

A similar experiment was also established covering five trees each of bigleaf maple.

The experiment was established between November 23 and February 6.

Results. Since final appraisal of the killing effects of the herbicides could not be made for at least a year after treatment, the records taken on July 4 were based upon ocular observations of the effect of the treatments on the crown and foliage. At the date of examination the foliage of many of the trees was affected in a variety of ways including yellowing in color, subnormal density, curling of the leaves, and twisting of the leaf petioles. Upon examination each tree was given a rating of "great", "little" or "none" depending upon the relative extent of the effect. From these data the summary below was prepared for the alder, where B-2 and B-3 represent the basal sprays; F-1 and F-C the frilling with and without ammate, respectively; and C, control involving no treatment whatsoever.

| Observed Rating | B-2 | B-3 | C | F-1 | F-C | Total |
|---|---|---|---|---|---|---|
| | Treatments | | | | | |
| | Number | | | | | |
| Great | 0 | 2 | 0 | 3 | 2 | 7 |
| Little | 2 | 3 | 0 | 6 | 4 | 15 |
| None | 13 | 10 | 15 | 6 | 9 | 53 |
| Totals | 15 | 15 | 15 | 15 | 15 | 75 |

The character of the data is suitable for the application of chi-square tests, but in the present form the data are insufficient for such an analysis. By consolidating some of the categories however, tests of a more general nature may be made. The "great" and "little" designations may be combined into one group, and since the data are insufficient for a comparison of the basal treatments 2 and 3 these may be combined also into a single group. On doing this the table hereunder is obtained.

| Observed Rating | B-2 & B-3 | B-C | F-1 | F-C | Total |
|---|---|---|---|---|---|
| | Treatments | | | | |
| | Number | | | | |
| Affected | 7 | 0 | 9 | 6 | 22 |
| Not Affected | 23 | 15 | 6 | 9 | 53 |
| Totals | 30 | 15 | 15 | 15 | 75 |

Even after this consolidation there are still insufficient basal control trees to permit a test of the basal sprays with respect to control. There are sufficient data to compare the ammate frill with the control frill. This test proved to be not significant at the five per cent level of probability, indicating that the evidence has not demonstrated that the addition of the ammate to the frill is definitely superior to the frill alone in affecting the foliage of the trees.

If the two frilling treatments are now combined into one group, and compared with the combined basal treatments, the observed value of chi-square 4.57 exceeds the tabular value of 3.84 at the five per cent level for 1 degree of freedom. This indicates that the frilling treatments are superior to the basal sprays at the given level of significance.

For bigleaf maple the following table was compiled:

| Observed Rating | Treatments B-2 | B-3 | C | F-1 | F-C | Total |
|---|---|---|---|---|---|---|
| | Number | | | | | |
| Great | 2 | 4 | 0 | 2 | 0 | 8 |
| Little | 1 | 1 | 0 | 2 | 2 | 6 |
| None | 2 | 0 | 5 | 1 | 3 | 11 |
| Totals | 5 | 5 | 5 | 5 | 5 | 25 |

These data are inadequate for any statistical tests of significance. There is some indication however that the several treatments have had some effect. The character of the foliage of the treated maples, especially after the basal sprays, was modified remarkably. The leaves were curled, crisp and slightly yellowed, while the leaf petiole and midrib carried numerous lengthwise splits.

EXPERIMENT NO. 4

The purpose of this experiment was to test various formulations of the 2,4-D and 2,4,5-T combination and the 2,4,5-T and M.C.P.A. combination using oil as a carrier and using water as a carrier in basal treatments of standing trees.

The study area chosen was a low hillside covered with a dense growth of Oregon white oak. Twenty-seven plots were required. The trees on each plot were separated by at least 10 feet, while a minimum distance of twenty feet was maintained between plots. On each plot the trees were first numbered and the treatment each was to receive determined by chance. All treatments were basal in which the lower eighteen inches of the bole of the standing tree was sprayed. Only Oregon white oaks were treated. The treatments were carried out between February 28 and March

11 of 1951. Final appraisal of the results was made on July 4, 1951.

The choice of Oregon White Oak as the species to be treated was most unfortunate insofar as completion of the study was concerned. Rarely was this hardy species affected by the basal treatments. Trees in heavy shade, that is, in dense clumps, were not affected at all. A few trees which were exposed to full sunlight were affected in direct proportion to their exposure to sunlight. Two reasons are suggested for this. First, the drier ground beneath these trees insures more rapid penetration of the herbicides. Secondly, the sunlight stimulates growth which hastens the action of the herbicides. The usual evidence of the activity of 2,4-D compounds such as curled leaves and twisted twigs was present to some extent in all treated trees fully exposed to the sun, but none of the trees was killed at date of final examination.

EXPERIMENT NO. 5

Experiment number five was established to determine the effect of ammate crystals, the 2,4-D + 2,4,5-T combination in controlling the sprouting of chopped and sawed stumps of Oregon white oak. Early in the season it appeared that the treatments were having some effect in controlling the sprouts but later examinations disclosed profuse sprouting from that part of the stump or roots beneath the surface of the soil. Since the writer was not able to follow further developments after July 4, it seems inadvisable to report further on this experiment.

SUMMARY OF EXPERIMENTAL TRIALS

From the foregoing experiments it is evident that dormant season applications of herbicides show some promise in controlling some of the local inferior hardwood tree species. Results of the experiments are summarized briefly below:

Experiment No. 1

A. There seems to be little difference between treatments 2 and 3, consisting of the 1:1 combination of 2,4-D and 2,4,5-T, and of 2,4,5-T and M.C.P.A., with diesel oil as the carrier, in controlling sprouting from cut stumps of bigleaf maple.

B. Significant differences were shown to exist among the trial concentrations of treatments 2 and 3 which were of 80, 160 and 240 c.c. of the 1:1 combination in one gallon of diesel oil. The stronger the concentration, the more effective was the treatment within the range employed in controlling sprouting from cut-stumps of bigleaf maple.

Experiment No. 2

A. Again, when applied to red alder stumps, no difference was apparent between treatments 2 and 3 in their control of sprouting, but both were very effective when compared with the untreated control stumps.

Experiment No. 3

A. Frilling of red alder and introduction of ammonium sulfamate in water did not prove to be significantly superior to frilling alone in its effect on the crown and foliage of the trees up to July 4, 1951.

B. The two frilling treatments combined had greater effect on the crowns and foliage of the trees than basal sprays of treatments 2 and 3, up to July 4, 1951.

C. Applications of the same treatments to a small number of bigleaf maple, were inadequate to yield any significant results, except that the foliage of the trees receiving the basal sprays were affected remarkably, in twisting and curling of the leaves, and lengthwise splitting of the leaf petiole and midrib.

Experiment No. 4

A. This test to determine the difference between diesel oil and water as the carrier for the treatment 2 and 3 combinations was applied to Oregon white oak in the form of basal sprays. The oak was rarely affected by the treatments and hence the main purpose of the experiment was defeated.

Experiment No. 5

A. The treatment 2 and 3 combinations and ammonium sulfamate crystals were applied to chopped and sawed stumps. Early observations indicated some control, but later observations revealed delayed sprouting from the stump and roots beneath the surface of the soil.

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