MONTANA STATE UNIVERSITY

Growth regulating substances for the control of weeds in Kentucky bluegrass lawns
by Jesse M Hodgson

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the degree of Master of Scienoe In Agronomy
Montana State University
© Copyright by Jesse M Hodgson (1946)

Abstract:
This Investigation consisted of a study of the chemical growth regulator 2,4-Dichlorophenoxyaoctie acid as a selective herbicide for the control ef weed in lawns. The most effective method and time of application were studied by comparing average percentage kills obtained when three rates and three concentrations were applied on three different dates during the growing season. The lawn weeds on which tests were conducted, were as fellows. dandelion (Taraxioum officinale), buekhern plantain (Plantago lanceolate), common chickened (StellarTa media), and mouce-ear-chickweed (Corastium Vulgaturn). In addition to the field study, the effect of 8,4-D on the germination of the seeds ef weed and crop species was determined in the laboratory.

Dandelion was found to be quite susceptible to 8,4-D. The earliest date of treatment (June 4) gave the best control. The difference in percentage kills of this and the other dates were significant as determined by statistical analysis. The heavier applications (.1 per cent concentration at 2 gallons per square rod and .2 per cent concentration at 1 1/2 gallons per square rod) gave the highest percentage kills but because of inhibition of the grass and the necessity of additional treatments to control new seedlings, the lighter applications (.1 per cent at 1 1/2 gallons per square red) are more practical.

Buekhorn plantain was also found to be quite susceptible to 2,4-D. The percentage kills of the June 4 treatments were 11 per cent higher and differed significantly from the July Q treatments. The heavier applications again gave better control ef this weed, but as in the ease of dandelion, the lighter applications would secs more economical.

Common and mouse-car-chickweed showed definite resistance to the 8,4-D treatments. Applications made August 5, showed this to be the best time of application that was studied. Successive treatments ef 8,4-D on chickwoods made within four weeks did not control this weed satisfactorily. The heavier applications (.2 per cent concentration at 1 1/2 gallons per square rod) in both tests of different rates and successive treatments, were the only treatments which were at all promising although they were still unsatisfactory for control.

Two, 4-D was found to inhibit germination of weed and crop seeds. Germination was inhibited by 2,4-D treatment for all species tested. The oats sprouted and developed chlorotic epicetyla, however seminal root development was definitely inhibited. Alfalfa, pigweed, dutch white clover and Kentucky bluegrass were found to have viable seeds after the 2,4-D treatment.

GROWTH REGULATING SUBSTANCES FOR
THE CONTROL OF WEEDS IN KENTUCKY BLUEGRASS LAWNS

by

Jesse M. Hodgson

A THESIS

Submitted to the Graduate Committee

in

partial fulfillment of the requirements

for the degree of

Master of Science in Agronomy

at

Montana State College

Approved:

A. H. Post
In Charge of Major Work

A. H. Post
Chairman Examining Committee

J. A. Nelson
Chairman Graduate Committee

Bozeman, Montana
November 1946

~~RESTRICTED STACK~~
N378
H668g
cop.2

ACKNOWLEDGEMENT

The writer wishes to acknowledge his indebtedness to Mr. A. H. Post under whose direction this investigation was made and express appreciation for his help and suggestions in designing and reporting the experiments. The writer also wishes to express his appreciation to Dr. Herman K. Schultz, who supervised the method of analysis of the data.

81296

g Graduate Committee

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

LIST OF TABLES

GROWTH REGULATING SUBSTANCES FOR THE CONTROL OF WEEDS IN KENTUCKY BLUEGRASS LAWNS

Abstract

This investigation consisted of a study of the chemical growth regulator 2,4-Dichlorophenoxyacetic acid as a selective herbicide for the control of weeds in lawns. The most effective method and time of application were studied by comparing average percentage kills obtained when three rates and three concentrations were applied on three different dates during the growing season. The lawn weeds on which tests were conducted, were as follows: dandelion (Taraxicum officinale), buckhorn plantain (Plantago lanceolata), common chickweed (Stellaria media), and mouse-ear-chickweed (Cerastium Vulgatum). In addition to the field study, the effect of 2,4-D on the germination of the seeds of weed and crop species was determined in the laboratory.

Dandelion was found to be quite susceptible to 2,4-D. The earliest date of treatment (June 4) gave the best control. The difference in percentage kills of this and the other dates were significant as determined by statistical analysis. The heavier applications (.1 per cent concentration at 2 gallons per square rod and .2 per cent concentration at 1½ gallons per square rod) gave the highest percentage kills but because of inhibition of the grass and the necessity of additional treatments to control new seedlings, the lighter applications (.1 per cent at 1½ gallons per square rod) are more practical.

Buckhorn plantain was also found to be quite susceptible to 2,4-D. The percentage kills of the June 4 treatments were 11 per cent higher and differed significantly from the July 6 treatments. The heavier applications again gave better control of this weed, but as in the case of dandelion, the lighter applications would seem more economical.

Common and mouse-ear-chickweed showed definite resistance to the 2,4-D treatments. Applications made August 3, showed this to be the best time of application that was studied. Successive treatments of 2,4-D on chickweeds made within four weeks did not control this weed satisfactorily. The heavier applications (.2 per cent concentration at 1½ gallons per square rod) in both tests of different rates and successive treatments, were the only treatments which were at all promising although they were still unsatisfactory for control.

Two, 4-D was found to inhibit germination of weed and crop seeds. Germination was inhibited by 2,4-D treatment for all species tested. The oats sprouted and developed chlorotic epicotyls, however seminal root development was definitely inhibited. Alfalfa, pigweed, dutch white clover and Kentucky bluegrass were found to have viable seeds after the 2,4-D treatment.

GROWTH REGULATING SUBSTANCES FOR THE CONTROL OF WEEDS IN KENTUCKY BLUEGRASS LAWNS

Jesse M. Hodgson

INTRODUCTION

Weeds cause tremendous annual losses by lowering crop yield and quality, reducing land values, crowding out desirable turf grasses and increasing the cost of production. They act as a tax on agricultural land, park recreation areas and private gardens and lawns. According to Taylor (35), these losses approach $3,000,000,000 annually. This annual loss is estimated to be larger than the combined losses caused by insects and diseases to both man and animals.

Although lawn and turf weeds constitute only a small portion of the weeds causing losses in the United States, there is considerable interest in the development of methods for their control. In recent years increasing attention has been given to the eradication of lawn weeds by means of chemicals. Chemical sprays that will eradicate weeds in lawns or turfs and not injure the grass, may be considered as selective herbicides. The use of such chemicals is not new, but there has been an increasing interest in their use because of new chemicals appearing on the market, particularly sinox and the growth regulating substances including 2,4-Dicholorphenoxyacetic acid. The abbreviation generally used for this acid is 2,4-D. The abbreviation will be used mostly in this paper.

Many of the earlier selective herbicides such as iron sulfate, ammonium sulfate, etc., have given fair results for certain weeds and under certain conditions. However, results have not been consistent and it is believed that better selective herbicides can be developed that will have wider adaptation. The new selective herbicide, 2,4-Dichlorophenoxyacetic acid, is a growth regulating substance which was first shown to have weed killing properties by Zimmerman and Hitchcock (44). They found that it was more effective as a weed killer than any of the other growth regulating substances tested.

This chemical was first tested on a field basis in Montana and other states in 1945. Since this substance is effective for the control of certain weeds and is toxic to many cultivated crops, it seemed advisable to determine the scope of its use in this area.

The investigations reported in this paper include the physiological effect of 2,4-D on weed and crop seeds and plants, and the effectiveness of different rates, concentrations and dates of application on the control of the following lawn weeds: dandelion (*Taraxicum officinale*, Weber), broad-leaved or common plantain (*Plantago major*, L.), buckhorn plantain (*Plantago lanceolata* L.), common chickweed (*Stellaria media* (L) Cyrill), and mouse-ear-chickweed (*Cerastium vulgatum*, L.).

LITERATURE REVIEW

The principle of selective weed killing has been known for over a half century. Iron sulfate was one of the first chemicals to be used as a selective herbicide on lawns and turfs. Many other substances have since been investigated for their value as selective sprays for lawns and other grass-like plants used for cropping purposes. Some of the substances which have been investigated as selective lawn weed sprays are: iron sulfate, sodium chlorate, sodium arsenite, kerosene, gasoline, ammonium sulfate, and sinox.

Early investigations of iron sulfate were made by Bolley (6). He stated that iron sulfate prevented dandelion from setting seeds when four sprays were applied in one season, however, the plants were not all killed. Adams (1) found that by spraying four or five times with iron sulfate, dandelion could be practically eradicated and that common chickweed (*Stellaria media*) was killed in his tests and could be controlled by the use of iron sulfate. French (8) and other investigators report that the leaves of dandelion quickly blackened but that plants resprouted from the roots even after several treatments with iron sulfate. French sprayed twelve times in two years without killing the stronger dandelion plants. On the other hand, Munn (30) and Longyear (17) reported satisfactory control with three or four treatments when properly applied. Loomis (18) achieved as high as forty per cent control with a single application of iron sulfate and heavy fertilization under favorable conditions. Under less favorable conditions three applications gave no control of dandelions.

The killing action of iron sulfate is probably due to the starvation of the roots by repeatedly removing the foliage rather than poisoning the plant. This is also characteristic of ammonium sulfate and the other fertilizer type chemicals used in controlling lawn weeds. Considering the number of applications of iron sulfate necessary, and the great inconsistency in the results reported, it is doubtful if this chemical should be used as a selective spray since other chemicals have proven more effective.

Kerosene has in recent years received much attention as a selective spray, especially on lawn weeds. Loomis (18) reports that results with kerosene and other distillates used on the Iowa State College campus, gave from 50 per cent mortality of dandelions from a single application and serious injury to the grass to 100 per cent mortality of the dandelions and no permanent injury to the bluegrass or white clover sod. The kind of kerosene and the weather at and after the time of application appears to be the factors that determine the success or failure of the treatment. Litzenberger and Post (21), in a test involving selective chemicals, found Meo-181 and kerosene to be the most satisfactory for eradication of dandelion and broad leaved plantain, while lawn sinox was the best for the control of common and mouse-ear-chickweed. Straight water-white kerosene applied once in the fall at the rate of 1½ and 1 3/4 gallons per square rod, were the most effective rates, giving 85.3 and 87.7 per cent kills respectively, for the years tested. They recommended that the time of application should be between September 20 and October 1,in Montana.

Meo-181 is a commercial product with a kerosene base. Litzenberger and Post (21) found this chemical to be about 15 per cent more effective than kerosene, but much higher in cost.

Sinox or sodium dinitro ortho cresylate was first used as a selective weed killer in France in 1933. In 1938 Raynor (32) and Westgate and Raynor (43)in 1940 used sinox as a selective spray to control certain lawn weeds at Davis, California. Westgate and Raynor (43) reported that a 1:20 dilution by volume with water was required to kill dandelions successfully when used at the rate of 3/4 gallon per 100 square feet. Common plantain was successfully controlled with two applications of a 1:28 dilution at 1 gallon per 100 square feet.

On the basis of the results obtained by Litzenberger and Post (21) in tests in Montana, sinox, lawn sinox, and lawn sinox-ammonium sulfate combinations were not effective in one or two applications for the eradication of dandelion. Single applications killed only the tops of the plants.

Welton and Carrol (11) report effective control of lawn weeds by sinox from tests made in 1938 and 1939. One application of a 2 per cent solution made at the rate of 10 gallons per 1000 square feet , killed ground-ivy, speedwell, and heal-all. Two applications killed buckhorn plantain and three applications killed broad-leaved plantain and most of the dandelion. Harris (13) recommended sinox-ammonium sulfate combinations over any other chemical or method used for lawn weed control. Broad-leaved plants such as dandelion, broad-leaved plantain, buckhorn plantain and the chickweeds, were the most successfully controlled. One application of 1 pint of sinox to

$3\frac{1}{2}$ pounds of ammonium sulfate in 6 gallons of water to 400 square feet, followed in two to three weeks with a second application of 2 ounces of sinox to 2 ounces of ammonium sulfate solution in one gallon of water, was the method he recommended.

Sodium chlorate is normally thought of as a soil sterilant, however, several investigators report its use in very light concentrations and repeated applications capable of controlling certain lawn weeds without destruction and permanent injury to the grass. Welton (42) stated that ground-ivy and speedwell were easily destroyed with a single spray of 1 to 2 ounces in one gallon of water, this quantity applied to 100 square feet. The spray discolored the grass but did not result in permanent injury. Litzenberger and Post (21) found sodium chlorate unsatisfactory for the control of chickweeds in a grassed area as when the solution was made strong enough to eradicate the chickweed, considerable grass was eradicated also. Welton and Caroll (41) with four applications of a one-half per cent solution of sodium chlorate, killed mouse-ear-chickweed and the grass was not killed. They also reported that common chickweed was killed with this strength solution of sodium chlorate, but did not mention the number of applications necessary.

Since the announcement in 1944 of the use of growth regulating substances as weed killers by the United States Department of Agriculture, many investigations have been and are being conducted to assure its most effective use in controlling weeds. The use of growth regulating substances on plants had previously been directed mostly towards improving their performance in terms of usefulness such as increasing fruit set, preventing premature dropping of fruit, speeding the rooting of cuttings and developing fruits which are seedless. Capitalizing on the fact that certain growth substances were toxic to plants in concentrations greater than those used to secure these desirable results, Mitchell and Hammer (27) suggested the possibility of growth regulating substances as selective herbicides, since species and varieties of plants show wide differences in the degree to which they react or respond to the various substances.

Because plant growth regulators operate on the principle of growth regulation rather than caustic action or poisoning, they are translocated throughout the plant and the killing action takes place internally. Special significance is given to this method of killing when such plants as bindweed (Convolvulus arvensis) and perennial sow thistle (Sonchus arvense), which regenerate by producing underground roots, are killed. The first tests by Hamner and Tukey (10) demonstrated that 2,4-Dichlorophenoxyacetic acid, and 2,4-5 Trichlorophenoxyacetic acid were selective herbicides. One thousand ppm and 500 ppm of 2,4-D were effective in killing perennial bindweed on nursery fruit trees. Similar concentrations of 2,4-5 T also possessed almost equally effective herbicidal properties against these weeds.

Two,4-D and probably other growth regulating substances, has several advantages over most of the established herbicides. It is non-inflammable, non-corrosive and has proven in numerous tests to be non-toxic to man and animals as reported at the North Central States Weed Control Conference (40). Another remarkable property of 2,4-D and related compounds, is the fact that they are so destructive to many plants in small amounts. One level teaspoon of the chemical properly dispersed or distributed, is sufficient to kill all susceptible weeds in 100 square feet of area. At very light concentrations

(10 ppm or less) growth regulators may be used to produce beneficial effects. Increased concentrations of 100 to 1000 ppm of 2,4-D stimulates abnormal growth and causes death to many plants. The usual rate of application for weed control is $\frac{1}{4}$ to $\frac{1}{2}$ ounce per square rod; therefore one pound incorporated into a spray, would cover from 32 to 64 square rods compared with $\frac{1}{4}$ to $\frac{1}{2}$ square rod for such chemicals as sodium chlorate, sodium arsenite and ammonium sulfate.

Broad leaf type plants are found to be most susceptible to the responses induced by 2,4-D, while grass-like plants generally have exhibited resistance. Hildebrand (14) reports that tomatoes are killed by a solution containing 100 ppm, while Kentucky bluegrass has withstood 10,000 ppm, or a 1 per cent solution of 2,4-D.

Under favorable conditions, plants which are susceptible to 2,4-D show various responses when treated with it. First evidence of injury after treatment, may not appear until 24 to 48 hours later. These first responses are usually acute curvature of stems and leaves. Later proliferated, pithy or tumor-like tissues may develop rapidly in the stems and roots, causing enlargement and splitting. Then in 10 to 30 days, gradual yellowing and death takes place.

Movement of the 2,4-D stimulus was studied by Mitchell and Brown (26) in tests with kidney bean plants. Plants whose sugar content was relatively low, such as those exposed to extended periods of darkness, or CO_2 free light, did not readily translocate a stimulus after treatment with 2,4-D. The stimulus apparently moved in a continual flow under favorable conditions for carbohydrate translocation. They concluded that movement of the 2,4-D stimulus was closely associated with translocation of organic food materials in bean plants.

Mitchell and Brown (26) also found that bean plants which had developed a marked response to applications of 2,4-D, recovered when the treated portions were removed a few hours after treatment. This would indicate that treated leaves of such plants as dandelion, plantain or the tops of other deep rooted weeds should not be mowed too soon following treatment with 2,4-D, since the effectiveness of the treatment might in this way be reduced.

An early view was that this chemical caused the plants to grow themselves to death. Experiments by Mitchell and Brown (26) have shown that treated plants do not grow, they cease growing. They concluded that plants die because their food reserves are depleted or burned up. In their experiment, the roots of dandelion and morning glory died because of food depletion within two weeks. They had disintegrated within two months. Tukey and Hamner (36), however, observed activated cell division in the vascular bundles of prennial sow thistle and bindweed, chlorophyl formation was checked, and there was enlargement and rupture of the cortical cells. Generally investigators now feel that death of the plant is caused by an inhibition of translocation and formation of food reserves, rather than stimulation or growing to death.

There are several factors which limit the effectiveness of 2,4-D as an herbicide, such as susceptibility of species, atmospheric temperature at the time of application, and growth activity of the plant. Also 2,4-D causes more rapid responses and greater ultimate effects when plants are in sunlight than in shade, as shown by tests made by Mitchell and Brown (26), and Weaver and DeRose (38).

Some investigators have demonstrated that temperature after application affects the effectiveness of 2,4-D, the optimum varying with different species. Below 50° F. translocation and activity is so slight that there is usually no response. However, if treated plants are moved or become warmed to above 65° or 70° F. the responses are soon noticeable. A report by the United States Golf Association Greens Section (2) stated that in treatments of flats of pennywort, healall and chickweed in a greenhouse maintained at 60° to 70° F., the chickweed in ten days curled and began to yellow, showing signs of death. The pennywort and healall gave no signs of having been treated with 2,4-D during this time. These two flats were then moved into an 80° greenhouse. At this higher temperature the effect of 2,4-D was evident within a few hours and in 4 to 5 days all weeds of both flats were dead. The chickweed, on the other hand, died in the cooler greenhouse.

All investigations seem to indicate that 2,4-D is especially effective against susceptible plants when they are active vegetatively. The increased activity tends to result in depletion of reserves to some extent and also to improve translocation of the chemical. Hammer and Tukey (9) found 2,4-D especially effective when plants were active meristematically. Lack of response of grasses at the time of these tests, suggested the possibility of controlling undesirable plants in lawns and turfs.

Some of the early tests with 2,4-D as a differential herbicide, were made by Marth and Mitchell (22). In tests with an aqueous spray, they found that concentrations of 250 to 1000 ppm killed dandelion and narrow leaf plantain. Those plants not killed by the acid were daisy, sheep sorrel, and yarrow. There was no apparent injury to Kentucky bluegrass lawns when applications of 500 ppm and 1000 ppm were used on the weeds present. Also Kentucky bluegrass germinated in soil treated with the above concentrations of the acid.

Hamner and Tukey (9) found that 2,4-D did not effect quack grass, Kentucky bluegrass, yellow and green foxtail, wild oats, barnyard, and crabgrass in concentrations which killed the susceptible weeds. The plants killed in their test were: bindweed, narrow-leaved plantain, dandelion, roundleaved mallow, lambs quarter and ragweed.

In a test to determine the residual effect of 2,4-D by Tukey, et al (36), 12 species of cereal, lawn, and pasture plants sown on the treated area two months after treatments germinated and young plants showed no curvature or formative effects. It is now generally believed that there is some residual effect in the soil for 30 to 60 days depending on the type of soil and moisture content.

Two, 4-D has proven to be one of the better weed killers of the growth regulating substances so far investigated, and quite toxic to many broadleaved weeds, and hence a selective herbicide in that some plants and especially grass-like plants tolerate it to a great extent. There are other growth regulating substances being tested which show more toxicity to grass-like plants than broadleaved plants. At present the possibility of new substances of this type which are highly selective in their toxic effects in the field of weed control is quite promising.

MATERIALS AND METHODS

The sodium salt of 2,4-Dichlorophenoxyacetic acid used in these tests was obtained from the Chipman Chemical Company. Comparative tests made in 1945 at this institution by Litzenberger (20) with various brands of 2,4-D showed that the brand prepared by the Chipman Chemical Company was one of the most effective. Therefore, it seemed logical to use this brand for the series of tests reported in this paper. It also seemed advisable to use one of the commercial products now on the market.

The three rates of application tested were 1, 1½, and 2 gallons per square rod at a constant concentration of .1 per cent, which is the generally recommended concentration. The three concentrations of .1, .15, and .2 per cent were tested at a constant rate of 1½ gallons per square rod, the generally recommended rate. These concentrations and rates of application were repeated in tests on three different dates, June 4, July 6, and August 3, during the growing season.

Applications of the spray solution were made with a knapsack type sprayer with a nozzle orifice of about .059 inches in diameter emitting a cone type of spray. The chemical to be used for each treatment was previously weighed up in individual envelopes. Enough material was included in each envelope for the three replications in each case. The contents of each envelope were then mixed with the required amount of tap water for the three plots at the time of treatment. After being thoroughly dissolved, the required amount of solution for each plot was measured into the knapsack sprayer and applied separately. Each plot consisted of ½ square rod of area (approx. 136 sq. ft.). The plot dimensions were 16½ feet long by 8¼ feet wide.

In order to determine the effects of the 2,4-D on each of the weeds, dandelion, plantain and the chickweeds, it was necessary to repeat the tests in three different areas on each date to get the desired rates and concentrations upon the desired weeds. June 4 was the earliest date of application. The three concentrations, .1, .15, and .2 per cent and also the three rates, 1, 1½ and 2 gallons per square rod were randomized and replicated three times with a check plot in each replication, and applied on dandelion and chickweed. Because of the limited available area for treatment on buckhorn plantain, the rates and concentrations were made in duplicate instead of triplicate; also this weed was treated only on the first two dates during the season.

The second date of treating was July 6. Each of the weed species was treated in the same manner as mentioned in the preceding paragraph. The tests were repeated again on August 3, on dandelion and chickweed.

Chickweed has shown very definite resistance to 2,4-D. For this reason a separate test, involving two treatments to each plot, was designed to test 2,4-D on this weed. The three rates used in the other tests were also used in this case. The first application was made on July 6. The second application followed four weeks later, and in each case the treatment on each plot was the same as the previous application. All treatments were made on the mixed Kentucky bluegrass and white clover lawns of the Montana State College Campus.

To observe the effect of 2,4-D on the germination of weed and crop seeds, forty-four petri dishes were equipped with blotters. Eleven of these were used as checks and the others were moistened with a .1 per cent solution of 2,4-D. The treated blotters were moistened with the same strength solution at intervals to prevent them from becoming dry.

Fifty seeds of each of the following species were placed in the petri dishes.

1. Oats (Avena sativa)
2. Alfalfa (Medicago sativa)
3. Dandelion (Taraxicum officinale)
4. Bindweed (Convolvulus arvensis)
5. Pigweed (Amaranthus retroflexis)
6. Kentucky bluegrass (Poa pratense)
7. Mouse-ear-chickweed (Cerastium vulgatum)
8. Common chickweed (Stellaria media)
9. Buckhorn plantain (Plantago lanceolata)
10. Broadleaf plantain (Plantago major)
11. White Dutch clover (Trifolium repens)

Three petri dishes of each of the above species were moistened with a .1 per cent solution of 2,4-D and one petri dish of each species was moistened with water and used as a check.

As most of the seeds remained dormant in the treatments, one petri dish of each species was removed from germination after 15 days. The seeds were washed and placed on clean blotters and moistened with water to determine viability following the treatment with 2,4-D.

EXPERIMENTAL RESULTS AND DISCUSSION

Two, 4-Dichlorophenoxyacetic acid was applied to heavy infestations of different weeds in Kentucky bluegrass lawns to determine the most effective method of using it as a selective herbicide. The results of this investigation which include a comparison of dates, concentrations, and rates of application of 2,4-D are presented in Tables I to V inclusive. The discussion of the results is divided into sections on the basis of the kind of weed treated.

Dandelion Control

All applications of 2,4-D were quite effective as a selective herbicide for dandelion which proved this plant to be quite susceptible to the spray solution. The results of this part of the investigation are recorded in Table I and Appendix Table VII.

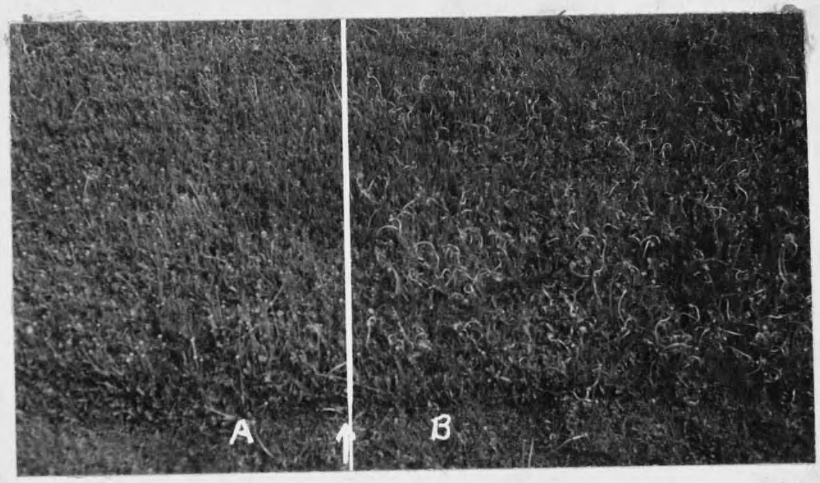

Figure 1: The effect of 2,4-D on Dandelion when used as a selective herbicide in a Kentucky bluegrass lawn. Area A untreated dandelion stems appear normal. Area B treated with a .1 per cent concentration of 2,4-D at $1\frac{1}{2}$ gallons per square rod. Dandelion stems severely twisted and deformed. This picture was taken 8 hours after the treatment was applied.

Dandelion plants usually show the effect of the treatment within 4 to 24 hours after application of the chemical. Atmospheric temperature and the vegetative activity of the plant at the time of application greatly influence the time necessary for these effects to appear. The plants show effects more quickly when they are in an active state and the temperatures are fairly high, 60° to 70° F.

The first effects to appear are severe curling of the stems and twisting of the leaves (see Figure 1). A few days after treatment the leaves become harsh and twisted in a partially upright position. The plants then begin to turn yellow in about two to three weeks. Figure 2 shows the curled stems and lack of leaves on a dandelion plant one week after treatment compared to a normal plant.

A B

Figure 2: The effect of 2,4-D on stems and leaves of a dandelion plant. A was sprayed with a .1 per cent concentration of 2,4-D. B a normal untreated dandelion plant.

The treated plants usually die within six weeks after treatment and the residue may disappear in this period as shown in Figure 3. The lawn shown in the B part of Figure 3 was photographed six weeks after treatment with a .1 per cent concentration of 2,4-D at the rate of 2 gallons per square rod. As is shown in Figure 3 the plants have all disappeared in the treated area and the open spots left in the turf have not as yet filled in with grass. (Note gray spots in Figure 3-B)

Figure 3: The effect of 2,4-D as a selective herbicide on dandelion in Kentucky bluegrass lawn. Area A untreated. Area B treated with a .1 per cent concentration of 2,4-D at the 2.0 gallon per square rod rate.

Date of application: Three rates of application were compared on three different dates during the season. All plots ($\frac{1}{2}$ square rod) were heavily infested with dandelion. The rates were 1, $1\frac{1}{2}$, and 2 gallons of a .1 per cent concentration of 2,4-D per square rod. All three rates of application gave best results when applied early in the season on June 4 (Table I and Appendix Table VII). The tables in the appendix include results by replication and also show how the data were studied statistically.

In order to determine the significance of the differences shown in Table 1, the data were analyzed statistically.

The least significant difference between averages of percentage kills of dandelions for the dates and for the treatments was found to be 3.29 per cent. Therefore the difference between the averages of percentage kill for treatments made June 4 and July 6 was highly significant as they differed by 10 per cent. The difference of 7 per cent for the averages of treatments made June 4 and August 3 also showed these treatments to be significantly different. However the July 6 and August 3 treatments did not quite meet the level required for significance.

Table I: The influence of date and rate of application on the effectiveness of 2,4-D for the control of dandelion in Kentucky bluegrass lawns.

Date of Treatment	Percentage of kill with .1 per cent conc. at rates of: (gal. per sq. rd.)			Average
	1.0	1.5	2.0	
June 4	86	94	96	92
July 6	78	84	86	82
August 3	81	84	89	85
Average	82	87	90	

Least significant difference between averages for dates and rates of treatment was 3.29 per cent.

Standard error was calculated by the analysis of variance method (see Table VII in appendix).

The higher percentage of kill reported for the June 4 treatment was undoubtably due to the ideal conditions of both the dandelion plants and soil on this date. The plants were mostly all blooming and quite active vegetatively and the soil moisture condition was apparently better than on July 6 and August 3. There was less dandelion control by the light (1.0 gallon) and heavy (2.0 gallon) rates when applied July 6 than was obtained for similar rates applied June 4 and August 3. The average percentage kill for the intermediate rate (1.5 gallon) on these last two dates was about the same. When the July 6 and August 3 treatments were made very few dandelions were blooming and the soil was quite dry. Warmer weather and dryer soil and air conditions seemed to have forced the plants into a much less active condition.

The results obtained for the August 3 treatment were slightly better than for the July 6 treatment at the light (1.0 gallon) and heavy (2.0 gallon) rates but the intermediate rate (1.5 gallon) gave almost identical control on these two dates. The dandelion on August 3 seemed to be starting into a period of greater activity than was shown by them during July, however, they were not as active as in June and less blooming was exhibited by the plants at this time than later in September.

Rate of application: Two, 4-D spray at the rate of 2 gallons per square rod gave better control of dandelion than the other rates. This was true for all three dates of application (see Table I and appendix Table VII). However, the one gallon rate applied on June 4 was about as effective in the control of dandelion as was the two gallon rate applied on July 6 and August 3. The highest percentage kill of dandelion (96 per cent) was obtained from the 2 gallon rate applied on June 4 while the lowest percentage kill was 78.3 per cent obtained from the 1 gallon rate applied on July 6. Average percentage kills for the three dates treatments were made, were 82.8, 87.4, and 90.8 per cent respectively for the 1.0, 1.5, and 2.0 gallon rates. The least significant difference between average percentage kills of dandelions for rates and treatments was found to be 3.29 per cent. The data in Table I show that average percentage kills of all rates varied more than 3.29 per cent, therefore, all rates of application of 2,4-D differed significantly in their control of dandelion.

Concentration of spray solution: Three different concentrations of 2,4-D were applied at the rate of $1\frac{1}{2}$ gallons per square rod on the three dates previously mentioned. The results of these treatments are presented in Table II and appendix Table VIII. The .2 per cent concentration gave better control of dandelion on all three dates than did the lower concentrations. There was a difference of 8 per cent between the average percentage kill obtained on June 4 and July 6 in favor of the June 4 treatment. This is a significant difference because 6.56 per cent was found to be the least significant difference between averages of dates and concentrations. The average percentage kill for the June 4 treatment was 6.2 per cent higher than the average for the August 3 treatment which is just below the level required for

Table II: The influence of concentration and date of application on the effectiveness of 2,4-D for the control of dandelion in Kentucky bluegrass lawns.

Date of Treatment	Percentage of kill with the $1\frac{1}{2}$ gallon rate at concentrations of:			Average
	.10%	.15%	.20%	
June 4	85.0	86.6	93.0	88.2
July 6	71.6	81.6	86.0	80.0
August 3	81.6	80.0	84.0	82.0
Average	79.4	82.8	88.0	

Least significant difference between averages of dates and concenrations is 6.56 per cent.

Standard error was calculated by the analysis of variance method. (see Table VIII appendix).

significance. There was no significant difference between the average percentage kills obtained for the last two dates that treatments were made.

The average seasonal percentage kills of dandelion for the .10, .15, and .20 per cent concentrations were 79.4, 82.8, and 88.0 per cent, respectively. There was a significant difference between the effectiveness of the high and low concentrations but the .15 per cent concentration did not show a significant difference from either of the other concentrations.

In both tests of different concentrations and different rates the first date of treatment was much more effective in controlling dandelion, which on the basis of the condition of the plants at the time of application was to be expected.

On all dates of application the higher rates and higher concentrations gave the best control of dandelion. This then should warrant the recommendation of the heavier treatments of 2,4-D to control dandelions in lawns if there were no other factors to be considered. Mitchell and Marth (28) in tests on three different turf grasses found that clipping weights from Kentucky bluegrass plots treated with 3/4, 1½, 2¼, and 3 pounds per acre were much lower than the untreated checks although the treated plots showed no change in appearance. The 3/4, and 1½ pound per acre treatments (approx. the same as a .1 per cent conc. at one gallon per square rod and .1 per cent conc. at 1½ gallons per square rod) recovered after 5 to 11 weeks while the heavier treatments were still retarded after 14 weeks. Although no definite measurements were taken to measure the inhibition by the different treatments in this investigation, the effect of 2,4-D was quite readily observed in the heavier applications of the chemical. Also more of the white clover was eradicated in the heavier application.

Observation of the treated dandelion plots at two and three months after treatments were made and it was noted that there were many new seedlings becoming established in the treated areas. Thus new infestations from dandelion seed already present in the turf or from neighboring infested areas may cause a new crop of weeds after one crop has been eradicated. For this reason the lighter (.1 per cent) concentration used once a season for two or three seasons in succession may be the most effective method of long time control of dandelions in Kentucky bluegrass lawns.

Plantain Control

The tests of 2,4-D on plantain were somewhat less extensive than for the dandelion and chickweeds because of a limited area of uniform infestation. Three rates 1, $1\frac{1}{2}$ and 2 gallons per square rod were applied in duplicate on June 4 and July 6 and results are recorded in Table III and appendix Table IX. This species (buckhorn plantain) was found to be quite

Table III: The effect of date and rate of application of 2,4-D in controling buckhorn plantain in Kentucky bluegrass lawns.

Date of Treatment	Percentage of kill with .1% conc. at rates of: (gal. per sq. rd.) 1.0	1.5	2.0	Average
June 4	87.5	96.0	95.5	92.6
July 6	77.5	82.5	85.0	81.6
Average	82.5	89.2	90.2	

Least significant difference between averages for dates after treatment was 4.78 per cent.

Least significant difference between averages for rates was 5.88 per cent. Standard error was calculated by the analysis of variance method. (See appendix Table IX)

susceptible to 2,4-D also. It reacted to the treatment much the same as dandelion with the first effects usually evident within eight hours after application of the chemical. The seed stems became severely curled and twisted within a few days and the entire plant gradually changed color from green to yellow and then to brown in a period of four to six weeks and all the plants critically affected had died within this period.

Date of application: Treatments of 2,4-D on buckhorn plantain on June 4 and July 6 gave a variation in percentage kill which was highly significant. The average percentage kill obtained (Table III) for the June 4 treatments was 11 per cent greater than was obtained for the treatments made on July 6.

Rate of application: The 2 gallon rate of application was about 8 per cent more effective in controlling buckhorn plantain than the 1 gallon rate. This difference was significant as was the difference of 7.2 per cent between the 1 and 1½ gallon rates.

Chickweed Control

There have been conflicting reports as to the susceptibility of chickweed to 2,4-D. Kephart (16) reported it in a class with those weeds which were most easily controlled and said it was killed with one application of a .1 per cent concentration of 2,4-D. Litzenberger (20) in preliminary tests with 2,4-D on lawn weeds in Montana reported chickweed as difficult to kill. The results of this investigation show this weed to be definitely resistant to 2,4-D treatment. Chickweed was slower to react to 2,4-D treatment than dandelion. The first effects were only noticable upon close observation and sometimes did not appear until about 48 hours after treatment. During the period of 3 to 14 days after treatment the plants gradually became quite brown and dry and at this stage it was supposed that the spray was effective in the control of chickweed. However, soon after the period of browning, the brown stems began to green up and grow new leaves and about six weeks after treatment most treated plots had stands of chickweed as heavy as before treatment. The check plots were of interest in these treatments because common plantain and dandelion were found in quite large numbers, whereas, in the treated plots these two weeds were almost entirely eradicated.

Date of application: Two, 4-D treatments made on June 4 and July 6 on plots containing chickweed were not effective (Table IV and appendix Table X). This was especially true for the July 6 treatments. Treatments made on August 3 were the most effective particularily where the 2 gallon rate was used. Although none of the dates of treatment gave results that could be considered satisfactory. Increased percentage kills obtained by treatments made August 3 suggest the possibility of a later date of treatment being more effective in controlling chickweeds. It is also possible that a higher rate or greater concentration might have been effective.

Rate of application: Results from the 1 and $1\frac{1}{2}$ gallon rates of application were practically nil for all dates of treatment (Table IV). The heavy rate

Table IV: The effect of date and rate of application on the effectiveness of 2,4-D for the control of chickweed in Kentucky bluegrass lawns.

Date of Treatment	Percentage of kill with .1% conc. at rates of: (gal. per sq. rod)			Average
	1.0	1.5	2.0	
June 4	10	15	26	17
July 6	0	3	6	3
August 3	18	36	73	42
Average	9	18	35	

(2.0 gallons per square rod) was a little more toxic for all dates of treatment. The August 3 treatment at this rate gave 73.3 per cent control. Although this percentage kill is not too good, it is probably an indication of what might be accomplished with this kind of herbicide for chickweed control.

Successive treatments on chickweed: In order to test the effectiveness of two successive treatments of 2,4-D for the control of chickweed, the same three rates used in the other tests were applied on July 6 and repeated on the same plots four weeks later. (Table V and appendix Table XI). Results

Table V: The effectiveness of successive treatments of 2,4-D at various rates for controlling chickweed in Kentucky bluegrass lawns.

	Percentage kill at .1 per cent conc. at these rates (gal. per sq. rd.) 1.0	1.5	2.0	Average
Estimated percentage kill after first treatment on July 6	11	18	20	16
Total percentage kill after 2nd treatment	26	56	75	52

from the two lighter rates gave slightly better control than the single treatments, but were still unsatisfactory. The 2 gallon rate was again the best rate of application according to the estimated percentage kill at the end of the season.

The average percentage kill for the 2 gallon rate and for two treatments was 75 per cent which was only slightly better than a single application at this rate made on August 3 (Table IV). Results obtained in attempting to control the chickweeds with 2,4-D indicate that it will be necessary to use more of the chemical or more applications than was used in these tests if effective control is obtained. Although heavier rates of application and greater concentrations may injure the grass to some extent they may be justified in controlling this weed. As shown in these tests treatments made late in the summer gave the best control of the chickweeds.

Other Plants Effected

There were other lawn weeds present in some of the plots on which no specific tests were conducted. A statement as to their observed susceptibility might be of interest.

Black medic (Medicago lupulina), sometimes called yellow trefoil, was found to be very susceptible to 2,4-D as observed in a series of plots treated for dandelion control. Dutch white clover was killed to some extent. In the lighter applications there was more recovery and survival of clover from the 2,4-D treatment. Speedwell (Veronica officinalis) was very readily killed by the lowest rates of application. Common plantain (Plantago major) was present in many of the treatments and proved very susceptible to 2,4-D.

Apparently most of the weeds occurring in Kentucky bluegrass lawns in this area are susceptible to 2,4-D except the common and mouse-ear-chickweed. It is suggested that if future work is done with chickweeds that higher rates of application and later seasonal treatments than were used in this investigation be studied.

Effect of Rainfall

Observations of percentage kills of a series of dandelion plots treated with different rates and concentrations of 2,4-D in aqueous spray a few hours before a heavy rain indicated that the chemical was readily absorbed by the dandelion plants. The treatments were begun on this series at 8 AM and completed by 12:00 noon. At 4:00 PM the same day a heavy rain began falling and rain continued intermittently for the next two days and the temperature did not rise above 60° F. Comparison of this series of treatments with a series treated after the storm showed the percentage kills to be very nearly equal for the two series, except for a few of the plots treated last in the first series. This is in accord with results reported by Weaver and De Rose (38). They concluded that maximum absorption of the chemical took place within 6 hours after application of 2,4-D on coleus and nasturtium plants. In another study by Weaver, et al (37) it was concluded that rainfall immediately following treatment with an oil solution of 2,4-D did not cause any dimunition in the response of plants to the herbicide as the rain drops were apparently shed from the oil covered leaves. However, when aqueous sprays were used it was found that rainfall within 24 hours after the time of application reduced the effectiveness of the herbicide.

The Effect of 2,4-D on the Seeds of Weed and Crop Species

The effect of 2,4-D on the germination of eleven species of weed and crop seeds was determined and the results are presented in Table VI and appendix Table XII. Germination was inhibited by 2,4-D for all species treated. Oats (Avena sativa) was the only species in which the number of germinating seeds in the treatments was about equal to the seeds germinating in the untreated controls. However, toxic effects of the 2,4-D were evident.

The .1 per cent concentration of 2,4-D proved to be very toxic to all but one of the species tested. The extremely inhibitive effects were partially due to the method of treatment in which the seeds were in forced contact with the herbicide at all times, perhaps causing them to absorb more of the chemical than they would under normal methods of spraying weeds.

Table VI: The effect of 2,4-D on the germination of weed and crop seeds.

Name of Plant	Percentage of germination of seeds with these treatments 1*	2*	3*
Oat	100	92	---
Alfalfa	76	0	32
Dandelion	80	0	2
Bindweed	6	0	0
Pigweed	94	0	46
Kentucky bluegrass	70	0	12
Mouse-ear-chickweed	36	0	0
Common chickweed	20	0	0
Buckhorn plantain	90	0	0
Common plantain	4	0	0
Dutch white clover	40	0	20

1* Seeds untreated
2* Seeds kept moist with a .1 per cent concentration of 2,4-D
3* After 15 days in the 2,4-D treatment these seeds were washed and placed on clean blotters and moistened with water to check viability after treatment. See Table VI appendix for more details.

Several of the seeds showed some viability after having been in the 2,4-D solution for 15 days. This was shown by germination counts after washing and removing one of the three 2,4-D treated units to clean blotters and petri dishes. The germination of all species except oats was inhibited to the extent of no germination by the 2,4-D treatment. Seed of several species germinated after the seeds were washed free of the 2,4-D solution.

Alfalfa seed which germinated 78 per cent in the untreated check and did not germinate in the 2,4-D solution, germinated 32 per cent after removal from the solution. Pigweed germinated 94 per cent in the control, none in the 2,4-D treatment, and 46 per cent in the test after removal from the solution. Kentucky bluegrass and dutch white clover were found to also have some viable seeds after the treatment. These four species were the only ones found to have any viable seeds after treatment with the .1 per cent solution of 2,4-D.

As was expected the oat species was the most tolerant of the species treated and although it germinated there was much inhibition exhibited. The treated seeds were 3 to 5 days slower in germinating than those not treated and the epicotyls were very chlorotic. A very interesting observation of

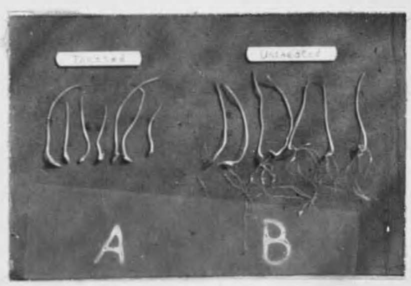

Figure 4: Oat seedlings. A treated seeds germinated in a .1 per cent conc. B untreated seeds germinated in water.

the treated seedlings was their lack of seminal root development (see Figure 4). The majority of the treated seedlings showed no root development whatsoever while the epicotyls appeared normal except for being chlorotic and weak.

It was also noted toward the end of the test that most of the untreated (control) petri dishes and seeds began showing a great amount of fungus and bacterial growth while the 2,4-D treatments remained clean through out the test and no such growth was evident. This observation has been made in other investigations of this substance.

SUMMARY

The effectiveness of 2,4-dichlorophenoxyacetic acid as a selective herbicide for the control of weeds in Kentucky bluegrass lawns was studied. Different dates, rates and concentrations of application of the selective spray were compared.

Dandelion was effectively controlled by all rates and concentrations of the 2,4-D spray on all three dates of application.

The earliest date of application (June 4) of the 2,4-D treatment resulted in percentage kills of dandelion that were higher and differed significantly from the July 6 and August 3 treatments.

The heaviest (2 gal.) rate of application resulted in percentage kills that were higher than the $1\frac{1}{2}$ or 1 gallon rate of treatment. The average percentage kill of all rates of application of 2,4-D on dandelion differed significantly.

The .2 per cent concentration of 2,4-D gave better control of dandelion on all three dates of application than the two lower concentrations. The percentage kills resulting from the .1 per cent and .2 per cent concentrations differed significantly in favor of the highest concentration.

Buckhorn plantain was controlled effectively on both dates of treatment by all rates of application of 2,4-D.

The variation in percentage control of buckhorn plantain of the two dates of application, June 4 and July 6, was highly significant, the greater control being obtained on June 4.

The 2 gallon rate of application of 2,4-D on buckhorn plantain gave significantly higher percentage kills than the 1 gallon rate.

Common and mouse-ear chickweeds showed a definite resistance to

all treatments of 2,4-D as applied in this investigation. Satisfactory control of these weeds was not obtained in any of the tests.

Percentage kills obtained from the August treatments of 2,4-D on chickweed indicated this to be the best date of application studied.

The 2 gallon rate of application of 2,4-D gave the best control of chickweed in tests conducted with this weed.

The effect of 2,4-D on the germination of the seed of weed and crop species was also studied.

Germination was inhibited by 2,4-D treatment for all species tested. Oats sprouted and developed chlorotic epicotyls although seminal root development was greatly inhibited.

There was no germination of any seeds except oats while in contact with the .1 per cent solution of 2,4-D.

Some seeds of four of the species tested were found to be viable following the treatment with 2,4-D. These species were; alfalfa, pigweed, dutch white clover and Kentucky bluegrass.

LITERATURE CITED AND CONSULTED

1. Adams, G. E. Weeds, their eradication and control. R. I. Agr. Exp. Sta. Bul. 133 p51-61. 1909

2. Anonymous Growth regulating substances give promising results as turf herbicides, Timely Turf Topics, U. S. Golf Assoc., Greens Sec. 1944

3. Arnold, L. E. A preliminary study of some herbicides of dandelions. Iowa Acad. Sci. Prod. 40: 67-72. 1933

4. Blackman, G. E. A comparison of certain plant growth substances with other selective herbicides. Nature 155: 500-01. 1945

5. Blackman, G. E. Weed control in cereals by chemical methods. Jour. of the Ministry of Agriculture Vol. LIII: 16-22 1946

6. Bolley, H. L. Weed control by means of chemical sprays. North Dakota Exp. Sta. Bul. 80. 1908

7. Brown, J. W. The effect of 2,4-Dichlorophenoxyacetic acid on water relations, solid matter, and respiration of bean plants. Bot. Gaz. 107: 332-43. 1946

8. French, G. T. Spraying to eradicate dandelions from lawns. New York State Agr. Exp. Sta. Bul. 335: 35-43. 1911

9. Hamner, C. L. and Tukey, H. B. Selective herbicidal action of midsummer and fall applications of 2,4-Dichlorophenoxyacetic acid. Bot. Gaz. 106: 232-45. 1944

10. ______, and _____. Herbicidal action of 2,4-Dichlorophenoxyacetic acid and 2,4-5 trichlorophenoxyacetic acid on bindweed. Sci. 100: 154-155. 1944

11. ______, and _____. Herbicidal action of 2,4-Dichlorophenoxyacetic acid on several vines, shrubs, and trees. Bot. Gaz. 107: 379-85. 1946

12. Hammer, C. L., Moulton, J. E., and Tukey, H. B. Effect of treating soil and seeds with 2,4-Dichlorophenoxyacetic acid on the germination and development of seedlings. Bot. Gaz. 107: 352-361. 1946

13. Harris, L. E. Controlling lawn weeds with sinox-ammonium sulfate solution. Oregon Agr. Exp. Sta. Cir. 240 5pp. 1941

14. Hildebrand, E. M. War on Weeds. Science 103: 465-68. 1946

15. Hitchcock, A. E. and Zimmerman, P. W. Absorption and movement of synthetic growth substances from soil as indicated by the response of aerial parts. Contrib. Boyce Thompson Inst. 7: 447-476. 1935

16. Kephart, L. W. Two, 4-Dichlorophenoxyacetic acid, new killer of weeds. Successful Farming. 1946

17. Longyear, B. O. The dandelion in Colorado. Colo. Agr. Exp. Sta. Bul. 236, 35 pp. 1918

18. Loomis, W. E. The control of dandelion in lawns. Jour. of Agri. Res. 56: 855-65. 1938

19. _____, and Noecker, N. L. Petroleum sprays for dandelions. Science 83: 63-64. 1936

20. Litzenberger, S. C. Weed control project, annual report. Mont. State Agr. Exp. Sta. 1945

21. Litzenberger, S. C., and Post, A. H. Selective sprays for the control of lawn weeds. Mont. Agr. Exp. Sta. Bul. 411. 1943

22. Marth, P. C., and Mitchell, J. W. Two, 4-dichlorophenoxyacetic acid as a differential herbicide. Bot. Gaz. 106: 224-232. 1944

23. _____, and_____. Period of effective weed control by the use of 2,4-dichlorophenoxyacetic acid. Science 104: 77-79. 1946

24. _____, and_____ The effect of spray mixtures containing 2,4-dichlorophenoxyacetic acid, urea, and fermate on the growth of grass. Bot. Gaz. 107: 217-23. 1946

25. Meunscher, W. C., and Justice, O. L. The control of Weeds in lawns. Cornell Extension Bul. 451: 1940

26. Mitchell, J. W., and Brown, J. W. Movement of 2,4-dichlorophenoxyacetic acid stimulus and its relation to the translocation of organic food materials in plants. Bot. Gaz. 107: 393-407. 1946

27. Mitchell, J. W., and Hamner, C. L. Polyethylene glycols as carriers for growth regulating substances. Bot. Gaz. 105: 474-483. 1944

28. ______, and Marth, P. C. The effect of 2,4-dichlorophenoxyacetic acid on the growth of grass plants. Bot. Gaz. 107: 276-84. 1945

29. ______, and ______ Germination of seeds in soil containing 2,4-dichlorophenoxyacetic acid. Bot. Gaz. 107: 408-16 1946

30. Munn, M. T. Spraying lawns with iron sulfate to eradicate dandelions. New York Agr. Exp. Sta. Bul. 179, 17 pp. 1919

31. Nutman, P. S., Thornton, H. G., and Quastel, J. H. Inhibition of plant growth by 2,4-dichlorophenoxyacetic acid and other plant growth substances. Nature 155: 498-500. 1945

32. Raynor, R. N., et al Weed Control. Revised Calif. Agr. Ext. Cir. 97 1-111. 1940

33. Robins, W. W., Crafts, A. S., and Raynor, R. N. Weed Control. McGraw Hill Book Co. 1942

34. Slade, R. E., Templeman, W. G., and Sexton, W. A. Plant growth substances as selective weed killers. Nature 155: 497-98. 1945

35. Taylor, F. J., Country Gentlemen 1943

36. Tukey, H. B., Hamner, C. L., and Imhoff, B. Histological changes in bindweed and sow thistle following applications of 2,4-dichlorophenoxyacetic acid in herbicidal concentrations. Bot. Gaz. 107: 62-73. 1945

37. Weaver, R. J. Capt. A. U. S. et al. Influence of rainfall on the effectiveness of 2,4-dichlorophenoxyacetic acid sprayed for herbicidal purposes. Bot. Gaz. 107: 540-44. 1946

38. Weaver, R. J. Capt. A. U. S. and DeRose, H. R. Capt. A. U. S. Absorption and translocation of 2,4-dichlorophenoxyacetic acid. Bot. Gaz. 107: 509-21 1946

39. Weed Control Conference, Report of seventh annual meeting western states. 1945

40. Weed Control Conference, Report of second annual meeting north central states. 1945

41. Welton, F. A., and Carroll, J. C. Control of lawn weeds and the renovation of lawns. Ohio Agr. Exp. Sta. Bul. 619. 1941

42. Welton, F. A. Sodium chlorate as a lawn weed killer. Ohio Agr. Exp. Sta. Bi-Mo. Bul. 141. 1929

43. Westgate, W. A. and Raynor, R. N. A new selective spray for the control of certain weeds. Calif. Agr. Exp. Sta. Bul. 643. 1940

44. Zimmerman, P. W., and Hitchcock, A. E. Substituted Phenoxy and benzoic acid growth substances and the relation of structure to physiological activity. Contrib. Boyce Thomp. Inst. 12: 321-44. 1942

APPENDIX

The tables (VII to XII inclusive) included here contain the complete data from which the summary tables (I to VI inclusive) of the text were derived. It also includes the statistical analysis of the data.

Table VII - The influence of date, and rate of application on the effectiveness of 2,4-D for the control of dandelion in Kentucky bluegrass lawns.

Date of Treatment	Replication	Percentage of Kill with .1% conc. at rates of (Gal. per sq. rd.) 1.0	1.5	2.0	Av.
June 4	1	90	95	98	94.3
	2	85	97	93	91.6
	3	90	90	98	92.6
	Average	86.3	94.0	96.0	92.9
July 6	1	75	88	95	86.0
	2	80	85	80	81.3
	3	80	80	85	81.3
	Average	78.3	84.3	86.6	82.9
August 3	1	90	92	90	90.6
	2	75	85	93	84.3
	3	80	75	85	80.0
	Average	81.6	84.0	89.3	84.9
Grand Average		82.8	87.4	90.8	

Calculations of the analysis of variance of percentage kills of various dates and rates of 2,4-D application of dandelions.

Variation due to	°f	Sums of Squares	Variance Mean Square	σ	F Value
Replication	2	153	76.5		6.22
Dates	2	484	242.0		19.67**
Rates	2	291	145.5		11.83**
Dates x Rates	4	14	3.5		0.28
Error	16	368	12.30	3.46	
Total	26	1,310			

$$\text{L.S.D.} = \frac{3.46 \times 2\sqrt{2}}{\sqrt{9}} = 3.29$$

Standard error was calculated by the analysis of variance method.

Table VIII - The influence of date and concentration of application on the effectiveness of 2,4-D for the control of dandelions in Kentucky bluegrass lawns.

Date of Treatment	Replication	Percentage kill with 1½ gal. rate at concentration .10%	.15%	.20%	Average
June 4	1	90	85	93	89.3
	2	80	90	98	89.3
	3	85	85	88	86.0
	Average	85.0	86.6	93.0	
July 6	1	80	90	95	88.3
	2	65	70	85	73.3
	3	70	85	80	78.3
	Average	71.6	81.6	86.6	80.0
August 3	1	80	85	80	81.6
	2	85	70	75	73.3
	3	80	85	98	87.6
	Average	81.6	80.0	84.3	82.0
	Grand Average	79.4	82.8	88.0	

Calculation of analysis of variance of percentage kills at various dates and conc. of 2,4-D application for dandelion.

Variation due to:	°F	Sums of Squares	Variance	σ	F - Value
Replication	2	204.74	102.3700		21.0637
Dates	2	330.96	165.4800		3.4049
Conc.	2	334.74	167.3700		3.4435
Error	20	972.08	48.6040	6.98	
Total	26	1,842.52			

$$L.S.D. = \frac{6.98 \times 2\sqrt{2}}{\sqrt{9}} = 6.56$$

Standard error was calculated by the analysis of variance method.

Table IX - The effect of date and rate of application of 2,4-D in controlling buckhorn plantain in Kentucky bluegrass lawns.

Date of Treatment	Replication	Percentage of Kill with .1% conc. at rates of (gal. per sq. rd.) 1.0	1.5	2.0	Av.
June 4	1	90	95	98	94.3
	2	85	97	93	91.6
	Average	87.5	96.0	95.5	92.6
July 6	1	75	80	80	78.3
	2	80	85	90	85.0
	Average	77.5	82.5	85	81.6
	Grand Average	82.5	89.2	90.2	

Part of Table III - Calculation of the analysis of variance of percentage kills of dates and rates of 2,4-D applications for buckhorn plantain.

Variation due to:	°F	Sums of Squares	Variance	σ	F - Value
Replications	1	12.33	12.33		
Dates	1	375.333	375.333		21.1657*
Rates	2	142.167	71.08		4.0083
Dates x Rates	2	18.167	9.08		0.512
Error	5	88.667	17.733	4.16	
Total	11	636.666	57.872		

$$\text{L.S.D.} = \frac{4.16 \times 2\sqrt{2}}{\sqrt{6}} = 4.78$$

Standard error was calculated by the analysis of variance method.

Table No. X - The effect of date and rate of application on the effectiveness of 2,4-D for the control of chickweed in Kentucky bluegrass lawns.

Date of Treatment	Conc. of Spray Solution (percent)	Rate per Square Rod (Gallons)	Percentage Kill of Replications 1	2	3	Average
June 4	.10	1.0	10	10	10	10.0
	.10	1.5	15	10	20	15.0
	.10	2.0	20	40	20	26.6
July 6	.10	1.0	0	0	0	-
	.10	1.5	0	0	10	3.3
	.1	2.0	0	0	20	6.3
August 3	.10	1.0	30	10	15	18.3
	.10	1.5	50	10	15	36.6
	.10	2.0	70	70	80	73.3

Table No. XI - The effectiveness of successive treatments of 2,4-D at various rates for controlling chickweed in Kentucky bluegrass lawns

Date of Treatment	Conc. of Spray Solution (percent)	Rate per Square Rod (Gallons)	Estimated Percentage Kill After First Treatment (Replications) 1	2	3	Average
July 6	.10	1.0	20	10	5	11.6
	.10	1.5	30	10	15	18.3
	,10	2.0	20	10	30	20
			Total Percentage Kill After Second Treatment			
July 27 (4 weeks after first treatment)	.10	2.0	30	20	30	26.6
	.10	1.5	40	60	70	56.6
	.10	2.0	70	75	80	75

Table No. XII - The effect of 2,4-D on the germination of weed and crop seeds

Plant	Treatment	Number of seeds germinated during the following intervals; Number of days after treatment 5	7	10	15	20	25	30	35	Total Seeds Germinated	Percent Germination
Oat	1*	30	15	5						50	100
	2*	5	27	12	2					46	92
	3*	Not applied on this species									
Alfalfa	1	26	11	1						38	76
	2	0	0	0						0	0
	3					4	11	1		16	32
Dandelion	1			1	3	16	10	8	2	40	80
	2									0	0
	3									1	2
Bindweed	1	2	1							3	6
	2									0	0
	3									0	0
Pigweed	1	43	4							47	94
	2									0	0
	3						9	9	5	23	46
Kentucky bluegrass	1		6	14	0	5				35	70
	2									0	0
	3						0	6	0	6	12

Table No. XII -(Continued)

Plant	Treat-ment	Number of Seeds germinated during the following intervals Number of days after treatment 5	7	10	15	20	25	30	35	Total Seeds Germi-nated	Percent Germi-nated
Mouse-ear-chickweed	1		8	6	3	1				18	36
	2									0	0
	3									0	0
Common chickweed	1				2	4	4			10	20
	2									0	0
	3									0	0
Buckhorn Plaintain	1	34	6	2	3					45	90
	2									0	0
	3									0	0
Common Plaintain	1				2					2	4
	2									0	0
	3									0	0
White Dutch Clover	1		6	2	5	5	1	1		20	40
	2									0	0
	3					2	5	3		10	20

*1 Seeds kept moist with water

*2 Seeds kept moist with a .1 per cent conc. of 2,4-D

*3 After 15 days in the 2,4-D treatment these seeds were washed and placed on clean blotters and moistened with water to check viability after treatment.

MONTANA STATE UNIVERSITY LIBRARIES
3 1762 10014335 1

N378 [redacted] 81296
H668g
cop.2
Hodgson, J. M.
Growth regulating substances for the control of weeds in Kentucky bluegrass lawns.

JUN 3 '52

~~RESTRICTED STACK~~
N378 81296
H668g
cop.2