STUDIES ON THE CONTROL OF *PTERIDIUM AQUILINUM* (L.) KUHN, VAR. *LATIUSCULUM* (DESV.) UNDERW.

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Richard Yeo

1952

This is to certify that the

thesis entitled

Studies on the Control of Pteridium
Aquilinum (L.) Kuhn, Var. Latiusculum (Desv.)
Underw.

presented by

Richard R. Yeo

has been accepted towards fulfillment
of the requirements for

M.S. degree in Botany

B. H. Grigsby
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Date Sept. 30, 1952

STUDIES ON THE CONTROL OF *PTERIDIUM AQUILINUM* (L.) KUHN, VAR. *LATIUSCULUM* (DESV.) UNDERW.

By

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A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Botany and Plant Pathology

1952

THESIS

1/8/52
3

TABLE OF CONTENTS

I. INTRODUCTION

The bracken fern, *Pteridium aquilinum* (L.) Kuhn, Var. *latiusculum* (Desv.) Underw., is a well-known pest to the farmer and the forester. It is found in open woods, thickets, burns and clearings, extending from northeastern United States throughout the middle-west and southwestward to northeastern Mexico. Wherever found, the bracken fern has generally become not only a nuisance but a competitive plant in pasture or rangeland, wildlife habitats and cottage sites, and means of eradicating it have long been desired. This study was undertaken with the hope that the information obtained will be an aid in the control of bracken fern.

II. REVIEW OF LITERATURE

The life cycle of the bracken fern makes it extremely difficult to eradicate. A germinating spore forms a small gametophyte which, on its underside, gives rise to numerous archegonia and autherozoids, one of which upon swimming to an archegonium, unites with the egg cell and forms a zygote. The zygote develops into a young sporophyte with a primary leaf, primary root, stem, and foot. Eventually it becomes a large, spore-producing organism. Braid (5) states that a single plant can grow to a clump more than one yard in diameter in a single year. The chief manner of distribution over a region is by wind blown spores and rhizome growth is responsible for the spread of local infestations.

Each year many of the plants in each locality produce spores. In some patches practically all the fronds produce spores while adjacent patches of fronds are barren. The barren fronds remain green late into automn, while the fertile ones turn brown early. In autumn, the fertile and barren bracken can thus be recognized from a distance. Spores are produced in great quantities, but the young bracken sporelings seldom are seen.

In an investigation of the life-history of bracken in Scotland, it was found that the viability of spores varies considerably from year to year (4). While the spores germinate throughout the year, the maximum crop appears in February and March. The two hazards of the sporelings are desiccation, by the drying winds of March, and late frosts. Thus the rapid increase of bracken for any period of time is thought to be due to seasons suitable for the development of bracken sporelings.

In vegetative multiplication the continuous rhizome system is broken up by the decay of older parts, hence, new plants arise from the detached groups of branches. The rapid spread by vegetative means is a function of the number of bracken patches and not of their size (4).

The rhizome system is best described as having three tiers (3). The lower, or leader, usually runs at a depth of 10 to 20 inches and is the main invading stem. It possesses the thickest branches, ending in a terminal fingerlike bud which periodically produces side buds. The side buds develop into branches which bend upward and, if they are within nine inches or less of the surface, often bear fronds. Side-buds also produce subsidiary buds which grow into shorter and thinner branches, often characteristically zigzagged and densely covered with many fine roots. These branches develop nearer the surface and frequently produce groups of fronds. In a friable soil of good fertility, the lower and middle tiers are produced abundantly, while if conditions are such as to check these the upper tier develops most. The lower and middle tiers are most abundant about the periphery of an area, and the upper tier in the center. In all cases the terminal bud of each tier is the most actively growing bud. By dichotomous division, the terminal cell gives rise to lateral buds which produce either rhizome branches or fronds. The buds may also lie dormant for some years. The fronds of each season normally arise from the side buds immediately behind the terminal buds of the upper and middle tiers, but sometimes subsidiary buds may also develop at the frond bases. The end of a frond-bearing branch in late autumn, will show the growing point with its lateral bud, farther back a well-formed frond-bud one-half to three inches high and, adjacent to the point where the lateral branch joins the main rhizome, a small dormant, scale-like bud at the base of an old stipe. If a frond is destroyed in the green stage, the bud destined for the next season's frond begins to develop.

In control measures to date the chief mode of attack has been to remove the fronds, as not only does this reduce the production of food, but the underground reserves are depleted in the development of fresh fronds. It has been shown by chemical analyses (15) that the amount of food reserve, expressed as soluble carbohydrates and nitrogen, diminishes rapidly from April and reaches a minimum in July, after which there is an increase.

Many methods have been proposed for removal of the fronds, most of which merely reduce the number of ensuing fronds over a long period of time and do not eliminate the plant entirely. Among the methods that have been suggested are plowing, cutting, burning, and grazing by livestock.

On tillable land, deep plowing is a most effective means of ridding an area of bracken. As the bracken rhizomes often lie at a depth of at least 20 inches, a heavy digger type of plow must be used. If a well-drained area, heavily infested with bracken, is plowed during the dry summer months the amount of bracken is so reduced as to become negligible and, if planted to a row crop such as potatoes, the fern is practically all killed during the second season (10).

An experiment conducted in Scotland (15) resulted in the conclusion that three years' cutting uncovered the grass and allowed the grazing of stock to take place. The cuttings did not entirely remove the bracken, so that when left undisturbed it eventually re-established itself. The number of cuttings made per year seemed to make little difference in the following year's emergence.

In the experiment just described, the rhizomes were examined and some interesting effects were noted. The rhizomes were shrunken a short distance behind the growing-point, and they contained a milky fluid instead of the firm white tissue of normal bracken. Considerable lengths of the older rhizomes had a loose, frequently ruptured cortex, so that long bands of the hard sclerenchyma were exposed as broad flat fibers. No growing-points were found on these parts. The effect of rhizome depletion was to break up a widespreading continuous plant into a number of pieces or separate plants. The fronds were produced from tufts of branches mainly near the surface. Hence, the water supply from deeper soil layers was not accessible, and the more superficial root-system competed for water with the grasses.

Another experiment (17) was begun in 1946, in which the bracken fronds were either cut or crushed regularly. Little difference in the number of fronds occurred until 1950 when four cuttings were made in May and June; yet complete eradication seemed unlikely for another year or two.

Burning is a hazardous and inferior means of eliminating bracken and is totally ineffective unless it is combined with certain other steps (8). In Australia it has been suggested that the subterranean clover or burr clover be sowed upon the ashes, superphosphate applied, the area stocked lightly and the process repeated the following year. The procedure may not be applicable in the midwestern United States, but it merely illustrates the difficulty of eradication by means of burning. More suitable for this region is the method suggested by Jenkins and Jackman (12) for the western variety of bracken fern, P. aquilinum (L.) Kuhn, Var. pubescens (Desv.) Underw. They recommend that, after burning, the area be seeded to good, permanent, adapted grasses, and then pastured as soon as the grasses are established. Chewing's fescue, tall fescue, creeping red fescue, highland bent grass, orchard grass, and tall oatgrass are all adapted to western fernland. Broadleaf birds' foot trefoil, alta fescue, redtop, common ryegrass and perennial ryegrass are acid-tolerant perennial species which are recommended for pastures in the midwestern area (1).

Cattle and other animals have been used to some extent for the control of bracken. Trampling by cattle in the spring, after previous burning, is a method which is extensively used in New Zealand (9). By removing the cattle to better grazing for short periods every three weeks, the risk of bracken poisoning can be appreciably reduced. It has been observed that the animals will eat bracken, as the only alternative to going hungry (11). The animals must be forced to trample

successfully, and this presents a problem on larger areas unless the areas are subdivided in order to concentrate the animals (13). Once the fern uncurls, however, control by crushing is more difficult, and the principle of rhizome starvation by trampling fails as a means of control.

Sheep and swine tend to be tolerant of the poisonous effects of bracken and have limited usefulness in bracken control because of their voracious eating habits. The hogs, desiring the abundant, starch-filled rhizomes, uproot the underground stems and the sheep close-graze the fronds (16). Close-grazing can be encouraged by the application of crushed rock salt, two hundred pounds per acre, when the fronds are emerging.

Another method of bracken eradication is by the use of chemicals. In reviewing the literature it was found that two types of chemicals, those which are translocated within the plant and may destroy distant parts of the plant along with those parts with which they are in contact, and those chemicals which effect only the parts of the plant actually in contact with the herbicide, were used.

Sodium chlorate is described as being the most effective of the chemicals. This chemical is extremely toxic to plant life, but is quite harmless to animals and humans. The effect on the animal system is somewhat similar to an equal quantity of Epsom Salts. Braid (4), Griffith (10), and Bates (2) have recommended the use of sodium chlorate at 200 pounds per acre for bracken eradication. Davies (9), describing Braid's work in Scotland, stated that plots treated with a single application of 200 pounds per acre in 1937 showed much less regrowth of bracken after 10 years than plots which were cut twice a year. Griffith (10) found that if sodium chlorate were applied during February or March, even to land very heavily infested with bracken, hardly any growth would take place on that plot for a very long time. In one instance, after seven years had elapsed, very little bracken had reappeared. Bates (2) also described a method for the direct application, using a hand-scythe attachment, of a concentrated solution to the cut surface of bracken fronds whereby only 15 to 20 pounds per acre was needed to effect a 50 to a 100 per cent kill, the lower kill being attributed to wet weather.

The contact herbicides, in single treatments, produce the same effect as one cutting of the fronds. Their use is not generally practical unless an abundant supply of water is readily available. Common salt, sodium chloride, has been used successfully at 200 pounds per acre in 75 gallons of water (14). The best results are obtained when the fronds have fully expanded. Although salt has the advantage of not permanently injuring grasses, the presence of salt on the fronds is detrimental to livestock, which may be induced to eat the salty fronds. A 10 per cent solution of sulphuric acid will also kill the current year's growth. Retreatment for a period of six years is necessary (4).

Sodium arsenite is also effective, but it is poisonous to man and animals (7). Trials were conducted by Millard, in Yorkshire, in which a proprietary selective hormone weed-killer was used at rates up to 300 pounds per acre. It was found to be totally ineffective in all cases (9). Burton (6) suggested a method which might be valuable if brought beyond the experimental stage. He implied that by the application of growth substances which would stimulate dormant buds to grow out of season there was the possibility of the production of a crop of fronds in autumn or early spring to be destroyed by the frost.

III. METHODS

The present experiments were started in 1950 and the first tests were located 100 miles northwest of East Lansing at Big Rapids and located on the eastern fringe of the Manistee National Forest. Because of the distance from East Lansing repeated observations could not be made. The infestation lay on an open, gradually sloping depression surrounded by a mixed oak and maple forest. A dense, but not smothering, turf of grass underlaid the bracken canopy. The soil consisted entirely of sand, except for a shallow organic layer, one to three inches deep.

The 1951 treatments were located on the farms of Steven Siple and Stanley Loomis, four miles north of East Lansing.

On the Loomis farm, the treated area was a low, poorly-drained area somewhat more fertile than the Big Rapids area, having a sandy soil through which the organic matter was distributed. Considerable vegetation other than the bracken fern was present and included witch hazel, black willow, red oak, white oak, solomon's seal, wild strawberry and a healthy growth of blue grass interspersed with some canary grass and woolly beardgrass.

The experiments conducted on the farm of Steven Siple were on land which was a sandy, well-drained upland, with a dense stand of white and red oak trees. The area was comparable to the one at Big Rapids in that the denser section of the infestation lay on a slope facing the south. The bracken had grown to the extent of crowding out nearly all other herbaceous plants. A section of the rhizomes at the maximum depth of the lower tier of rhizomes contained 22¼ lineal feet of rhizomes, including the lateral branches. Seventy-six active and potential growing points were present. These included terminal buds, frond buds and scale-like buds, giving an average of 3.4 potential growing points per foot of rhizome.

The size of the bracken varied somewhat in the wooded and open areas. In the wooded area the fronds ranged from 2 to 3 feet in height and the number of rhizomes per square foot were considerably reduced. The more flourishing open area produced fronds 3 to 4 feet in height and had more rhizomes per square foot. The differences in vigor were attributed to the open area receiving abundant runoff following heavy rains, lack of tree competition, shade, and its exposure on the sunny southern slope, thus providing the necessary soil moisture and temperature to begin early growth. The reduced size of the fronds in the wooded area occurred because of competition of the bracken fern with the oak trees for soil moisture and the decreased soil temperature, due to shading by the early appearance of the oak leaves, delaying emergence of the fronds.

Soil samples from the wooded and open areas were taken to determine the correlation between the size of the fronds and the soil fertility. The soil analyses were made at the Michigan State College Soils Laboratory. It was found that the soil was decidedly acid, pH 4.5 in the wooded area, and pH 4.2 in the open area.

The methods employed in this study are, in part, a duplication of the chemical methods described in the literature. The duplication

was made in order to obtain a basis for comparison between the results derived from the work of other investigators and the results derived from the experiments conducted in this study. Single applications of the chemicals with one exception were made to determine the effects of the chemicals on the stage of growth present at the time of the application. In this way the need for additional applications could be predicted for future investigational work.

The field experiments were performed during three stages of growth of the fronds, namely: 1. when the frond buds were in the dormant stage, 2. when emerging as young, tender, unfolded fronds, 3. and when the foliage was completely expanded and the stipe somewhat woody. The dormant treatments were made early in the year when the fronds had not yet emerged. The cut- and uncut-emerging-frond treatments were made when the fronds were emerging, and the older of the fronds had attained a height of twenty-six inches. During the stage when the foliage had fully expanded treatments were applied as follows: cut- and uncut-mature-frond applications, plowed-rhizome applications, foliage applications, and direct-rhizome applications. Single applications of contact herbicides usually do not give complete control; therefore, soil sterilants and translocated herbicides were used in most of the experiments. The objective in making the dormant applications was to have the translocated herbicides and soil sterilants leach to the rhizome layers and affect the roots and growing points. Applications were made early in the season, while snow was still on the ground and until the middle of May, before the fronds had emerged. Treatment at this time of the year is advantageous from the farmer's viewpoint because farming activities are at a minimum.

In 1950, translocated, soil sterilizing, and contact herbicides were applied to the emerging fronds. In 1951, only the translocated herbicides, some of which were of a soil sterilizing nature, were applied. In the latter experiments two plots were sprayed at the same rate; one plot was left undisturbed and the fronds on the other plot were cut with a scythe. The cutting was done to secure a direct contact with the exposed food and water transporting structures of the plant. By having both cut and uncut plots, a means was provided for determining the effectiveness of each method as well as which herbicide offered the best control.

The cut- and uncut-mature-frond sprays were applied to both the entire outer surfaces and to the cut surfaces. Translocation to the rhizomes was thought to be more effective late in the season because the foliage was expanded and the synthesis of food was taking place. The movement of translocated herbicides to the rhizome system seemed more likely to occur while in the foliage stage than during the emerging-frond stage. At the time the fronds are emerging, the young succulent stipes contain large amounts of water and which tends to flow freely for a short time after cutting. At this stage of growth the downward movement of foods is at a minimum.

The foliage applications were made late in the season to insure the presence of a maximum number of expanded fronds.

The chemicals used were translocatable herbicides, soil sterilants and contact herbicides. All herbicides were applied at rates that ordinarily are toxic to most plants upon contact.

Another method of eradication was tried on the Siple Farm. Two areas, devoid of heavy undergrowth, were plowed to a depth of twelve inches. The soil was overturned as completely as possible to expose the rhizomes. Square-rod plots were then measured and the rhizomes sprayed with a number of herbicides. The purpose of the experiment was to simulate a method used to destroy quackgrass, Agropyron repens L., where the rhizomes are exposed by cultivation and then sprayed with sodium trichloroacetate. Desiccation is also an important factor to be considered because the exposed rhizomes are subject to drying.

When response was observed from applications of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid to the foliage and exposed rhizomes an additional experiment was conducted to further test their action. Solutions of 2,4-D at concentrations of 500, 1,000 and 2,000 ppm, and similar solutions of 2,4,5-T, were placed in plastic bags of approximately one quart capacity and sealed to the ends of freshly cut rhizomes. The bags were elevated to allow gravity to assist in the movement of the growth regulators into the rhizome. The large volumes of dilute herbicides were then available for absorption by the rhizome.

In addition to the bracken experiments, test plantings of bromegrass, Bromus sp., and Norway pine seedlings, Pinus resinosa Ait.,

were made on several of the treated plots. Bromegrass was chosen because of its popularity as a grazing species in Michigan. Approximately six grams of bromegrass seeds were sowed in two square feet in each of the herbicide treated plots. The seeds were then scratched into the soil. A heavy rain occurred a week after planting, and provided the soil moisture needed for germination. The Norway pine seedlings were planted, two in each plot, on the plowed-rhizome areas. The purpose of the plantings was to determine if the bromegrass and tree seedlings could survive the residual action of the herbicides.

In the laboratory, several experiments were made to determine the magnitude of reaction with mixtures of 2,4-D and 2,4,5-T at .01 and .02 per cent concentrations made up in paste form using Carbowax, polymerized ethylene glycol, as a solvent. The paste mixture allowed the growth regulators to remain in contact with the rhizomes for a long period of time. The following treatments were made: 1. 2,4-D paste, .02%, was applied to one end of eight rhizomes, each supporting a frond in a different stage of development, 1, 2½, 3, 5, 6, 8, 10, and 12 inches in height. The frond 10 inches tall was beginning to unfold. The 12 inch frond was fully expanded at the time of application. 2. Small portions of the .01% and .02% mixtures were applied to the cut surfaces of several rhizomes, each having an unfolded frond attached. 3. An experiment was performed applying .01% mixtures of 2,4-D and 2,4,5-T to the ends of a section of rhizomes. 4. Spores from a frond that was grown in the greenhouse were sowed on a flat of soil. The gametophytes appeared three to four weeks

later followed by the formation of the embryo and first leaves. One leaf tip from each of four young sporelings was smeared with the mixtures of 2,4-D and 2,4,5-T. Two sporelings were left untreated for controls.

Another experiment was conducted to determine if 2,4-D and 2,4,5-T were translocated to the rhizomes and frond buds. Weighed samples of rhizomes from the direct rhizome application, buds from the dormant-cut- and uncut-emerging-frond experiments and buds from the cut- and uncut-mature-frond experiment were ground separately in a Waring Blendor. The resulting solutions were allowed to stand for at least twenty-four hours to permit the herbicides to diffuse from the ground plant material.

Cucumber seedling tests were then made to determine the presence of the growth regulators. Twenty-five cucumber seeds were placed between blotting papers in germination dishes. On the first and second day two milliliters of the solutions described above were added to each of the germination dishes. The length of the primary root of each of the seedlings was then measured on the third or fourth day, preferably the fourth day when the difference between the affected and nonaffected roots are greater. The lengths of the seedling roots in each dish were totaled and an average taken. The different averages were then compared with normal seedlings.

The chemicals generally were applied by broadcasting or spraying with a Champion Knapsack Sprayer. A two-nozzled boom was made in order to increase the width of the swath. Teejet nozzles with

an aperture of .01 or .06 of an inch, depending on the type and quantity of the chemical sprayed, were used. Broadcasting was done only when the chemical was insoluble in water or when low air temperatures prevented the use of aqueous solutions.

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IV. RESULTS

Results of the dormant, cut- and uncut-emerging-frond, cut- and uncut-mature-frond, and plowed-rhizome treatments are based upon the number of fronds per square yard, buds per square foot and per cent germination of sowed bromegrass. The number of fronds per square yard on a plot was used as a measure of that plot's usefulness for pasturing, during the same year as when the application is made. The fronds, which emerged and then were killed due to the chemical were not counted. Counts of the buds per square foot, made in the fall, gave an indication of the following year's probable crop of fronds and is probably the best criterion in determining the effect of a treatment. Because of the labor involved in digging, but counts were made only on the plots showing effects due to the chemical and on those plots treated with translocated herbicides. The bromegrass plantings were also made on only these plots. The results of the pine seedling plantings in the plowed-rhizome treatments were not tabulated as no injury occurred in any of the plots. Data on the foliage spray treatments were recorded as per cent kill of the fronds in each plot. A measure of the effectiveness of the herbicides was obtained by dividing the average root length of the treated seedlings by the average root length of the control seedlings.

The results of the laboratory experiments using mixtures of 2,4-D and 2,4,5-T showed several interesting facts. The first experiment, as described in the discussion on methods, where .02 per cent

2,4-D was applied to fronds in different stages of development showed that 2,4-D will affect bracken if the proper penetration can be achieved. The effects vary in different stages of frond formation. Ten days after application the 1 and 2½ inch fronds which had not begun to unfold were shriveled and dried. The 3, 5, 6 and 8 inch fronds which had not unfolded were unaffected, except that the 8 inch frond drooped slightly. The 10 inch frond, partially unfolded, was the first to show a reaction to the herbicide. Twenty-four hours after application it was observed that the frond was in an extremely drooped position, the pinna nearly touching the soil. The frond was dead at the end of the 10 day period. The tips of the pinnae on the 12 inch, completely-unfolded frond were brown while the rest of the pinnae were chlorotic.

Application of a .02 per cent mixture of 2,4,5-T on the cut surface of a rhizome, in experiment 2, caused the unfolded frond to wilt within two hours and to turn brown in 72 hours. Mixtures of .01 per cent and .02 per cent 2,4-D and the .01 per cent mixture of 2,4,5-T produced the same results, but at a slower rate. At the end of three weeks all the fronds were chlorotic.

In the third laboratory experiment, where the four mixtures were applied to the rhizomes, four with single unfolding fronds, and four with single expanded fronds, it was found that, after a lapse of four hours, the unfolding fronds drooped considerably while the expanded fronds were unaffected. At the end of seven days the treated unfolding fronds were dead; the treated unfolded fronds were chlorotic on the edges of the pinnae.

The treated sporelings, after three months, were in a stunted condition. The fronds still had the appearance of a two months old sporophyte and were approximately one-third the size of the untreated plants.

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TABLE I

METHODS OF APPLICATION, MATERIALS, RATES, GALLONS PER ACRE, DATE OF APPLICATION AND RESULTS OF THE TREATMENTS MADE AT BIG RAPIDS IN 1950

Method: Dormant

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Ammonium sulfamate	160 lbs.	80	Water	5/14		
Pentachlorophenol	10 lbs.	80	Kerosene	4/30		
Sodium chlorate	160 lbs.	160	Water	5/14	9.5	
Sodium pentaborate and sodium borate	320 lbs.		Dry	5/14	8.5	
Sodium pentaborate and sodium borate	640 lbs.		Dry	5/14	9.0	
Sodium trichloroacetate	40 lbs.	80	Water	4/30		
Trichlorobenzene		80	None	4/30		
2,4-dichlorophenoxyacetic acid (sodium salt)	5 lbs.	80	Water	4/30		
Check					10.5	

Method: Emerging-frond

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Ammonium sulfate	80 lbs.	80	Water	6/11		
Ammonium sulfate	160 lbs.	80	Water	6/11		
Copper nitrate	10 lbs.	80	Water	6/11		
Copper nitrate	20 lbs	80	Water	6/11		
Copper sulfate	80 lbs.	80	Water	6/11		
Copper sulfate	160 lbs.	80	Water	6/11		
Dinitro-ortho-secondary-butyl-phenate (ammonium salt)	2 lbs.	80	Kerosene	6/11		
Dinitro-ortho-secondary-butyl-phenol (ammonium salt)	4 lbs.	80	Kerosene	6/11		

TABLE I

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Pentachlorophenol	4 lbs.	80	Kerosene	6/11		
Pentachlorophenol	8 lbs.	80	Kerosene	6/11		
Phenyl mercuric acetate	10 lbs.	80	Water	6/11		
Phenyl mercuric acetate	20 lbs.	80	Water	6/11		
Sodium trichloroacetate (ester)	6 lbs.	80	Kerosene	6/11		
Sodium trichloroacetate (ester)	12 lbs.	80	Kerosene	6/11		
2,4-dichlorophenoxyacetic acid (ester)	2 lbs.	80	Kerosene	6/11		
2,4-dichlorophenoxyacetic acid (ester)	4 lbs.	80	Kerosene	6/11		
2,4,5-trichlorophenoxyacetic acid (ester)	2 lbs.	80	Kerosene	6/11		
2,4,5-trichlorophenoxyacetic acid (ester)	4 lbs.	80	Kerosene	6/11		
2,4,5-trichlorophenoxyacetic acid (ester)plus 2,4-dichlorophenoxyacetic acid (ester) (1:1)	2 lbs.	80	Kerosene	6/11		
2,4,5-trichlorophenoxyacetic acid (ester) 2,4-dichlorophenoxyacetic acid (ester) (1:1)	4 lbs.	80	Kerosene	6/11		
Xanthogen disulfide	10 lbs.	80	Water	6/11		
Xanthogen disulfide	20 lbs.	80	Water	6/11		
Method: Mature-frond						
Disodium-3,6-endoxohexahydrophthalate plus ammonium sulfate	5 lbs.	80	Water	7/23		
Disodium-3,6-endoxohexahydrophthalate plus ammonium sulfate	10 lbs.	80	Water	7/23		
Polyethylene chloride	5 lbs.	80	Kerosene	7/23		
Polyethylene chloride	10 lbs.	80	Kerosene	7/23		

TABLE I

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Sodium pentaborate and sodium borate	80 lbs.	160	Water	7/23		
Sodium pentaborate and sodium borate	160 lbs.	160	Water	7/23	4.5	
Sodium pentaborate and sodium borate plus sodium chlorate (10:3)-mixed	80 lbs.	160	Water	7/23		
Sodium pentaborate and sodium borate plus sodium chlorate (10:3)-mixed	160 lbs.	160	Water	7/23	9.5	
Sodium trichloroacetate	160 lbs.	80	Water	7/23	2.0	
Trichlorobenzene		80	None	7/23	6.0	
2,4,5-trichlorophenoxyacetic acid (ester)	2 lbs.	80	Kerosene	7/23		
2,4,5-trichlorophenoxyacetic acid (ester)	4 lbs.	80	Kerosene	7/23		
Check					9.5	

TABLE II

METHODS OF APPLICATION, MATERIALS, RATES, GALLONS PER ACRE, DATE OF APPLICATION AND RESULTS OF THE TREATMENTS MADE AT EAST LANSING IN 1951

Method: Dormant

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per sq. Yd.	Buds per Sq. Ft.
Anhydrous sodium borate and boron trioxide	160 lbs.		Sand	12/15	0.0	
Anhydrous sodium borate and boron trioxide	320 lbs.		Sand	12/15	0.0	11.00
Anhydrous sodium borate and boron trioxide	640 lbs.		Sand	12/15	0.0	11.33
Anhydrous sodium borate and boron trioxide	976 lbs.		Sand	4/27	0.0	2.33
Anhydrous sodium borate and boron trioxide	1,958 lbs.		Sand	2/11	0.5	14.66
Anhydrous sodium borate and boron trioxide	3,917 lbs.		Sand	1/1	0.0	8.33
Ammonium sulfamate	320 lbs.	160	Water	12/15	2.5	
Ammonium sulfamate	320 lbs.	160	Water	5/6	0.0	0.66
Ammonium sulfamate	480 lbs.	160	Water	3/26	0.0	3.00
Ammonium sulfamate	640 lbs.	160	Water	5/6	0.0	23.66
Ammonium thiocyanate	560 lbs.	160	Water	3/26	5.0	
Ammonium thiocyanate	1,120 lbs.	320	Water	3/4	3.5	
Isopropyl-n-phenyl-carbamate (powder)	10 lbs.		Sand	3/26	3.0	
Isopropyl-n-phenyl-carbamate (powder)	20 lbs.		Sand	3/26	0.5	
Isopropyl-n-phenyl-carbamate (powder)	40 lbs.		Sand	3/26	2.5	
Isopropyl-n-phenyl-carbamate (powder)	80 lbs.		Sand	3/26	2.0	11.66
Polyethylene chloride	10 lbs.	80	Kerosene	3/26	0.0	
Polyethylene chloride	20 lbs.	80	Kerosene	3/26	5.6	
Polyethylene chloride	40 lbs.	80	Kerosene	3/26	2.5	
Sodium borate and boron trioxide	160 lbs.		Sand	12/15	0.5	
Sodium borate and boron trioxide	320 lbs.		Sand	12/15	4.0	

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Sodium borate and boron trioxide	640 lbs.		Sand	12/15	2.5	14.66
Sodium borate and boron trioxide	976 lbs.		Sand	4/27	0.0	7.66
Sodium borate and boron trioxide	1,952 lbs.		Sand	4/27	0.0	26.33
Sodium chlorate	381 lbs.		Sand	1/1	8.0	
Sodium chlorate	400 lbs.	160	Water	3/4	2.5	1.00
Sodium chlorate	800 lbs.	160	Water	3/4	1.0	2.66
Sodium pentaborate and sodium borate	320 lbs.		Sand	5/7	0.0	
Sodium pentaborate and sodium borate	640 lbs.		Sand	5/6	0.0	9.66
Sodium pentaborate and sodium borate	1,280 lbs.		Sand	5/6	0.0	4.66
Sodium pentaborate and sodium borate plus sodium borate and boron trioxide (1:26)-mixed	1,152 lbs.		Sand	1/1	0.0	
Sodium pentaborate and sodium borate plus sodium chlorate (10:1)-mixed	160 lbs		Sand	5/6	3.5	
Sodium pentaborate and sodium borate plus sodium chlorate (10:1)-mixed	320 lbs.		Sand	5/6	0.C	
Sodium pentaborate and sodium borate plus sodium chlorate (10:1)-mixed	640 lbs.		Sand	5/6	0.0	10.00
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)	160 lbs.		Sand	12/15	0.0	
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)	320 lbs.		Sand	12/15	0.5	
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)	640 lbs.		Sand	12/15	4.0	
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)	976 lbs.		Sand	4/22	0.0	0.66
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)	1,523 lbs.		Sand	1/1	0.5	6.33

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)	1,923 lbs.		Sand	4/27	0.0	0.00
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)-mixed	320 lbs.		Sand	12/15	2.0	
Sodium pentaborate and sodium borate plus sodium chlorate (3:1)-mixed	640 lbs.		Sand	12/15	4.5	
Sodium pentaborate and sodium borate plus sodium chlorate (5:1)-mixed	320 lbs.		Sand	5/6	0.0	
Sodium pentaborate and sodium borate plus sodium chlorate (5:1)-mixed	640 lbs.		Sand	5/6	0.0	13.00
Sodium pentaborate and sodium borate plus sodium chlorate (5:1)-mixed	1,280 lbs.		Sand	5/6	0.0	9.33
Sodium trichloroacetate	160 lbs.		Sand	4/22	10.0	
Sodium trichloroacetate	320 lbs.		Sand	4/22	9.5	14.33
Sodium trichloroacetate	480 lbs.		Sand	4/22	7.5	2.66
2,4-dichlorophenoxyacetic acid (ester)	6 lbs.	80	Water	2/11	0.5	
2,4-dichlorophenoxyacetic acid (ester)	12 lbs.	80	Water	2/11	0.0	13.66
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent		20	None	4/7	4.5	
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent		40	None	4/7	1.5	1.00
2,4,5-trichlorophenoxyacetic acid (ester)	6 lbs.	80	Water	2/11	1.5	
2,4,5-trichlorophenoxyacetic acid (ester)	12 lbs.	80	Water	2/11	3.5	13.66
Check					6.0	13.66

TABLE II

Method: Cut- and Uncut-emerging-frond

Chemical	Rate per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Ammonium sulfamate	160 lbs.	80	Water	6/3	3.0	35.33
Ammonium sulfamate (cut)	160 lbs.	80	Water	6/3	1.0	24.33
Ammonium sulfamate	320 lbs.	80	Water	6/3	0.0	19.66
Ammonium sulfamate (cut)	320 lbs.	80	Water	6/3	0.0	16.33
Isopropyl-n-phenyl-carbamate (emulsion)	5 lbs.	20	Diesel oil	6/2	2.0	
Isopropyl-n-phenyl-carbamate (emulsion)-(cut)	5 lbs.	20	Diesel oil	6/2	7.0	
Isopropyl-n-phenyl-carbamate (emulsion)	10 lbs.	20	Diesel oil	6/2	6.5	
Isopropyl-n-phenyl-carbamate (emulsion)-(cut)	10 lbs.	20	Diesel oil	6/2	6.0	
Isopropyl-n-phenyl-carbamate (emulsion)	15 lbs.	20	Diesel oil	6/2	4.5	21.33
Isopropyl-n-phenyl-carbamate (emulsion)-(cut)	15 lbs.	20	Diesel oil	6/2	7.0	25.66
Maleic hydrazide	2½ lbs.	40	Diesel oil emulsion	6/4	6.5	45.66
Maleic hydrazide (cut)	2½ lbs.	40	Diesel oil emulsion	6/4	6.5	61.00
Maleic hydrazide	5 lbs.	40	Diesel oil emulsion	6/4	5.0	19.00
Maleic hydrazide (cut)	5 lbs.	40	Diesel oil emulsion	6/4	4.0	57.00
Pentachlorophenol, trichloroacetic acid, 2,4-dichlorophenoxyacetic acid	10 gal.	40	Diesel oil	6/2	3.5	
Pentachlorophenol, trichloroacetic acid, 2,4-dichlorophenoxyacetic acid (cut)	10 gal.	40	Diesel oil	6/2	5.0	
Pentachlorophenol, trichloroacetic acid, 2,4-dichlorophenoxyacetic acid	20 gal.	40	Diesel oil	6/2	9.0	
Pentachlorophenol, trichloroacetic acid, 2,4-dichlorophenoxyacetic acid (cut)	20 gal.	40	Diesel oil	6/2	2.5	

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Sodium chlorate	160 lbs.	80	Water	6/4	0.0	13.33
Sodium chlorate (cut)	160 lbs.	80	Water	6/4	0.0	7.66
Sodium chlorate	320 lbs.	80	Water	6/4	0.0	11.33
Sodium chlorate (cut)	320 lbs.	80	Water	6/4	0.0	12.66
Sodium chlorate	640 lbs.	80	Water	6/4	0.0	2.66
Sodium chlorate (cut)	640 lbs.	80	Water	6/4	0.0	4.33
3-(P-chlorophenyl)-1,1-dimethyl urea	10 lbs.	40	Water	6/3	5.0	14.66
3-(P-chlorophenyl)-1,1-dimethyl urea (cut)	10 lbs.	40	Water	6/3	7.5	23.33
3-(P-chlorophenyl)-1,1-dimethyl urea	20 lbs.	40	Water	6/3	5.0	60.33
3-(P-chlorophenyl)-1,1-dimethyl urea (cut)	20 lbs.	40	Water	6/3	8.5	35.00
Sodium trichloroacetate	80 lbs.	80	Water	6/3	0.5	23.66
Sodium trichloroacetate (cut)	80 lbs.	80	Water	6/3	2.0	20.66
Sodium trichloroacetate	160 lbs.	80	Water	6/3	0.0	23.66
Sodium trichloroacetate (cut)	160 lbs.	80	Water	6/3	1.0	22.33
Sodium trichloroacetate	320 lbs.	80	Water	6/3	0.0	33.66
Sodium trichloroacetate (cut)	320 lbs.	80	Water	6/3	0.0	38.00
2,4-dichlorophenoxyacetic acid (amine salt) plus phosphoric acid (2.5 c.c. per plot)	1 lb.	40	Water	6/2	14.5	
2,4-dichlorophenoxyacetic acid (amine salt) plus phosphoric acid (2.5 c.c. per plot) (cut)	1 lb.	40	Water	6/2	17.0	
2,4-dichlorophenoxyacetic acid (amine salt) plus phosphoric acid (2.5 c.c. per plot)	2 lbs.	40	Water	6/2	21.0	67.66
2,4-dichlorophenoxyacetic acid (amine salt) plus phosphoric acid (2.5 c.c. per plot) (cut)	2 lbs.	40	Water	6/2	10.5	53.33
2,4-dichlorophenoxyacetic acid (amine salt) plus phosphoric acid (2.5 c.c. per plot)	4 lbs.	40	Water	6/2	11.0	31.33
2,4-dichlorophenoxyacetic acid (amine salt) plus phosphoric acid (2.5 c.c. per plot) (cut)	4 lbs.	40	Water	6/2	18.5	44.66

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
2,4-dichlorophenoxyacetic acid (ester	1 lb.	40	Water	6/2	12.0	
2,4-dichlorophenoxyacetic acid (ester)-(cut)	1 lb.	40	Water	6/2	8.5	
2,4-dichlorophenoxyacetic acid (ester)	2 lbs.	20	Diesel oil	5/30	16.0	14.00
2,4-dichlorophenoxyacetic acid (ester)-(cut)	2 lbs.	20	Diesel oil	5/30	15.5	34.00
2,4-dichlorophenoxyacetic acid (ester)	4 lbs.	20	Diesel oil	5/30	13.0	8.00
2,4-dichlorophenoxyacetic acid (ester)-(cut)	4 lbs.	20	Diesel oil	5/30	9.0	13.66
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent		20		6/2	3.0	
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent (cut)		20		6/2	17.5	
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent		40		6/2	8.0	25.33
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent (cut)		40		6/2	9.0	35.66
2,4-dichlorophenoxyacetic acid (sodium salt) plus phosphoric acid (2.5 c.c. per plot)	1 lb.	40	Water	5/30	6.0	
2,4-dichlorophenoxyacetic acid (sodium salt) plus phosphoric acid (2.5 c.c. per plot) (cut)	1 lb.	40	Water	5/30	7.5	
2,4-dichlorophenoxyacetic acid (sodium salt) plus phosphoric acid (2.5 c.c. per plot)	2 lbs.	40	Water	5/30	5.5	5.00
2,4-dichlorophenoxyacetic acid (sodium salt) plus phosphoric acid (2.5 c.c. per plot) (cut)	2 lbs.	40	Water	5/30	6.0	19.66
2,4-dichlorophenoxyacetic acid (sodium salt) plus phosphoric acid (2.5 c.c. per plot)	4 lbs.	40	Water	5/30	7.0	18.00
2,4-dichlorophenoxyacetic acid (sodium salt) plus phosphoric acid (2.5 c.c. per plot) (cut)	4 lbs.	40	Water	5/30	8.5	9.66

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
2,4,5-trichlorophenoxyacetic acid (ester)	1 lb.	20	Diesel oil	5/30	15.0	
2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	1 lb.	20	Diesel oil	5/30	5.5	
2,4,5-trichlorophenoxyacetic acid (ester)	2 lbs.	20	Diesel oil	5/30	19.0	14.00
2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	2 lbs.	20	Diesel oil	5/30	15.0	34.00
2,4,5-trichlorophenoxyacetic acid (ester)	4 lbs.	20	Diesel oil	5/30	15.5	8.00
2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	4 lbs.	20	Diesel oil	5/30	21.0	13.66
Check					4.5	32.33
Method: Cut- and Uncut-mature-frond						
Ammonium sulfamate	160 lbs.	80	Water	7/4	0.0	22.66
Ammonium sulfamate (cut)	160 lbs.	80	Water	7/4	0.0	8.66
Ammonium sulfamate	320 lbs.	80	Water	7/4	0.0	7.33
Ammonium sulfamate (cut)	320 lbs.	80	Water	7/4	0.0	10.66
Ammonium sulfamate	480 lbs.	80	Water	6/29	0.0	18.66
Ammonium sulfamate (cut)	480 lbs.	80	Water	6/29	0.0	22.66
Ammonium sulfamate plus 2,4-dichlorophenoxyacetic acid (ester)	160 lbs. 10 lbs.	80	Water	6/29	0.0	17.33
Ammonium sulfamate plus 2,4-dichlorophenoxyacetic acid (ester)-(cut)	160 lbs. 10 lbs.	80	Water	7/4	0.0	24.66
Ammonium sulfamate plus 2,4,5-trichlorophenoxyacetic acid (ester)	160 lbs. 10 lbs.	80	Water	6/29	0.0	24.66
Ammonium sulfamate plus 2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	160 lbs.	80	Water	7/4	0.0	20.00
Dinitro-o-sec-butyl phenate (amine salt)	4 lbs.	40	Diesel oil	7/7	0.5	9.00
Dinitro-o-sec-butyl phenate (amine salt)-(cut)	4 lbs.	40	Diesel oil	7/7	0.5	28.66

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
2,4,5-trichlorophenoxyacetic acid (ester)	1 lb.	20	Diesel oil	5/30	15.0	
2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	1 lb.	20	Diesel oil	5/30	5.5	
2,4,5-trichlorophenoxyacetic acid (ester)	2 lbs.	20	Diesel oil	5/30	19.0	14.00
2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	2 lbs.	20	Diesel oil	5/30	15.0	34.00
2,4,5-trichlorophenoxyacetic acid (ester)	4 lbs.	20	Diesel oil	5/30	15.5	8.00
2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	4 lbs.	20	Diesel oil	5/30	21.0	13.66
Check					4.5	32.33
Method: Cut- and Uncut-mature-frond						
Ammonium sulfamate	160 lbs.	80	Water	7/4	0.0	22.66
Ammonium sulfamate (cut)	160 lbs.	80	Water	7/4	0.0	8.66
Ammonium sulfamate	320 lbs.	80	Water	7/4	0.0	7.33
Ammonium sulfamate (cut)	320 lbs.	80	Water	7/4	0.0	10.66
Ammonium sulfamate	480 lbs.	80	Water	6/29	0.0	18.66
Ammonium sulfamate (cut)	480 lbs.	80	Water	6/29	0.0	22.66
Ammonium sulfamate plus 2,4-dichlorophenoxyacetic acid (ester)	160 lbs. 10 lbs.	80	Water	6/29	0.0	17.33
Ammonium sulfamate plus 2,4-dichlorophenoxyacetic acid (ester)-(cut)	160 lbs. 10 lbs.	80	Water	7/4	0.0	24.66
Ammonium sulfamate plus 2,4,5-trichlorophenoxyacetic acid (ester)	160 lbs. 10 lbs.	80	Water	6/29	0.0	24.66
Ammonium sulfamate plus 2,4,5-trichlorophenoxyacetic acid (ester)-(cut)	160 lbs.	80	Water	7/4	0.0	20.00
Dinitro-o-sec-butyl phenate (amine salt)	4 lbs.	40	Diesel oil	7/7	0.5	9.00
Dinitro-o-sec-butyl phenate (amine salt)-(cut)	4 lbs.	40	Diesel oil	7/7	0.5	28.66

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Dinitro-o-sec-butyl phenate (amine salt)	8 lbs.	40	Diesel oil	7/7	0.0	12.66
Dinitro-o-sec-butyl phenate (amine salt)-(cut)	8 lbs.	40	Diesel oil	7/7	0.0	21.66
Dinitro-o-sec-butyl phenate (ammonium salt)	4 lbs.	40	Diesel oil	7/28	0.0	16.00
Dinitro-o-sec-butyl phenate (ammonium salt)-(cut)	4 lbs.	40	Diesel oil	7/28	0.0	15.33
Dinitro-o-sec-butyl phenate (ammonium salt)	6 lbs.	40	Diesel oil	7/28	0.0	19.00
Dinitro-o-sec-butyl phenate (ammonium salt)-(cut)	6 lbs.	40	Diesel oil	7/28	0.0	15.66
Sodium chlorate	20 lbs.	40	Water	7/28	0.0	19.00
Sodium chlorate (cut)	20 lbs.	40	Water	7/28	0.0	17.00
Sodium chlorate	40 lbs.	40	Water	7/28	0.0	27.66
Sodium chlorate (cut)	40 lbs.	40	Water	7/28	0.0	21.00
Sodium chlorate	160 lbs.	160	Water	7/7	0.0	6.00
Sodium chlorate (cut)	160 lbs.	160	Water	7/7	0.0	3.33
Sodium chlorate	320 lbs.	160	Water	7/7	0.0	6.00
Sodium chlorate (cut)	320 lbs.	160	Water	7/7	0.0	6.33
Sodium chlorate	640 lbs.	160	Water	7/7	0.0	6.66
Sodium chlorate -(cut)	640 lbs.	160	Water	7/7	0.0	8.66
Sodium pentaborate and sodium borate plus sodium chlorate	640 lbs.		Sand	7/7	0.0	4.00
Sodium pentaborate and sodium borate plus sodium chlorate -(cut)	640 lbs.		Sand	7/7	0.0	3.33
Sodium pentaborate and sodium borate plus sodium chlorate	1,280 lbs.		Sand	7/7	0.0	0.33
Sodium pentaborate and sodium borate plus sodium chlorate -(cut)	1,280 lbs.		Sand	7/7	0.0	0.66
Sodium trichloroacetate	160 lbs.	80	Water	7/4	0.0	16.00
Sodium trichloroacetate -(cut)	160 lbs.	80	Water	7/4	0.0	12.00

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Sodium trichloroacetate	320 lbs.	80	Water	7/4	0.0	12.00
Sodium trichloroacetate -(cut)	320 lbs.	80	Water	7/4	0.0	26.66
Trichlorobenzene		80	None	7/4	0.5	
Trichlorobenzene -(cut)		80	None	7/4	0.0	
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent		80	None	6/29	1.0	34.33
2,4-dichlorophenoxyacetic acid (ester) plus oil solvent -(cut)		80	None	6/29	3.5	14.33
Check					2.0	26.33

Method: Plowed-rhizome

Section I

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
Ammonium sulfamate	160 lbs.	80	Water	6/17	3.0	
Ammonium sulfamate	320 lbs.	80	Water	6/17	0.0	
Diesel oil		40	None	6/17	17.5	
Sodium chlorate	160 lbs.	80	Water	6/17	2.5	
Sodium chlorate	320 lbs.	80	Water	6/17	1.5	
Sodium trichloroacetate	80 lbs.	80	Water	6/17	17.0	
Sodium trichloroacetate	160 lbs.	80	Water	6/17	15.5	
2,4-dichlorophenoxyacetic acid (ester)	1 lb.	80	Diesel oil	6/17	11.5	
2,4-dichlorophenoxyacetic acid (ester)	2 lbs.	40	Diesel oil	6/17	10.0	
2,4-dichlorophenoxyacetic acid (ester) in oil solvent		20	None	6/17	7.5	
2,4-dichlorophenoxyacetic acid (ester) in oil solvent		40	None	6/17	22.5	

TABLE II

Chemical	Rate Lbs. per A.	Gal.	Carrier	Date	Fronds per Sq. Yd.	Buds per Sq. Ft.
2,4,5-trichlorophenoxyacetic acid (ester)	1 lb.	40	Diesel oil	6/17	18.5	
2,4,5-trichlorophenoxyacetic acid (ester)	2 lbs.	40	Diesel oil	6/17	22.0	
Check					33.0	
Section II						
Diesel oil		80	None	8/5	0.0	
Dinitro-ortho-secondary-butyl-phenol	4 lbs.	80	Diesel oil	8/5	0.0	
Dinitro-ortho-secondary-butyl-phenol	8 lbs.	80	Diesel oil	8/5	0.0	
Isopropyl-n-phenyl-carbamate (emulsifiable)	5 lbs.	80	Diesel oil	8/5	0.0	
Isopropyl-n-phenyl-carbamate (emulsifiable)	10 lbs.	80	Diesel oil	8/5	0.0	
Maleic hydrazide	2.5 lbs.	80	Water	8/5	0.0	
Maleic hydrazide	5 lbs.	80	Water	8/5	0.0	
3-(P-chlorophenyl)-1,1-dimethyl urea	10 lbs.	80	Water	8/5	3.0	
3-(P-chlorophenyl)-1,1-dimethyl urea	20 lbs.	80	Water	8/5	0.0	
Check					1.5	

TABLE III

METHOD OF APPLICATION, MATERIALS, RATES PER ACRE, GALLONS, DATE AND RESULTS OF FOLIAGE TREATMENTS AT EAST LANSING IN 1951

Chemical	Rate per A.	Gal.	Carrier	Date	Per cent Kill
Alpha hydroxy beta trichlorethyl sulfonic acid	50 lbs.	40	Water	8/12	10
Alpha hydroxy beta trichlorethyl sulfonic acid	100 lbs.	40	Water	8/12	10
Ammonium sulfamate	40 lbs.	40	Water	8/12	100
Ammonium sulfamate	80 lbs.	40	Water	8/12	100
Ammonium thiocyanate	80 lbs.	40	Water	8/12	100
Ammonium thiocyanate	160 lbs.	40	Water	8/12	100
Calcium cyanamid	100 lbs.	320	Water	8/12	50
Calcium cyanamid	200 lbs.	320	Water	8/12	95
Calcium trichloroacetate	40 lbs.	40	Water	8/12	100
Calcium trichloroacetate	80 lbs.	40	Water	8/12	100
Copper sulphate	80 lbs.	40	Water	8/12	70
Copper sulphate	160 lbs.	40	Water	8/12	40
Diesel oil		40	None	8/12	80
Diesel oil		80	None	8/12	95
Isopropyl-n-phenyl-carbamate (emulsifiable)	1 lb.	40	Kerosene	8/12	95
Isopropyl-n-phenyl-carbamate (emulsifiable)	2 lbs.	40	Kerosene	8/12	100
Disodium-3,6-endoxohexahydrophthalate	5 lbs.	40	Water	8/12	90
Disodium-3,6-endoxohexahydrophthalate	10 lbs.	40	Water	8/12	90
Disodium-3,6-endoxohexahydrophthalate plus ammonium sulphate	5 lbs.	40	Water	8/12	60
Disodium-3,6-endoxohexahydrophthalate plus ammonium sulphate	10 lbs.	40	Water	8/12	100
Kerosene		40	None	8/18	30
Kerosene		80	None	8/18	30

TABLE III

Chemical	Rate per A.	Gal.	Carrier	Date	Per cent Kill
Maleic hydrazide	1 lb.	40	Water	8/18	10
Maleic hydrazide	2 lbs.	40	Water	8/18	10
Octochlorocyclohexenone	2½ lbs.	40	Kerosene	8/18	100
Octochlorocyclohexenone	5 lbs.	40	Kerosene	8/18	100
1,2,3,4,5,6,7,8,8-octachloro-4,7-3a,4,7,7a-tetrahydroindane	7 lbs.	40	Kerosene	8/18	85
1,2,3,4,5,6,7,8,8-octachloro-4,7,3a,4,7,7a-tetrahydroindane	7 lbs.	80	Kerosene	8/18	50
Pentachlorophenol	8 lbs.	40	Kerosene	8/18	95
Pentachlorophenol	16 lbs.	40	Kerosene	8/18	100
Phenyl mercuric acetate	10 lbs.	40	Water	8/18	100
Phenyl mercuric acetate	20 lbs.	40	Water	8/18	100
Polyethylene chloride	5 lbs.	40	Water	8/18	90
Polyethylene chloride	10 lbs.	40	Water	8/18	90
Potassium chloride	100 lbs.	80	Water	8/18	20
Potassium chloride	200 lbs.	80	Water	8/18	30
Potassium cyanate	8 lbs.	40	Water	8/12	80
Potassium cyanate	16 lbs.	40	Water	8/12	100
Sodium chlorate	40 lbs.	40	Water	8/12	90
Sodium chlorate	80 lbs.	40	Water	8/12	100
Sodium chloride	100 lbs.	80	Water	8/12	95
Sodium chloride	200 lbs.	80	Water	8/12	90
Sodium cyanamid	20 lbs.	40	Water	8/12	95
Sodium cyanamid	40 lbs.	40	Water	8/12	100
Sodium isopropyl xanthate	20 lbs.	40	Water	8/12	90
Sodium isopropyl xanthate	40 lbs.	40	Water	8/12	90

TABLE III

Chemical	Rate per A.	Gal.	Carrier	Date	Per cent Kill
Sodium pentaborate and sodium borate	40 lbs.	160	Water	8/12	30
Sodium pentaborate and sodium borate	80 lbs.	160	Water	8/12	50
Sodium pentaborate and sodium borate plus sodium chlorate	40 lbs.	160	Water	8/12	100
Sodium pentaborate and sodium borate plus sodium chlorate	80 lbs.	160	Water	8/12	100
Sodium pentachlorophenate	8 lbs.	40	Water	8/12	100
Sodium pentachlorophenate	16 lbs.	40	Water	8/12	100
Sodium trichloroacetate	40 lbs.	40	Water	8/12	100
Sodium trichloroacetate	80 lbs.	40	Water	8/12	100
Sodium trichloroacetate (ester)	6 lbs.	40	Kerosene	8/12	100
Sodium trichloroacetate (ester)	12 lbs.	40	Kerosene	8/12	100
Stanisol		40	None	8/18	5
Stanisol		80	None	8/18	5
Sulphuric acid	2.5 gal.	100	Water	8/18	15
Sulphuric acid	5 gal.	100	Water	8/18	15
3-(P-chlorophenyl)-1,1-dimethyl urea	2 lbs.	40	Water	8/12	10
3-(P-chlorophenyl)-1,1-dimethyl urea	4 lbs.	40	Water	8/12	10
Trichloroacetic acid, pentachlorophenol and 2,4-dichlorophenoxyacetic acid	20 gals.	80	Kerosene	8/18	100
Trichloroacetic acid, pentachlorophenol and 2,4-dichlorophenoxyacetic acid	40 gals.	80	Kerosene	8/18	100
Trichlorobenzine		40	None	8/18	80
Trichlorobenzine		80	None	8/18	95
2-chloro-6nitro-toluene	160 lbs.	40	Kerosene	8/12	90
2-chloro-6-nitro-toluene	320 lbs.	40	Kerosene	8/12	95

TABLE III

Chemical	Rate per A.	Gal.	Carrier	Date	Per cent Kill
Xanthogen disulphide	5 lbs.	40	Water	8/18	95
Xanthogen disulphide	10 lbs.	40	Water	8/18	95
Xylene and ethylbenzine mixture		40	None	8/18	30
Xylene and ethylbenzine mixture		80	None	8/13	90

TABLE IV

EFFECTS OF WATER EXTRACTS FROM TREATED BRACKEN ON GROWTH OF CUCUMBER SEEDLINGS

Chemical	Rate	Plant Part	Distance	Per cent of Normal
2,4-dichlorophenoxyacetic acid (ester)	12 lbs./ac.	Buds		86.0
2,4,5-trichlorophenoxyacetic acid (ester)	12 lbs./ac.	Buds		47.8
2,4-dichlorophenoxyacetic acid (amine salt)	4 lbs./ac.	Buds		81.8
2,4-dichlorophenoxyacetic acid (ester)	4 lbs./ac.	Buds		75.3
2,4-dichlorophenoxyacetic acid (sodium salt)	4 lbs./ac.	Buds		93.0
2,4,5-trichlorophenoxyacetic acid (ester)	4 lbs./ac.	Buds		85.7
2,4-dichlorophenoxyacetic acid (ester)	500 ppm.	Rhizomes	2 ft.	49.9
2,4-dichlorophenoxyacetic acid (ester)	500 ppm.	Rhizomes	16 ft.	75.6
2,4-dichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	1 ft.	88.2
2,4-dichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	12 ft.	74.7
2,4-dichlorophenoxyacetic acid (ester)	2,000 ppm.	Rhizomes	3 ft.	46.1
2,4,5-trichlorophenoxyacetic acid (ester)	500 ppm.	Rhizomes	2 ft.	46.6
2,4,5-trichlorophenoxyacetic acid (ester)	500 ppm.	Rhizomes	6 ft.	63.1
2,4,5-trichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	2 ft.	45.8
2,4,5-trichlorophenoxyacetic acid (ester)	2,000 ppm.	Rhizomes	3 ft.	67.5
2,4,5-trichlorophenoxyacetic acid (ester)	2,000 ppm.	Rhizomes	21 ft.	68.7

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2,4-dichlorophenoxyacetic acid (ester)	500 ppm.	Rhizomes	16 ft.	75.6
2,4-dichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	1 ft.	88.2
2,4-dichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	12 ft.	74.7
2,4-dichlorophenoxyacetic acid (ester)	2,000 ppm.	Rhizomes	3 ft.	46.1
2,4,5-trichlorophenoxyacetic acid (ester)	500 ppm.	Rhizomes	2 ft.	46.6
2,4,5-trichlorophenoxyacetic acid (ester)	500 ppm.	Rhizomes	6 ft.	63.1
2,4,5-trichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	2 ft.	45.8
2,4,5-trichlorophenoxyacetic acid (ester)	2,000 ppm.	Rhizomes	3 ft.	67.5
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2,4-dichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	12 ft.	74.7
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2,4,5-trichlorophenoxyacetic acid (ester)	1,000 ppm.	Rhizomes	2 ft.	45.8
2,4,5-trichlorophenoxyacetic acid (ester)	2,000 ppm.	Rhizomes	3 ft.	67.5
2,4,5-trichlorophenoxyacetic acid (ester)	2,000 ppm.	Rhizomes	21 ft.	68.7

TABLE V

RESULTS OF SOIL ANALYSIS ON THE SIPLE FARM

	Wooded Area	Open Area
pH	4.5	4.2
Nitrogen	0.0 ppm	0.4 ppm
Phosphate	0.3 ppm	0.7 ppm
Potash	5.0 ppm	1.0 ppm

V. DISCUSSION OF RESULTS

Dormant

No frond counts were made in 1950, but two square-yard counts in several plots were recorded in 1951. It was observed that pre-emergent treatments with a mixture of sodium pentaborate and sodium borate, at rates of 320 and 640 pounds per acre, gave good control of the fronds during 1950 and partial control during 1951. In 1951 a more extensive use of borax compounds in dormant applications was made. Rates from 160 to 3,917 pounds per acre of a mixture of anhydrous sodium borate and boron trioxide were effective in controlling the fronds. Rates of 976 pounds per acre and greater prevented emergence of new growth until the second week in August when a few greatly stunted fronds, less than three inches tall, emerged. Lower rates did not prevent emergence early in the season but did kill the fronds later. A rate of 976 pounds per acre applied late in April had a greater effect on the buds per square yard than did applications two and four times greater made in January and February. Thus it appeared that the timing of the applications was more important than the rate of application in obtaining control.

An examination of plots containing the higher rates, 976 pounds per acre and greater, showed the buds growing abnormally in small clusters. The plots were denuded of all vegetation except for bluegrass which covered 30 per cent of the areas.

The April applications of a mixture of sodium borate and boron trioxide, 976 and 1,952 pounds per acre, had a greater effect on the fronds than earlier applications of lesser quantities. The number of buds per square foot was considerably larger than in the untreated plot. Clusters of buds appeared on the rhizomes. Seventy to ninety-five per cent of the grass remained uninjured on the plots.

A mixture of sodium pentaborate and sodium borate also controlled the fronds throughout the 1951 season. The number of buds in the plots was somewhat less than in the untreated plot, but too numerous to indicate effective control. Clustering of the buds was not observed in any of the plots. Grass covered 95 per cent of the area in the plots with the lower rates, 320 and 640 pounds per acre; while the 1,280 pounds per acre plot had 50 per cent grass cover.

Low rates of the commercial mixture of sodium pentaborate and sodium borate plus sodium chlorate, at a 3 to 1 ratio, were not effective in preventing emergence of the fronds. Late in the summer where 160 and 320 pounds per acre were applied the fronds died. A rate of 640 pounds per acre was not as effective as lower rates probably due to the variation in density of the infestation. Applications in May of 976 and 1,952 pounds per acre prevented emergence of the fronds. A rate of 1,952 pounds per acre was totally effective in controlling the bracken. One-fourth the area in the treated plot was excavated and all rhizomes and buds were completely dead. Application of 1,523 pounds per acre in January did not prevent emergence of the fronds and did not decrease the number of buds as did the next lower rate applied later in the season. The time of application was important in obtaining the maximum effect on the bracken. Prepared mixtures at a 3 to 1 ratio, 320 and 640 pounds per acre, gave results similar to those of the commercial preparation. The same rates of a 10 to 1 ratio were more effective. Emergence was prevented with 640 pounds per acre, but the rate was not large enough to destroy the buds. The grass flourished on all plots with 640 pounds per acre or less. In the plot treated with 1,952 pounds per acre only 5 per cent of the area remained in grass.

A mixture of sodium pentaborate and sodium borate plus sodium borate and boron trioxide, 1,152 pounds per acre, did not prevent the fronds from emerging. The fronds that emerged, however, were completely brown by September 2.

A prepared mixture of sodium pentaborate and sodium borate and sodium chlorate plus sodium borate and boron trioxide, at rates of 640 and 1,280 pounds per acre, prevented emergence of the fronds, but did not reduce the number of buds per square foot by September. At 640 pounds per acre 80 per cent of the plot was covered by grass, while at 1,280 pounds per acre only 40 per cent of the plot had grass.

Pre-emergent applications of 400 and 800 pounds per acre of sodium chlorate applied in March greatly reduced the number of fronds and buds. The fronds in these plots were two-thirds the size of the fronds in the untreated area. A rate of 381 pounds per acre applied in early January did not reduce the number or size of the fronds. Most of the grass was eradicated from the plots.

April applications of sodium trichloroacetate stunted all the fronds growing in the treated plots. A rate of 480 pounds per acre caused 50 per cent of the fronds that emerged to be killed; the remaining fronds were uninjured until the first frost. The number of buds per square foot in the plot receiving 480 pounds per acre was considerably less than in the plots sprayed with lower rates and all treatments had fewer buds than untreated plots. The number of fronds in each of the treated plots was greater than in the untreated plot; a stimulation of the formation of fronds apparently had taken place.

Ammonium sulfamate, at 320 pounds per acre, applied in December did not give control of the fronds. A rate of 320 pounds per acre applied in May did not completely prevent the fronds from emerging, but only four fronds appeared in the whole plot. These four fronds did not exceed fourteen inches in height. Ammonium sulfamate, at 480 pounds per acre, produced a similar effect with eight brown fronds. The fronds were eliminated for the entire season with 640 pounds per acre. In May, 320 pounds per acre gave fair control; 480 pounds per acre in March gave poor control. A rate of 640 pounds per acre in March resulted in a large increase in the number of buds. There was no clustering of the buds like that occurring with the borax compounds. The grass in all the plots treated with ammonium sulfamate was uninjured and in the March and May sprayed plots there appeared to be an increase as compared to the untreated areas.

Pre-emergent applications of 2,4-D did not eliminate the fronds entirely. The fronds that emerged were nearly all brown by September 5. 2,4-D (plus oil solvent) and 2,4,5-T had little affect on the number of fronds that emerged. The number of buds was not affected in the 2,4-D or 2,4,5-T plots.

Applications of maleic hydrazide, disodium-2,6-endoxohexahydrophthalate and ammonium sulfate, zinc sulfate, copper sulfate, dichloral urea, 2-chloro-6-nitro-toluene, isopropyl-n-phenyl-carbamate, and polyethylene chloride had no noticeable effects on the bracken fronds. Isoprophy-n-phenyl-carbamate and 10 pounds per of polythylene chloride gave reductions in the number of fronds, but as the higher rates of each compound showed little effects and the reductions were attributed to the variation in density of the infestation.

Cut- and Uncut-Emerging-Fronds

Good control of the fronds was had during the summer of 1950 with 160 pounds per acre of ammonium sulfamate when sprayed on the young unfolded fronds. Abundant new growth of fronds with distorted pinnae appeared later. A low rate of ammonium sulfamate also caused distortion of the pinnae and gave them a leathery appearance.

In 1951 ammonium sulfamate, at 160 pounds per acre, on the uncut plot gave only 75 per cent control of the fronds due to poor application. On the cut plot 95 per cent of the regrowth was killed. The pinnae were distorted and stunted. On the cut and uncut plots,

sprayed with 320 pounds per acre of ammonium sulfamate, no fronds grew for the entire season. The absence of fronds did not necessarily mean complete control of the bracken was obtained. Buds for the next year's crop of fronds were present in an amount approximately half that of the untreated plot. The number of buds in the plots receiving 160 pounds per acre showed little reduction. Both treatments where the fronds were cut gave slightly lower bud counts than the uncut plots.

Sodium chlorate did not prevent the emergence of the fronds, but within three months those that did emerge were all dead. The plot which was treated with 160 pounds per acre had the largest number of fronds and the greatest height, while the plot receiving 640 pounds per acre had fewer and shorter fronds. The regrowth was light green in color. The number of buds was not reduced to the point where complete control could be expected. The application of 640 pounds per acre to uncut fronds gave the best results with 2.66 buds per square foot. The data showed no correlation between the cut and uncut treatments.

In September, three months after application, 90 to 95 per cent of the fronds in all the sodium trichloroacetate plots were brown. The fronds emerged and appeared normal for two months, and then turned brown. Late regrowth did not turn brown. Leaching of the sodium trichloroacetate in the sandy soil apparently destroyed the fine mass of roots on the rhizomes. Late regrowth was apparently unaffected by this root destruction. The number of buds in both the cut and uncut areas did not show a large variation from those in the untreated area.

The low rate of 3-(P-chlorophenyl)-1,1-dimethyl urea had little effect on either fronds or buds. The high rate had no effect on the fronds, but the buds on the uncut plot were approximately twice the number of the untreated plot and had the clustered appearance similar to that occurring with the boron applications in the dormant treatments. These effects were not present on the cut plot possibly because of poor application at the time of spraying.

Eighty per cent of the fronds that emerged on the maleic hydrazide plots were brown at the time the frond counts were made. Later regrowth did not appear to be affected. The number of buds was greatly increased in three of the four treated plots. The low count in the high rate, uncut plot is attributed to poor application methods.

In general, the number of fronds on the 2,4-D and 2,4,5-T treated plots was increased as a result of the treatments. There was no consistency between an increase in the number of fronds and increases in the rate of application, nor between the cut and uncut plots. The young pinnae were distorted into a variety of oblong and narrow shapes. Many fronds which had extremely twisted stipes were killed. Distortions were prominent on all the fronds a week after spraying, but the regrowth displayed no effects of 2,4-D or 2,4,5-T whatsoever, indicating that the growth regulators were not translocated to the buds in toxic amounts. Variations occurred in the results obtained with the three formulations of 2,4-D. With an increase in the number of fronds there also was an increase in the number of buds per square foot in the 2,4-D amine plots. The opposite was found with the other formulations. Cucumber seedling tests showed the presence of growth inhibiting in the buds. There was no correlation between the per cent reduction of cucumber root length and the number of buds per square foot or fronds per square yard.

The commercial mixture of pentachlorophenol, trichloroacetic acid and 2,4-dichlorophenoxyacetic acid appeared to have no other effect than that of a contact herbicide. The fronds that were present on the plots at the time of spraying were killed, but the subsequent regrowth was unaffected.

The various rates of isopropyl-n-phenyl carbamate showed no effects on the young fronds present nor on the regrowth. The number of buds per square foot also appeared to be unaffected.

Cut- and Uncut-Mature-Frond

Applications of 160, 320 and 480 pounds per acre of ammonium sulfamate on plots with mature fronds and on those which the fronds had been cut eliminated the fronds completely for the remainder of the growing season. The number of buds per square foot appeared to be reduced, but not in proportion to the amount of chemical used. The bromegrass planting flourished on the 160 pounds per acre plot,

was slightly reduced on the 320 pounds per acre plot and almost totally killed on the 480 pounds per acre plot.

The combination of ammonium sulfamate, at 160 pounds per acre, and 2,4-D or 2,4,5-T, at 10 pounds per acre, killed the fronds present on the uncut plot and prevented the emergence of any further regrowth on both plots. The bud counts showed only slight reductions. The bromegrass planting was slightly reduced.

The fronds on the uncut plot treated with 2,4-D (plus oil solvent), at 80 gallons per acre, were killed at the time of spraying, but regrowth on this plot, and on the cut plot occurred. The number of buds on the plot left uncut showed a slight increase and the cut plot showed a slight decrease as when compared to the check plot. The bromegrass was unaffected by the chemical.

Sodium chlorate sprayed at rates varying from 20 to 640 pounds per acre killed all the fronds present on the uncut plots and prevented further emergence of the fronds on all the plots for the remainder of the season. The number of buds on the plots treated with 20 and 40 pounds per acre was only slightly reduced, while on the plots with 160, 320 and 640 pounds per acre the buds were reduced by one-third or less. The plot with 640 pounds per acre did not appear to be more effective than the plots with 160 pounds per acre nor was there any conclusive evidence that the sprays were more effective on the plot which was cut than those left uncut. The bromegrass plantings were entirely exterminated on all plots.

In 1950 a water-soluble mixture of sodium pentaborate and sodium borate to which sodium chlorate was added at a ratio of 10:3 was sprayed at the rates of 80 and 160 pounds per acre on the mature fronds. All the fronds were killed and further emergence was prevented.

The commercial mixture of sodium pentaborate and sodium borate plus sodium chlorate, at 640 and 1,280 pounds per acre, gave good control of the fronds, preventing further emergence. The bud counts were greatly reduced. No correlation between the cut and uncut plots appeared. The bromegrass planting was reduced only slightly.

Sodium trichloroacetate at 160 and 320 pounds per acre killed the fronds on the uncut plots and prevented the emergence of regrowth, with the exception of one frond in each of the four treated plots. Similar results were obtained in 1950 using 160 pounds per acre. All but one of the four plots had reduced bud counts; this normal-appearing plot could not be accounted for. The chemical killed nearly all the bromegrass sowed in each of the two plots.

Fronds treated with dinitro-o-sec-butyl phenate (ammonium salt), at 4 and 8 pounds per acre, were completely killed. Regrowth on both plots cut and uncut showed no injurious effects. The bud counts on the plots uncut showed considerable reductions over those cut plots indicating possible translocation to the rhizome system. The bromegrass was greatly reduced in both plantings.

Dinitro-o-sec-butyl phenate (amine salt), at 4 and 6 pounds per acre, gave 100 per cent browning in all plots and prevented

regrowth for the remainder of the season. The number of buds in each treated plot was less than in the check plot. There were no distinct differences between the plots cut and uncut. The bromegrass was partially killed at the low rate, but almost entirely killed at the high rate.

At 80 gallons per acre trichlorobenzine only partially browned the fronds on the uncut plot. Regrowth, showing no effects on the chemical, appeared on both plots. No bud counts were taken. Only a very small amount of bromegrass was present.

Plowed-Rhizome

Chemical treatment of the freshly plowed rhizomes, using ammonium sulfamate at 160 and 320 pounds per acre, did not give complete control even with repeat applications made one month later. The fronds in the 320 pounds per acre plot were greatly stunted, none reaching a height greater than eight inches. Both bromegrass plantings were greatly reduced.

Some browning occurred on the fronds in the plots treated with diesel oil, at 40 gallons per acre, but a complete kill was not obtained. The number of fronds appearing was reduced to nearly half the number in the untreated plot. The bromegrass was uninjured.

Sodium chlorate, at 160 and 320 pounds per acre, gave reasonable control of the fronds. Several stunted fronds appeared late in the season on each of the plots. The bromegrass was unaffected two months after application of the chemical.

Sodium trichloroacetate, at 80 and 160 pounds per acre, killed several of the fronds shortly after they emerged. Those fronds present at the time of the second application were killed. Regrowth appeared abundantly after the second spraying. The bromegrass was nearly all killed at both rates.

2,4-D, at 1 and 2 pounds per acre, did not prevent emergence of the fronds, but they were reduced in number. The repeated spray partially browned the fronds present. This was probably due to the carrying agent, diesel oil. The plots treated with 2,4,5-T, at 1 and 2 pounds per acre, responded in the same manner. The bromegrass was uninjured.

The commercial preparation of 2,4-D (in oil solvent), at 20 and 40 gallons per acre, caused some of the earlier emerging fronds to die. The later emerging fronds were unaffected. The bromegrass was not affected.

The number of fronds in the second part of the experiment was almost nil on the check plot and marginal area surrounding the treated area and it is assumed that plowing the rhizomes in the middle of the summer drought resulted in the obvious lack of fronds. Repeated treatments were not made in this part of the experiment. Each of the plots usually had at least one or two fronds.

The results of the bromegrass plantings varied. The diesel oil check did not injure the grass seedlings. Dinitro-ortho-secondary-butyl phenate (ammonium salt) slightly reduced the germination at both rates. Isopropyl-n-phenyl-carbamate, at 5 and 10 pounds per acre, killed all the seedlings. While the low rate of maleic hydrazide did not cause injury the high rate was effective in causing a slight reduction. 3-(P-chlorophenyl)-1,1-dimethyl urea at the high rate reduced germination and almost completely destroyed all the young, grass seedlings.

Foliage

Visual estimates of the percentage kill of the fronds made with the contact sprays varied from 0 to 100 per cent. As most of the sprays were applied using low volumes and the density of the fronds varied considerably, percentages ranging from 90 to 100 per cent were acceptable as giving good control. The herbicides that gave good control when applied at the following rates per acre are: ammonium sulfamate, at 40 and 80 pounds per acre; ammonium thiocyanate, at 80 and 160 pounds per acre; calcium cyanamid, at 200 pounds per acre; calcium trichloroacetate, at 40 and 80 pounds per acre; diesel oil, at 80 gallons per acre; isopropyl-n-phenyl-carbamate (emulsifiable), at 1 and 2 pounds per acre; disodium-3,6-endoxohexahydrophthalate, at 5 and 10 pounds per acre; disodium-3,6-endoxohexahydrophthalate plus ammonium sulphate, at 10 pounds per acre; octochlorocyclohexenone, at 2½ and 5 pounds per acre; pentachlorophenol, at 8 and 16 pounds per acre; phenyl mercuric acetate, at 10 and 20 pounds per acre; polyethylene chloride, at 5 and 10 pounds per acre; potassium cyanate, at 16 pounds per acre; sodium chlorate, at 40 and 80 pounds per acre; sodium chloride, at 100 and 200 pounds per acre; sodium pentaborate and sodium borate plus sodium chlorate, 3 to 1 ratio, at 40 and 80 pounds per acre; sodium pentachlorophenate (ammonium salt), at 8 and 16 pounds per acre; sodium trichloroacetate, at 40 and 80 pounds per acre; sodium trichloracetate (ester), at 6 and 12 pounds per acre; sulphuric acid, mixtures of 2½ and 5 per cent at 100 gallons per acre; commercial preparation of trichloroacetic acid, pentachlorophenol and 2,4-dichlorophenoxyacetic acid, at 20 and 40 gallons per acre; trichlorobenzine, at 80 gallons per acre; 2-choro-6-nitrotoluene, at 160 and 320 pounds per acre; xanthogen disulphide, at 5 and 10 pounds per acre; and xylene and ethylbenzine mixture, at 80 gallons.

The herbicides which were effective in giving 100 per cent control at the low rate should be used at reduced rates to determine the lowest rate at which toxicity will occur. Those chemicals which were not effective in maintaining good control should be used at higher rates, i.e., where economically feasible.

Direct-Rhizome

The evidence obtained from direct applications of 2,4-D and 2,4,5-T to the rhizomes indicated that translocation does occur. Tissue from all dilutions showed some reduction of cucumber seedling root length. The samples taken nearest the solution bags had the

greatest concentration of herbicide present; those farthest from the bags contained a lesser amount. It was observed that five weeks after application the fronds attached to the treated rhizomes had been killed for a distance of several feet.

VI. DISCUSSION OF THE RESULTS - SECOND YEAR

Visual observations made in the second year, 1952, showed that rates of 3,917 and 1,958 pounds per acre of mixtures of anhydrous sodium borate and boron trioxide in the dormant applications were uneffective in obtaining complete control of the bracken. At the high rate a few stunted fronds emerged; the plot treated at low rate likewise contained fronds. The 480 pounds per acre of ammonium sulfamate did not give complete control of the fronds. The number of fronds were few and stunted, possibly due to the fact that the grass was successfully competing with the bracken. Although the brush in the sodium trichloroacetate plots was entirely dead the fronds were numerous. Four fronds were present in the plot treated with the mixture of sodium pentaborate and sodium borate plus sodium chlorate, at 1,952 pounds per acre. This was attributed to an invasion of the rhizomes surrounding the plot.

In the cut- and uncut-emerging-frond plots ammonium sulfamate, at 320 pounds per acre and sodium chlorate, at rates of 160, 320 and 640 pounds per acre, gave complete control of the bracken. Some stunting of the fronds was noted in the sodium trichloroacetate plots.

The bracken was completely controlled in the cut- and uncut-mature-frond plots with sodium chlorate, at rates of 160, 320 and 640 pounds per acre; ammonium sulfamate, at 160 pounds per acre; ammonium sulfamate plus 2,4-D, at 160 pounds per acre and 10 pounds per acre;

ammonium sulfamate plus 2,4,5-T, at 160 pounds per acre and 10 pounds per acre; and a mixture of sodium pentaborate and sodium borate plus sodium chlorate, at 1,280 pounds per acre. Satisfactory control was obtained with ammonium sulfamate, at 320 pounds per acre and sodium pentaborate and sodium borate plus sodium chlorate, at 640 pounds per acre. Better results were obtained with 160 pounds per acre than with 320 pounds per acre of ammonium sulfamate and were possibly due to the latter presence of a litter of leaves covering the plots receiving the latter amount. One hundred and sixty pounds per acre of ammonium sulfamate did not give complete control at Big Rapids in 1950, but did at East Lansing in 1951. The greater density of the infestation at Big Rapids probably was the reason for the failure at this location.

In the plowed rhizome area which had a repeat application, the sodium chlorate, at 320 pounds per acre, plot contained a few fronds and the ammonium sulfamate plot, treated with two applications of 320 pounds per acre, was satisfactorily controlled, having only two fronds. The area plowed during the drought had fronds growing in all plots.

VII. CONCLUSIONS

Dormant or pre-emergent applications were not effective in obtaining the complete eradication of the bracken fern. Time of spraying and density of the infestation are important factors. Late applications appeared to be more effective. Areas where the rhizomes are more numerous require a greater concentration of the herbicide. The various boron compounds were approximately equal in their toxicity; rates of 320 pounds per acre, applied in late April and May are effective in controlling the fronds for the remainder of the season. Combinations of boron compounds and sodium chlorate have a greater herbicial value than boron compounds alone. Rates of approximately 2,000 pounds per acre gave complete eradication. Early applications of sodium chlorate gave only partial control of the fronds. Applications of ammonium sulfamate, at 320 pounds per acre, in May, and, at 480 pounds per acre, in March, did not completely destroy the fronds, but allowed the grass present to become well-established and crowd out the fronds.

The bracken can be successfully controlled with 320 pounds per acre of ammonium sulfamate, applied when the fronds are emerging. Sodium chlorate, at 160 pounds per acre, will eradicate the bracken. 2,4-D and 2,4,5-T affected the emerging fronds, but did not give control. Sodium trichloroacetate destroyed the emergent fronds with little effect on the next year's growth.

Mid-summer application to the mature fronds is the easiest time to completely control the fern. Ammonium sulfamate, at 160 pounds per acre; ammonium sulfamate plus 2,4-D or 2,4,5-T, at 160 and 10 pounds per acre respectively; sodium chlorate, at 160 pounds per acre; and a mixture of sodium pentaborate and sodium borate plus sodium chlorate, at 1,280 pounds per acre, gave complete control. Satisfactory control was obtained with a mixture of sodium pentaborate and sodium borate plus sodium chlorate, at a rate of 640 pounds per acre.

Two sprayings of ammonium sulfamate, at 320 pounds per acre, gave satisfactory control in the plowed-rhizome treatments. The plowing of bracken during a drought does not give complete eradication.

Many herbicides have been found to kill the fronds when applied at relatively low volumes. Absorption of dilute solutions of 2,4-D and 2,4,5-T in direct contact with the rhizomes and translocation through the rhizome was observed.

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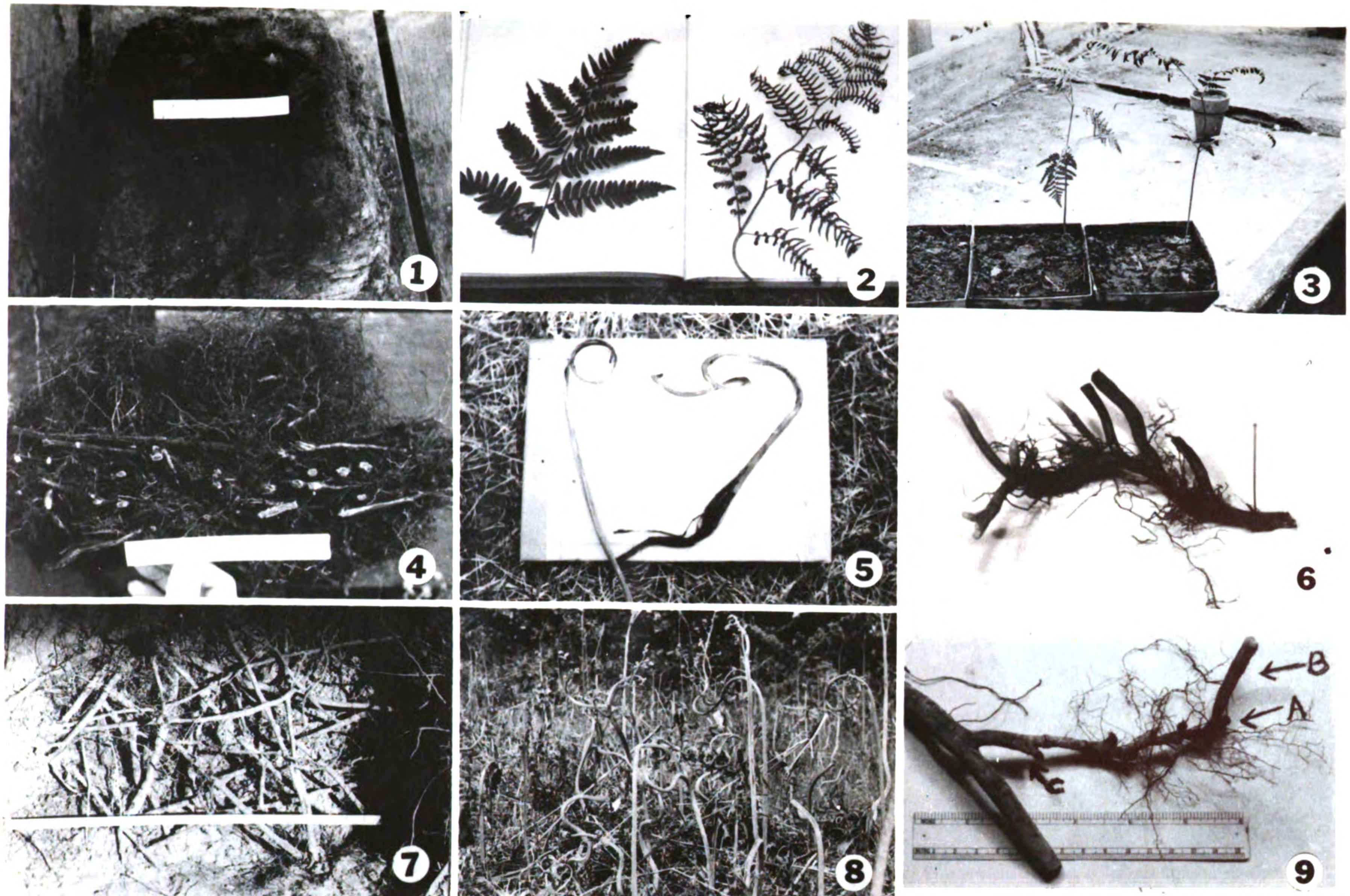
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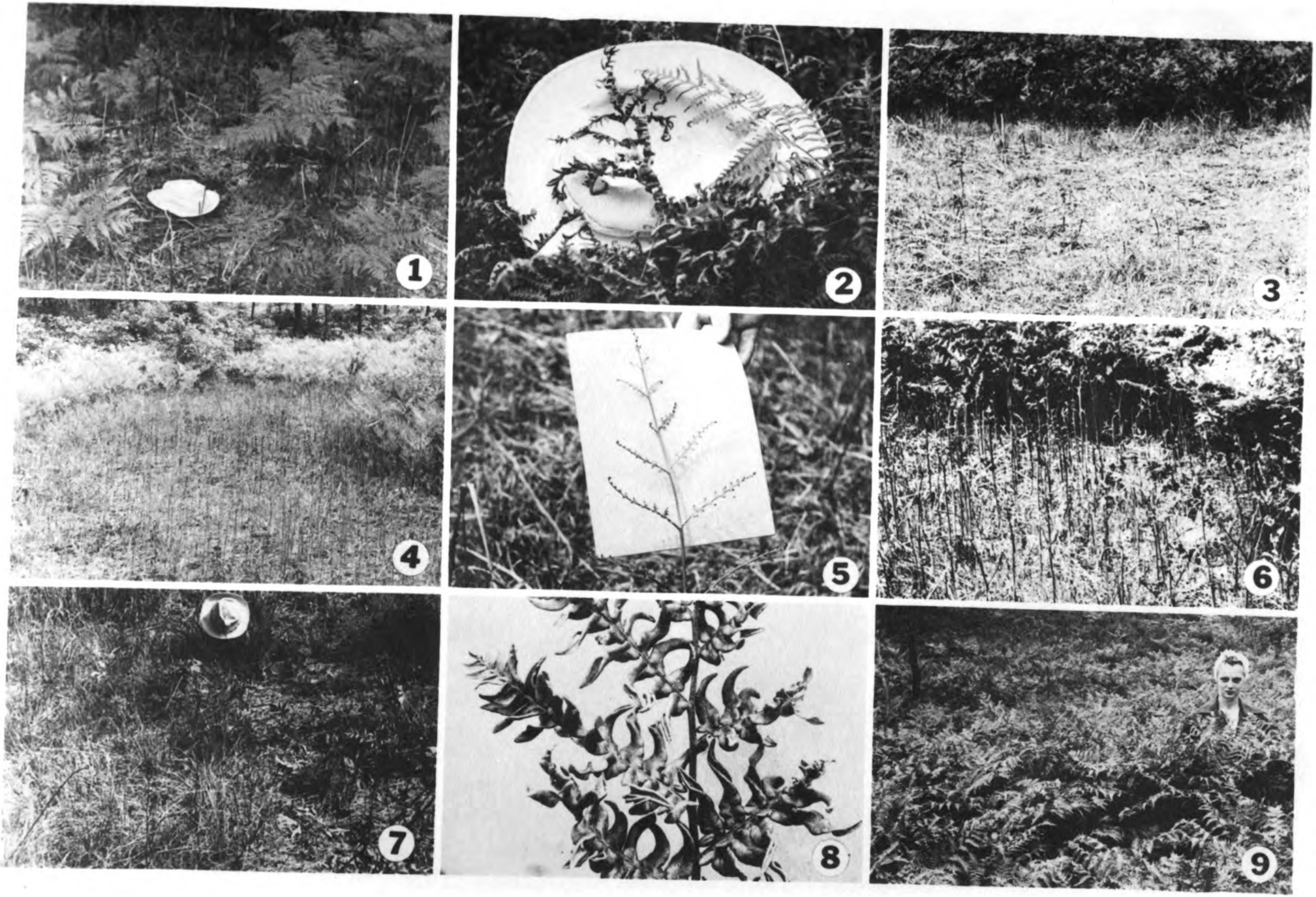
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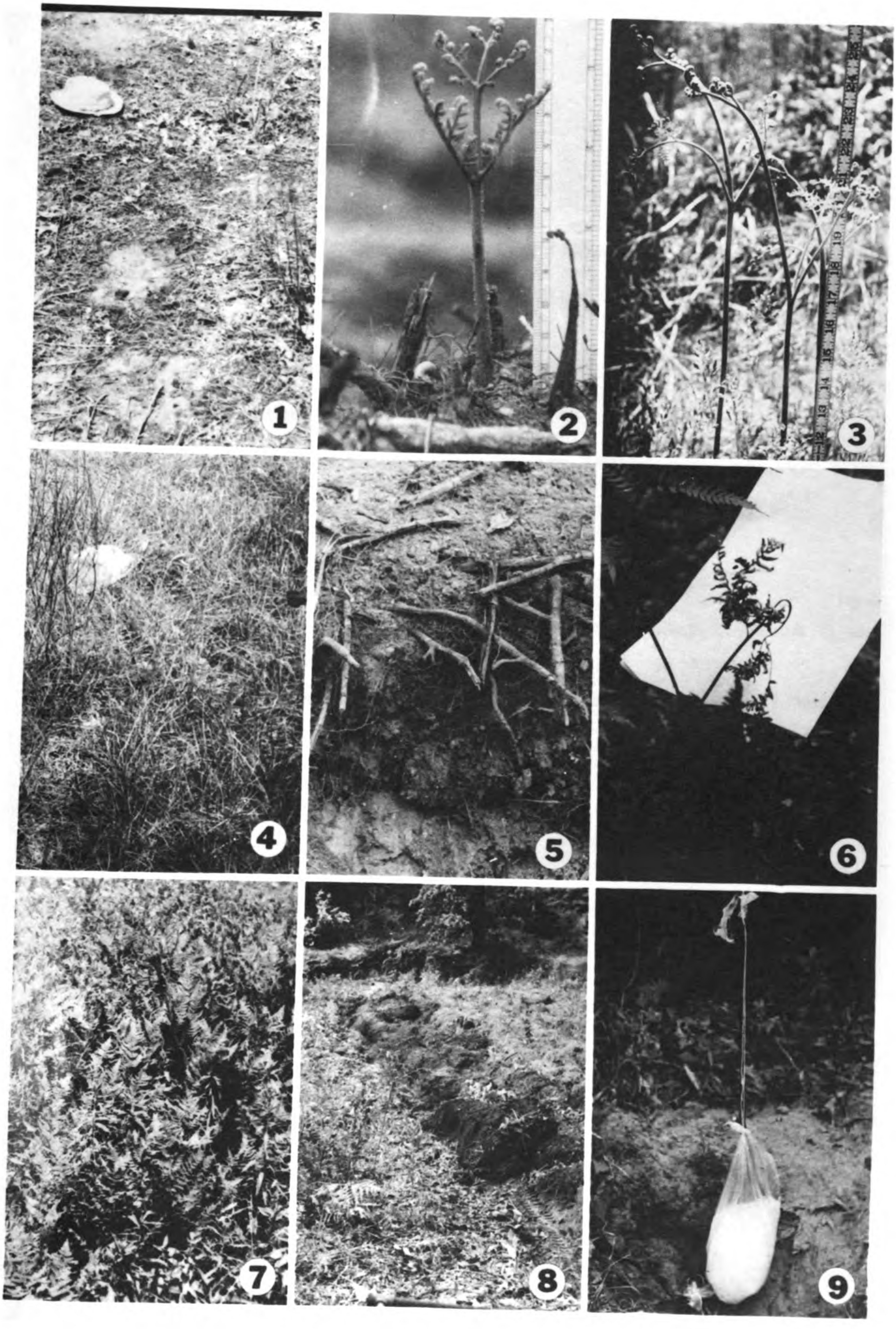
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APPENDIX

PLATE I

1. Cubic foot of soil from a bracken infestation.
2. (Left) Portion of normal frond (Right) Portion of frond affected by 2,4-D.
3. Wilting of the pinnae caused by 2,4-D applied to rhizome.
4. Roots and rhizomes from a cubic foot of soil.
5. Fronds killed by 2,4-D in the emerging stage.
6. Abnormal clustering of buds from a plot treated with a high rate of boron mixture.
7. Habit of rhizomes in an infestation.
8. Twisted fronds, 24 hours after being treated with 2,4-D in emerging stage.
9. Lateral branch showing: A. Terminal bud; B. Frond bud; and C. Dormant bud.

PLATE II

1. Regrowth in plot treated with 2,4-D (in oil solvent), at 80 gallons per acre, applied when fronds were mature.
2. (Left) Frond killed by sodium trichloroacetate, at 320 pounds per acre, applied when fronds were emerging.
   (Right) Normal frond.
3. Effects of ammonium sulfamate, at 320 pounds per acre, on regrowth.
4. Effects of sodium chlorate when applied at 320 pounds per acre to the emerging fronds.
5. Effects of ammonium sulfamate, at 160 pounds per acre, on regrowth, applied when fronds were emerging.

6. Regrowth of fronds in plot treated with 160 pounds per acre of ammonium sulfamate, applied on the emerging fronds.

7. (Left) A mixture of anhydrous sodium pentaborate and sodium borate, at 976 pounds per acre, in the dormant treatments. (Right) A 3 to 1 mixture of sodium pentaborate and sodium borate plus sodium chlorate, at 1,952 pounds per acre, in the dormant treatments.

8. Effects of ammonium sulfamate, at 80 pounds per acre on the pinnae, applied when emerging.

9. Bracken infestation at Big Rapids.

PLATE III

1. Dormant application of sodium pentaborate and sodium borate plus sodium chlorate at 320 pounds per acre.

2. Regrowth in the plowed-rhizome plot treated with ammonium sulfamate at 320 pounds per acre.

3. Young fronds prior to unfolding.

4. Grass flourishing in dormant plot treated with ammonium sulfamate at 480 pounds per acre.

5. Rhizomes exposed by plowing.

6. Frond affected by 2,4-D in direct-rhizome application.

7. Untreated area.

8. Area being prepared for plowed-rhizome applications.

9. Direct-rhizome method and materials.