Technical Bulletin 190 May 1950

Environmental Factors Relating to the Pre-emergence Treatment of Corn with 2, 4-D and Soybeans with TCA

H. R. Arakeri and R. S. Dunham
Division of Agronomy and Plant Genetics

University of Minnesota
Agricultural Experiment Station

Environmental Factors Relating to the Pre-emergence Treatment of Corn with 2, 4-D and Soybeans with TCA

H. R. Arakeri and R. S. Dunham
Division of Agronomy and Plant Genetics

University of Minnesota
Agricultural Experiment Station

Submitted for publication August 1, 1949

4M—12-49

CONTENTS

Environmental Factors Relating to the Pre-emergence Treatment of Corn with 2, 4-D and Soybeans with TCA[1]

H. R. Arakeri and R. S. Dunham[2]

INTRODUCTION

APPROXIMATELY 1,600,000 acres of crops were sprayed with selective herbicides in Minnesota during 1948. All but 43,000 acres were sprayed with 2,4-D. The limitations of 2,4-D with respect to grass weeds are well known and constitute one of the more serious shortcomings of this chemical. TCA (trichloroacetic acid) was used only in experimental quantities but showed such promise for killing grasses that it created widespread interest.

Post-emergence and pre-emergence sprayings are the two principal methods for applying these herbicides with ground equipment in Minnesota. In the post-emergence method, the spray is applied after the crop has fully emerged, the recommended time differing with the crop. Pre-emergence applications are made to the soil after the crop has been sown or planted and prior to its emergence. The first method has been much the more popular because it has been much more dependable. The pre-emergence method, however, offers several distinct advantages and would undoubtedly be widely used if it could be depended upon. In the north central states results from this method have been so variable that it has not been recommended.

Observations made where pre-emergence applications have been used indicate clearly that certain environmental factors have a marked effect on the results obtained. A study of some of these factors under controlled condi-

[1] From a thesis submitted by the senior author to the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2] Graduate student and Professor, Division of Agronomy and Plant Genetics, University of Minnesota, St. Paul, respectively.

The authors are indebted to Dr. H. L. Thomas of the Division of Agronomy and Plant Genetics, University of Minnesota, and to Dr. C. O. Rost, Dr. J. M. MacGregor, and Professor P. R. MacMiller of the Division of Soils, University of Minnesota, for their assistance with the problem and to Dr. H. K. Hayes, Chief of the Division of Agronomy and Plant Genetics, University of Minnesota, for critical reading of the manuscript.

tions was the object of the investigations reported in this publication. Pre-emergence treatment studies were made with the butyl ester of 2,4-dichlorophenoxyacetic acid on corn and with ammonium trichloroacetate on soybeans. Factors studied were (1) water applied after treatment, (2) depth of planting the crop, (3) dosage of the chemical, (4) time of application, (5) types of soils, (6) soil *p*H, and (7) organic matter content of the soil. Data were obtained on stand, kind, and extent of injury; regrowth after cutting; dry weight, height, yield, and maturity of corn; and stand, injury, height, and yield of soybeans. Besides the effects of the herbicides on the crop, control of weeds in the growing crop and persistence of the chemicals in soil were studied.

Literature Review

Akamine *(1)*[3] and Heal *(18)* have reviewed the available literature on 2,4-D and isopropyl-n-phenylcarbamate through 1948, and Thompson *(18)* has continued the review of literature on 2,4-D through 1949. The following is a digest of articles directly concerned with pre-emergence treatment.

Early work by Slade, *et al. (34)* led to the conclusion that sodium 2-methyl-4-chlorophenoxyacetic acid is effective whether absorbed through the root or the leaf of a weed. Allard, *et al. (3)* observed selective action of 2,4-D when applied to the soil. Taylor *(36)*, after a series of investigations, thought that "the results of these tests strongly indicate that with proper management of treatment, a combination of weed control with desirable stimulation of crop growth might be possible."

Pre-emergence Treatment of Field Crops

That weeds could be controlled by pre-emergence treatments was indicated by the work of Hamner, *et al. (16)* in Michigan, Hudson *(21)* in England, Greaney *(15)* in Canada, Leonard, *et al. (26)* in Mississippi, Anderson and Wolf *(5)* in New Jersey, Willard *(42)* in Ohio, and Timmons *(38)* in Utah. Alban *(2)*, Danielson *(10)*, and Jorgensen and Hamner *(23)* were able to control grass weeds in addition to broadleaf weeds. Frequently, however, this weed control was accompanied by crop injury.

Dunham *(12)* concluded from investigations made in several north central states and Canada that the varied reactions resulting from pre-emergence treatments with 2,4-D are due to factors such as soil, climate, and crop variety. Leonard, *et al. (26)* reported no injury to corn on fine sandy loam treated with 2,4-D. The work of Hernandez, reported by Warren *(39)*, showed that 2,4-D caused excessive damage to onions on silt loam, whereas there was no significant injury with the same treatments on adjacent peat. Alban *(2)* observed greater damage to crops on sandy loam than on silt loam. Klingman *(24)* recommended that pre-emergence treatments are more effective on moderately heavy soils than sandy soils. It was observed by Hurd-Karrer *(22)* that chemicals other than 2,4-D were most toxic in acid soils, least in alkaline, and intermediate in slightly acid to neutral soils. Martin *(27)* found more toxic effects on soil microorganisms under acid than under alkaline conditions. Weaver *(41)* showed that an adsorbed growth regulator is nontoxic.

Warren and Hernandez *(40)* found little or no delay in the growth of onions when 2,4-D was sprayed on the soil surface after planting, but when it was mixed into the soil, emergence of the onions was delayed from 10 days to two weeks. Hernandez, *et al (20)* observed more injury to onions when rain occurred soon after application of 2,4-D, and Anderson and Wolf *(4) (5)* re-

[3] Numbers in parentheses refer to literature cited, page 26.

ported reduced yields of corn under similar conditions and treatment.

Fuelleman *(14)*, Klingman *(24)*, and Anderson and Wolf *(5)* state that delayed pre-emergence spraying is less harmful to crop plants than immediate spraying.

Ryker *(33)* reported that TCA may be used in pre-emergence treatment of broadleaf crops to control grass weeds. McCall *(28)* stated that TCA applied as a pre-emergence treatment controlled most of the annual grasses and some broadleaf weeds but injured crop plants like corn, soybeans, and lima beans. Helgeson, *et al.* *(19)* obtained conflicting results with sugar beets. Warren *(39)* observed complete failure of treated lima beans to develop although the stand was perfect. Barrons *(8)* stated that beans and other legumes are quite sensitive to this chemical. McCall and Zahnley *(29)* observed little injury to snap beans and good control of grass weeds with five pounds per acre. They stress, however, the importance of moisture in the effectiveness of the soil applications.

The research committee of the North Central Weed Control Conference of 1948 *(6)* stated that the residual toxicity persists for 30 days or more, depending upon precipitation. Barrons *(8)* reported that toxicity might persist for about 60 days. McCall and Zahnley *(29)* also state that it persists in the soil for about 30 to 90 days, depending upon the amount of rainfall.

Methods for Determining the Presence and Persistence of 2,4-D in Soil

Various bio-assay methods for the detection of growth regulators and estimation of their phytocidal action have been used with different degrees of success. Thompson, *et al.* *(37)* tested the growth inhibiting action of different organic compounds by using a corn germination test and a kidney bean test. Swanson *(35)* found that an unknown concentration of 2,4-D can be accurately determined by measuring the inhibition in the elongation of the primary root of germinating corn seed. Offord *(31)* suggested *Lemma minor* as a test plant. Ready and Grant *(32)* recommended a method based on the activity of the acid in inhibiting the growth of the primary root and shoot of cucumber seed. DeRose *(11)* used stem bending and epinasty developing characteristics on treated young tomato and bean plants as indication of the presence of 2,4-D in leachates. Brown and Mitchell *(9)* used the survival and yield data of mustard plants to detect 2,4-D in soil.

Some methods other than bio-assay tests have also been suggested. Bandurski *(7)* has developed a spectrometric method, and Freed *(13)* has suggested a chemical method.

Investigations regarding the persistence of 2,4-D in the soil indicate in general that it disappears within 40 days. DeRose *(11)* stated that in unleached soil, 2,4-D remains for 8 weeks in the greenhouse and for 80 days in the field when applied at heavy rates. Mitchell and Marth *(30)*, Hanks *(17)*, and Brown and Mitchell *(9)* observed quick dissipation in soils relatively high in organic matter. According to Kries *(25)*, 2,4-D persists longer in calcareous soils than in unlimed soils. Brown and Mitchell *(9)* obtained rapid inactivation in moist soils and under high temperatures.

MATERIALS AND METHODS

Effective pre-emergence treatment is dependent upon a number of factors as seen from the erratic results obtained under different conditions. All the variables proposed for study could not be included in a single experiment. Therefore, pre-emergence treatments with 2,4-D were made in the field on corn, and similar trials with TCA were made on soybeans. More intensive studies were carried on in the greenhouse. A commercial butyl ester, "Agricultural Weed No More," containing 40 per cent active ingredient was the formulation of 2,4-D used. The acid equivalent was listed as 32 per cent and the specific gravity, 0.99. Ammonium trichloroacetate (TCA) containing 69 per cent active ingredient was obtained in liquid form from the E. I. du Pont de Nemours and Company, Incorporated.

An outline of the investigation follows.

Pre-emergence Treatment with 2,4-D on Corn

Field Studies

Experiment 1. Effects of dosage and depth of planting.

Experiment 2. Effects of time of treatment.

Experiment 3. Effects of application of water.

Greenhouse Studies

Experiment 4. Effects of soil types.

Experiment 5. Effects of soil properties.

The field experimental area was located at University Farm. It was plowed in early spring and was well prepared by subsequent tillage. The previous crop had been soybeans. When corn was planted, June 12, 1948, there was insufficient moisture for immediate germination, so the area was irrigated artificially. Since water was one of the treatments, whenever rain was expected, all plots were covered by waterproof material fixed to frames until emergence of the crop was complete.

The materials and methods of study will be given in detail for each of the five experiments. Three replications were used in all studies except Experiment 5 where they were limited to two. Plot layout is shown in figure 1 and further explained for each experiment in following paragraphs.

For the studies of dosage and depth of planting in Experiment 1, a split-plot design was used with six dosages per acre—0, 8, 16, 24, 32, and 64 ounces, respectively—as main treatments, and the two depths of planting, 2 and 3 inches, respectively, as subplots. These treatments were all made immediately after planting at a uniform rate of 40 gallons of solution per acre.

In Experiment 2, times of treatment were used as the main plots and the 2- and 3-inch depths as subplots. The dosage was 24 ounces per acre for all treatments which were made immediately after planting and five days later.

In Experiment 3, rates of water—¼ inch and ½ inch, respectively—were used as main plots with depth of planting as subplots. Studies were made of time of treatment immediately after planting and five days later. The dosage, times of treatment, and depths were the same as in Experiment 2. Adjoining plots were partitioned by metal sheets to prevent water from moving laterally.

Experiments 4 and 5, conducted in the greenhouse, were also split-plot designs with three replications in Experiment 4 and two in Experiment 5. In Experiment 4 the five soil types were used as main plots with two depths of planting as subplots.

Five soil types—Waukegan silt loam, Le Sueur silty clay loam, Dakota fine sandy loam, unsterilized low lime peat, and sterilized low lime peat—were studied in Experiment 4. The soil for each type was removed from 9 inches of the upper surface and mixed. The greenhouse benches were partitioned for each plot with wood planks. Each compartment was filled to a depth of 5 inches with one of the soils; the soil was watered and allowed to settle. When soil and moisture conditions were favorable, Minhybrid 505 corn was planted on all plots.

Corn Series with 2,4-D | **Soybean Series with TCA**

Field Studies

Experiment 1

Corn Series with 2,4-D:

Amounts (Ounces)	0	64	32	16	24	8
Planting depth in inches	2	3	3	2	3	3
Planting depth in inches	3	2	2	3	2	2

Soybean Series with TCA:

Amounts (Pounds)	0	12	2	4	8	16
Planting depth in inches	2	3	2	2	3	3
Planting depth in inches	3	2	3	3	2	2

Experiment 2

Corn Series with 2,4-D:

Days after planting	0	5
Planting depth in inches	3	3
Planting depth in inches	2	2

Soybean Series with TCA:

Days after planting	0	5
Planting depth in inches	3	3
Planting depth in inches	2	2

Experiment 3

Corn Series with 2,4-D:

Days after planting	0		5	
Water in inches	½	¼	¼	½
Planting depth in inches	2	3	3	2
Planting depth in inches	3	2	2	3

Soybean Series with TCA:

Days after planting	0		5	
Water in inches	¼	½	½	¼
Planting depth in inches	3	3	3	2
Planting depth in inches	2	2	2	3

Greenhouse Studies

Experiment 4

Corn Series with 2,4-D:

Soil types	E	C	B	D	A
Planting depth in inches	2	3	2	2	2
Planting depth in inches	3	2	3	3	3

Soybean Series with TCA:

Soil types	A	E	C	D	B
Planting depth in inches	1	2	1	1	2
Planting depth in inches	2	1	2	2	1

Experiment 5

Chemical treatments	a	b	d	e	c
Planting depth in inches	2	3	2	3	3
Planting depth in inches	3	2	3	2	2

Fig. 1. Plan of layout on one replication of each experiment.

The results of Experiment 4 led to a more intensive study of the probable causes of differences observed. Particular attention was paid to *p*H and organic matter. Additional laboratory studies were made on rate of percolation and depth of penetration of water in the different soil types.

The five soil types used in Experiment 4 are given in table 1. The source, *p*H content, and percentage of separates and organic matter are given for Waukegan silt loam, Le Sueur silty clay loam, and Dakota fine sandy loam. For the low lime peat unsterilized and sterilized, only *p*H is given.

With Waukegan silt loam, a special study was made by adding chemicals and organic matter and comparing it with untreated soil. By changing certain properties, it seemed probable that the importance of certain soil constituents could be made more evident. The chemicals and organic matter added and the final *p*H and organic matter content are given in table 2 for the original soil and for the four treatments.

Calcium hydroxide was added to raise the *p*H of the soil, calcium sulphate to provide an equal amount of calcium without changing the *p*H of the soil to a great extent, and sulphur to lower the *p*H and supply an amount of sulphur in the soil equal to that in the second treatment. These counterchecks were provided so that the influence, if any, of the Ca and S might be detected. The chemicals were mixed evenly with the soil and the mixture was allowed to stand for 12 days after watering.

The soil for these five comparisons was used in Experiment 5 to determine the importance of *p*H and organic matter in relation to the effect of 2,4-D on

Table 1. Source, Type, pH, Mechanical Analysis, and Organic Matter Content of the Soils Used in Experiments 1-5

Soils used	I	II	III	IV	V
Source	University Farm	Waseca	Rosemount	North of University Farm	
Soil type	Waukegan silt loam	Le Sueur silty clay loam	Dakota fine sandy loam	Low lime peat	Low lime peat sterilized
pH	5.1	6.6	5.7	4.6	4.9
	per cent	per cent	per cent		
Separates					
Very coarse sand	0.8	0.7	6.2		
Coarse sand	3.2	1.6	12.5		
Medium sand	2.0	1.6	12.7		
Fine sand	3.9	5.6	40.3		
Very fine sand	11.4	4.5	28.2		
Silt	64.6	44.2	19.7		
Clay	14.4	41.2	7.7		
Organic matter	3.2	6.8	2.5		

Note: Mechanical analysis and the organic matter content are representative of the soil type, not of the actual soil used. pH was determined of the soil used.

corn. In this experiment the five treatments were used as main plots and two depths of planting as subplots.

For soybeans TCA was used in place of 2,4-D. The experiments were of the same general plan as with corn except that the dosages, which for Experiment 1 were 0, 2, 4, 8, and 16 pounds of active ingredient per acre, were 8 pounds for the other three experiments. As the soybeans were injured severely in all 4 treatments, Experiment 5 would have been without value.

To determine the persistence of each herbicide in Waukegan silt loam, samples were taken from the experimental plots at University Farm. As there were three replications, samples were taken for each of the three plots for each treatment and bulked. The four depths that were used were 0—0.25, 0.25—1.25, 1.25—2.25, and 2.25—3.25 inches. The leachate of each sample was tested for the presence of 2,4-D by using yellow seeded flax seeds of the Crystal variety. It was observed by Dunham and Robinson in unpublished studies that a very small quantity of 2,4-D inhibits the germination of yellow seeded flax.

For detecting the presence of TCA the leachate was collected in a similar manner, but the seeds of yellow flax did not respond as they did for 2,4-D. Seeds of wheat, oats, soybeans, sugar beets, timothy, brome grass, and quack grass were tried but without success so that tests of field samples were abandoned. Subsequently, it was found that the soybean plant was very sensitive to

Table 2. Amount of Chemical and Organic Matter Added and the pH and Organic Matter Content of Soil Used in Experiment 5

Chemicals added	Quantity per plot	Rate per acre	Final pH of soil	Final organic matter in soil
	pounds	tons		per cent
Calcium hydroxide	0.50	2.00	6.8	3.2
Calcium sulphate	1.15	4.60	4.5	3.2
Sulphur	0.21	0.84	3.8	3.2
Organic matter	15.00	60.00	4.9	13.2
None	0.0	0.0	5.0	3.2

even small amounts of TCA in the soil and developed typical symptoms on leaves. Habaro soybeans were used for greenhouse studies of the persistence of TCA in soil.

A 2-inch layer of treated soil was removed from the greenhouse bench and was transferred to two 8-inch pots. Ten soybean seeds were planted in each pot. When the seedlings showed TCA injury they were pulled out, the soil was stirred, and after a few days ten seeds were planted again. This procedure was continued for seven months.

The data obtained in the field trials included stand count, number of abnormal plants, dry weight of top growth, regrowth after cutting, height, date of maturity, and yield of corn. Similar data were obtained for soybeans except for regrowth after cutting since all plants were allowed to remain until harvest. Counts of weeds separated into broadleaf and grass types were made on both corn and soybean plots. In the greenhouse, stand counts and number of abnormal plants were the major characters studied. Because of the nature of the results, description of the type of injury and other responses will be given when the results of the experiments are presented.

Data were analyzed by the analysis of variance method, separately for each experiment using residual variance as error. In a few cases modification of analysis seemed desirable, and these will be explained when experimental data are presented.

EXPERIMENTAL RESULTS AND DISCUSSION

Pre-emergence Treatment with 2,4-D on Corn

Experiment 1. Effects of dosage and depth of planting.

The experimental area was irrigated immediately before planting as the soil was too dry to insure germination of the seed. At planting the soil contained 35.2 per cent moisture which was ample for immediate germination. Immediately after planting, the plots were protected from rain until emergence of the corn was complete. During this period, no water was added but humidity was high since rain fell on 6 days, totaling 1.44 inches. Subsequently, there was a period of dry weather for 25 days. Even though the maximum dosage was 64 ounces per acre, none of the treatments significantly reduced emergence of the corn or injured the seedlings.

The dry weight of 15 plants per plot was taken on two dates—30 and 45 days after planting. No significant differences appeared between treatments in these data. Heights were measured on four dates at intervals of about two to three weeks, beginning a month after planting and continuing until harvest. Final height was not ob-

Table 3. Average Height of Six Plants per Plot; Average for Two Depths

2,4-D applied per acre	Height on following dates:			
	July 14	July 28	August 14	September 6
ounces	centimeters			
0	16.3	34.1	70.9	116.9
8	15.8	32.2	64.1	107.7
16	15.1	30.5	58.9	108.0
24	16.8	32.7	63.5	108.8
32	15.1	30.1	58.9	106.1
64	14.8	30.2	60.8	105.1
Least significant difference at 5 per cent level	....	....	....	6.95

Note: Least significant difference given only where differences were significant at the 5 per cent level.

Table 4. Variances for Number of Broadleaf and Grass Weeds per Plot on July 28 and September 13

Source of variation	Degrees of freedom	Mean Squares			
		Broadleaf weeds		Grass weeds	
		July 28	Sept. 13	July 28	Sept. 13
Replications	2	11,709.39	60.15	3,443.72	90.05
Amounts of 2,4-D	5	65,192.62*	103.02	15,415.38*	610.45*
Error	10	8,030.65	36.91	1,863.25	41.15

* Significant at 1 per cent level.

tained because the tops of the plants had blown away. Data are presented in table 3. Treated plants were shorter than untreated in every instance except with the 24-ounce treatment on July 14, but differences in height of plant were not significant at the 5 per cent level until September 6. On this date treated plants at all dosages were shorter than untreated by 8—11.8 centimeters. The reduction in height, however, did not significantly affect yield.

Moisture content and yield of grain were determined on the basis of three plants per plot. The sample was small but was comparative. No significant differences in maturity based on moisture content or yield resulted.

The stands of broadleaf and grass weeds were counted separately on each plot July 28 and September 13, respectively. Species of broadleaf weeds were mainly purslane *(Portulaca oleracea)* and rough pigweed *(Amaranthus retroflexus)*; those of the grasses, purple love grass *(Eragrostis pilosa)*, tickle grass *(Panicum capillare)*, and stink grass *(Eragrostis megastachya)*. Variances are reported in table 4.

Although weeds were not sown on the plots, the original stands were not significantly different from each other.

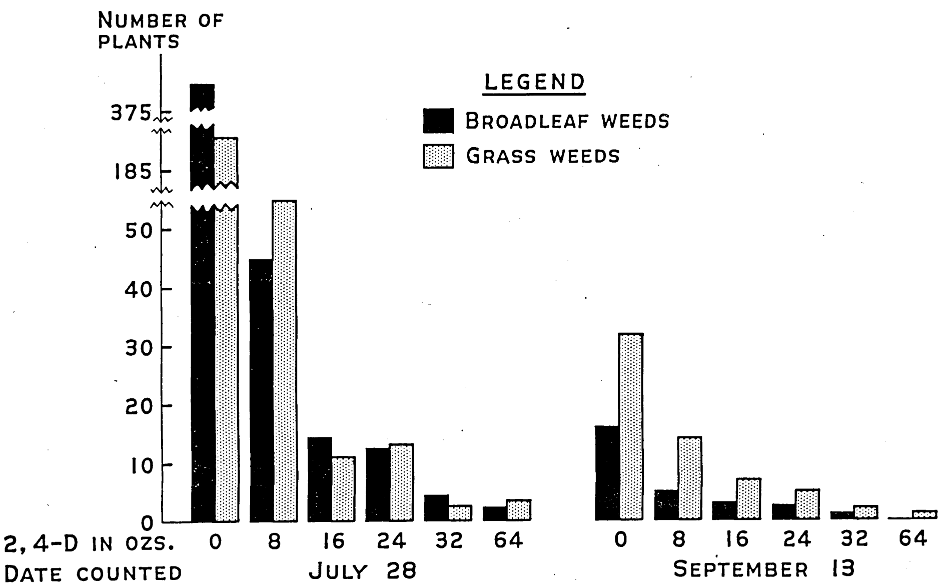

Fig. 2. Stand of weeds on plots sprayed with 2,4-D at different dosages on the day of planting.

Fig. 3. Complete control of weeds with 64 ounces of 2,4-D on left; check plot on right. Photograph was taken 45 days after treatment.

Control was effected, as illustrated in figure 2, by all dosages but best with 24 ounces or more per acre. Of particular interest is the reduction of grass weeds by all dosages and the almost complete eradication by 32 ounces per acre. Figure 3, taken 45 days after treatment, shows the excellent results obtained from 64 ounces.

Experiments 2 and 3. Effects of time of treatment and rates of application of water.

These experiments are considered together since time of treatment caused no differential results in Experiment 2, which received no added water, and since all variables were the same in the two experiments except that water was added in Experiment 3. To conveniently control applications of water, those plots receiving water were laid out in one block and those receiving none in another. The blocks were adjacent and together covered a distance of 108 feet. Since the entire area was worked together and all plantings were made on the same day, comparisons are made between the two experiments using Experiment 2 for the unwatered plots. Data are presented in tables 5-11 inclusive. Analyses of variance were made by combining the results of both experiments, using the average residual variance of the two experiments as experimental error.

The emergence of corn was delayed 2 to 3 days on those plots receiving water in addition to 2,4-D, and the number of plants emerging was re-

Table 5. Effects of 24 ounces of 2,4-D Plus Additional Water Applied Immediately or Five Days After Planting on Emergence of Corn; Stand Counted 12 Days After Planting; Average of Two Depths of Planting

Days after planting until sprayed	Rates of water in inches			Least significant difference
	0	¼	½	
		number of plants		
0	52	46.5	45	5%—1.77
5	52.5	50.5	49.5	1%—2.41
Average	52.25	48.5	47.25	
Least significant difference	5%— 2.16	1%— 2.94		

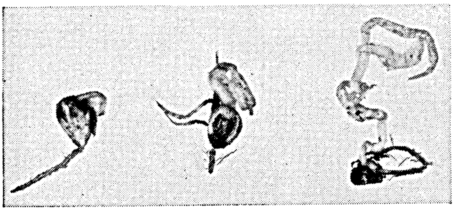

Fig. 4. Corn seedlings that were unable to emerge because of severe injury from 2,4-D.

duced. As an average of both depths, 52.25 plants emerged out of a total of 54 seeds planted where no water was applied, 48.5 on plots that received ¼-inch of water, and 47.25 on plots receiving ½-inch of water (table 5). These differences are highly significant.

Time of treatment was another factor where water was added. The emergence was reduced more severely by treatments made immediately after planting than by those delayed for 5 days. The severe injury that prevented emergence is illustrated in figure 4. Some plants were able to emerge but were abnormal in appearance. Normal seedlings and two representatives of abnormal plants are shown in figure 5.

In table 6, the number of abnormal plants is given. Large increases in this number resulted from the application of water in addition to the 2,4-D. Again, immediate treatment was more hazardous than delayed spraying, especially with the larger amount of water.

Not only were the differences due to rates of water and time of application significant but also the interaction of rates of water times depths. The combined effect of rates of water and depth of planting is given in table 7 for pre-emergence treatments with 2,4-D. There were no very significant differences resulting from planting at 2- or 3-inch depths in numbers of abnormal plants with a water application of ¼ inch. When ½ inch of water was applied the number of abnormal plants was only about half as great from

Fig. 5. Three corn seedlings on the left injured by 2,4-D; normal seedling on extreme right.

Table 6. Number of Abnormal Corn Plants as Result of 24 ounces of 2,4-D Plus Additional Water Applied Immediately or Five Days After Planting; Average of Two Depths of Planting

Days after planting until sprayed	Rates of water in inches 0	¼	½	Least significant difference
	number of plants			
0	1.8	12.2	13.1	5%—2.22
5	1.6	10.8	7.6	1%—3.02
Least significant difference	5%—2.76	1%— 3.75		

Table 7. Number of Abnormal Plants as Result of 24 ounces of 2,4-D Plus Additional Water Applied to Corn Planted at Two Depths; Average of Two Dates of Application

Depth of planting	Rates of water in inches 0	¼	½	Least significant difference
inches	number of plants			
2	1.4	12.3	6.8	5%—2.22
3	2.0	10.6	14.1	1%—3.02
Least significant difference	5%—2.76	1%—3.75		

plantings made 2 inches deep as from 3-inch deep plantings.

Rates of water were found to have a highly significant effect on dry weights of plants cut 30 and 45 days after planting (table 8). The differences in plot weights between those that received water and those that did not are as much as 10 grams 30 days after planting and 80 grams 45 days after planting.

Although time of application significantly affected the number of abnormal plants as pointed out in table 6, there was no significant effect on dry weights as determined from an analysis of variance.

Differences in height of the corn due to water applications were significant for all four dates on which the plants were measured. As illustrated in figure 6, the corn was much shorter on those plots receiving water following application of 2,4-D, regardless of time of application. The differences increased as the season progressed, reaching a maximum on August 14. By September 6, however, this difference was much reduced. As may be noted in the figure, the rate of increase in height was slow until about 60 days after planting. Treated plants then increased relatively fast, and it appeared that they might have reached a height equal to untreated plants by harvest time. These figures, however, could not be obtained because plant tops had broken off and were blown away. Differences in height due to depths and time of application were small and did not persist during the season.

The only significant differences in yield were due to rates of water but these were significant at the 1 per cent level. Yields in grams per plot are given in table 8. Reduction in yield is shown from each rate of water used.

The differences in percentage of moisture due to rates of water and the interaction of rates of water and depths were significant at the 5 per cent

Table 8. Effects of 24 ounces of 2,4-D Plus Additional Water on Dry Weight of Corn 30 Days and 45 Days after planting; Average of Two Depths and Two Dates of Application

Rates of water	Dry weight 30 days after	45 days after
inches	grams	
0	32.7	181.3
¼	22.2	104.1
½	23.1	100.5
Least significant difference at 5 per cent level	2.66	11.41
Least significant difference at 1 per cent level	3.61	15.51

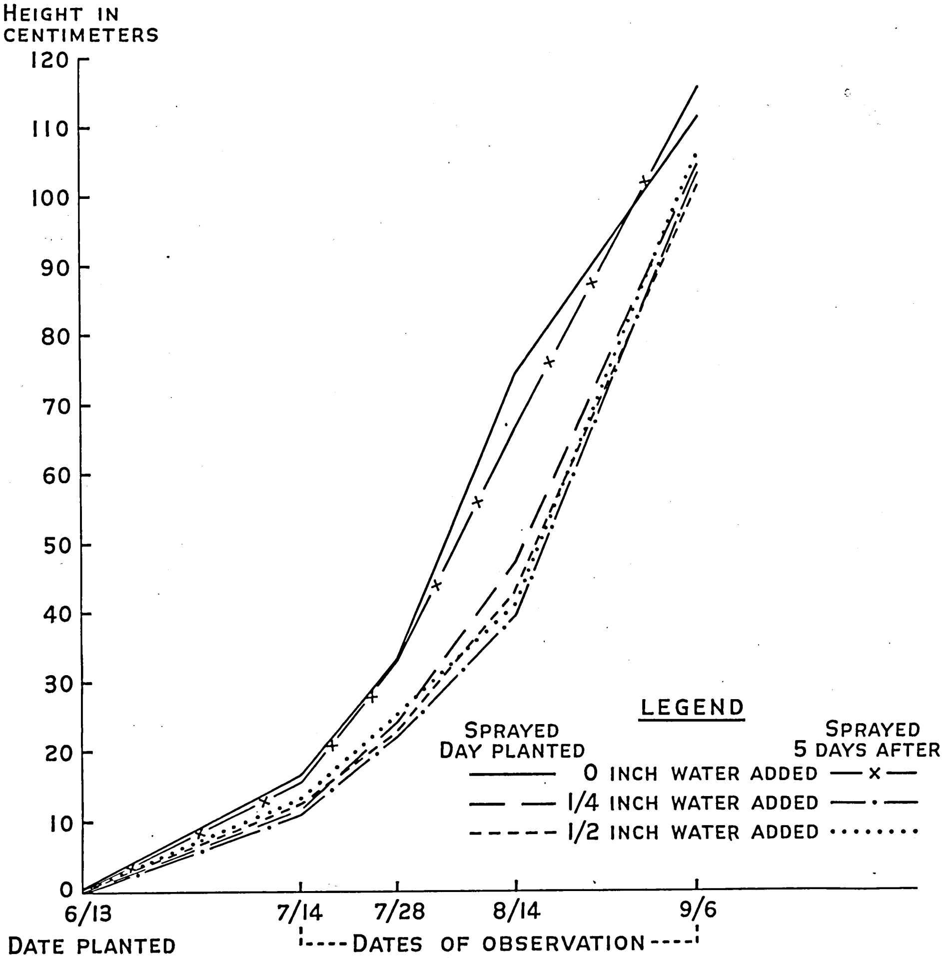

Fig. 6. Height of corn on plots sprayed with 24 ounces of 2,4-D per acre immediately or 5 days later plus additional water.

Table 9. Effects of 24 ounces of 2,4-D Plus Additional Water on Moisture in Ears at Harvest and on Yield; Average of Two Depths of Planting and Two Dates of Application

Rates of water	Moisture	Yield
inches	per cent	grams
0	61.5	213.8
¼	77.3	136.1
½	82.7	117.8
Least significant difference at 5 per cent level	16.93	33.82
Least significant difference at 1 per cent level	....	45.97

level. In table 9, averages of two depths of planting and two dates of application are given. The 82.7 per cent of moisture in the ears from plots that received ½ inch of water is significantly higher than where no water was added, and the treatment with ¼ inch of water caused a delay in maturity that is only slightly less than significant.

A comparison of moisture percentage in the corn at harvest is given in table 10, averaging the results from ¼ and

Table 10. Effects of 24 ounces of 2,4-D Plus Additional Water Applied Immediately or Five Days After Planting on Moisture Percentage in Ears at Harvest

Depths of planting	Days after planting until sprayed			
	0		5	
	No water	Water	No water	Water
inches	per cent	per cent	per cent	per cent
2	52.3	74.3	72.0	68.4
3	55.0	62.1	67.0	90.7
Least significant difference for depth x time of application at 5 per cent level = 27.22				

½ inches of water in comparison with no water. The moisture percentages are given for two depths of planting and for two times of treatment. The data show that immediate application on corn planted at 2 inches and delayed application at 3 inches resulted in increased moisture. This delay may be attributed to the general inhibition of growth as pointed out in the presentations of height measurements (figure 6) and dry weights (table 8).

Variances for numbers of grass and broadleaf weeds are reported in table 11. The only significant differences occurred at the first count, July 28, when both rates of water and time of application influenced the results with grass weeds. These differences largely disappeared by September 30, the date of the final count. It must be remembered that all plots in these two experiments received 24 ounces of 2,4-D per acre and comparisons are between rates of water and time of application. Weed control on all plots was good when compared with the check plot which received no 2,4-D reported under Experiment 1. On the plots not treated with 2,4-D there was an average of 375 broadleaf and 186 grass weeds. There were less than 10 of either broadleaf or grass weeds on the poorest of the treated plots.

In table 12 the average number of grass weeds per plot is given for July 28, the only instance when rates of water and time of application had any influence on either grass or broadleaf species. The averages of both times of application show 6.4 and 5.3 weeds per

Table 11. Variances for Stands of Grass and Broadleaf Weeds on Different Dates

Source of variation	Degrees of freedom	Mean squares		
		Grass weeds		Broadleaf weeds
		July 28	Sept. 30	July 28
Rates of water	2	47.15*	6.50	10.89
Time of application	1	56.10*	1.40	26.89
Time of application x water levels	2	9.80	4.05	0.22
Within (Error)	12	7.83	9.50	13.38

* Significant at 5 per cent level.

Table 12. Average Number of Grass Weeds July 28 on Plots Treated with 24 ounces of 2,4-D per Acre on the Day of Planting and 5 Days Later, and for Three Rates of Water Applications

Days after planting until sprayed	Water rates in inches			Least significant difference at 5%
	0	¼	½	
		number of plants		
0	1.6	8.3	8.3	1.65
5	0.6	4.6	2.3	
Average	1.1	6.4	5.3	
Least significant difference at 5 per cent level	3.51			

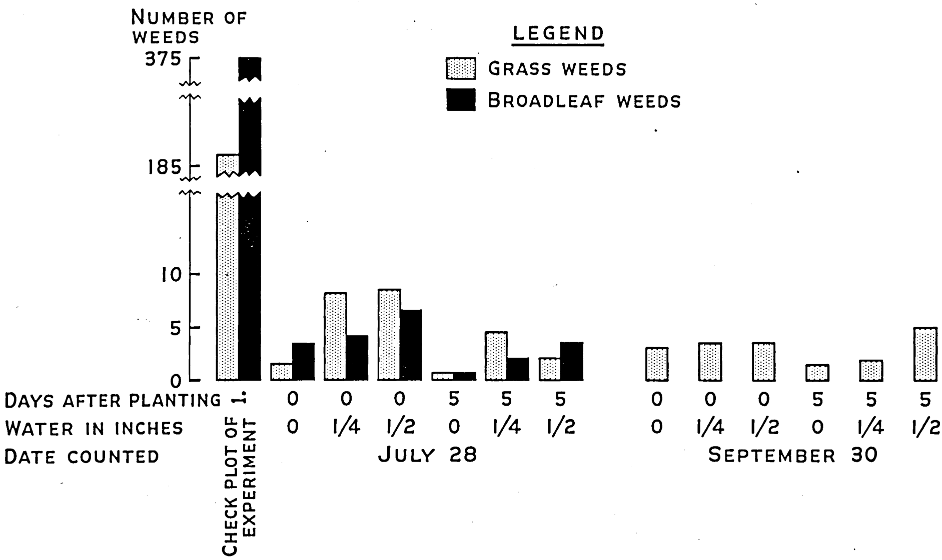

Fig. 7. Stand of weeds on plots sprayed with 24 ounces of 2,4-D per acre immediately after planting or 5 days later plus additional water.

plot for ¼ and ½ inches of water, respectively, as compared with only 1.1 where no water was added. Where no water was applied, the control of grass weeds was affected very little by time of application. Where water was added there was an average of 8.3 weeds per plot on plots treated immediately and 3.4 where treatment was delayed five days. Broadleaf weeds showed much the same trend although differences were not significant. Figure 7 illustrates the weed population on all treatments on both July 28 and September 30. There were so few broadleaf weeds on September 30 that no counts were taken on that date.

Regrowth of Corn Cut Off in Experiments 1, 2, and 3

The dry weight of plants, already reported, was obtained by cutting the corn to the ground surface 30 and 45 days after planting. Those plants cut at the first date started regrowth immediately. Since it was evident that regrowth varied between plots, a study was made of this plant response. In Experiment 1 differences in regrowth of corn were significant only due to depths of planting. The number of plants regrowing was significantly lower where the seed had been planted at 2 inches as compared with 3 inches. There was no significant difference due to treatment with 2,4-D or to the interaction of depths and amounts of herbicide. This difference, therefore, may be explained quite logically on the assumption that the growing point of plants from the shallower depth was injured by cutting and that it was too deeply buried for injury where the seed was planted 3 inches below the surface.

Where water was added, differences in regrowth were highly significant due to rates of water application and the interaction of rates of water times time of application was significant at the 5 per cent level (table 13). The number of plants that regrew was reduced considerably by water applications. To discover the reason, a few apparently healthy plants that had not been cut were dug from each treated plot. It was

Table 13. Number of Plants Sprayed with 24 ounces of 2,4-D Plus Additional Water that Regrew After They were Cut Back to Soil Surface; Average of Two Dates of Application

Depth of planting	Rates of water in inches			
	0	¼	½	Average
inches	number of plants			
2	11.1	2.6	2.6	5.4
3	16.8	8.4	4.5	9.9
Average	13.9	5.5	3.5	
Least significant difference for water levels	5%— 1.58	1%—2.16		
Least significant difference for depths	5%— 1.29	1%—1.76		
Least significant difference for water levels x depths	5%— 2.22			

observed that the first internode of each plant was elongated considerably beyond normal. This elongation resulted in the elevation of the growing point above ground level. Figure 8 shows two affected plants with a first internode about 1½ inches long as compared with one about ½ inch long on an untreated plant. It is apparent from this observation that the growing point of many treated plants was cut off in those harvested for dry weights, and the number regrowing was consequently reduced.

Experiment 4. Effects of soil types

In Experiments 1, 2, and 3 trials were carried out on a single type of soil, Waukegan silt loam. Experiment 4 was conducted to investigate any possible difference due to different soil types. Ample moisture was provided for immediate germination of the corn. In table 14, significant differences in the number of plants emerging are shown to be due to soil types and depth of planting.

In table 15 data for number of plants that emerged, number of abnormal

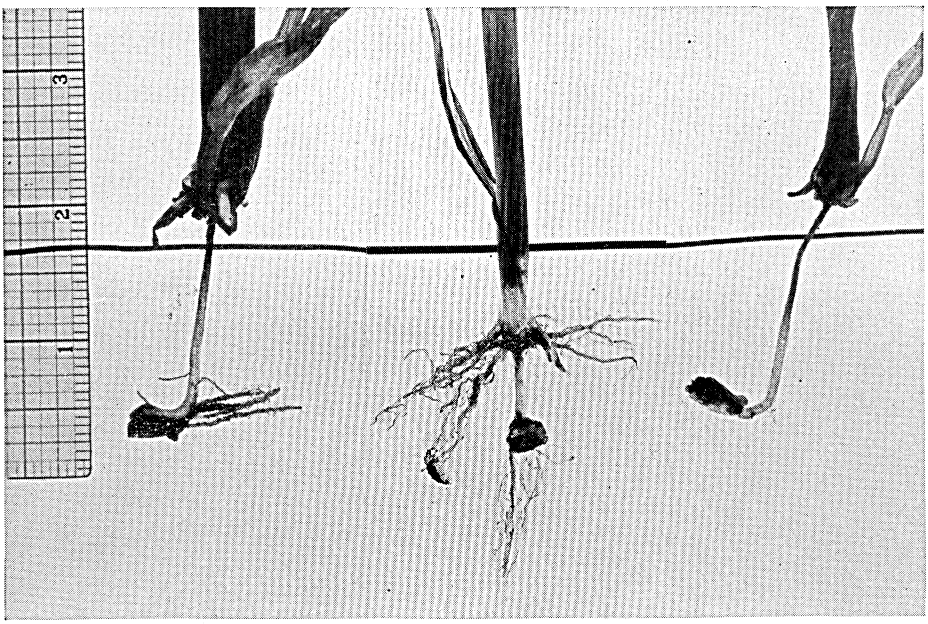

Fig. 8. Plants on extreme left and right show elongation of first internode compared with normal in the center.

Table 14. Variances for Emergence

Source of variation	Degrees of freedom	Mean squares emergence
Replications	2	4.08
Soil types	4	1,767.66*
Error (a)	8	4.77
Depth	1	18.77*
Depth x soil types	4	2.97
Error (b)	10	2.13

* Significant at 1 per cent level.

plants, and degree of injury are presented for each soil type, together with certain soil properties—*p*H, per cent organic matter and per cent clay.

Emergence was significantly poor only on the Waukegan silt loam where it was reduced from 25 to 32 per cent compared with the other soil types. The average number of abnormal plants also varied with soil type. As an average 26.6 plants per plot on silt loam were abnormal, only 9.8 on fine sandy loam, and none on the other soils. Not only the number of abnormal plants but also the severity of the injury was greatest on the silt loam. It was a striking fact that, with the same amount of 2,4-D, the degree of injury to plants grown on different soils varied from practically none to very severe. Figure 9 is a photograph of the plots in a greenhouse bench showing the stand of corn on fine sandy loam, silt loam, and peat.

Fig. 9. Variable injury to corn planted in different soils treated with 2,4-D. From left to right, Dakota fine sandy loam, Waukegan silt loam, and peat. Photograph was taken 12 days after planting.

Experiment 5. Effects of soil properties.

The variation in *p*H and content of organic matter and clay in the soils suggested a study to see if these properties were associated with the injury to the crop. The amendments listed in table 16 were added to the Waukegan silt loam and mixed with the soil. After 10 days the original *p*H was changed to those shown in the second column, and the organic matter in one plot was increased to 13.2 per cent. The average number of plants that emerged, the average number of abnormal plants, and the degree of injury are also reported in this table. No analysis of variance was made since there were only two replicates.

Table 15. Stand of Corn Seedlings, Number of Abnormal Plants, and Degree of Injury in Five Types of Soils Differing in their *p*H, Organic Matter Content, and Clay Content; Average for Two Depths

Soil type	Average number: Seedlings	Average number: Abnormal plants	Degree of injury	pH	Organic matter	Clay
					per cent	per cent
Waukegan silt loam	29.5	26.6	++++	5.1	3.2	14.4
LeSueur silty clay loam	37.0	0.0	0	6.6	6.8	41.2
Dakota fine sandy loam	38.0	9.8	+	5.7	2.5	7.7
Low lime peat	39.0	0.0	0	4.6	......	......
Low lime peat (sterilized)	39.0	0.0	0	......	......	......
Least significant difference at 5%	2.41	......	......	......	......	......
Least significant difference at 1%	4.30	......	......	......	......	......

++++ Very severely affected + Slightly affected 0 Not affected

Table 16. Effects of Change in pH and Organic Matter Content by Soil Amendments on the Stand and Injury of Corn Sprayed with 24 ounces of 2,4-D on the Day of Planting Plus ½ Inch of Water; Average for Two Depths

Amendments	pH	Organic matter	Average number		Degree of injury
			Seedlings	Abnormal plants	
		per cent			
Sulphur	3.8	3.2	34.2	26.7	++++
Calcium sulphate	4.5	3.2	38.7	19.0	+++
Organic matter	4.9	13.2	38.5	10.5	+
None	5.0	3.2	33.2	18.5	+++
Calcium hydroxide	6.8	3.2	37.7	9.2	+

++++ Very severely injured +++ Severely injured ++ Moderately injured + Slightly injured 0 Not injured

Organic matter content remaining the same, the number of abnormal plants and the degree of injury were closely associated with *p*H. The trend was not as clearly defined in the number of plants emerging since emergence was just as good on the calcium sulphate plot as on those treated with calcium hydroxide or where organic matter was added. Similar reduction in number of abnormal plants and severity of injury was obtained by increasing the organic matter although the *p*H remained low. Emergence also was satisfactory.

Referring to Experiment 4, the variation in injury to corn planted in the different soils may be attributed to variation in *p*H and organic matter content since in Experiment 5 injury was less in soil with either a high *p*H or large organic matter content. The abnormalities and injury on the silt and sandy loam soils (table 15) may be explained on the basis of low *p*H and low organic matter, the lack of injury on the peat on the basis of high organic matter, and the lack of injury on the LeSueur silty clay loam to a combination of high *p*H and relatively high organic matter content.

The commonly unsuccessful results of pre-emergence treatments on sandy soils are sometimes attributed to the loose structure of those soils. To study this possibility, the rate of percolation and the depth to which ½ inch of water would penetrate were determined for each of the soil types. A liter of water was allowed to percolate through dry soil, and the time taken for the first drop to appear and the total time for percolation of the entire amount were noted. The quantity of water percolated was also measured (table 17).

There was a wide difference in the rate of percolation through silt loam, which was very slow, and the other soil types. Likewise, the depth to which ½ inch of water percolated in the silt

Table 17. Rate of Percolation and the Depth to Which ½ Inch of Water Penetrated in Different Soils

Type of soil	Time taken for the first drop	Total time taken for 1,000 ml. to percolate through dry soil	Quantity percolated out of 1,000 ml.	Depth to which ½ inch of water penetrated in ¼ hour*
	minutes	minutes	milliliters	inches
Waukegan silt loam	40	210	428	1.62
LeSueur silty clay loam	18	60	404	2.20
Dakota fine sandy loam	7	35	515	3.10
Low lime peat	1	20	450	2.75
Low lime peat (sterilized)	½	15	505	2.25

* In soil that was in optimum moisture condition for planting.

loam was from 0.58 to 1.48 inches less than in other soil types. This may be one of the reasons why there was more injury in this soil than in others. There was also a difference in the total quantity of water percolated. The results from mineral soils are comparable among themselves, but in the case of the peat, the water percolated so rapidly that the soil was only partially wet. To wet it thoroughly required six repetitions of the procedure. The total quantity of water in the last percolation measured 283 milliliters for the unsterilized peat and 293 milliliters for the sterilized peat.

Penetration and Persistence of 2,4-D in the Soil

This study was carried on with samples of the Waukegan silt loam from the field plots and the various soil types used in Experiment 4. The 2,4-D was easily detected by the inhibited germination of yellow flax seed in leachate from the soil sample. In previous work Dunham and Robinson found this test sensitive to 15 parts per million. Figure 10 is a photograph of the method which consisted of soaking filter paper in the leachate and using it in a Petri dish for the substrate.

Samples of soil from the field were taken June 22, June 30, July 21, and August 12 which represented intervals of 10, 18, 39, and 61 days after planting. In those plots protected from rain until emergence was complete on June 28, 2,4-D was found only in the surface ¼ inch on June 22. By June 30, 0.54 inch of rain had fallen but the 2,4-D was detected in the 0.25-1.25-inch layer only where 64 ounces of the chemical had been applied. By July 21, it had disappeared from all plots except where treated with 32 ounces and 64 ounces per acre. In these plots it was present in the surface ¼ inch in small amounts and in the 1.25-2.25-inch layer where 64 ounces of the chemical had been used. By August 12 there was no indication of 2,4-D in any plot at any depth. Rain fell as follows: July 1-21, 1.44 inches; July 22-August 12, 4.81 inches.

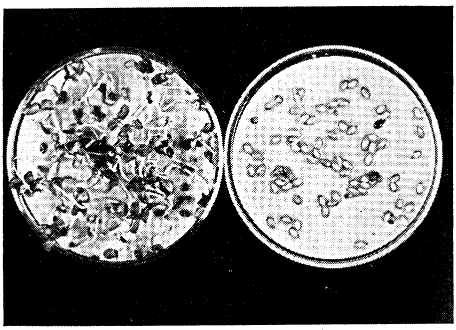

Fig. 10. Inhibited germination of Crystal flax on filter paper substrate soaked in leachate from soil treated with 2,4-D. Right, a relatively high concentration; left, water.

In those plots where water was added, the 2,4-D was carried into the 0.25-1.25-inch layer almost immediately. It appeared in this layer June 22 and was present again June 30. On this latter date it was found in small quantities in the 1.25-2.25-inch layer where ½ inch of water had been applied five days after planting. On July 21, small quantities were found in the surface layer where water had been applied on the day of planting and on August 12, the herbicide could not be detected in any sample. This set of plots was exposed to the same rain as those discussed in the preceding paragraph.

The presence of 2,4-D 15 days after application in various layers of five soil types is indicated by + signs in table 18.

The chemical was carried to greatest depths in peat and fine sandy loam by ½ inch of water applied immediately after spraying with 2,4-D. It was completely removed from the surface layer of the Dakota fine sandy loam, appeared in large amount in the second layer, and was found in small amount in the 1.25-2.25-inch layer. On the contrary, much of it remained in the top

Table 18. Presence of 2,4-D at Different Depths in Five Soils 15 Days After Application of 2,4-D Followed by ½ Inch of Water

Soil type	Depths in inches			
	0—¼	¼—1¼	1¼—2¼	2¼—3¼
Waukegan silt loam	+++	++	0	0
Dakota fine sandy loam	0	+++	+	0
LeSueur silty clay loam	++++	+	0	0
Low lime peat	++	++	++	0
Low lime peat (sterilized)	++	++	+	0

++++ Present in very large quantity
+++ Present in large quantity
++ Present in moderate quantity
+ Present in small quantity
0 Absent

layer of the LeSueur silty clay loam and very little reached the next layer. In the Waukegan silt loam, it was well distributed in the two upper layers, and in both peats it was present in moderate amounts in the top three layers.

Summary and Discussion for Pre-emergence Treatments On Corn

It is clear from the results of this study that successful pre-emergence spraying of corn with 2,4-D is dependent upon a number of environmental factors and that these factors are more important than the amounts of chemical used. The factors influencing results in these trials were water, soil type, time of application, depth of planting, and dosages of the butyl ester of 2,4-D.

Of these factors water was of greatest importance. On plots protected from rain until after emergence of the corn, there was no reduction in stand, dry weight, or grain yield of the crop and no delay in maturity even when 64 ounces of 2,4-D acid had been applied per acre. At the same time, there was good control of both grass and broadleaf weeds with as little as 8 ounces per acre. Corn, sprayed with 2,4-D, however, was shorter on all plots than unsprayed.

When water was added following the application of 2,4-D, fewer plants emerged, there were more abnormal plants, maturity was delayed, the plants were shorter, and dry weights of plants and grain yields were reduced. Weed control on these plots was good compared with plots untreated with 2,4-D but not as satisfactory as on plots receiving no additional water. The control of broadleaf weeds was excellent on all treated plots, but grass weed control was best where water was not added. These results obtained on Waukegan silt loam indicate that 2,4-D should not be incorporated in the soil before corn plants have completely emerged and that successful weed control can be obtained in this type of soil without injury to the crop provided that there is no rain between the application of the chemical and complete emergence.

The factor next in importance was the soil type. Tests in the greenhouse with different soils and on the same soil to which various amendments were added showed that the *p*H, organic matter, and clay content, acting singly or collectively, were important factors affecting pre-emergence treatment. Injury to corn plants was most severe in soil with low *p*H, low organic matter content, and a small clay fraction. When the percentage of organic matter remained constant, injury was closely associated with low *p*H, but increasing the amount of organic matter of a soil with low *p*H also effectively reduced injury.

The reason for these responses is not known. Certain explanations, however, are possible. It may be that 2,4-D is more toxic in acid soils than in neutral soils. It is also possible that in soils with high organic matter and clay content the chemical is adsorbed on colloids and thus becomes less toxic. The results of the studies on rate of percolation and depth of penetration of water were probably further expressions of the influence of soil texture and organic matter content since they are so closely related to them.

The third factor that influenced the pre-emergence treatments made on the Waukegan silt loam soil was the time of application. No difference was observed between the two dates used, if no additional water followed the 2,4-D treatment. But when water was added, there was a reduction in the number of plants emerging, increase in the number of abnormal plants, and poorer weed control from the treatments made immediately after planting as compared with those made five days after planting. The time of application, however, did not affect the dry weight of plants, the maturity, or the yield of grain. This fact indicates that the visible injury was more pronounced in the case of immediate treatment than delayed treatment, but the physiological injury probably was of the same degree. More pronounced injury in the case of the immediate treatment plus water was due, probably, to the early incorporation of 2,4-D in the soil which resulted in contact of the chemical with the plant in an early stage of development. The most important effect from the practical point of view was the reduction in stand and poorer weed control by the immediate treatment plus water.

The better control of weeds from delayed treatment probably resulted because the seeds were germinating when the 2,4-D was applied. The poorer control from immediate treatment plus water may be explained by the dilution of the chemical below the toxic level as it was washed down by the added water. The control from immediate treatment without water was almost as good as delayed treatment, probably because the chemical remained at the surface in sufficient concentration to be lethal at the time the weed seeds were germinating. The control on all plots, however, was good when compared with check plots that received no 2,4-D.

In general, depth of planting did not appear to influence pre-emergence treatment greatly. Most differences observed were small and could have been attributed to depth of placement exclusive of any effect from the 2,4-D. The interaction of rates of water times depths, however, was highly significant. More injury with ¼ inch of water at the 2-inch depth and with ½ inch of water at the 3-inch depth; and less injury with ½ inch of water at the 2-inch depth and ¼ inch of water at the 3-inch depth is difficult to explain. The possibility that 2,4-D was carried beyond the seed at 2 inches by ½ inch of water and that it was taken closer to the seed at 2 inches by ¼ inch of water is not substantiated by the penetration study which showed that the chemical was not taken below the 1¼-inch level by either amount of water.

Dosages were included as a variable only in Experiment 1 where no water applications were made and the plots were protected from rain until emergence. Under these conditions, dosages had practically no differential effects. The plants were shorter on treated plots but the reduction in height was not correlated with dosage of chemical. There was no reduction of stand, dry weight of plants, or grain yield and no delay in maturity related to dosages. For weed control, 24 ounces or more were best but the control was satisfactory even with 8 and 16 ounces. In the other experiments one dosage—24 ounces—was used. It is possible that this was a marginal amount and that no injury resulted in LeSueur silty clay loam and peat because the dosage was low for those soils. It is also possible that plants might not have been injured on Waukegan silt loam with less than 24 ounces when water was applied.

From these studies it is clear that good weed control of both broadleaf and grass species was obtained by pre-emergence treatment with butyl ester of 2,4-D at 24 ounces per acre without injuring the corn used as a crop. In heavy soils like LeSueur silty clay loam and in peats there does not appear to be any danger in using 2,4-D at this dosage. But in soils that are low in *p*H and organic matter like Waukegan silt loam, successful results can be expected only if no rain occurs after the chemical treatment and before the complete emergence of crop plants. It is very difficult to forecast the weather 10 days ahead, but danger can be reduced by delaying spraying as long as possible.

The most practical method for such soils is to correct the acidity before treatment with 2,4-D. The danger of injury to the crop may also be minimized by the addition of organic matter but the amount required makes it impracticable in many instances. Another possibility is the use of an insoluble 2,4-D formulation that can be suspended in water for distribution. It was observed in these studies that maximum injury to corn was caused only when the 2,4-D was thoroughly incorporated with the soil before emergence. If insoluble 2,4-D were used, there would be less danger of mixing with the soil by rain. It has to be ascertained, however, whether insoluble 2,4-D will kill weeds.

The residual effect of 2,4-D is an important consideration in its use. One of the advantages claimed for this herbicide is its lack of persistence in the soil. In these studies, it had completely disappeared in field samples taken to a depth of 3¼ inches within two months after treatment even when a sensitive test for its detection was used. Deepest penetration occurred in peat and Dakota fine sandy loam and shallowest in Waukegan silt loam and LeSueur silty clay loam.

PRE-EMERGENCE TREATMENT OF SOYBEANS WITH TCA

The methods and procedure used for each of the experiments with soybeans were similar to those used with 2,4-D treatment on corn. Results were so uniformly unsatisfactory because of injury to the crop that tables of data are omitted and a summary discussion is presented.

Of the factors studied, water was most important as in corn. On those plots protected from rain until emergence was complete, both emergence and stand of the soybeans were normal. As soon as these same plants were exposed to the rain, they showed injury and the yield of seed was reduced in proportion to the amount of TCA used. A yield of 135 grams on the check plot was reduced to 100 grams by 2 pounds of the chemical; to 62 grams by 4 pounds; to 27 grams by 8 pounds; to 6 grams by 12 pounds; and to 0 by 16 pounds. A photograph taken about a month after planting is shown in figure 11. Injury to the soybeans increased as the season progressed and more rain fell. At harvest time there was no crop on this plot. Where water was added after spraying with the chemical, the crop was a complete failure.

The control of broadleaf weeds was not expected with TCA. The grass weeds which were mainly *Eragrostis pilosa, Panicum capillare,* and *Eragrostis megastachya* were controlled as well by 8 pounds of TCA as by any larger amount and the addition of water after spraying had no important effect. Time of application, however, was important. Significantly better control of grass

Fig. 11. Injury to soybeans from TCA. Right foreground, check plot; left foreground, plot receiving 16 pounds per acre of active ingredient. Photograph was taken one month after planting.

weeds was obtained with treatments made immediately after planting than with treatments delayed five days. It is the conclusion of the writers that grass seedlings develop some resistance and that best control will result if the TCA is present in solution at the time the seeds are germinating.

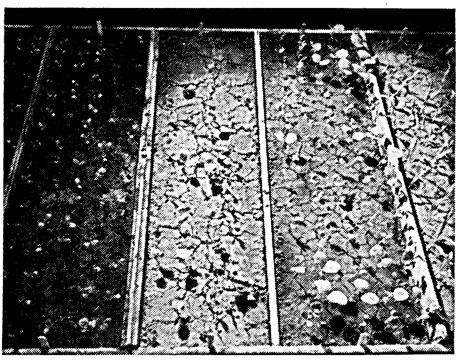

Fig. 12. Variable emergence of soybeans planted in different soils treated with TCA. From left to right, Dakota fine sandy loam, Waukegan silt loam, and peat.

Soil type influenced the stand of soybeans. As in corn, emergence was significantly poorer on Waukegan silt loam than the other soils but this differential response was lost a few days later when all plants on all types of soils showed injury that later proved severe. Differences in emergence are shown in figure 12.

The depth of planting was not an important factor affecting the preemergence treatment. Differences in stand between plantings at 2 inches and 3 inches were significant, the stand being poorest from the 3-inch depth. Differences, however, were similar on the check plot.

Persistence of TCA in the Soil

Leachates of soil samples taken from the field plots were obtained as for corn. Since seeds of various crops tried did not respond to TCA as yellow flax seed did to 2,4-D, these tests had to be abandoned. Observations in the field indicated that the treated soil remained toxic to soybeans for about 50 days in plots treated with 2 to 4 pounds per acre and about 80 days in plots treated with 8 to 12 pounds. In plots treated with 16 pounds, the chemical persisted at least until harvest of the crop, about four months.

The susceptibility of soybeans to small quantities of TCA in the soil made possible a test of persistence of the chemical in a shallow layer of different soil types. No differential results were obtained among the soils tried. TCA applied at 8 pounds per acre on September 20 was still present January 15 in amounts that caused crinkling of leaves and severe inhibition of growth. The development of soybeans after January 15 was normal except for the formation of white specks on the leaves. Tests were continued until May 5 but this indication of the presence of TCA did not disappear even after leaching duplicate samples with 4 inches of water. It is possible that this chemical was adsorbed by soil particles and released slowly.

Under the conditions of these experiments, TCA persisted in lethal amounts to soybeans for about four months, and it remained in smaller quantities for at least another three months. Its disintegration was not affected by such different soil types as Waukegan silt loam, Dakota fine sandy loam, LeSueur silty clay loam, unsterilized peat and sterilized peat. The largest proportion of the chemical disappeared without leaching with water and small quantities did not disappear more rapidly in 2 inches of soil leached with 4 inches of water than in unleached soil.

SUMMARY

Of the factors studied, those most seriously affecting the pre-emergence treatment of corn were water, soil type, *p*H, and organic matter content of the soil; less important was time of application; and least important were depths of planting and dosages.

Good control of both grass and broadleaf weeds was obtained with 24 ounces of 2,4-D acid in the butyl ester form without injuring the corn crop provided that the *p*H or organic matter of the soil was high or that no rain fell between planting and emergence of the crop on soil of low *p*H and low organic matter.

With 6.79 inches of rainfall plus 0.5 inch of added water, 2,4-D at 64 ounces per acre persisted in Waukegan silt loam less than two months.

Results with TCA as a pre-emergence treatment for soybeans were very unsatisfactory because of injury to the crop. Under the conditions of this experiment, TCA persisted in the soil in lethal amounts to soybeans for four months and in smaller quantities for at least another three months. Its disintegration was not affected by such soil types as Waukegan silt loam, Dakota fine sandy loam, LeSueur silty clay loam, low lime peat, and sterilized low lime peat.

LITERATURE CITED

1. AKAMINE, ERNEST K. Plant-growth regulators as selective herbicides. University of Hawaii Agr. Expt. Sta. Circ. 26. 1948.

2. ALBAN, E. K. Chemical weed control in horticultural crops. Proc. Fifth Annual N. C. Weed Control Conf.: pp. 58-65. 1948.

3. ALLARD, R. W., DEROSE, H. ROBERT, and SWANSON, C. P. Some effects of plant growth-regulators on seed germination and seedling development. Bot. Gaz. **107**:575-583. 1946.

4. ANDERSON, J. C., and WOLF, D. E. Pre-emergence control of weeds in corn with 2,4-D. Jour. Amer. Soc. Agron. **39**:341-342. 1947.

5. ———— and ————. Pre-emergence control of weeds in corn with 2,4-D. Jour. Amer. Soc. Agron. **40**:453-458. 1948.

6. ANONYMOUS. Recommendations of the Research Committee of the North Central Weed Control Conference. Proc. Fifth Annual N. C. Weed Control Conf., pp. 226-233. 1948.

7. BANDURSKI, ROBERT S. Spectrophotometric method for determination of 2,4-dichlorophenoxyacetic acid. Bot. Gaz., **108**:446-449. 1947.

8. BARRONS, KEITH C. TCA—A promising new chemical for grass control. Down to Earth. **4**:(4) 8-9. 1949.

9. BROWN, JAMES W. and MITCHELL, JOHN W. Inactivation of 2,4-dichlorophenoxyacetic acid in soil as affected by soil moisture, temperature, the addition of manure, and autoclaving. Bot. Gaz. **109**:314-323. 1948.

10. DANIELSON, L. L. Selectivity of 2,4-D and Sinox when applied to soil. Plant Physiol. **22**:635-636. 1947.

11. DEROSE, H. ROBERT. Persistence of some plant growth-regulators when applied to the soil in herbicidal treatments. Bot. Gaz. **107**:583-589. 1946.

12. DUNHAM, R. S. Summary of reports on pre-emergence trials. Proc. Fourth Annual N. C. Weed Control Conf., pp. 238-240. 1947.

13. FREED, VIRGIL H. Qualitative reaction for 2,4-dichlorophenoxyacetic acid. Science **107**:98-99. 1948.

14. FUELLEMAN, R. F. Pre-emergence treatment of corn for weed control. Proc. Fifth Annual N. C. Weed Control Conf., pp. 11-15. 1948.

15. GREANEY, F. J. Pre-emergence treatments of weeds in corn. Proc. Fourth Annual N. C. Weed Control Conf., pp. 45-46. 1947.

16. HAMNER, C. L., TUKEY, H. B., and CARLSON, R. F. Application of 2,4-dichlorophenoxyacetic acid to soil as a pre-emergence spray to prevent lodging and to control weeds in sweet corn. Mich. Agr. Expt. Sta. Quart. Bul. **30**:194-200. 1947.

17. HANKS, ROBERT W. Removal of 2,4-dichlorophenoxyacetic acid and its calcium salt from six different soils by leaching. Bot. Gaz. **108**:186-191. 1946.

18. HEAL, R. R. and THOMPSON, D. G. Bibliographical report on herbicides. Minn. Agr. Expt. Sta. Mimeographed. 1949.

19. HELGESON, E. A., SWANSON, C. R., and STAHLER, L. M. Chemical weed control investigations in sugar beets at Fargo, North Dakota. Proc. Fifth Annual N. C. Weed Control Conf., pp. 108-111. 1948.

20. HERNANDEZ, T. P., WARREN, G. F., and BUCHHOLTZ, K. P. Weed control in corn with 2,4-D soil treatments. Proc. Fourth Annual N. C. Weed Control Conf., pp. 241-242. 1947.

21. Hudson, H. G. Weed control in Norfolk; a new method. Gt. Brit. Min. Agr. Agriculture. **53**:22-27. 1946.

22. Hurd-Karrer, Annie M. Relation of soil reaction to toxicity and persistence of some herbicides in greenhouse plots. U. S. Dept. of Agr. Tech. Bul. **911**:1-31. 1946.

23. Jorgensen, Carl J. C. and Hamner, Charles L. Weed control in soils with 2,4-dichlorophenoxyacetic acid and related compounds and their residual effects under varying environmental conditions. Bot. Gaz. **109**:324-333. 1948.

24. Klingman, G. C. Will chemical weed killing replace cultivation? What's New in Crops and Soils. **I**(1):89. 1948.

25. Kries, Olive H. Persistence of 2,4-dichlorophenoxyacetic acid in soil in relation to content of water, organic matter, and lime. Bot. Gaz. **108**:510-525. 1947.

26. Leonard, O. A., Arle, H. F., and Harris, V. C. Sodium salt of 2,4-D as a pre-emergence herbicide for field corn. Proc. Fourth Annual N. C. Weed Control Conf., p. 250. 1947.

27. Martin, J. P. The hormone weed killer 2,4-D. Calif. Citrograph **31**:248 and 264-265. 1946.

28. McCall, G. L. Effect on crop plants of residual 2,4-D in the soil. Proc. Third Annual N. C. Weed Control Conf., pp. 97-101. 1946.

29. ———— and Zahnley, J. W. Control of noxious perennial grasses with trichloroacetates. Kan. Agr. Expt. Sta. Circ. **255**:3-8. 1949.

30. Mitchell, John W. and Marth, Paul C. Germination of seeds in soil containing 2,4-dichlorophenoxyacetic acid. Bot. Gaz.**107**:408-416. 1946.

31. Offord, H. R. Rapid estimation of the phytocidal action of chemicals. Science **103**:474-476. 1946.

32. Ready, Daniel and Grant, Virginia Q. A rapid sensitive method for determination of low concentrations of 2,4-dichlorophenoxyacetic acid in aqueous solution. Bot. Gaz. **109**:39-44. 1947.

33. Ryker, T. C. Ammonium trichloroacetate. Proc. Fourth Annual N. C. Weed Control Conf., pp. 58-59. 1947.

34. Slade, R. E., Templeman, W. G., and Sexton, W. A. Plant-growth substances as selective weed killers. Differential effect of plant-growth substances on plant species. Nature (London) **155**:497-498. 1945.

35. Swanson, Carl P. A simple bio-assay method for the determination of low concentrations of 2,4-dichlorophenoxyacetic acid in aqueous solutions. Bot. Gaz. **107**:507-509. 1946.

36. Taylor, D. L. Growth of field crops in soil treated with chemical growth-regulators. Bot. Gaz. **108**:432-445. 1947.

37. Thompson, H. E., Swanson, Carl P., and Norman, A. G. New growth-regulating compounds. I. Summary of growth-inhibitory activities of some organic compounds as determined in three tests. Bot. Gaz. **107**:476-507. 1946.

38. Timmons, F. L. Control of annual weeds in sweet corn by pre-emergence treatment with 2,4-D. Proc. Eleventh Annual Western Weed Conf., pp. 43-44. 1949.

39. WARREN, G. F. Pre-emergence treatments for onions, lima beans, beets and asparagus. Proc. Fifth Annual N. C. Weed Control Conf., pp. 39-44. 1948.

40. ———— and HERNANDEZ, T. P. Weed control in certain vegetable crops with soil applications of 2,4-D. Proc. Amer. Soc. Hort. Sci. **51**:515-525.

41. WEAVER, ROBERT J. Reaction of certain plant growth-regulators with ion exchangers. Bot. Gaz. **109**:72-84. 1947.

42. WILLARD, C. J. Pre-emergence treatments of weeds in corn. Proc. Fourth Annual N. C. Weed Control Conf., p. 48. 1947.