THE EFFECT OF PRE-EMERGENT TREATMENTS WITH 2,4-DICHLOROPHENOXYACETIC ACID ON WEEDS IN CERTAIN CROPS

by

ROGER DALE HAMILTON

B. S., Kansas State College
of Agriculture and Applied Science, 1948

A THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1949

TABLE OF CONTENTS

Page

INTRODUCTION 1

REVIEW OF LITERATURE 2

MATERIALS AND METHODS. 11

Corn 11

Potatoes 11

Sweetclover, Bromegrass, Flax, and Oats. 12

EXPERIMENTAL RESULTS 14

Results with Corn. 14

Results with Oats. 31

Results with Potatoes. 37

Results with Flax, Bromegrass, and Sweetclover . . 42

RAINFALL FOR THE 1948 GROWING SEASON AT MANHATTAN, KANSAS. . 43

SUMMARY AND CONCLUSIONS 44

ACKNOWLEDGMENTS 47

BIBLIOGRAPHY 48

INTRODUCTION

Probably every farmer has observed that many species of weeds germinate and emerge before the crop. This is particularly true with slow germinating crops. Many methods of tillage have been used to kill the weeds without injuring the crop. The latest concept of controlling such weeds is by pre-emergent treatment with chemicals. At present, the most widely recommended chemical for this purpose is that known as 2,4-D.[1] Three formulations of 2,4-D commonly used in pre-emergent tests are ester, amine and sodium salt.

Pre-emergent treatments are those made after the crop is planted, but before it emerges. Hence, reference is made to the emergence of the crop and not to the weeds. Pre-emergent treatment is based on the fact that 2,4-D when applied to the soil in heavy dosages leaves a toxic residue in the surface soil which will destroy weed seedlings starting from seed in the shallow zone of toxicity.

The project reported on in this thesis was undertaken to study the effect of pre-emergent treatments on growth and yield of corn, oats, flax, bromegrass, sweetclover and potatoes. Another purpose was to establish the rates at which 2,4-D must be applied to control weeds by this method.[2] For this study it was assumed that effective weed control could be obtained by applications of 2,4-D at rates in the range of 3/8 pound and 4 pounds per acre, but the exact amount was not known.

---

[1] 2,4-Dichlorophenoxyacetic acid.
[2] Rates are expressed in terms of pounds of 2,4-D acid per acre.

Another object of this study was to determine the effect of chemical application relative to the time of planting and emergence of the crop. With this object in mind, 2,4-D was applied immediately after planting on one set of plots and three days after planting on another set.

REVIEW OF LITERATURE

The chemical 2,4-D was first used as a herbicide some five years ago. However, not until the spring and summer of 1946 was it used as a pre-emergent treatment to control weeds in growing crops.

During the winter of 1947 Barrons (6) wrote:

> Pre-emergence spraying has certain limitations, but it seems to have a definite place in the production of some crops as a practical method of reducing hand weeding and hoeing costs. It appears to have a place in home gardens, nurseries and outdoor flower culture, as well as in the production of certain vegetable and field crops.
>
> One should avoid the concept that pre-emergence spraying will eliminate the need for other control methods. Some weeds will always emerge too late to be killed by pre-emergence treatment, and these must be controlled by other means. Just how much good a pre-emergence treatment will do depends upon the length of time that elapses between seeding and crop emergence, on the species of weed seeds present, and on soil temperature conditions.
>
> The weather, also, plays a part in deciding whether pre-emergence treatment will prove of value. Not only does the potential value of pre-emergence spraying depend upon conditions but proper timing of the application is very important if one is to avoid risk to the crop itself. The sprays used will be just as deadly to tiny crop plants once they break the surface as they are to weeds. If rain interferes and the application is delayed one may have to skip it entirely in order to avoid injury. Experiments have indicated some crop damage when heavy rains followed treatment.
>
> Because the rate of germination and emergence varies

so much with soil temperature and moisture no absolute rule can be laid down for timing an application in relation to the time of seeding. Keen observation will be the primary key to successful spraying. One must observe the development of seedlings below the surface and decide for each planting just when the latest safe time for spraying has arrived. Of course, the longer one can wait without risk to the crop, the more weeds will have a chance to emerge.

Species that push a husky leaf through the ground first, such as potatoes, gladioli and various flowering bulbs, can be seen readily and even if an occasional leaf tip should be "burned" by the spray, no permanent damage to the crop will result.

Barrons (7) reports that two types of pre-emergent treatments as to the amount of chemical applied and time of application are recognized--contact pre-emergent and residual pre-emergent.

In contact pre-emergent, a small amount of a contact type chemical which leaves a minimum amount of residue is employed to kill small weeds before the crop emerges. Not enough chemical is applied to leave a residual effect. While in the case of a residual pre-emergent, heavier rates of the chemical are applied at planting or shortly thereafter. The chemical remains active in the soil for varying lengths of time, often long after the crop has emerged. Since the weeds are killed and the crop remains unharmed, selectivity is involved.

According to Craft (9), there are four distinct weather conditions that might affect a pre-emergent treatment designed to act through the soil. First, no rainfall following application would result in failure in most conditions because the chemical would not get into the soil surrounding the roots of the weeds. Second, light rainfall and foggy weather may cause serious injury to the crop plants because of the higher concentration of the chemical in the shallow top soil layer. Third, moderate rainfall is the most favorable for successful selective action and should result in control of the weeds. Fourth, heavy rainfall or flood may result in failure for if the chemical is leached from the soil, weed seedlings will survive.

In summarizing the results obtained by use of 2,4-D as pre-emergent treatments, Derscheid and Stahler (11) report that research results have been inconsistent. Some research workers have obtained excellent control of weeds without injury to the crop, while others have obtained results showing no effect on the weeds or the crop. Still others have received damage to both the crop and the weeds.

Timmons (30) gave the following account of pre-emergent treatments with 2,4-D:

> This pre-emergence principle has in some cases given control of seedling grassy weeds as well as control of most broad-leaved annual weeds. It is not effective against perennial weeds. Many factors governing the success or failure of pre-emergence treatments have not been determined and general recommendations for this practice cannot be made at present. Successful experiments in some areas have been made with large seeded crops (corn and some others) planted in finely pulverized seedbeds on heavy soils in which 2 pounds of 2,4-D per acre have given good control of small seeded weeds for a period of 4 to 6 weeks. On lighter soils in areas of frequent rainfall during the planting season the 2,4-D has leached down and killed or severely injured the germinating crop. The seed bed should be carefully fitted and the seed planted slightly deeper than usual. For most effective results it is best not to disturb the soil following the application of the chemical.

In Canada, Wood and Olson (32) report that results of pre-emergent treatment have shown so much variation that further experimentation will be required before any recommendations can be made. They report that the chemical remains for a period of

30 to 45 days varying with the moisture content of the soil and the soil temperature.

Anderson and Wolf (4) controlled weeds in five inbred lines of corn by pre-emergent treatments of 2,4-D. Annual grasses as well as annual broad-leaved weeds were controlled for about six weeks. By the end of this period the corn was past the stage at which new weeds could compete with it. The year's work at Rutger's University indicated that 2.7 pounds of 2,4-D effectively controls weeds without detrimental effect on the yield of corn.

Results from pre-emergent treatments the following year (3) gave reason for some modification of previous statements by these investigators as indicated in the following generalizations: There appears to be no advantage in using more than 1½ pounds of 2,4-D acid per acre. Application of 2,4-D several days after planting was more effective in controlling weeds than that made at time of planting. Emergence of the corn was least inhibited by the 1½ pound rate of application. The earlier application affected a much larger percentage of corn plants than the later one, due to causes not fully explained. Pre-emergent applications of 2,4-D on sandy soil failed completely for causes unknown. There are large differences between hybrids with respect to percent of plants affected by 2,4-D.

Aldrich, Shaw and Willard (1) report that when butyl ester was applied at two different dates on hybrid corn, the application five days after planting resulted in better stand and yield than immediately after planting. The average yield of all treated plots was 15 bushels per acre more than the untreated plots. No plots were cultivated; therefore, any difference was due to complete control of the annual weeds and weedy grasses. Results from an experiment conducted by Derscheid and Kratochvil (10) have shown that treatments made at emergence of the corn gave about 25 percent control of broad leaved annuals, such as rough pigweed (Amaranthus retroflexus), common ragweed (Ambrosia artemisiifolia), Kochia (Kochia scoparia), and lamb's quarters (Chenopodium album), while about 10 percent of the foxtails (Setaria viridis and S. glauca), were controlled. Earlier treatments than the one mentioned gave no weed control. No differences in the date of application of the 2,4-D could be established statistically. According to Fuelleman and Slife (15) when the ester, amine and sodium salt of 2,4-D were used at three rates and applied at two different dates, broad leaved weeds in corn were reduced in number, but the grassy weeds such as crabgrass (Digitaria sp.), barnyard grass (Echinochloa sp.), lovegrass (Erogrostis sp.), and panic grass (Panicum sp.), were not controlled. The corn showed no observable effect from the various materials or concentrations of 2,4-D. No marked differences in yield were observed.

Elder (14) obtained results which show that two and four pounds of 2,4-D gave a reduced stand and vigor of corn. Annual weedy grasses were partially controlled; however, nutgrass and climbing milkweed were not controlled. Some of the broad leaved annuals were controlled by the two and four pound rates. Annual smartweed was only partially controlled. Yields when compared with cultivated plots where weeds were removed, gave a reduction of 15 percent for the two pounds of ester, 29 percent for the one pound of ester, 35 percent for the uncultivated and no treatment, and 40 percent for the four pounds of ester. Lee (18) reported that two pounds of 2,4-D gave control of the annual broad leaved weeds, but the plots were heavily infested with foxtail and crabgrass. Applications of 2,4-D alone gave the lowest yield. One cultivation in addition to 2,4-D gave an intermediate yield while two cultivations with no 2,4-D treatment gave the highest yield.

Fewer pre-emergent tests have been conducted on potatoes than on corn. According to Helgeson and Swanson (17), potatoes treated with butyl ester five days after planting controlled broad leaved annuals consisting chiefly of Frenchweed, pigweed, and lamb's quarters. Fair control of pigeon grass, a weedy grass, was obtained at four pounds per acre. No marked injury to the potatoes was observed. Andersen and Mantell (2) reported slight control of weeds after the potatoes emerged when butyl ester and sodium salt were applied. Some distortion of the potato stems could be noticed. Analysis of yield data indicated no statistically significant reduction in yields with any of the treatments when applied at different dates. In summarizing the data obtained on potatoes in the North Central States area, Helgeson (16) stated: "Used as a pre-emergence treatment at rates up to four pounds per acre, various formulations of 2,4-D gave some indication of practical weed control with no reduction in yield".

Templeman (29), in England, reported that pre-emergent dressings up to two pounds per acre had no effect on spring oats; however, four pounds per acre occasionally reduced plant establishment.

Tests conducted by Pavlychenko (26) have shown that oats are more sensitive to 2,4-D than any other cereal on which pre-emergent treatments were applied. Two pounds of 2,4-D gave reduction in height of five to six inches. Varying degrees of weed control were obtained, depending largely upon the date of application. Shaw and Willard (28) reported weed control with one and one-half pounds of 2,4-D. MacDonald, Slough, and Zinter (21, 22, 23, 24) received varying results as to injury of the oats and control of weeds at four different locations. Wolfe and Shafer (31) obtained the following results when pre-emergent treatments were applied to two varieties of oats:

> At emergence no difference could be noted in stand or appearance of the oat seedlings. Several weeks after emergence a darker green color was noticed on the plants sprayed with the four pound applications, and to a lesser extent on plots sprayed at rate of two pounds per acre. Several days following the change in color, onion leafing and abnormal roots were apparent on the plants sprayed with four pounds of 2,4-D. At heading time color differences were diminishing. Plants sprayed with four pounds of 2,4-D were reduced in height. The onion leafing in most instances prevented the heads from emerging normally and in many cases heading did not occur. Many of the heads showed characteristic goose necking which was the result of having to split the leaf sheath in order to appear. Many of the florets were sterile. With the exception of the one-half pound treatments, yields were decreased in direct proportion to the amount of 2,4-D applied. The one-half pound plot yields were equal to or greater than the check plots. No apparent difference as to varietal response was noted.

Derscheid, Stahler and Kratochvil (12) obtained reduction of flax stand in proportion to amount 2,4-D applied when 0.3 of an inch of rain fell the evening following the application. However, these thin stands were not apparent at harvest time. Any difference in yield was not significant when analysis of variance was applied. When 2,4-D was applied three days after planting, common ragweed (Ambrosia artemisiifolia) and Kochia (Kochia scoparia) were controlled, but it did not affect the foxtails (Setaria sp.). Results obtained by Pavlychenko (25) showed a low percent of germination in all plots treated immediately after planting. These plots were slow in growth and at maturity were two to six inches shorter than the check. Another series treated just before emergence gave a higher germination and only slight stunting at maturity. The highly susceptible weeds were controlled effectively. However, red root pigweed (Amaranthus sp.), Russian thistle (Salsola sp.), and wild buckwheat (Polygonum sp.) were injured but not controlled. Varying results were obtained by MacDonald, Slough, and Zinter (19,20) at two locations. No injury to the flax was noted and weeds were about the same in all plots regardless of the rate of 2,4-D used.

Dunham (13), in summarizing reports on pre-emergent trials made in the North Central States, stated:

> The following indications are shown in work reported although more data are necessary before conclusions may be drawn.
>
> 1. Dormant seeds are not killed by soil treatment.
>
> 2. Weeds in general become more resistant with age; this is particularly true of the grasses. Considerable reduction in annual grasses can be accomplished.
>
> 3. Weed seedlings may grow uninhibited if there is inadequate rain and they may emerge later in the season from seeds that did not germinate earlier after toxicity has disappeared from the soil.
>
> 4. Smartweed, Russian thistle and field bindweed seedlings were more resistant than pigweed, chickweed,

shepherd's purse and purslane but there may be differences in species and strains common to various regions.

MATERIALS AND METHODS

Two experiments were conducted on the Agronomy farm at Manhattan, Kansas during the 1948 growing season. Sweet clover, bromegrass, flax, oats and potatoes were included in one experiment while corn was grown in the other. In each of these experiments plots were replicated in randomized block design.

Corn

The area to be planted to corn was plowed in the fall of 1947. The area was disked and harrowed before Pride of Saline, an open pollinated variety of corn, was planted with a surface planter on May 11. The seedbed was in excellent condition when the corn was planted.

Seven rates of 2,4-D, 3/8, 3/4, and 1 1/8 pounds triethanol amine, 3/4 and 1½ pounds of isopropyl ester and monhydrate sodium salt, and two checks, one of which was untreated and the other hoed, were included in each of four replications. These replications, each consisting of 9 plots, were on soil of different fertility levels. Each plot consisted of four rows 30 feet long and data were obtained from the center two rows.

The 2,4-D was applied on May 15, four days after the corn was planted, with a tractor sprayer. Some of the corn seedlings were emerging at the time of 2,4-D application.

Potatoes

The area to be planted to potatoes was plowed in the fall of 1947. It was disked and harrowed before two rows of potatoes were planted in each 5 by 10 feet plot about 6 inches deep on April 3. At the time of planting the surface soil was dry and cloddy.

Due to the fact that potatoes are slow emerging, the 2,4-D was not applied until two weeks and three weeks after planting. Four rates, ½, 1, 2, and 4 pounds of isopropyl ester and monhydrate sodium salt forms of 2,4-D were used at each date of application. A control plot, which was neither treated nor cultivated, was included in each replication. The plots treated at each date were replicated three times. At the last date of 2,4-D application the potatoes were emerging. All treatments were applied with a knapsack sprayer.

The potatoes were sprayed on June 4 with lead arsenate to control the Colorado potato beetle. No other harmful insects were observed throughout the growing season.

The number of hills were counted and recorded before the potatoes were dug. As near as possible the soil was removed from all of the tubers at the time of digging. After all the potatoes had been dug, the yield of each plot was determined.

Sweetclover, Bromegrass, Flax and Oats

The area was plowed in the fall of 1947 and disked and harrowed before planting the following spring. The surface soil was dry and cloddy at planting time, although some moisture was available at a depth of about two inches.

Sweetclover, bromegrass, flax and oats were planted in 5 by 10 feet plots at two different dates, April 6 and 10. The plots planted at each date were replicated three times.

The plots were seeded lengthwise with a hand planter. The oats averaged 8 rows, sweetclover 9 rows, bromegrass 10 rows and flax 12 rows per plot. The oats and flax were seeded about two inches deep while the sweetclover and the bromegrass were covered about one-half inch.

Isopropyl ester and monhydrate sodium salt forms of 2,4-D were used at four rates ½, 1, 2 and 4 pounds. A control plot, which was neither treated nor cultivated, was included in each replication. The plots planted on April 6 were treated the following day, while those planted on April 10 were treated three days later.

Of these crops only the oats were harvested. The average height was determined before the entire plot was harvested with a hand scythe and tied into bundles. After the bundles had cured in the field, the oats were threshed with a nursery thresher. The oats were cleaned with a fanning mill before the yield of each plot was taken.

EXPERIMENTAL RESULTS

Results with Corn

The effect of pre-emergent application of 2,4-D on vegetative growth of corn and the various species of weeds was observed throughout the growing season. Data on stand, tillering, lodging, yield, number of ears and average ear size were obtained at harvest. These data are shown in Tables 1 to 6 inclusive.

Table 1. Stand of corn

Treatment	Number of hills per plot			
	Blocks			
Pounds of 2,4-D acid per acre	A	B	C	D
Triethanol amine, 3/8 lb.	32	34	21	29
Sodium salt, 3/4 lb.	34	40	24	33
Isopropyl ester, 3/4 lb.	32	36	26	30
Triethanol amine, 3/4 lb.	32	36	21	30
Triethanol amine, 1 1/8 lb.	31	41	34	37
Isopropyl ester, 1 1/2 lb.	29	38	23	29
Sodium salt, 1 1/2 lb.	34	34	31	39
Check	32	37	26	29
Hoed check	28	35	27	27

Table 2. Amount of tillering.

Treatment Pounds of 2,4-D acid per acre	Number of stalks per plot Blocks A	B	C	D
Triethanol amine, 3/8 lb.	62	66	22	35
Sodium salt, 3/4 lb.	75	90	43	42
Isopropyl ester, 3/4 lb.	67	91	52	48
Triethanol amine, 3/4 lb.	63	84	34	36
Triethanol amine, 1 1/8 lb.	67	82	43	60
Isopropyl ester, 1 1/2 lb.	67	89	49	50
Sodium salt, 1 1/2 lb.	86	66	57	61
Check	59	55	32	32
Hoed check	53	82	35	32

Table 3. Yield of corn.

Treatment Pounds of 2,4-D acid per acre	Pounds of ears per plot Blocks A	B	C	D
Triethanol amine, 3/8 lb.	24.1	27.5	9.3	9.6
Sodium salt, 3/4 lb.	30.2	28.6	19.1	16.6
Isopropyl ester, 3/4 lb.	27.9	31.2	19.3	16.9
Triethanol amine, 3/4 lb.	26.7	31.2	15.9	13.9
Triethanol amine, 1 1/8 lb.	28.3	31.2	15.9	22.7
Isopropyl ester, 1 1/2 lb.	23.3	41.5	21.9	16.4
Sodium salt, 1 1/2 lb.	27.6	30.8	20.9	22.9
Check	23.6	24.5	5.4	11.5
Hoed check	28.6	36.4	22.6	19.1

Table 4. Lodging expressed as number of stalks per plot broken below the ear or leaning 45° or more.

Treatment Pounds of 2,4-D acid per acre	Number of broken stalks per plot Blocks A	B	C	D
Triethanol amine, 3/8 lb.	32	21	1	7
Sodium salt, 3/4 lb.	34	29	12	4
Isopropyl ester, 3/4 lb.	37	39	3	6
Triethanol amine, 3/4 lb.	36	25	5	7
Triethanol amine, 1 1/8 lb.	22	15	6	11
Isopropyl ester, 1 1/2 lb.	35	39	6	2
Sodium salt, 1 1/2 lb.	52	20	11	16
Check	31	8	2	6
Hoed check	15	33	10	2

Table 5. Ears.

Treatment Pounds of 2,4-D acid per acre	Number of ears per plot Blocks A	B	C	D
Triethanol amine, 3/8 lb.	44	58	19	32
Sodium salt, 3/4 lb.	65	62	40	40
Isopropyl ester, 3/4 lb.	59	66	40	35
Triethanol amine, 3/4 lb.	58	64	28	34
Triethanol amine, 1 1/8 lb.	52	61	38	49
Isopropyl ester, 1 1/2 lb.	54	79	42	35
Sodium salt, 1 1/2 lb.	70	61	43	55
Check	50	42	27	30
Hoed check	57	71	39	35

Table 6. Size of ears.

Treatment	Average wt. per ear per plot			
	Blocks			
Pounds of 2,4-D acid per acre	A	B	C	D
	Pounds	Pounds	Pounds	Pounds
Triethanol amine, 3/8 lb.	.54	.47	.49	.30
Sodium salt, 3/4 lb.	.47	.46	.48	.42
Isopropyl ester, 3/4 lb.	.47	.47	.48	.48
Triethanol amine, 3/4 lb.	.46	.48	.57	.41
Triethanol amine, 1 1/8 lb.	.54	.51	.42	.46
Isopropyl ester, 1 1/2 lb.	.43	.53	.52	.47
Sodium salt, 1 1/2 lb.	.39	.51	.49	.42
Check	.47	.58	.20	.38
Hoed check	.50	.51	.58	.55

The relationship between stand, tillers, and yield was the first study to be made. In order to show this relationship, if such exists, the data were analyzed statistically by analysis of covariance and correlation studies were made between yield and stand, yield and tillers, and tillers and stand. A summary of these data is recorded in Tables 7, 8 and 9, respectively.

Table 7. Summary of analysis of covariance for yield and stand.

Source of variation	Degrees of freedom	Sum of squares for yield	Sum of squares for stand	Sum of products	Correlation value
Total	35	2173.98	900.75	883.04	.64*
Treatments	8	426.19	186.00	79.87	.28
Blocks	3	1485.92	533.86	723.36	.82
Interaction	24	261.87	180.89	79.81	.36

*highly significant

Table 8. Summary of analysis of covariance for yield and tillers.

Source of variation	Degrees of freedom	Sum of squares for yield	Sum of squares for tillers	Sum of products	Correlation value
Total	35	2173.98	12852.75	4640.84	.90*
Treatments	8	426.19	2393.50	811.57	.80*
Blocks	3	1485.92	8800.97	3605.44	.99*
Interaction	24	261.87	1658.28	223.83	.34

*highly significant

Table 9. Summary of analysis of covariance for stand and tillers.

Source of variation	Degrees of freedom	Sum of squares for stand	Sum of squares for tillers	Sum of products	Correlation value
Total	35	900.75	12852.75	2563.75	.75*
Treatments	8	186.00	2393.50	404.75	.61
Blocks	3	533.86	8800.97	1845.08	.85
Interaction	24	180.89	1658.28	313.92	.57*

*highly significant

A significant correlation was established between stand and tillers. However, to study the effects of 2,4-D treatments, data on yield, stand, tillers, lodging, number of ears, and average ear size were analyzed statistically by analysis of variance. The summary of analysis of variance for stand, tillers and yield is shown in Table 10, while the summary for lodging, number of ears and the average ear size is shown in Table 11.

The F ratios established by treatments in case of average ear size and the number of stalks lodged per plot were nonsignificant. Any difference in average ear size and broken stalks per plot is due probably to sampling variation.

The F ratios established by treatments in the case of yield, number of tillers and number of ears per plot were significant. Any difference in the yield, number of tillers, number of ears and number of hills per plot is due probably to treatments and not sampling variation alone. These differences produced by 2,4-D treatments can be shown by least significant difference. Least significant difference as summarized for yield, number of tillers, number of ears and number of hills per plot is shown in Tables 12, 13, 14 and 15, respectively.

The check plots which were neither treated nor hoed produced the lowest yield of all plots. The plots treated with 3/4 pound triethanol amine were significantly increased at the 5 percent level and the plots treated with 1 1/8 pound triethanol amine, 3/4 pound sodium salt and isopropyl ester, and 1½ pounds of sodium salt and isopropyl ester were significantly increased at the 1 percent level when compared with the check plot.

Table 10. Summary of analysis of variance for stand, tillers and yield.

Source of variation	Degrees of freedom	Mean square	Calculated F ratio	F Value for significance .05	.01
		Stand			
Total	35	25.74			
Treatments	8	23.25	3.08	2.36	3.36
Blocks	3	177.95	23.60	3.01	4.72
Interaction	24	7.54			
		Tillers			
Total	35				
Treatments	8	299.19	4.33	2.36	3.36
Blocks	3	2933.66	42.46	3.01	4.72
Interaction	24	69.09			
		Yield			
Total	35				
Treatments	8	53.27	4.88	2.36	3.36
Blocks	3	495.30	45.40	3.01	4.72
Interaction	24	10.91			

Table 11. Summary of analysis of variance for lodging, and number of ears.

Source of variation	Degrees of freedom	Mean square	Calculated F ratio	F Value for significance .05	.01
		Lodging			
Total	35				
Treatments	8	70.46	1.16	2.36	3.36
Blocks	3	1604.96	26.35	3.01	4.72
Interaction	24	60.90			
		Number of ears			
Total	35				
Treatments	8	174.25	4.13	2.36	3.36
Blocks	3	1643.30	39.01	3.01	4.72
Interaction	24	42.13			
		Ear size			
Total	35				
Treatments	8	.005	.83	2.36	3.36
Blocks	3	.006	1.00	3.01	4.72
Interaction	24	.006			

Table 12. Summary of least significant difference for average yield per plot for each treatment.[1]

Treatment Lbs. of 2,4-D acid per acre	Average yield lbs./plot	Significance compared with Check	Significance compared with Hoed check
Hoed check	26.7	**	
Isopropyl ester, 1½ lb.	25.8	**	
Sodium salt, 1½ lb.	25.5	**	
Triethanol amine, 1 1/8 lbs.	24.5	**	
Isopropyl ester, 3/4 lb.	23.8	**	
Sodium salt, 3/4 lb.	23.6	**	
Triethanol amine, 3/4 lb.	21.9	*	*
Triethanol amine, 3/8 lb.	17.6		**
Check	16.3		**

[1] Least significant difference at 5 percent and 1 percent level is 4.7 lbs. and 6.4 lbs. respectively.
* Significant at 5 percent level.
**Significant at 1 percent level.

Table 13. Summary of least significant difference for average number of corn tillers per plot for each treatment.[1]

Treatment Lbs. of 2,4-D acid per acre	Average number of tillers per plot	Significance compared with Check	Significance compared with Hoed check
Sodium salt, 1½ lb.	67.5	**	**
Isopropyl ester, 3/4 lb.	64.5	**	*
Isopropyl ester, 1½ lb.	63.8	**	*
Triethanol amine, 1 1/8 lb.	63.0	**	*
Sodium salt, 3/4 lb.	62.5	**	*
Triethanol amine, 3/4 lb.	54.2		
Hoed check	50.4		
Triethanol amine, 3/8 lb.	46.2		
Check	44.5		

1/ Least significant difference at 5 percent and 1 percent level is 12.1 tillers and 16.4 tillers respectively.
* Significant at 5 percent level.
**Significant at 1 percent level.

Table 14. Summary of least significant difference for average number of ears of corn per plot for each treatment.[1]

Treatment Lbs. of 2,4-D acid per acre	Average number of ears per plot	Significance compared with Check	Significance compared with Hoed check
Sodium salt, 1½ lb.	57.5	**	
Isopropyl ester, 1½ lb.	52.5	**	
Sodium salt, 3/4 lb.	51.8	**	
Hoed check	50.4	**	
Isopropyl ester, 3/4 lb.	50.0	*	
Triethanol amine, 1 1/8 lb.	50.0	*	
Triethanol amine, 3/4 lb.	46.0		
Triethanol amine, 3/8 lb.	38.3		*
Check	37.3		**

[1] Least significant difference at 5 percent and 1 percent level is 9.4 ears and 12.8 ears respectively.
* Significant at 5 percent level.
**Significant at 1 percent level.

Table 15. Summary of least significant difference for average number of hills per plot for each treatment.[1]

Treatment Lbs. of 2,4-D acid per acre	Average number of hills per plot	Significance compared with Check	Significance compared with Hoed check
Triethanol amine, 1 1/8 lb.	35.8	*	**
Sodium salt, 1½ lb.	34.5		*
Sodium salt, 3/4 lb.	32.8		
Isopropyl ester, 3/4 lb.	31.0		
Check	31.0		
Isopropyl ester, 1½ lb.	29.8		
Triethanol amine, 3/4 lb.	29.8		
Hoed check	29.3		
Triethanol amine, 3/8 lb.	29.0		

[1] Least significant difference at the 5 percent and 1 percent level is 4.0 hills and 5.4 hills respectively.
* Significant at the 5 percent level.
**Significant at the 1 percent level.

The plots which were hoed produced the highest yield. The yield of the plots treated with 3/4 pound triethanol amine was significantly decreased at the 5 percent level, and 1/8 pound triethanol amine and the check were significantly decreased at the 1 percent level when compared with the hoed check.

The check plots which were neither treated nor hoed produced the least number of tillers. The number of tillers in the plots treated with 1 1/8 pounds triethanol amine, 3/4 pound and 1½ pounds of sodium salt and isopropyl ester were significantly increased at the 1 percent level when compared with the check. The number of tillers in the plots treated with 1 1/8 pounds triethanol amine, 3/4 pound sodium salt, and 3/4 pound and 1½ pounds of isopropyl ester were significantly increased at the 5 percent level, while 1½ pounds sodium salt were significantly increased at the 1 percent level when compared with the hoed check.

Data shown in Table 13 indicate that the number of tillers per plot varies with the amount of 2,4-D applied; that is, as the rate of 2,4-D applied was increased there was a tendency for the number of tillers per plot to increase.

Many different factors could account for the increase in the number of tillers in plots treated with the heavy rates of 2,4-D. Possibly tillering is associated with 2,4-D injury. More 2,4-D injury was observed in the plots treated with the higher rates than in plots treated with the lower rates of 2,4-D. There may be a physiological change within the plant resulting from the 2,4-D which tends to stimulate tiller formation. Weather conditions also may be a factor influencing the amount of tillering. Since weather plays a very important role in the success or failure of pre-emergent treatments, the prevailing conditions of the 1948 growing season may have been such as to favor increased tillering in the 2,4-D treated plots.

The check produced the least number of ears of any of the plots. The number of ears in the plots treated with 3/4 pound and 1 1/8 pounds triethanol amine were significantly increased at the 5 percent level. While the number of ears of the plots treated with 3/4 pound and 1½ pounds of sodium salt and isopropyl ester and the hoed check were significantly increased at the 1 percent level when compared with the check. The number of ears in the 3/8 pound triethanol amine plots were significantly decreased at the 5 percent level and in the check plot was significantly decreased at the 1 percent level when compared with the hoed check.

Several factors may account for the increased number of ears in the plots treated with the heavier rates of 2,4-D and in the hoed check. Since fairly good weed control was obtained with the 3/4 pound, 1 1/8 pounds and 1½ pounds rates of 2,4-D and complete weed control was obtained in the hoed check, the corn by removal of the weed competition was provided with better growing conditions which in turn stimulated tillering. Some of the 2,4-D treated plots produced more tillers as well as more ears of corn. This additional increase of tillers could possibly account for some of the increase in the number of ears.

The influence of 2,4-D treatments on various species of weeds and on the development of corn was made the object of a special study. The control of weeds and the effect on the corn plant vary considerably with the rate and formulation of 2,4-D used.

Several species of weeds were found in the 36 plots of corn grown for this study, the species differing somewhat in the four blocks of different fertility level. The predominating species on the more fertile blocks were crabgrass (Digitaria sanguinalis) and smooth pigweed (Amaranthus hybridus). On the two blocks of low fertility, shoofly (Hibiscus trionum) and crabgrass predominated with occasional patches of buffalo bur (Solanum rostratum) and annual smartweed (Polygonum pennsylvanicum).

Weed control obtained in the plots treated with 3/8 pound and 3/4 pound triethanol amine was less than or equal to that obtained in those treated with 3/4 pound of isopropyl ester and sodium salt. Weed control obtained in the plots treated with 1 1/8 pounds of triethanol amine was equal to or better than that obtained in the plots treated with 3/4 pound sodium salt and isopropyl ester.

The degree of weed control of the sodium salt was intermediate. That is, the 3/4 pound of sodium salt controlled the weeds as much as or more than any of the triethanol amine rates and about equal to the 3/4 pound of isopropyl ester. The 1½ pounds of sodium salt were less effective than the 1½ pounds of isopropyl ester.

Isopropyl ester applied at a rate of 1½ pounds gave excellent control of weeds. In some plots almost 100 percent control of both broad leaved weeds and annual weedy grasses was obtained.

Results of these tests under the conditions that prevailed in 1948 show that pre-emergent treatments with 2,4-D controlled crabgrass seedlings for a few weeks, but had little or no effect upon those seedlings which developed after the relatively short period of soil toxicity. Shoofly and buffalo bur as seedlings are susceptible while annual smartweed is tolerant to 2,4-D applied as a pre-emergent treatment.

Soil toxicity was obtained in all plots for a period of 2 to 6 weeks depending upon the rate of 2,4-D and to a lesser extent upon the formulation used. However, after this period, crabgrass became established and grew to maturity. Fewer weeds were present at harvest time in the plots treated with the rates of 1½ pounds of sodium salt and isopropyl ester than in those treated with lighter rates.

The corn plant is affected by 2,4-D in many ways; however, the most noticeable effect is abnormal growth of the brace roots. In some cases the brace roots would grow vertically while in others they would curl and grow around the culm. Still others would grow until they reached the surface soil where elongation ceased and many fine fibrous roots developed. When injury was severe a gelatinous substance formed beneath the brace roots.

All rates and forms of 2,4-D used affected the brace roots. Somewhat less injury was observed in the plots treated with 3/8 pound triethanol amine. All other plots showed about the same injury. In one plot treated with 1½ pounds of isopropyl ester some of the stalks were bent and the boots were curled at tasseling time.

Results with Oats

The effect of 2,4-D treatments on growth characters and yield of oats and the control of weeds was studied. Yield and height data were obtained at harvest time. The yield in pounds per plot and average height in inches are shown in Table 16.

To study the effects of 2,4-D treatments, both yield and height data were analyzed statistically by analysis of variance. The summary of this analysis is shown in Table 17.

The F ratio established by treatments in case of yield of oats was highly significant. This would indicate that any difference in yield of oats probably is due to the treatments and not sampling variation alone.

The F ratos established by treatments, dates, and interaction in case of height of oats were highly significant. Any difference in height probably is due therefore to treatments and date of application and not sampling variation alone.

These differences which exist in yield and in height can readily be shown by least significant difference. A summary of the results of these calculations is shown in Tables 18 and 19.

The yield of plots treated with 2 pounds of sodium salt was significantly decreased at the 5 percent level, while the yield of plots treated with 2 and 4 pounds of isopropyl ester and 4 pounds of sodium salt was significantly decreased at the 1 percent level when compared with the check plots.

Possibly the decrease in yield in the plots treated with the heavier rates of 2,4-D can be associated with the amount of 2,4-D

Table 16. Yield and average height of oats.

Treatment	2,4-D applied the day after planting						2,4-D applied 3 days after planting					
	Blocks						Blocks					
	1		2		3		1		2		3	
	Yield lbs.	Ht. In.	Yield lbs.	Ht. In.	Yield lbs.	Ht. In.	Yield lbs.	Ht. In.	Yield lbs.	Ht. In.	Yield lbs.	Ht. In.
Sodium salt, ½ lb.	2.80	39	3.77	37	2.50	36	3.93	32	3.59	36	2.67	34
Isopropyl ester, ½ lb.	2.64	38	3.64	37	2.52	36	3.67	32	3.69	35	3.07	34
Sodium salt, 1 lb.	3.49	38	3.82	36	2.75	35	3.56	30	3.56	35	3.11	31
Isopropyl ester, 1 lb.	3.82	38	4.04	36	2.79	34	3.36	31	2.88	34	2.43	29
Sodium salt, 2 lbs.	2.89	36	3.75	36	1.99	34	3.12	30	2.52	32	2.47	28
Isopropyl ester, 2 lbs.	2.46	35	3.65	33	2.06	31	2.72	29	2.37	33	2.83	29
Sodium salt, 4 lbs.	2.61	33	2.87	31	1.68	30	2.31	29	2.01	34	2.94	31
Isopropyl ester, 4 lbs.	2.67	34	2.19	28	1.88	29	1.77	25	2.31	33	2.27	29
Check	2.57	40	3.82	37	3.12	36	3.81	36	3.21	36	3.68	35

Table 17. Summary of analysis of variance for yield and height of oats.

Source of variation	Degrees of freedom	Mean square	Calculated F ratio	F Value for significance .05	.01
		Yield			
Total	53				
Treatments	8	1.16	7.32	2.25	3.12
Blocks	4	1.59	11.36	2.67	3.97
Dates	1	.02	.14	4.15	7.50
Interaction	8	.21	1.50	2.25	3.12
Remainder	32	.14			
		Height			
Total	53				
Treatments	8	31.46	7.25	2.25	3.12
Blocks	4	31.26	7.04	2.67	3.97
Dates	1	121.48	27.99	4.15	7.50
Interaction	8	4.34	3.29	2.25	3.12
Remainder	32	1.32			

Table 18. Summary for least significant difference for average yield per plot for each treatment.[1/]

Treatment Lbs. of 2,4-D acid per acre	Average yield lbs. per plot	Significance compared with check
Sodium salt, 1 lb.	3.38	
Check	3.36	
Isopropyl ester, 1 lb.	3.22	
Sodium salt, ½ lb.	3.21	
Isopropyl ester, ½ lb.	3.20	
Sodium salt, 2 lb.	2.79	*
Isopropyl ester, 2 lb.	2.68	**
Sodium salt, 4 lb.	2.40	**
Isopropyl ester, 4 lb.	2.18	**

1/ Least significant difference at 5 percent and 1 percent level is .44 pounds and .59 pounds respectively.
* Significant at the 5 percent level.
**Significant at the 1 percent level.

Table 19. Summary of least significant difference for average height per plot for each treatment.[1]

Treatment Lbs. of 2,4-D acid per acre	Average height (expressed in inches)	Significance compared with check
Check	36.6	
Sodium salt, ½ lb.	35.6	
Isopropyl ester, ½ lb.	35.3	*
Sodium salt, 1 lb.	34.1	**
Isopropyl ester, 1 lb.	33.6	**
Sodium salt, 2 lb.	32.6	**
Isopropyl ester, 2 lb.	31.6	**
Sodium salt, 4 lb.	31.3	**
Isopropyl ester, 4 lb.	29.6	**

[1] Least significant difference at 5 percent and 1 percent level is 1.4 inches and 1.8 inches respectively.
* Significant at 5 percent level.
**Significant at 1 percent level.

injury. More injury was observed in these plots.

The oats in the check plot were taller than the oats in the other plots. The height of oats in the plots of 1, 2 and 4 pounds isopropyl ester and 2 and 4 pounds of sodium salt was significantly decreased when compared with height of the oats in the check plot.

When 2,4-D was applied at heavy rates the oat plants were stunted and injured. This injury was observed early in the season and was so pronounced that the oat plants never fully recovered, which resulted in a significant reduction in height.

The oats were relatively free of weeds throughout the growing season. Probably the most prevalent weed was annual smartweed (Polygonum pennsylvanicum). Later in the season, ivy leaved morning-glory (Ipomoea hederacea) began to grow and twine about the oat plants. The growth and development of the ivy leaved morning-glory was probably due to lack of competition because it was most prevalent in the plots treated with the heavier rates of 2,4-D. Some control of crabgrass (Digitaria sanguinalis) and other weedy grasses was obtained with treatment of 1 pound or more.

It is known that crabgrass is more tolerant to 2,4-D than ivy leaved morning-glory when it is used as a foliage application; however, when the 2,4-D is used as a pre-emergent treatment, it would appear that a lethal concentration of 2,4-D remains near the surface of the soil at about the depth of root penetration for annual weedy grasses, thus, preventing the establishment of crab-grass seedlings. On the other hand dicots, such as ivy leaved morning-glory, having ample reserves in the seed to extend the root well below the zone of lethal toxicity in the soil, are able to survive the pre-emergent treatment.

Injury to the oat plants was evident in all plots treated with 1 pound of 2,4-D or more. During the early part of the growing season injured plants were characterized by a stunted growth. A few of the plants showed unusual leaf development with the leaves approaching the tubular form known as "onion top". Some of the oat plants in the plots treated with 2 pounds and 4 pounds of isopropyl ester and 4 pounds of sodium salt were grassy in appearance.

Later in the season the oat plants remained somewhat stunted with enlarged nodes. A few tillers developed two heads from one boot at heading time. In some cases there was abnormal exsertion of the head which instead of extending upward protruded from the side of the boot. Still other plants produced no heads, but continued to grow vegetatively.

Severe injury was noted in the plots treated with 2 pounds and 4 pounds of isopropyl ester and 4 pounds of sodium salt. This effect was more pronounced in the plots treated with the isopropyl ester.

Results with Potatoes

The effect of 2,4-D on growth characters and the yield of the potatoes was studied. The yields are recorded in Table 20. These data were analyzed statistically by analysis of variance which is summarized in Table 21.

The F values established by treatments and dates were non-signiffcant. This would indicate that treatments and dates of application probably had little or no effect upon the yield of potatoes.

The effect of different rates and formulations of 2,4-D on sugar content of the potato tubers was studied. A sample of the tubers grown under each treatment was analyzed for sugar content by the Quisumbing and Thomas method (33). The results obtained are shown in Table 22.

These results indicate that the sugar content of the tubers varied considerably with the formulation of 2,4-D used. The tubers from the plots treated with isopropyl ester showed an increase while those from the plots treated with sodium salt were about equal to or slightly lower in sucrose content when compared with the tubers of the check plot.

Smooth pigweed (Amaranthus hybridus) and annual smartweed (Polygonum pennsylvanicum) were the most prevalent weeds in the potato plots. However, scattered plants of shoofly (Hibiscus trionum), buffalo bur (Solanum rostratum), nut grass (Cyperus rotundus) and barnyard grass (Echinochloa crusgalli) were present also. Early in the season crabgrass (Digitaria sanguinalis) seedlings were controlled; however, those seedlings which developed later were not affected. Scattered plants of ivy leaved morning-glory (Ipomoea hederacea) were present at harvest time.

Varying degrees of weed control were obtained. The ½, 1 and 2 pound rates of 2,4-D partially controlled the weeds. In some cases, 4 pounds sodium salt controlled 85 percent or more of the weeds; however, results with this rate were inconsistent. Four pounds of isopropyl ester controlled 95 percent or more of all weeds except the late germinating ones, ivy leaved morning-glory and crabgrass.

The soil remained toxic for a period of 4 to 6 weeks where treated with 2 pounds and 4 pounds of isopropyl ester and 4 pounds sodium salt. The weeds emerging in the 4 pounds of isopropyl ester treated plots showed 2,4-D injury exhibited by crooked stems and wrinkled leaves.

Potato plants in the plots treated with 2 and 4 pounds of isopropyl ester and 4 pounds of sodium salt showed leaf injury at the time of emergence. Early in the growing season the lower leaves of the potato plants were wrinkled and yellowish in color; however, none of this injury was apparent at harvest time.

Table 20. Yield of potatoes (pounds per plot).

Treatment	2,4-D applied 2 weeks after planting			2,4-D applied 3 weeks after planting		
	Blocks			Blocks		
Lbs. of 2,4-D acid per acre	1	2	3	1	2	3
Sodium salt, ½ lb.	2.47	12.96	6.45	6.85	8.21	2.68
Isopropyl ester, ½ lb.	1.10	14.63	6.90	5.26	7.61	6.77
Sodium salt, 1 lb.	3.09	11.78	5.32	7.07	9.38	4.71
Isopropyl ester, 1 lb.	9.19	10.00	6.54	1.74	6.63	6.38
Sodium salt, 2 lbs.	6.48	3.88	7.63	5.04	11.41	6.89
Isopropyl ester, 2 lbs.	6.28	7.10	8.77	6.03	12.50	10.00
Sodium salt, 4 lbs.	6.46	6.73	7.32	14.24	9.35	13.44
Isopropyl ester, 4 lbs.	9.32	11.08	9.83	4.44	9.16	14.29
Check	.61	2.39	5.18	3.83	5.30	9.60

Table 21. Summary of analysis of variance for yield of potatoes.

Source of variation	Degrees of freedom	Mean square	Calculated F ratio	F Value for significance .05	.01
Total	53				
Treatments	8	15.99	1.84	2.25	3.12
Blocks	4	27.40	3.16	2.67	3.97
Dates	1	6.91	.80	4.15	7.50
Interaction	8	11.77	1.36	2.25	3.12
Remainder	32	8.68			

Table 22. Summary of sugar analysis of potatoes.

Treatment Lbs. of 2,4-D acid per acre	Percent dry matter	Total* sugars	Reducing* sugars	Sucrose*
Sodium salt, ½ lb.	18.9	1053	42	1011
Isopropyl ester, ½ lb.	20.1	1114	40	1074
Sodium salt, 1 lb.	19.5	1182	266	916
Isopropyl ester, 1 lb.	18.8	1550	318	1232
Sodium salt, 2 lbs.	19.9	920	101	819
Isopropyl ester, 2 lbs.	18.7	1710	479	1231
Sodium salt, 4 lbs.	19.0	1090	21	1069
Isopropyl ester, 4 lbs.	18.9	1750	317	1433
Check	19.6	1320	305	1015

*Expressed as mg invert sugar per 100 gm dry weight.

Results with Flax, Bromegrass and Sweetclover

Flax was probably influenced by the weather conditions more than any other crop used in these tests. The unusual amount and distribution of rainfall is recorded on page 43. A deficiency of moisture at planting time resulted in uneven germination and a poor stand. The seeds which were placed in contact with moist soil germinated immediately, while those placed in dry soil remained dormant until the first rain on April 23, three weeks after planting. In some cases the 2,4-D applied at the rate of 2 pounds and 4 pounds leached down to the seed and killed the seedlings as soon as the seed coat was broken. This part of the experiment was abandoned since the effects of environmental conditions could not be differentiated from the effects of 2,4-D treatments.

Bromegrass and sweetclover were covered about one-half inch deep at planting time. None of the seeds was placed in contact with moist soil; therefore, they did not germinate until after the first rain. The 2,4-D was leached to the region of the germinating seed and both bromegrass and sweetclover were killed while in the process of germination. Good stands were obtained in the check plots.

It is an established fact that most plants are more susceptible to 2,4-D at the time of germination than any other stage of growth. Many plants which are highly resistant in the vegetative form can be severely injured or killed if 2,4-D is in contact with the seed at time of germination.

RAINFALL FOR THE 1948 GROWING SEASON AT
MANHATTAN, KANSAS

Day	March	April	May	June	July	Aug.	Sept.	Oct.
	inches							
1	.07	.01				.07		
2	.85					trace	trace	
3					.11		2.81	trace
4		trace	.01					trace
5	.17							
6	.27		.09				.04	.41
7				.03			.62	.70
8								trace
9					.10			
10	.08		.06		.56			
11	.04		trace		.05	trace		
12					.04	trace		
13		trace						
14						.04		
15				2.41	.30			
16	trace							
17				.17	.10			
18				.01	.08	.21		
19	.85				.58			
20			trace	.92	1.38			
21			.17	1.02	.32		.21	
22			1.42	.03	.56			
23		1.27		3.14				
24		.26						
25		.07		.28	trace		trace	
26	.26	1.95		.01	.02			
27	trace	trace		3.02	trace	.25		
28	trace	trace						
29				.07				.02
30		trace			1.75			.56
31	trace							
Total	2.59	3.56	1.75	11.11	5.95	.57	3.68	1.69

SUMMARY AND CONCLUSIONS

Two experiments using 2,4-D as pre-emergent treatment to control weeds were conducted on the Agronomy farm at Manhattan, Kansas, in 1948. One experiment included corn while the other included oats, potatoes, flax, bromegrass and sweetclover.

Statistical procedure was applied to the corn data. The interaction, treatments by blocks, produced a significant correlation between tillers and stand. Analysis of variance was used to study the effects of treatments on corn. The F values established by treatments in the case of tillers, yield, stand and number of ears were significant while the F values established by treatments in the case of ear size and broken stalks were nonsignificant. The number of tillers, number of ears, and yield per plot increased as the rate of 2,4-D increased. The amount of weed control obtained in the corn plots varied from practically none in the plots treated with 3/8 pound of triethanol amine to almost complete control in the plots treated with 1½ pounds of isopropyl ester.

Some corn plants were injured in practically all plots. The least injury was observed in the plots treated with 3/8 pound of triethanol amine and the most injury in the plots treated with 1½ pounds of isopropyl ester. Soil toxicity was obtained in all plots for a period of 2 to 6 weeks depending upon the rate and formulation of 2,4-D used.

The F values established by treatments in the case of yield and height of oats were significant. Both yield and height of oats decreased as the rate of 2,4-D was increased. The oats were not weedy at any time during the growing season; however, some control of annual weedy grasses was obtained. A stunted and "onion top" condition was characteristic of some plants. Some of the oat plants in the plots treated with 2 pounds and 4 pounds of 2,4-D were injured to the extent that normal heading did not occur.

While there was some noticeable effect upon the top growth of potatoes, statistical analysis of the yield data showed that the effect of treatments was nonsignificant. Chemical analysis of the potato tubers for sugar content showed that those from the sodium salt treated plots possessed less sucrose than those from the plots treated with isopropyl ester. The sucrose content of the tubers from the check plots was equal to or slightly more than that of the tubers from the plots treated with sodium salt.

Flax was affected by weather conditions more than any other crop used in the study. This part of the experiment was abandoned since the effect of prevailing weather conditions could not be distinguished from the effects of 2,4-D treatments.

Bromegrass and sweetclover were more sensitive to soil toxicity produced by 2,4-D than any of the other crops used in these tests. Both were killed by all rates of 2,4-D while excellent stands were obtained in the check plots.

The effects of the various formulations of 2,4-D varied considerably with the crop upon which it had been applied and with the species of weeds that were present. Generally speaking, more crop injury and weed control were obtained in the plots treated with isopropyl ester than with sodium salt or triethanol amine.

These results indicate that weed control can be obtained with 1½ pound to 2 pounds of 2,4-D acid per acre when applied as a pre-emergent treatment. Heavier rates will cause excessive crop injury with very little or no decrease in number of weeds. Rates less than 1½ pounds do not control the weeds.

The period that elapsed between the time of application of the chemical and emergence of the crop appeared to be of little importance in these tests. It is believed, however, that application should be delayed until near the time for emergence to begin.

The prevailing weather conditions determine to a large extent the success or failure of pre-emergent treatments. It was evident that lack of moisture at Manhattan, Kansas, during the early part of the 1948 growing season was the main cause of the failure to control weeds by pre-emergent treatments of 2,4-D.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the following persons: Professor J. W. Zahnley, major professor, for his guidance and suggestions which were invaluable both in conducting the research and in writing the thesis; Dr. G. L. McCall for making available many of the chemicals needed for the experiments and for his co-operation in collecting and compiling the data; Dr. H. C. Fryer and Dr. H. H. Laude for their suggestions on statistical procedure to be used and for checking the statistical interpretation of results; and Dr. H. L. Mitchell for determining the sugar content of the potato tubers.

BIBLIOGRAPHY

(1) Aldrich, Richard J., Warren C. Shaw and C. J. Willard.
The effect of pre-emergence 2,4-D on stand and yield of corn at Columbus, Ohio. Report of the Department of Agron., Ohio Agr. Exp. Sta.: Fifth Annual North Central Weed Control Conference Research Report, Abstract IV-9. 1948. (Mimeographed)

(2) Andersen, E. T. and A. B. Mantell.
Effect of pre-emergence sprays with two formulations of 2,4-D on potatoes. Report of Division of Plant Science, University of Manitoba, Winnipeg, Canada. Fifth Annual North Central Weed Control Conference Research Report. Abstract V-50. 1948. (Mimeographed)

(3) Anderson, J. C.
Pre-emergence weed control in corn with 2,4-D. Down to Earth. 3(4):13. Spring, 1948.

(4) Anderson, J. C. and D. E. Wolf.
Pre-emergence control of weeds in corn with 2,4-D. Journal American Society of Agronomy. 39: 341-342. 1947.

(5) Anderson, J. C. and D. E. Wolf.
Pre-emergence control of weeds in corn with 2,4-D. Journal American Society of Agronomy. 40: 453-458. May, 1948.

(6) Barrons, Keith C.
Pre-emergence weed control. Down to Earth. 3(3):2-4. Winter, 1947.

(7) Barrons, Keith C.
Pre-emergence weed control. Down to Earth. 4(3):2-4. Winter, 1948.

(8) Bordeleau, R. and F. Coiteux.
Pre-emergence treatments with 2,4-D and other herbicides to control weeds in field crops. Report of Experimental Farms Service. L'Assomption, Quebec, Canada. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-10. 1948. (Mimeographed).

(9) Craft, A. S.
Results of soil treatment vs contact spray in corn and cane. Agricultural Chemicals. 3(5):25. May, 1948.

(10) Derscheid, Lyle A. and D. E. Kratochvil.
The effect of 2,4-D and contact dinitro on the yield and maturity of corn when applied as pre-emergence sprays at three different dates. Report of the Dept. of Agron., South Dak. Agr. Exp. Sta. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-4. 1948. (Mimeographed).

(11) Derscheid, Lyle, A. and L. M. Stahler.
Chemical control of weeds in South Dakota. South Dakota Agr. Exp. Sta. Cir. 69, February, 1948.

(12) Derscheid, Lyle A., L. M. Stahler and D. E. Kratochvil.
Effects of 2,4-D, TCA, IPC, and contact dinitro on the yields and test weight of flax when applied as pre-emergence sprays. Report of Agronomy Department of the South Dakota Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-38. 1948. (Mimeographed)

(13) Dunham, R. S.
Summary of reports on pre-emergence trials. (Unpublished) Report of University of Minnesota Division of Agronomy and Plant Science, St. Paul, Minnesota. 1948. (Mimeographed).

(14) Elder, W. C.
Pre-emergent treatments with 2,4-D on corn. Report of Department of Agronomy, Oklahoma Agricultural Experiment Station. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-3. 1948. (Mimeographed).

(15) Fuelleman, R. F. and F. W. Slife.
Surface soil moisture conditions reduce effect of pre-emergence treatments of corn with 2,4-D. Report of Department of Agronomy, Illinois Agricultural Experiment Station. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-1. 1948. (Mimeographed).

(16) Helgeson, E. A.
Summary of regional studies on potatoes. Fifth Annual Weed Control Conference Research Report. V-S. 1948. (Mimeographed).

(17) Helgeson, E. A. and C. R. Swanson.
Pre-emergence weed control in potatoes. Report of North Dakota Agricultural Experiment Station and Division of Cereal Crops and Diseases. BPISAE, U.S.D.A. Fifth Annual North Central Weed Control Conference Research Report. Abstract V-51. 1948. (Mimeographed).

(18) Lee, Oliver C.
Response of corn to pre-emergence application of 2,4-D, Cultivation and combination of the two. Report of Department of Botany and Plant Pathology, Purdue University Agricultural Experiment Station. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-6. 1948. (Mimeographed).

(19) MacDonald, W. P., A. T. Slough and Clinton Zinter.
Pre-emergence treatment of flax with 2,4-D and Sinox-W in 1948 at Beulah, North Dakota. Report of Agriculture Department, F. H. Peavey and Co. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-39. 1948. (Mimeographed).

(20) MacDonald, W. P., A. T. Slough and Clinton Zinter.
Pre-emergence treatment of flax with 2,4-D and Sinox-W in 1948 at Howard, South Dakota. Report of Agriculture Department, F. H. Peavey and Co. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-40. 1948. (Mimeographed).

(21) MacDonald, W. P., A. T. Slough and Clinton Zinter.
Pre-emergence treatment of oats with 2,4-D and Sinox-W in 1948 at Beulah, North Dakota. Report of Agriculture Department, F. H. Peavey and Co., Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-28. 1948. (Mimeographed).

(22) MacDonald, W. P., A. T. Slough and Clinton Zinter.
Pre-emergence treatment of oats with 2,4-D and Sinox-W in 1948 at Merrifield, North Dakota. Report of Agriculture Department, F. H. Peavey and Co., Fifth Annual North Central Conference Research Report. Abstract IV-27. 1948. (Mimeographed).

(23) MacDonald, W. P., A. T. Slough and Clinton Zinter.
Pre-emergence treatment of oats with 2,4-D and Sinox-W in 1948 at Howard, South Dakota. Report of Agriculture Department, F. H. Peavey and Co. Fifth Annual North Central Conference Research Report. Abstract IV-25. 1948. (Mimeographed).

(24) MacDonald, W. P., A. T. Slough and Clinton Zinter.
Pre-emergence treatment of oats with 2,4-D and Sinox-W in 1948 at Orient, South Dakota. Report of Agriculture Department, Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-26. 1948. (Mimeographed).

(25) Pavlychenko, Thomas K.
Response of Royal flax to pre-emergence treatments with systemic (hormone) chemicals. Report of Agriculture Field Research, American Chemical Paint Co. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-41. 1948. (Mimeographed).

(26) Pavlychenko, Thomas K.
Response of spring oats to pre-emergence treatments with systemic (hormone) chemicals. Report of Agriculture Field Research, American Chemical Paint Co. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-29. 1948. (Mimeographed).

(27) Pavlychenko, Thomas K.
Effect of various systemic (hormone) herbicides on potatoes and weeds. Report of Agriculture Field Research, American Chemical Paint Co., Fifth Annual North Central Weed Control Conference Research Report. Abstract V-46. 1948. (Mimeographed).

(28) Shaw, Warren C. and C. J. Willard.
Effect of pre-emergence 2,4-D on yields on Clinton oats at Columbus, Ohio. Report of Ohio Agricultural Experiment Station. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-24. 1948. (Mimeographed).

(29) Templeman, W. G.
Selective weed control by plant growth promoting substances. Journal Ministry of Agriculture. 53:105-108. 1946.

(30) Timmons, F. L.
Controlling weeds in the Southern Great Plains. U.S.D.A. Agricultural Research Administration, Bureau of Plant Industry, Soils and Agricultural Engineering, Division Cereal Crops and Diseases. 101CC:9. February 1948. (Mimeographed)

(31) Wolfe, Henry and N. E. Shafer.
The effect of 2,4-D when applied as pre-emergence spray on oats. Report of Department of Agronomy, Nebraska University. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-48. 1948. (Mimeographed)

(32) Wood, H. E. and P. J. Olson.
2,4-D and its use. Manitoba Department of Agriculture and Immigration, Publication No. 216. 1948.

(33) Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. Sixth Edition. 1945.