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Using 2,4-D for Selective and Non-Selective Weed Control

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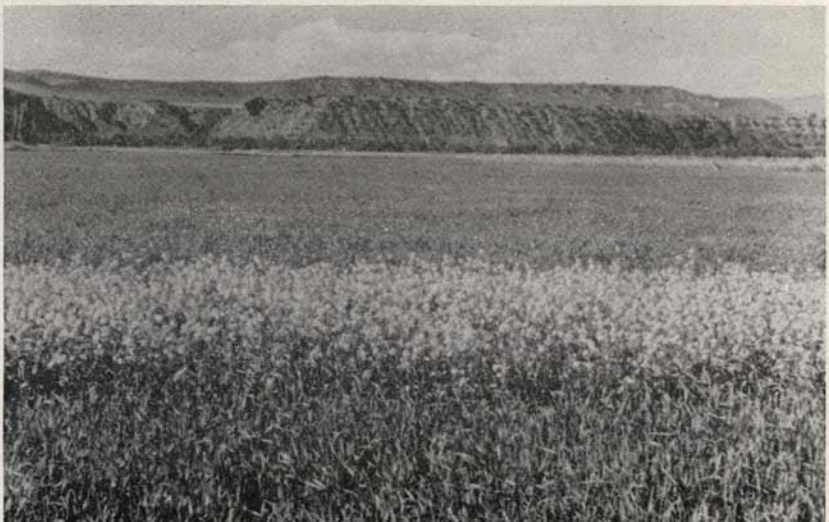

Unsprayed strip (center foreground) in a grain field badly infested with Wild Mustard.

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2,4-D

Uses

1. It can be used as a selective or as a non-selective herbicide.
   A. Treatments in grain fields will damage or kill numerous kinds of weeds and still leave the crop for harvest.
   B. It is effective in controlling many weeds which are commonly found in uncultivated ground.

Advantages

1. It is the most reliable of the selective herbicides tested for the weeding of grain fields.
2. It will provide effective weed control at a reasonable cost, under a variety of conditions, when applied at recommended rates.
3. In present commercial forms it is non-poisonous, non-explosive. and non-corrosive.

Disadvantages

1. Its effectiveness depends upon so many factors that results cannot be predicted.
2. Re-treatments will be required to bring any weed infestation under control.
3. It causes soil sterility of indefinite duration.

Cautions

1. The treatment itself will damage any crop to which it is applied but the effect of less weed competition may produce increased yields of grains.
2. Do not expect one treatment to completely eradicate an infestation of any weed.
3. Keep livestock away from poisonous plants which have been treated.
4. Treat at low pressures and keep within area to be treated.
5. Clean equipment thoroughly before using it for any other purpose than for weed control.

Using 2,4-D in Selective and Non-Selective Weed Control[1]

LAMBERT C. ERICKSON, C. I. SEELY,
AND EUGENE W. WHITMAN[2]

Introduction

WEEDS are now causing the largest unnecessary crop losses on the average farm. Because of the hidden way by which weeds spread they frequently go unnoticed until they seriously reduce crop yields. If weed infestations are not checked when they are first seen they will soon dominate the land. When land becomes badly infested, only intensive and costly weed control methods and good soil management will bring it back into good productivity.

This nation, as a whole, has been slow in recognizing the seriousness of its weed problem. Only since 1930 have we recognized the real losses weeds impose upon agriculture. Unfortunately, by that time millions of acres were already infested by our most harmful noxious weeds.

Weed control, as a science, has also been slow in its development, but much progress has been made in the past 20 years. Methods of deferred cultivation and competitive cropping have been developed and have resulted in great savings in weed control costs. Chemicals such as sodium chlorate and carbon bisulfide have also found their place in weed control.

New organic chemicals (plant extracts and closely related manufactured compounds) have only recently been used as herbicides. A herbicide is any material used for killing plants. The recent emphasis upon chemical weed control has produced chemicals and methods that will help in controlling many weeds, but, all the control methods combined will not cure or produce an economical solution to the weed problem without an adequate prevention program.

Prevention will always cost less than control. Clean seed is the first step in prevention. Clean seed is always the cheapest seed to use although it may cost a little more per pound or per bushel. If prevention is not combined with control, costs for control cannot be eliminated. Unless the toll of weeds is drastically reduced the costs of production will climb and remain persistently higher.

2,4-D

The new herbicide, 2,4-D, was tested for several years as a plant growth regulator before its strong plant-killing qualities were recognized. The development of 2,4-D as a herbicide was undertaken

(1) Funds for these investigations were supplied under terms of the Special Research Program administered by the University of Idaho Research Council.

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between 1940 and 1944. The first public announcement of its ability to kill dandelions and other lawn weeds came from the U. S. Department of Agriculture in November, 1944. Since that time, extensive studies have been made by many state experiment stations and commercial firms.

Although scores of studies and thousands of treatments have been made throughout Idaho, much is still to be learned about the efficient use of 2,4-D in weed control. Despite the lack of information on its proper use, 2,4-D has attained unparalleled popularity. One reason why it has been so widely accepted is that its application presents no health hazards to man or animals. It is neither inflammable or explosive, nor is it corrosive to machinery.

There are two uses of 2,4-D in weed control: selective and non-selective control. In selective weed control the grain field is treated, applying the chemical to both the weeds and the crop with the intent of killing the weeds present without seriously injuring the crop. In non-selective work a patch of weeds is treated without regard for the desirable plants that may be present in the weed patch. 2,4-D is used extensively for both purposes but since chemicals such as sodium chlorate, carbon bisulfide, and borax are more positive for non-selective work, the greater emphasis is now placed upon its use as a selective herbicide.

The actual effectiveness of 2,4-D will vary widely according to the place, time, weeds, and other conditions. Many definite claims have been made that this herbicide will kill certain weeds and that it will not injure certain crops. Few such definite statements should be made because its action is dependent upon the effect of many factors, and in addition, the inter-effects of these same factors. For example, serious crop damage will lessen the damage to the weeds because a slow recovering crop will not offer the competition supplied by a vigorously growing one.

The relations of some factors such as rate, soil, moisture, climate (environment) to kind and type of plant growth; and their influence upon weed and crop injury are illustrated in Figure 1.

Common Commercial Types of 2,4-D

Pure 2,4-D is a white crystalline powder. It frequently has the smell of carbolic acid, which is not surprising since it is made by combining carbolic acid and chlorine. In this pure form it will not dissolve in water. It is therefore necessary to change it from its pure form to make it soluble in water. One way of doing this is to mix the pure 2,4-D with baking soda, and the chemical change will take place when it is poured into water. Some of the early commercial 2,4-D preparations were of this mixture.

Two chemical forms of 2,4-D spray materials and three forms of dusts are now commonly found on the market. The two common spray materials are of the salt or ester forms. The three dust forms are either esters, or salts, or acids.

The Salts of 2,4-D most common are the sodium salt and the

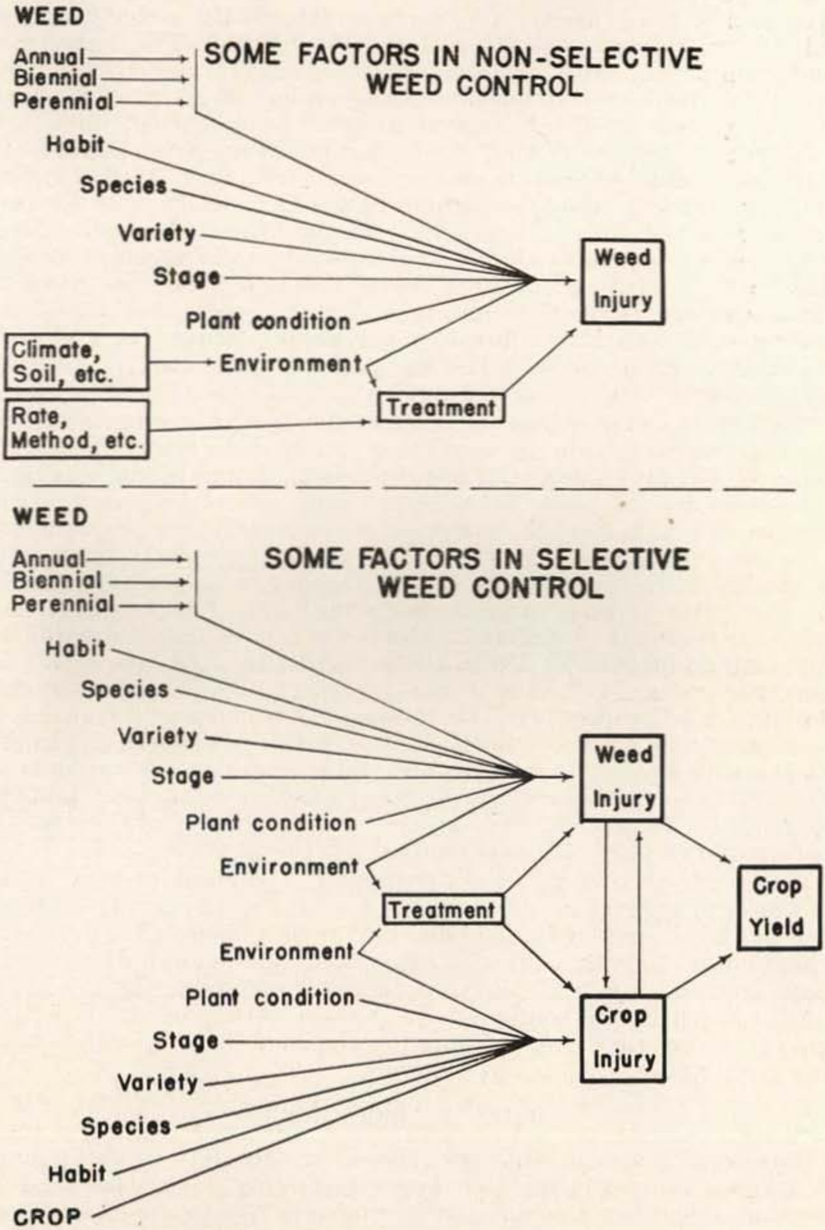

Figure 1.—Some factors affecting the results obtained when using 2,4-D for weed control.

triethanol or alkinol amine forms. The sodium salt is a dry white soluble powder usually containing 60 to 90 percent pure 2,4-D. Dyes and wetting agents (soaps) are frequently added to them and this may change the color of the preparation. The same color conditions prevail with the more rare ammonium and morphalene salts. The triethanol amine and other amine forms are brownish liquid preparations. These disperse in water immediately, and usually contain 20 to 40 per cent of the 2,4-D parent acid. Buyers are cautioned to read the labels on the 2,4-D containers. A label which states 40 percent triethanol amine of 2,4-D contains only 24 percent pure 2,4-D. Percentages given in the triethanol amine form contain only 60 percent of the acid equivalent. (Therefore 40% x 60% = 24% acid equivalent.) More frequently this is given in acid equivalent. Most companies now give the strength of this form directly in pounds acid equivalent per gallon. Some states require all sellers of 2,4-D to state the strength of their materials on the basis of parent 2,4-D acid content.

The Esters are prepared by reacting 2,4-D with various alcohols. These are appearing in an increasing number of forms. Most common are the butyl, ethyl, and isopropyl ester forms. Some less common esters are the methyl and amyl forms. Since the esters do not dissolve well in water, the common commercial ester preparations come dissolved in oils. When these are mixed with water, they form an emulsion. By this method, the 2,4-D ester is dispersed throughout the water forming a mixture in the tank. Frequently in low gallonage spraying (5 gallons or less per acre) the esters are diluted only with additional oil. Up to the present time, the labels on containers of ester 2,4-D have usually given the 2,4-D content in the combined 2,4-D ester form. To determine the pure acid content, it is necessary to know the acid content of the respective esters. To get the acid equivalent of the three most common esters multiply the butyl ester by 80 percent, the ethyl ester by 89 percent, and the isopropyl by 84 percent. For example: a 40 percent butyl ester will contain 32 percent 2,4-D acid equivalent. ($40 \times 80\% = 32\%$.)

The commercial dusts of 2,4-D contain 5 percent or less of the acid or acid equivalent. In the acid dust the acid content is given directly. Most commonly the label on the salt forms also gives the acid content directly. Only two ester dusts are widely distributed; these are the ethyl and isopropyl form. Their strengths are again usually given in the combined 2,4-D ester form and to find their acid equivalent they can be figured in the same way as in the examples given above.

Rates of Application

Rates of application will vary from approximately ½ to 4 pounds of 2,4-D acid equivalent per acre, depending upon the kind of weeds and whether it is selective or non-selective in the place where it is used. (*See Tables 3 and 4.*) To get the desired rate of application, it is necessary to determine the total gallons of liquid that will be sprayed per acre, or the total number of pounds of dust that will be dusted per acre.

All weed-treating equipment should be tested for its rate of delivery before field work is started. The gallons of spray a machine will deliver per acre can be determined by the following procedure:

Liquids

1. Put a known number of gallons of water into the spray tank.
2. Know the width of the boom—for example, 1 rod.
3. Spray at field speed until the tank is empty.
4. Measure the distance traveled. The spray rate per acre can now be figured. Example: If this machine delivered 50 gallons going ½ mile its spray rate will be equal to 50 gallons per acre. (1 rod × 160 rods = 160 square rods, or 1 acre.)

Note: This spray rate may be increased by slowing down the rate of travel or it may be reduced by increasing the travel speed.

Knowing the spray delivery rate, the next step is to know the strength of the material to be used. Calculating the poundage of the dry powders you wish to use per acre is relatively easy. Simply divide the percentage of acid of the powder into the pounds of 2,4-D you wish to use per acre.

Example: You wish to apply 2 pounds and you have a 60 percent powder, then $2 \div .60 = 3.33$ lbs. This is the number of pounds of a 60 percent powder you will need to equal 2 pounds of pure 2,4-D per acre.

The liquids may sometimes be more difficult to figure. In some instances, the label will give the number of pounds of pure 2,4-D contained per gallon. If it contains 4 pounds of 2,4-D per gallon, then 1 quart will contain 1 pound of pure 2,4-D. If this is not given, then the percentage of pure 2,4-D will have to be determined and multiplied by the weight per gallon of the particular material. Example: A label might state: "Isopropyl 2,4-dichlorophenoxyacetic acid 46%. Net weight per gallon 8.6 pounds." To find the acid equivalent multiply the ester 2,4-D content by the reduction factor 84 percent (given earlier) $46 \times .84 = 38.64$. The acid equivalent is then 38.64 percent. 38.64×8.6 (pounds per gallon) $= 3.32$. This is the number of pounds of 2,4-D equivalent contained per gallon.

Dusts

To calibrate a duster, disconnect the fan and the lead-off hoses to the boom or nozzles. This will leave the hopper rotor as the only moving part. Know the duster width or swath, and the distance you will travel per hour. For example: a boom 1 rod wide moving at 3 miles per hour will cover 6 acres per hour or 1 acre in 10 minutes. If you should want to apply the equivalent of 1 pound pure 2,4-D per acre it will require 20 pounds of a 5-percent dust per acre. In this event set the hopper opening at an estimated flow of 20 pounds per 10 minutes, at the desired motor speed. At the end of 10 minutes close the hopper, weigh the dust that has passed through the hopper and re-adjust the hopper opening. Continue until the desired flow is obtained. Further minor adjustments will be required when the actual field treatments are begun.

It should be noted that different brands of dusts usually flow differently. This is because of the difference in carriers or fillers that make up the greater portion of the dust. Caution must always be used when working with dusts. They drift easily and carry great distances. Calibrating should, therefore, be done in a shed or out in the grain field where highly sensitive plants will not be injured.

Methods of Application

The method of applying 2,4-D will depend upon the problem and the equipment at hand. It may be applied as a spray or as a dust from ground rigs or from aeroplanes. Sprays have been applied at rates varying from a few quarts to over 300 gallons per acre; and at pressures ranging from only the force of gravity to 500 pounds.

Low pressures (under 100 pounds) are generally used in spraying for weed control. High pressures are neither necessary nor desirable. They cause greater drift, vaporization of the sprays, and excessive wear on the machinery. Also, high pressures require more costly equipment and additional power. High pressure machines can be adapted to low-pressure spraying by proper adjustment and special low-pressure attachments. Exact pressure control becomes more important as the volume of spray per acre is reduced. About 30 pounds pressure is all that is desired with low volume (less than 20 gallons per acre) spraying.

The volume (gallons of spray) delivered per acre is determined by the size of the holes in the nozzles, the distance between the nozzles on the boom, the speed traveled, and the pressure. Ground spray rigs usually have nozzles spaced from 12 to 18 inches apart. Field travel speeds vary from 2 to 4 miles per hour. Most operators prefer a speed of 3 miles per hour. Pressures should be such that they will form the proper spray pattern with the type of nozzle used. The three factors: nozzle spacing, speed of travel, and spray pressure are therefore quite fixed and any major change in the number of gallons used per acre must be made by changing the nozzle size.

Boom dusters are preferred to the row-crop type for weed control work, but even the boom dusters must be properly machined to give uniform dust distribution.

Dusting is often preferred to spraying in the dry-land grain-growing areas because greater acreages can be covered in less time, and the labor and equipment costs for hauling water are eliminated. Dusting is not recommended on the small or irrigated farm where water is plentiful. Disadvantages of dusting are: drift injury to other crops, lack of uniformity in application, lower efficiency in weed kill, and higher cost per pound of effective chemical. Dusting has also been done by aeroplane. Aeroplane applications should not be used in a diversified cropping area because of danger of damaging susceptible crops from the drifting of the dust.

The Effect of 2,4-D on Plants

How this new herbicide kills is still not fully understood. It acts differently from our old selective herbicides in that with 2,4-D the whole plant does not have to be covered in order to get effective results. It acts on the plant system, moving through part or all of the plant. The amount and direction of its movement depends upon the kind of plant and the conditions under which it is growing. Contrary to earlier beliefs plants do not grow themselves to death as a result of this treatment. Any treatment strong enough to kill weeds will also injure any grain crop; but, when a treatment destroys the weeds the crop may benefit enough to give increases in grain yields.

2,4-D usually acts much more slowly than other weed killers. Commonly it causes some twisting of the stems and yellowing of the leaves within a few days after treating. Some plants will show a lot of twisting, bending, and coiling. The amount of this twisting has often been taken as a measure of killing effect. This is not the case. Weed kills have often been better where little or no twisting took place after treating. On annual weeds only the plants that actually die should be counted. This count should be made about 6 weeks after treating. For perennial plants only the regrowth that

Figure 2.—Untreated Crowfoot left, treated right.

occurs the following year is a fair measure of the result of the treatment.

The statement that 2,4-D is generally more effective in killing the broad-leaved plants than the grasses does not mean that it will kill all broad-leaved plants and that it will not kill any of the grasses. It will not kill some broad-leaved plants, and it will injure or kill some grasses. Plants with the widest leaves are not always the most sensitive to 2,4-D. Resistance to this chemical is part of the nature of the particular plant and the condition under which it grows. All plants possess some resistance but the amount of resistance varies with the kind of plant and the growing conditions.

Selective Weed Control

Spraying and dusting 2,4-D to control weeds in wheat, barley, and oats have been studied under both experimental and general field conditions in Idaho for the past 2 years. Studies now being made indicate that selective treatments may also be possible for controlling weeds in other crops.

More exact methods and rates of application are needed in selective than in non-selective weed control. Both the effect on the weeds and the effect on the crop must be considered. The objectives are two-fold: (a) to kill the highest possible number of weeds, and (b) to do the least possible damage to the crop. Preliminary trials conducted in 1947 indicate that grain yields of wheat, barley, or oats may be reduced 5 to 15 percent when treated with 2,4-D at rates high enough to kill 90 percent or more of a mixture of common annual weeds. Other studies have shown that the variety of the crop and the section in which it is grown also influences the amount of injury. The competition of weeds in themselves will frequently reduce yields by 10 to 50 percent or more. For this reason great increases in yields are frequently obtained where the weed infestation is heavy and the weed kill is good.

Rates of application in selective control range from ½ to 1½ pounds of 2,4-D or its equivalent per acre. Lower rates of application are sometimes used and frequently good grain yields have also been reported. Low rates, of less than ½ pound per acre, frequently do not kill many weeds. It merely stunts them, giving the crop the advantage. These exceedingly low rates are not economical because the stunted weeds often recover and produce seed which maintain the weed infestations. Effective kills (not stunting) each year are necessary if we are to reduce the weed stands. Many fields are so heavily infested with weed seeds that the present supply will provide new weed infestations for several years.

Time to treat depends upon the stage of crop growth and the type of weeds present. To control annual weeds the treatment should be made when the grain is stooling. At this stage the grain is usually 4 to 6 inches high. Delaying the treatment after this stage is reached gives the annual weeds time to increase their resistance.

The longer annual weeds remain the more plant food and moisture they remove.

For best control of perennial weeds the treatment must usually be delayed until the grain is 12 inches or more high. This delay is necessary to allow for the emergence of additional shoots from the roots of the creeping type of perennials. Only a few shoots from the rootstalks of field bindweed (morning glory) and many of the perennials will be through the ground when the grain is 4 to 6 inches high. Spraying at this time would not injure the mass of shoots that will emerge later in the season. Do not apply selective treatments while the grain is in the boot or while it is heading. Applications of 2,4-D at these times have seriously reduced crop yields.

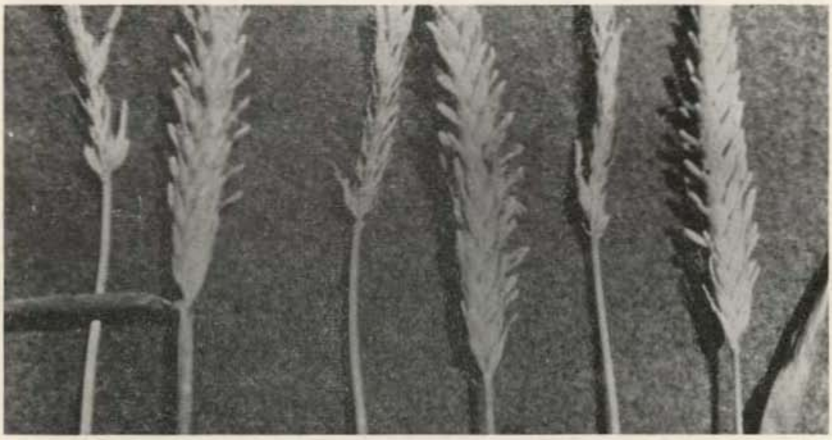

Figure 3.—Barley treated at heading time. Note sterile heads.

Tests in 1947 have shown that grain is injured most severely when it is less than 4 inches high and again when it is in the boot and heading stages. If the perennial weeds are not far enough developed to be treated before the grain is in the boot the treatment may be delayed until the grain is headed. Treating after the grain is headed is not recommended if the grain is to be used for seed. There is evidence that the germination may be delayed for several months after harvest if the grain is treated after it has headed.

Controlling Crowfoot in Winter Wheat

Our most extensive selective tests have been on the control of crowfoot *(Ranunculus arvensis)* in winter wheat. Thousands of acres of crop land in central northern Idaho are solidly infested by this weed.

Intensive experimental studies were conducted in 1946 and again in 1947. These experiments were designed to determine: (1) the efficiency of 6 chemically different 2,4-D compounds, Methoxone, Sinox, and Dow G 506 as selective herbicides for killing crowfoot,

(2) their effect upon crop growth, and (3) their effect upon straw and grain yields. All these chemicals were applied as sprays.

Table 1 gives the average results obtained when using each of 6 2,4-D compounds. Four rates of application were used: ⅓, ⅔, 1⅓, 2⅔ pounds of pure acid or acid equivalent per acre. Sinox was applied at 2⅔, 5⅓, 8, and 10⅔ pints per acre. Dow G 506 was applied at 1, 2, 3, and 4 pints per acre. The average rates of application were: 2,4-D at 1¼ pounds per acre, Sinox at 6⅔ pints per

Figure 4.—Experimental plots at Grangeville. Determining the effectiveness of 2,4-D in controlling crowfoot in winter wheat.

acre, and Dow G 506 at 2½ pints per acre. Each figure presented in table 1 is an average of 12 plots. These treatments were applied on May 2 and 3, 1946 when the wheat was 4 to 8 inches high. On an average there were about 1,400 crowfoot plants per square rod.

Table 1 shows mainly two things: (1) that all the 2,4-D compounds were capable of killing over 90 percent of the crowfoot plants; and (2) that on the average all the treated plots produced higher grain yields than the untreated plots. The dinitro compounds (Sinox and Dow G 506) were not effective in killing crowfoot. It should be noted that the unactivated Sinox did not kill any crowfoot plants, but it did stunt them, and as a result the Sinox treatment plots gave the highest average yield. None of the dinitro compounds stopped seed production and, therefore, they cannot be considered as a control measure for crowfoot.

The addition of ammonium sulphate in these trials apparently reduced the selectivity of both 2,4-D and Sinox. This resulted in increased damage to the crop growth and also reduced the grain

Table 1.—The effect upon crowfoot and Orfed winter wheat from spraying with six chemically different 2,4-D and two dinitro materials. All figures indicate difference from comparable untreated checks. (1946)

Materials	Crowfoot killed percentage	Wheat height inches	Straw tons per acre	Grain bushels per acre
(2,4-D compounds)				
Acids	90.5	—7.0	—.75	+ 2.7
Amines	95.4	—7.3	—.04	+ 3.2
Butyl ester	99.4	+0.2	+.54	+ 9.4
Ethyl ester	99.8	—3.3	+.70	+10.2
Ammonium salt	99.3	—1.1	—.03	+ 7.2
Ammonium salt activated*	99.0	—1.7	—.86	+ 5.8
Sodium salt	96.8	—3.4	+.39	+ 5.7
Untreated check	0.0	33.4	2.91	33.16
(Dinitro compounds)				
Sinox	0.0	+3.3	+.66	+11.8
Sinox activated*	9.3	—1.2	+.40	+ 4.0
Dow G 506	1.5	—4.2	.0	+ 1.5
Dow G 506 activated*	11.4	—1.6	+.17	+ 4.6

*Activated—addition of ammonium sulphate at the average rate of 46 pounds per acre, applied simultaneously.

yields. Conversely, when ammonium sulphate was added to Dow G 506 the grain yields were increased.

Much of the work done in 1946 on controlling crowfoot in winter wheat was repeated in 1947. The 1947 treatments were made on May 1. Table 2 gives the results of these tests.

The data in Table 2 show some differences from the results obtained the previous year. In 1946 the ester treated plots produced the highest yields, but in 1947 both the ammonium and amine treated plots outyielded the plots treated with the butyl ester. The variation in results obtained in 1946 and 1947 were not

Table 2.—The effect upon crowfoot and Rex winter wheat from selectively applying four different compounds of 2,4-D and Methoxone. All figures indicate differences from comparable untreated checks. (1947)

Materials	Crowfoot killed (percentage)	Wheat height inches)	Straw tons per acre	Grain bushels per acre
(2,4-D compounds)				
Amine	87	—1.3	+.26	+3.7
Ammonium salt	91	—1.6	+.44	+4.7
Butyl ester	93	—2.4	+.50	+3.5
Sodium salt	79	—0.9	—.12	+0.2
Untreated checks	0.0	40.0	2.6	27.9
Methoxone	83	—1.7	+0.7	+1.6

always because of difference in materials. The rates of application have shown even wider differences. In some instances the results were directly reversed.

Two factors appeared to be constant: (1) the lower rates killed less weeds than the higher rates, and (2) the 0.6-pound rate was equally if not more detrimental to straw and grain yield than the 1.2-pound rate. Except for the kill of crowfoot, the 0.3- and the 1.2-pound rates were reversed in their effect upon the crop in 1946 as compared to 1947. In 1946, the least stunting and the highest straw and grain yields were obtained at a rate of 0.3 pounds as an average of all materials. But in 1947 the 0.3-pound rate was consistently the poorest. It gave the lowest kill of crowfoot, the greatest stunting, the lowest straw tonnage, and the lowest grain yield.

Since it is probable that an average of the 2 years' results would provide a more reliable basis than either year alone, Table 3 has been compiled to show the combined results.

Table 3.—Effect of three different rates of 2,4-D upon crowfoot and winter wheat. Average of two years results when a total of six different chemical forms were used. All figures indicate differences from untreated checks. (Average 1946-47)

2,4-D per acre Rate pounds	Crowfoot killed percentage	Wheat height inches	Straw tons per acre	Grain bushels per acre
1.2	94.5	—2.9	+.23	+5.1
0.6	92.2	—2.8	+.13	+4.6
0.3	87.2	—1.9	+.26	+5.2
Check	0	36.7	2.76	30.6

It was pointed out earlier that the main objective in selective weed control was to kill or damage the highest number of weeds possible; and secondly, to leave a decent crop for harvest. In view of the objective the higher rate of application would best serve the purpose.

Non-Selective Weed Control With 2,4-D

Non-selective weed control is in a sense simpler than selective control. In non-selective control all effort is directed toward destroying the weed and the crop is not considered. Non selective treatments may be used for controlling annual, biennial or perennial weeds. Small patches, roadsides, ditchbanks, and waste places have received much attention in non-selective work.

The object in non-selective work on annuals and biennials is to stop all such weeds from producing seed in the year the treatment is applied. In the case of biennials it is, of course, also desirable to destroy the ground rosettes (the first year growth). Either annuals or biennials can, however, eventually be controlled by preventing seed production. Perennial weeds present two problems.

Seed production must be prevented and in addition the old plants and also the new seedlings must be destroyed.

Generally, 85 percent or more of the perennial weeds must be killed or seriously retarded with one application to call the treatment successful. When re-growth indicates a recovery of 25 percent or more by the middle of the following growing season it is questionable if the work can be successful even with several re-treatments.

The chief difficulty in using 2,4-D is the frequent variation in results. This is true when treating the same kind of weed in different parts of the state. Still more confusing is the difference in susceptibility of different patches of the same weed in the same field. In spite of many disappointments, results have generally been good enough to continue further work.

Studies on the use of 2,4-D as a non-selective herbicide in Idaho have been in progress under both irrigated and dry-land conditions for the past 3 years. These studies were outlined to determine proper rates and dates for treating perennial noxious weeds under the varying conditions found in the state. The average weed kills obtained, using all the common commercial materials and our own acid-carbowax mixtures, are given in Table 4. All figures given are

Table 4.—Average percentage re-growth obtained as a result of three to five rates of 2,4-D on nine perennial weeds. Figures represent re-growth June 1 to 30 in the year following the original treatment.

Kind of weed	Av. percent re-growth at different rates (pounds) 2,4-D per acre					Av., of 0.6, 1.2, 2.4 lb. rate
	0.6	1.2	2.4	4.8	8.0	
Susceptible						
Perennial ragweed (Ambrosia psilostachya)	20	9	3	—*	—	11
Intermediate						
Bindweed—morning glory (Convolvulus arvensis)	40	19	9	—	—	23
Canada thistle (Cirsium arvensis)	55	44	20	—	—	39
Perennial sow thistle (Sonchus arvensis)	48	26	9	7	—	28
Tansy (Tanacetum vulgare)	50	20	7	5	—	26
White top (Cardaria spp.)	65	25	8	5	—	33
Willows (Salix spp.)	47	29	18	9	—	31
Resistant						
Leafy spurge (Euphorbia esula)	—	61	59	31	24	60
Russian knapweed (Centaurea repens)	94	49	37	12	11	59

*Dash (—) indicates treatments omitted or too few to be included.

on the percentage of re-growth present in June of the year following the treatment. The rates of application given are on the pure 2.4-D acid or acid equivalent basis per acre.

The figures given in Table 4 indicate that rate of application is very important in securing desired results. From these results 2 pounds per acre of the acid equivalent 2,4-D is suggested as a general rate in non-selective control of the more sensitive perennials (Perennial ragweed). Two to 3 pounds per acre may be used on weeds intermediate in susceptibility, such as: bindweed, white top, tansy, Canada thistle, willows, and perennial sow thistle. It is doubtful if 2,4-D is effective for the resistant weeds (leafy spurge and Russian knapweed). More generally the economy of the treatment and the results desired will determine the rate that should be used. Although the high rates of 4 pounds and more per acre will kill more weeds, it may not be desirable or economical to use such high rates. A complete kill should not be expected at any rate of application.

Re-treatments

It is a fact that any plant will die if it is starved long enough. Therefore, re-treatments which are successful in causing repeated and continuous top-kills should starve perennial weeds to death. Assuming that continuous top-kills can be obtained, the question is not can it be eradicated; but is this an economical eradication?

Two treatments appear to be the practical maximum number that can be applied in any one growing season. Sixty to 90 days should elapse between the two treatments in order to get a good amount of regrowth for the re-treatment. (If grain crops have been treated selectively in the spring for the control of perennial weeds it is questionable if a fall treatment should be applied. Instead plowing immediately after harvest and cultivating for the balance of the year may give equally good or better results if continued over a period of years.)

Some Factors That Influence the Effectiveness of 2,4-D

The rate of application (pounds 2,4-D per acre) is the most important controllable factor that influences the kill.

The type of 2,4-D used (acid, ester, salt) has in some instances influenced the kill obtained. Present results indicate that each kind may have advantages over the others under certain conditions. Tests to date are not sufficiently conclusive to merit any specific statement on this point.

Soil moisture is important. 2,4-D has proved to be more uniformly effective under irrigated than under dry-land conditions. Treatments on sub-irrigated land have been the most successful. Where surface irrigation is used water should be applied immediately after treating.

Rainfall immediately following treatment may reduce the effectiveness of the treatment. Treating just before a rain should be avoided. If 24 hours elapse between the treatment and the rain there should be no hindering effects, and a heavy rain may give the same response as irrigating.

Soil types apparently also influence the results. Weeds growing in sandy soils have sometimes shown greater susceptibility than weeds growing in heavy soils.

High temperatures are apparently not essential to obtain the best results. Any temperature between 60° F. and 90° F. is satisfactory. Tops of plants are killed down faster at higher temperatures, but the final effect upon the plant is perhaps the same. Temperatures of over 90° F. may decrease the toxicity of the more volatile ester compounds.

The best time to treat will depend upon the habits of the plant and the conditions under which it grows. Generally, the treatment should be made at the time when the perennial weeds have reached maximum emergence, but before any viable seeds have developed.

Varieties within a given kind of weed may respond differently to 2,4-D. It is known that certain varieties of crops (corn and wheat) for instance vary in their susceptibility to this chemical. Further studies may show that some of the variations in kills of bindweed and Canada thistle in the past were partly due to varietal differences.

Soil sterility caused by 2,4-D is apparently dependent upon the rate of application, the weather, the soil type, and the amount of organic matter present in the soil. Sterility may persist from a period of a week to several months. The usual duration of soil sterility is 4 to 8 weeks. Two factors: moisture and temperature appear to be most important in the breakdown of 2,4-D. Irrigation or ample rainfall will aid in leaching or in carrying away the 2,4-D. High temperatures combined with good soil moisture increases the activity of the soil bacteria. These bacteria plus the increased soil temperature combine to break down the 2,4-D in the soil. When leaching and bacterial action are speeded up the sterility is short. When one or both are slowed down sterility is prolonged. Sterility, under cold or dry weather conditions, may continue into the following growing season causing failures in germination of such crops as peas and beans and many garden crops. Failures in germination have even resulted where wheat was planted following fall treatments on dry soil.

A SCHEDULE FOR USING 2,4-D AS A NON-SELECTIVE HERBICIDE

Time of Treatment

Annuals

1. Treat at point of maximum emergence, but before any viable seeds have formed.
2. Annual weeds are most easily killed when they emerge.

Perennials

1. Same as for annuals — point of maximum emergence is usually later with perennials.
2. Many perennial weeds are not easily killed when small.

Rate of Treatment

Annuals

1. Use 1 pound 2,4-D acid equivalent per acre on mustards, fanweed.
2. Use 1 to 2 pounds on more resistant weeds.

Perennials

1. Use 1 to 2 pounds 2,4-D acid equivalent per acre on perennial ragweed, poison hemlock.
2. Use 2 to 3 pounds on bindweed, tansy, white top, willows, Canada thistle.
3. Use over 3 pounds on leafy spurge and Russian knapweed.

Method of Treatment
(*Advantages*)

Spraying

1. Most useful method on small or diversified farms.
2. Usually more efficient per pound of 2,4-D equivalent used.
3. Less injury to other crops resulting from drift.
4. Easier to figure the desired amount of chemical before application.
5. Less unpleasant to apply.

Dusting

1. Normally covers greater acreages in less time on large grain farms.
2. May be more economical where water must be hauled great distances.
3. Usually less labor required.
4. May penetrate deeper into dense vegetation.

Kind of Chemical
(*Advantages*)

Esters

1. Faster acting.
2. Less affected by adverse weather.
3. Vapor may penetrate deeper in dense vegetation.
4. May be diluted with either water or oil.
5. May be more effective in killing certain plants.

Salts

1. May penetrate deeper into the root system of some weeds.
2. Less hazardous near susceptible plants.
3. Destructive only in areas where applied.
4. May be diluted with water or with water adding a small amount of oil.
5. May cost less per pound of 2,4-D contained.
6. May be more effective in killing certain plants.

IDAHONIAN, MOSCOW