THE EFFECT OF 2, 4-DICHLOROPHENOXYACETIC ACID, 3-AMINO-1, 2, 4-TRIAZOLE AND 2, 2-DICHLOROPROPIONIC ACID ON GROWTH OF OATS, SOYBEANS AND CORN, WITH SPECIAL REFERENCE TO MORNING VERSUS EVENING APPLICATION

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Percival Emanuel Jackson

1959

THE EFFECT OF 2,4-DICHLOROPHENOXYACETIC ACID, 3-AMINO-1,2,4-TRIAZOLE AND 2,2-DICHLOROPROPIONIC ACID ON GROWTH OF OATS, SOYBEANS AND CORN, WITH SPECIAL REFERENCE TO MORNING VERSUS EVENING APPLICATIONS

by

PERCIVAL EMANUEL JACKSON

A THESIS

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

MASTER OF SCIENCE

Department of Farm Crops

1959

ABSTRACT

2,4-Dichlorophenoxyacetic acid (2,4-D) at 1 and 2 pounds per acre stimulated vegetative growth of oats. Stimulation of growth was greater from evening than from morning spraying. 3-Amino-1,2,4-triazole (Amitrol) and 2,2-Dichloropropionic acid (Dalapon) reduced the length of panicle, number of panicles, number of kernels per panicle, and yield. In general, evening treatments with amitrol were more injurious than morning treatments, while the reverse of this was true for dalapon. The effect of amitrol on yields could be predicted from injuries observed soon after spraying.

2,4-D at 1/4 and 1/2 pounds per acre reduced the yields of soybeans. Evening treatments tended to be more injurious than morning treatments at the high rate of application as measured by maturity and yield. Both amitrol and dalapon reduced yields of soybeans at rates used in this experiment. In general, evening treatments were more injurious. Both chemicals reduced size of seed.

2,4-D applied to corn at 1 and 3 pounds per acre caused injury as shown by rolled leaves, crooked stalks and malformed brace roots. Evening applications were the most injurious. Evening applications of amitrol on corn showed more visual injury than morning applications. However, plants outgrew the injury.

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Professor Boyd R. Churchill, under whose guidance this investigation was conducted, and for his untiring assistance in the preparation of this manuscript.

Expressions of gratitude go to Dr. S.T. Dexter for his inspiration and encouragement in the pursuance of the experiment, his constructive criticisms and unflinching cooperation in the preparation of this manuscript.

Thanks are extended to Kalapatti M. Srinivasan, M.S., for advice on the collection and analysis of the data; to my house mates Andrew D. Dunbar and Horace F. Hamilton for their unsolicited help in the collection of samples; and to John H. Showers, Jr. of the Farm Crops Laboratory, for providing additional help when experimental procedures demanded it.

I owe a special debt of gratitude to my wife Pearline, who was a source of inspiration and encouragement throughout the entire program, and to Paula and Eda, our children, for their sustained loyalty and understanding, not having seen Dad for the full duration of this investigation.

LIST OF FIGURES

INTRODUCTION

The discovery and synthesis of 2,4-Dichlorophenoxyacetic acid (2,4-D) and allied substances initiated an unprecedented era in the control of weeds by chemicals. The type of weed species, crops, stage of growth, time and mode of application, formulation of chemical employed, weather conditions and soil type considerably influence the action of these chemicals, contributing to their success or failure.

Users of chemicals often express contrasting views on the effectiveness of a given chemical on a particular crop applied at recommended rates. It is therefore obvious that factors other than the chemical itself are responsible for the successful usage of these herbicides. Since these factors are often included in spray recommendations with no specific reference to time of day that applications are made, it is reasonable to assume that "time of day" may be a limiting factor. This is the hypothesis that led to this experiment to determine the effects, if any, of time of day upon the rate of absorption and translocation of herbicides by crops.

The ability to control weeds without imparing crop yields has not always been easy. Many investigators have directed their attention on the effect of 2,4-D and allied substances on crop yields, and particular attention seemed to have been paid to oats, soybeans and corn. Results have not always been consistent and both increase and reduction of yields have been reported. The rate, time of application, and stage at which the crop should be treated appear to be of paramount significance in terms of measuring success of weed control and in terms of crop yields.

Only limited studies seem to have been undertaken in this direction.

REVIEW OF LITERATURE

Mitchell and Brown (20) found that leaves in the dark responded more slowly to 2,4-D than did those in the light. They observed that 2,4-D growth stimulus was translocated only in the presence of light, indicating that the movement was associated with the products of photosynthesis, and the translocation of organic food materials. Linder et al (18) obtained similar results. Rohrbaugh and Rice (25) found that addition of sucrose to plants treated with 2,4-D in the dark increased the amount of translocation. Very marked stem curvatures resulted when red kidney bean plants were treated and kept in bright light, while there was no reaction when plants were kept in a shaded location or in darkness (33).

Tam (30), working under Hawaiian conditions, stated that temperatures ranging from a minimum of 70° F to a maximum of 85° F through the larger percentage of days is highly favourable for the action of 2,4-D. Hamner and Tukey (13), Marth and Davis (19) and Kelly (17) have all shown that 2,4-D sprays are more effective in warm weather, and the herbicidal effectiveness increases with high temperatures.

Several investigators (1, 7, 10, 27, 32) have reported reduction of yields of oats from applications of 2,4-D at the 1/2 and 1 pound per acre rates. Aldrich (1) reported that fertility levels influenced the effect of 2,4-D on yield, tillering, number of seeds per tiller and seed weight. He observed significant reduction in yield at high fertility levels, increased tillering and mean seed weight at high fertility levels, and that reductions in number of seeds per tiller were consistently associated with reductions in yields. Aldrich also noted that an increase in seed weight normally occurs with a reduction in number of seeds per tiller, providing fertility is adequate.

In addition to lower yields, Brown (5) reported injuries expressed in the form of stiffened, discolored foliage, onion leaf, enlarged nodes, twining of stems, panicles and spikelets, "side oats", uneven length of stem and weakened straw in oats.

Grigsby and Churchill (12) stated that several varieties of oats sprayed when 4 - 6 inches in height did not show any evidence of injury to vegetative tissue from 2,4-D at 3/4, 1-1/2 and 2 lb. per acre rate. There was also no reduction in yield. Derscheid et al (10) pointed out that applications of 2,4-D significantly decreased the average number of seeds per panicle, but the seed weights on treated plots were significantly higher than from untreated plots. They noted an onion-like leaf effect. Leaves had definite onion-like appearance (32) and were not as numerous as in untreated plots. Plants were later in heading, shorter and had a tendency to lodge. Shaw, Willard and Bernard (27) undertook a study at the Ohio State Exp. Station to determine the effect of 2,4-D on Clinton 59 oats when applied at 6 rates of application and nine stages of growth. They concluded that the pre-tiller, boot and early heading stages were clearly defined as the least tolerant stages while the full tiller, bloom and milk stages were the most tolerant stages in the life cycle response of oats to 2,4-D. Oats were found to be more sensitive to injury from 2,4-D than wheat and barley. Stahler (29) claimed that oats showed a definite retardation in flowering when treated with the higher rates of 2,4-D compounds, while Rice (22) observed no apparent differences in time of flowering or amount of flowering in any of the sprayed plants as compared with the controls.

Stahler (29) and Wolfe et al (35) classified soybeans as being very sensitive to 2,4-D sprays. Soybeans were affected more quickly and to a

greater extent when grown in nutrient solutions high in nitrogen than in those with a low nitrogen level (35). Weaver et al (34) found that 2,4-D applied at 1/2 pound per acre to soybeans 6 - 8 inches in height caused severe distortion of plants and retard growth, but plants later recover to produce normal yields of beans. Applications at later stages of growth reduced yields significantly. Floral and aerial structures were also affected. It was pointed out by Rice (23) that there was greater absorption of 2,4-D by beans at a temperature series of 86 - 92° F than one of 79 - 82° F. He observed stem curvatures in all plants in series 79 - 82 and 86 - 92° F while there was no curvature in series 46 - 58° F. Rohrbaugh and Rice (25) found that 2,4-D was not translocated out of destarched bean leaves in the dark unless sugar was added to the leaves. However, the application of a 10% sugar solution resulted in stem curvature and inhibition of trifoliate leaf blades. Fructose and glucose were found to be more effective than sucrose in augmenting the translocation of the growth regulator. Slife (28) experienced curling of leaves and bending of upper part of plant within 3 hours after spraying with 2,4-D. Injury increased in severity up to 48 hours after treatment, at which time recovery at the lower rates (1/16 and 1/8 pound per acre) began. Hanson and Freeman (14) reported a 10% reduction in hay yield from 1/16 and 1/8 pound per acre rates of 2,4-D on Wabash soybeans.

Root proliferation has been reported (6, 16, 21, 24) as one of the common 2,4-D injuries in corn. Buchholtz (6) observed greatest root injury when corn plants between 10 and 40 inches in height were treated, but others (3) have tentatively recommended spraying the plants at heights varying from 12 to 36 inches. Rodgers (24) noted considerable stalk bending from 2,4-D applications to plants in the 6 - 11 leaf stage. He also found leaf rolling and

reduced yield to be noticeable injuries. Other investigators (11, 16, 31) reported that 2,4-D reduced yields in corn. Hoffman (16) reported a reduction in corn yield in one instance from the use of 1/2 pound of 2,4-D per acre and a 50% increase in growth in another instance when applied at the rate of 1 1/2 pounds per acre. He also observed varietal differences in brittleness when plants were treated with 2,4-D. Warren and Hernandez (31) and Rodgers (24) report reduction on yield of corn by use of 2,4-D; whereas Dearborn (9) reports an actual increase in the yield of corn and Havis and Sweet (15) report that no significant reduction in yield of corn was noted, even when corn plants were badly malformed by 2,4-D sprays. Ellis and Bullard (11), after experimenting on 18 varieties of sweet corn with 5 formulations of 2,4-D, indicated that there was no significant increase or decrease in number of marketable ears, yield or stand for any of the varieties tested. The maturity of varieties did not appear to be affected.

Dalapon at rates as low as 4 and 6 pounds acid equivalent per acre effectively controlled heading of wild oats when applied from the seedling stage up to and including the fully tillered stage (2). There was no noticeable effect from any rate at the end of the first week, but two weeks after treatment, tip burning was noted on all plants and stunting was apparent. They also observed retardation in the elongation of the flowering stalk, leaving the panicle partially or completely enclosed in the boot at maturity. It was noted that dalapon increased tiller production even when applied after the plant had ceased normal tillering. Severity of damage and speed of kill are directly proportional to the concentration of dalapon (26). Santelman and Willard (26) placed plants in the dark before and after treatment and observed that the degree of kill of treated shoots compared to plants which

had received no treatment was not affected. Danielson and Shumaker (8) noted that dalapon produced necrotic areas on leaves of tomato by the second day following application. Necrotic areas on leaves were accompanied by marginal burns and a tendency for edges of leaves to curl under. New foliage became chlorotic.

Bondarenko and Willard (4) stated that the most striking effect of amitrol on plants is the loss of chlorophyll from the leaves within a week after treatment. Plants treated with amitrol first became yellow, then usually white and then turned brown and died. They indicated that if the initial dose of amitrol was low, some yellowed leaves regained their green color and continued to grow.

MATERIALS AND METHODS

In this experiment, performed at East Lansing, Michigan, an attempt was made to determine the influence of time of day on the effect of applications of 2,4-D, 3-Amino-1,2,4-triazole (Amitrol) and 2,2-Dichloropropionic acid (Dalapon) on crop growth.

Oats, soybeans and corn were the crops selected for the experiment. Garry oats were seeded on May 5, Chippewa soybeans were planted on May 20, and Michigan 350 hybrid corn was planted on May 27. Oats were drilled in 7 inch rows and the other two crops in 14 inch rows.

Plots were 6.75 x 36 feet in size and treatments were randomized in four replications. Herbicides were applied between 6 and 7 a.m., between 1 and 2 p.m., and between 7 and 8 p.m. A "low" and a "high" rate of each chemical was used in all cases. An attempt was made to select a "low" rate which would be near the minimum that would still show some crop injury. The actual rates in pounds of active ingredients per acre selected for the three crops are shown in Table 1.

TABLE 1

Pounds per acre of active ingredients applied at low and high rates

	OATS		SOYBEANS		CORN	
CHEMICAL	Low	High	Low	High	Low	High
2,4-D	1	2	1/4	1/2	1	3
Amitrol	2	4	2	4	1	2
Dalapon	2	4	1	2	2	4

Methods of Application: Plots were sprayed with a 6 foot boom mounted on a Farmal Cub tractor, delivering 35 gallons of spray per acre. Drift was controlled by the use of a hood (Fig. 1 and 2). Spraying equipments were thoroughly washed before changing chemicals and low rates preceded high rates in the case of each chemical.

Stages of application for each crop were as follows:

Oats - at the five leaf stage, sprayed June 9, (35 days after seeding);

Soybeans - 5 to 6 inches in height, sprayed June 17, (28 days after planting);

Corn - sprayed at the 7 to 9 leaf stage July 3, (31 days after planting).

Collection of samples: Half square yard samples were harvested from the three center rows of each plot at ten day intervals up to 40 days, and the dry weights determined. Ten running feet of row of oats were harvested to determine yield, tillering, kernels per panicle, and length of panicles. Ten running feet of row of soybeans were harvested to determine yield. The yield data on oats and soybeans were converted into standard measurement as bushels per acre. Six plants from each plot in the first replication of oats and soybeans were dug up with a spade and the roots washed and examined for injury. 25 consecutive plants from each 2,4-D plot in the first two replications were examined for injury to brace roots in corn.

Climatological data: Relative humidity and temperature were taken at time of spraying operations.

Fig. 1 Tractor and hood attachment used for applying the herbicides.

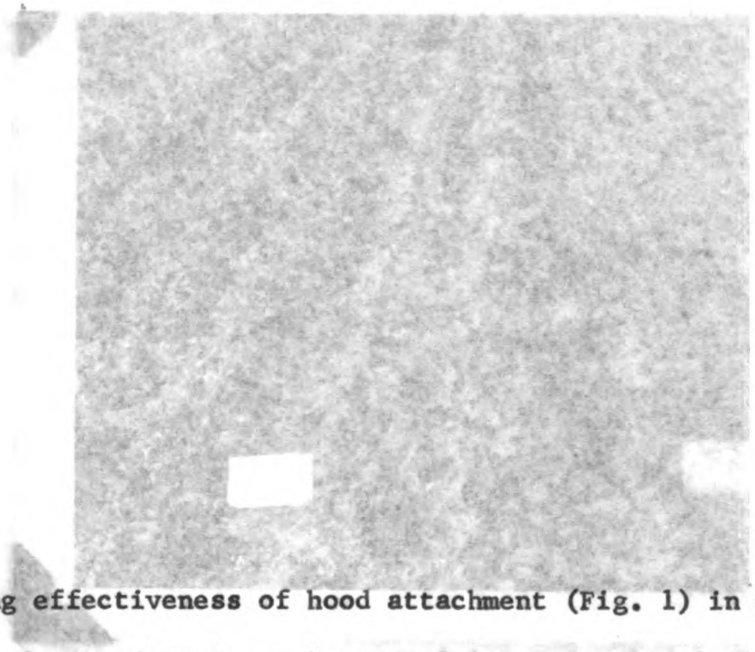
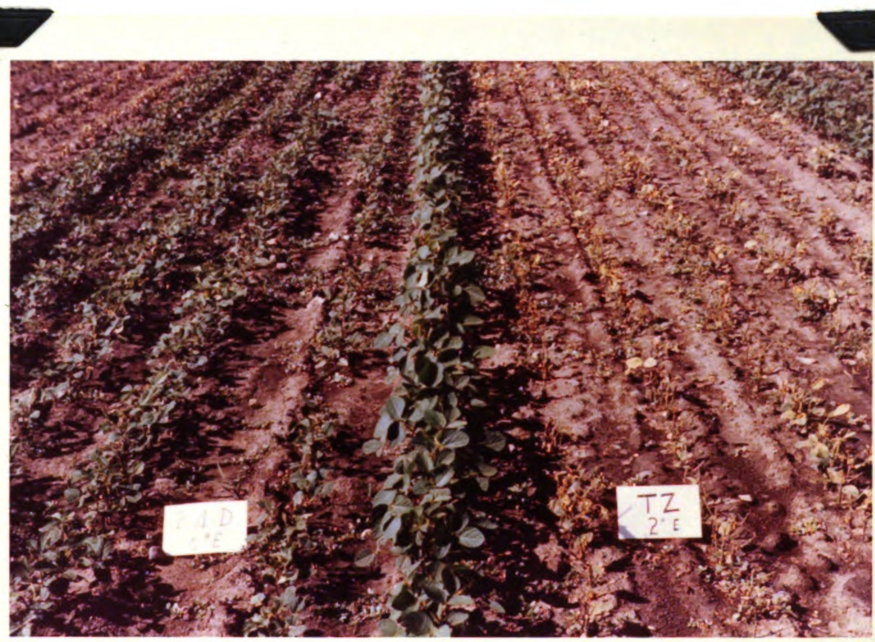


Fig. 2 Showing effectiveness of hood attachment (Fig. 1) in controlling drift. Note unsprayed row of soybeans between 2,4-D and amitrol plots.

Fig. 1 Tractor and hood attachment used for applying the herbicides.

Fig. 2 Showing effectiveness of hood attachment (Fig. 1) in controlling drift.

Note unsprayed row of soybeans between 2,4-D and amitrol plots.


TZ
2°E

RESULTS AND DISCUSSION

OATS

The dry matter accumulation at 10 day intervals following treatment with herbicides in comparison with the check and the final yield of grain in percent of the check are given in tables 2, 4 and 6.

Tables 3, 5 and 7 show the final yields, number of panicles, grains per panicle, weight per 300 kernels, and other data pertinent to the condition at harvest time.

Table 8 summarizes the data concerning accumulation of dry matter at the end of 40 days and grain yield in relation to rate and time of application of herbicides based on percentage of the check. Table 9 summarizes the data concerning number of panicles, number of kernels per panicle and weight of kernels in relation to yield for rates and times of application of herbicides based on percentage of the check.

The relative humidities were 70, 40 and 72 percent at morning, noon and evening applications respectively. Temperatures at time of application were 72, 91 and 81° F for morning, noon and evening treatments. Neither relative humidity nor temperature showed any correlation with dry matter accumulation at the end of 40 days nor with final grain yields.

2,4-Dichlorophenoxyacetic Acid

Injuries observed:

Injury to early growth of the oats was difficult to observe. Marginal and apical yellowing of lower leaves, stunting of plants and onion leaf effects were noted. There was no difference between time of flowering of the check plants and plants sprayed with 2,4-D. Some lodging occurred on

sprayed plots. It was the most severe on plots receiving the evening application and least in those with morning application. The severity of lodging increased with increased concentration. Some crooked panicles were observed.

Effect on dry matter accumulation:

2,4-D stimulated growth as measured by the accumulation of dry matter at the end of 40 days, regardless of the time or rate of applications (Table 2). These differences varied from slight in the case of 1 pound rate of application made in the morning and at noon, to very substantial at the 2 pound rate applied in the evening. When the dry matter accumulation for each of the ten day intervals is totaled, the greatest increase resulted when 2,4-D was applied in the evening and was 11 percent for the 1 pound rate and 9 percent for the 2 pound rate.

Effect on yield of grain:

Lowest yields were obtained from plots where oats were sprayed in the morning. Spraying at 2 pounds per acre resulted in lower yields than at 1 pound per acre. Oats sprayed in the morning at the higher rate produced approximately 10 bushels per acre less than oats not sprayed (Table 3).

The early growth of oats was not in direct relation to final grain yields. Plots producing the lowest yield, produced slightly more dry matter in early growth (40 days after treatment) than untreated plots (Table 8). Length of panicle measured from the top to the bottom node of the head was not responsible for the yield differences. The treatment giving the lowest yield averaged the same panicle length as oats that were not sprayed. The number of kernels per panicle were not in agreement with yields. 2,4-D applied at the 1 pound rate tended to increase kernel weight but did not necessarily cause increased yields. The weight of kernels and the number of panicles per unit of row were inter-related in their effect on yield.

Table 2. Effect of 2,4-D at low and high rates applied morning, noon and evening, on the accumulation of dry matter of oats harvested at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	136	233	341	329	100
2,4-D	1	morning	183	225	343	346	105
2,4-D	1	noon	132	223	298	336	102
2,4-D	1	evening	158	281	356	354	114
2,4-D	2	morning	125	220	344	362	110
2,4-D	2	noon	139	208	325	388	118
2,4-D	2	evening	118	228	313	473	144

Table 3. Effect of 2,4-D at low and high rates, applied morning, noon and evening, on length of panicles, number of panicles, number of kernels per panicle, weight of kernels and yields in bushels per acre of oats.

Treatment	Rate lbs/A	Time of day	Length* of panicles	Number+ of panicles	No. of kernels per panicle	Weight of 300 kernels	Yield bu/ acre	Yield % of check
Check	-	-	4.94	166	41	7.89	92.4	100
2,4-D	1	morning	4.98	156	40	8.22	87.8	95
2,4-D	1	noon	5.12	167	39	8.13	90.9	98
2,4-D	1	evening	5.06	165	35	8.55	89.8	97
2,4-D	2	morning	4.96	159	39	7.89	82.8	90
2,4-D	2	noon	4.99	164	38	8.19	88.0	95
2,4-D	2	evening	5.12	175	41	7.83	96.4	104

* Distance between the first and the last node of the panicle in inches.

+ Per 10 running feet randomly selected from center rows of plots.

Difference between means needed for significance when using R.E. (range of equality) at 5% level is 23.9 bushels per acre, and at 1% level is 31.3 bushels per acre.

3-Amino-1,2,4-triazole

Injuries observed:

Amitrol, unlike the other herbicides, caused severe injuries to the vegetative phase of the crop. Injury developed rapidly, suggesting that amitrol was absorbed in larger amounts, more injurious or was translocated more rapidly than the other herbicides. Higher rates were definitely more injurious than lower rates irrespective of the time of application (Tables 5 and 7). All applications caused injury to plant growth. Injury varied from a brownish cast to a severe chlorotic condition and increased in severity to the third day after which a period of recovery occurred. In the early stages following treatment, the high rate applied in the morning showed greatest injury. However, as time progressed, evening treatment at the high rate became more injurious than all morning and noon applications. Plants recovered sooner from injuries resulting from morning than from noon and evening applications. Flowering was delayed.

Effect on dry matter accumulation:

Amitrol reduced the dry matter as measured 40 days after treatment, regardless of time or rate of application (Table 4). Dry matter was reduced more by evening than by morning applications.

Effect on yield of grain:

All rates and times of application of amitrol reduced yields (Table 5). Reduction in yield was greater for evening than for morning applications. These differences were more pronounced at the lighter (2 pound) rate.

Amitrol reduced the length of the panicles in all cases. Evening spraying produced the shortest panicles and morning treatments the longest panicles (except the untreated plots). High rates shortened the heads more

Table 4. Effect of amitrol at low and high rates, applied morning, noon and evening, on the accumulation of dry matter of oats harvested at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	136	233	341	329	100
Amitrol	2	morning	97	162	253	250	76
Amitrol	2	noon	111	157	202	294	92
Amitrol	2	evening	98	148	219	247	75
Amitrol	4	morning	78	122	198	200	61
Amitrol	4	noon	93	133	188	195	59
Amitrol	4	evening	88	112	195	170	52

Table 5. Effect of amitrol at low and high rates, applied morning, noon and evening on length of panicles, number of panicles, number of kernels per panicle, weight of kernels and yields in bushels per acre of oats.

Treatment	Rate lbs/A	Time of day	Length of panicles	Number of panicles	No. of kernels per panicle	Weight of 300 kernels	Yield bu/ acre	Yield % of check
Check	-	-	4.94	166	41	7.89	92.4	100
Amitrol	2	morning	4.69	162	31	7.59	64.7	70
Amitrol	2	noon	4.52	155	29	7.62	59.2	64
Amitrol	2	evening	4.51	154	29	7.38	56.3	61
Amitrol	4	morning	4.08	145	22	7.29	39.0	42
Amitrol	4	noon	4.22	150	21	7.23	38.4	42
Amitrol	4	evening	3.97	146	19	7.38	35.9	39

Difference between means needed for significance when using R.E. (range of equality) at 5% level is 23.9 bushels per acre, and at 1% level is 31.3 bushels per acre.

than low rates. The number of panicles per unit area were reduced by all treatments. At the lower rates, evening applications were more injurious than morning treatments. Number of kernels per panicle were affected in the same way as length of panicles; the greatest reduction resulting from evening treatments. The weight per 300 kernels was reduced by all treatments. At the lighter rates of application, evening spraying was more injurious than morning treatments.

Unlike 2,4-D and dalapon treatments, it was possible to predict the yields of amitrol treated plots based on injuries observed during the vegetative phase of the crop. Yields varied directly with degree of injury. This was also true for the accumulation of dry matter (Table 8).

2,2-Dichloroproprionic Acid

Injuries observed:

Dalapon treated plants did not show conspicuous injury in early growth. Some marginal and apical yellowing of lower leaves and stunting of plants were observed. Injury was more severe at high than at low rates. Some of the heads were partially enclosed in the boot at harvest time and some showed crooked panicles. In general, dalapon treatments produced peduncles that were shorter and thin with fewer spikelets.

Effect on dry matter accumulation:

Dalapon reduced the dry matter at the end of 40 days when applied in the morning and at noon, but did not when applied in the evening (Table 6).

Effects on yields of grain:

All treatments, regardless of time or rate of application, reduced yields more than low rates. At the low rates, evening applications were less injurious than noon, and noon less than morning treatments. Length of panicle,

Table 6. Effect of dalapon at low and high rates, applied morning, noon and evening, on the accumulation of dry matter of oats harvested at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	136	233	341	329	100
Dalapon	2	morning	116	218	233	293	89
Dalapon	2	noon	121	219	310	298	91
Dalapon	2	evening	123	199	303	344	105
Dalapon	4	morning	127	188	300	287	87
Dalapon	4	noon	111	128	283	267	81
Dalapon	4	evening	117	185	296	321	98

Table 7. Effect of dalapon at low and high rates, applied morning, noon and evening on length of panicles, number of panicles, number of kernels per panicle, weight of kernels and yields in bushels per acre of oats.

Treatment	Rate lbs/A	Time of day	Length of panicles	Number of panicles	No. of kernels per panicle	Weight of 300 kernels	Yield bu/ acre	Yield % of check
Check	-	-	4.94	166	41	7.89	92.4	100
Dalapon	2	morning	4.70	162	32	7.80	69.3	75
Dalapon	2	noon	5.00	164	35	7.71	76.1	82
Dalapon	2	evening	4.81	176	38	7.74	87.7	95
Dalapon	4	morning	4.33	145	35	7.35	63.9	69
Dalapon	4	noon	4.04	141	36	6.99	60.8	66
Dalapon	4	evening	4.44	162	35	6.96	66.8	72

Difference between means needed for significance when using R.E. (range of equality) at 5% level is 23.9 bushels per acre, and at 1% level is 31.3 bushels per acre.

Table 8. Effect of 2,4-D, amitrol and dalapon at low and high rates on dry matter 40 days after treatment and grain yield of oats, in percent of check as influenced by time of application

Treatment	Morning				Noon				Evening			
	Low		High		Low		High		Low		High	
	dry mat.	yield	dry mat.	yield	dry mat.	yield	dry mat.	yield	dry mat.	yield	dry mat.	yield
2,4-D	105	95	110	90	102	98	118	95	114	97	144	104
Amitrol	76	70	61	42	89	64	59	42	75	61	52	39
Dalapon	89	75	87	69	91	82	81	66	105	95	98	72

Table 9. Relative importance of (A) number of panicles, (B) number of grains per panicle and (C) weight of individual grain and yield (% of check) finally obtained from oats treated with 2,4-D, amitrol and dalapon. High and low rates were used for each chemical and applications were made 6 - 7 a.m., 1 - 2 p.m. and 7 - 8 p.m.

RATE		2,4-D								RATE		AMITROL							RATE		DALAPON						
lbs/A	TIME OF DAY	A	B	C	AB	AC	BC	ABC	Yield	lbs/A	A	B	C	AB	AC	BC	ABC	Yield	lbs/A	A	B	C	AB	AC	BC	ABC	Yield
1	morning	96	95	100	91	96	95	91	90	2	98	76	96	74	94	73	72	70	2	98	78	99	76	97	77	75	75
1	noon	99	93	104	92	103	97	96	96	2	93	71	97	66	90	69	64	64	2	99	85	98	84	97	83	82	82
1	evening	105	100	99	105	104	99	104	104	2	93	71	94	66	87	67	62	61	2	106	93	98	99	104	91	96	95
2	morning	94	98	104	92	98	102	96	95	4	87	54	92	47	80	50	44	42	4	87	85	93	74	81	79	67	69
2	noon	101	95	103	96	104	98	99	98	4	90	51	91	46	82	46	41	42	4	85	88	89	75	76	78	66	66
2	evening	99	85	108	84	107	92	91	97	4	88	46	94	40	83	43	38	39	4	98	85	88	83	86	75	74	72

number of panicles, and number of kernels per panicle were reduced by the treatments. Higher rates were more injurious than lower rates. At the low rate, evening applications were less injurious than morning treatments. Accumulation of dry matter at the end of 40 days was directly related to yield of grain (Table 8). Length of panicle, number of panicles and number of grains per panicle were directly related to yield (Table 9).

SOYBEANS

The dry matter accumulation at 10 day intervals following treatment with the herbicides, in comparison with the check and the final yields in percent of the check are given in Tables 10, 12 and 14.

Tables 11, 13 and 15 give data concerning total yield, size of seed and moisture content at time of harvest.

Table 16 summarizes the data concerning accumulation of dry matter and yield in relation to rate and time of application of herbicides.

The relative humidities were 72, 56 and 58 percent at morning, noon and evening applications respectively. Temperatures at time of application were 54, 73 and 66° F for morning, noon and evening treatments. Neither relative humidity nor temperature showed any correlation with growth.

2,4-Dichlorophenoxyacetic Acid

Injuries observed:

2,4-D was in every respect less damaging to the soybeans than either amitrol or dalapon. Plants were stunted in early growth and later leaves were crimped. As the plants advanced in maturity, there was profuse development of collar roots. This was more pronounced at the higher rate. Stems became crooked and lodging occurred by harvest time. More lodging occurred

at the higher rate but differences due to time of application could not be observed. At the lower rate, however, more lodging occurred in plots sprayed in the evening, (Figures 3 and 4). Treated plants developed larger stems and showed splitting of the stems and peeling of the bark. Stems of treated plants were more woody and brittle.

Effect on dry matter accumulation:

All treatments, regardless of time or rate of application reduced dry matter in growth up to 40 days following treatment (Table 10). With the exception of the first 10 day period, the higher rate reduced dry matter more.

Effect on yields of seed:

All treatments reduced yields (Table 11). With one exception, the high rates reduced yields more than the low rate. Evening treatments reduced yields more than morning treatments at the higher rate of application (Table 16). Weight of seed was not associated with yield. The high rate delayed maturity as indicated by the percent of dry matter at harvest time (Table 11). Podded beans contained less dry matter when plants were sprayed in the evening.

3-Amino-1,2,4-triazole

Injuries observed:

Amitrol caused more severe injuries than the other herbicides. Injuries developed rapidly. There was a general chlorosis followed by defoliation. Greater injury resulted from the high rate although the low rate resulted in severe injury. As a result of a few showers late in the growth stage of the beans, rejuvenation of vegetative growth was initiated from the basal nodes of the plants. Consequently, plants that were totally defoliated

Table 10. Effect of 2,4-D at low and high rates, applied morning, noon and evening, on the accumulation of dry matter of soybeans harvested at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	45	103	174	301	100
2,4-D	1/4	morning	36	90	143	261	87
2,4-D	1/4	noon	38	89	149	312	104
2,4-D	1/4	evening	36	83	143	285	95
2,4-D	1/2	morning	35	75	134	244	81
2,4-D	1/2	noon	35	76	122	252	84
2,4-D	1/2	evening	36	74	131	234	78

Table 11. Effect of 2,4-D at low and high rates, applied morning, noon and evening, on percent dry matter at harvest, weight of seeds and yields in bushels per acre of soybeans.

Treatment	Rate lbs/A	Time of application	% dry mat.* at harvest	Weight of 100 seeds	Yield bu./A	Yield % of check
			grams	grams		
Check	-	-	83.0	13.8	62.8	100
2,4-D	1/4	morning	83.6	13.4	47.9	76
2,4-D	1/4	noon	82.2	13.5	53.5	85
2,4-D	1/4	evening	84.9	13.1	48.4	77
2,4-D	1/2	morning	79.0	13.3	52.8	84
2,4-D	1/2	noon	76.1	14.4	49.2	78
2,4-D	1/2	evening	75.9	12.3	42.1	67

* Percent dry matter was determined on the basis of the moisture content of beans and pods.

Difference between means needed for significance when using R.E. (range of equality) at 5% level is 18.3 bushels per acre, and at 1% level is 24.0 bushels per acre.

Fig. 3 Lodging in Chippewa soybeans from morning application of 2,4-D at 1/4 pound per acre. Picture taken 95 days following treatment.

Fig. 4 Lodging in Chippewa soybeans from evening application of 2,4-D at 1/4 pound per acre. Picture taken 95 days following treatment.

Fig. 3 Lodging in Chippewa soybeans from morning application of 2,4-D at 1/4 pound per acre. Picture taken 95 days following treatment.

Fig. 4 Lodging in Chippewa soybeans from evening application of 2,4-D at 1/4 pound per acre. Picture taken 95 days following treatment.

NOV • 59

NOV • 59

resumed growth and went on to produce a crop. Pods at harvest time were larger than pods from plants sprayed with dalapon, but smaller than those from plants sprayed with 2,4-D or unsprayed plants.

Effect on dry matter accumulation:

All treatments drastically reduced dry matter due to defoliation. This reduction was directly proportional to the rate used. Evening applications were more injurious than morning treatments (Table 12).

Effect on yield of seed:

All treatments reduced yields very drastically and in proportion to the amount of the chemical used. Lowest yields resulted from plots sprayed at noon. Evening treatments resulted in yields slightly lower than morning treatments, (Table 13). Size of seed was reduced by all treatments. Podded seeds from noon applications were the most immature at harvest. At the lighter rate of application, the plants sprayed in the morning were more mature than plants sprayed at other times of the day (Figures 5 and 6).

2,2-Dichloroproprionic Acid

Injuries observed:

Action of dalapon on soybeans was slower than either 2,4-D or amitrol. Characteristic symptoms were stunting, and subsequent death of the apical buds. Leaves were rugose and showed chlorosis of the younger leaves. Later there was a profuse development of lateral stems, thus giving the plants a bushy appearance. Leaves developed a bronze color. Pods were smaller than pods of the other treatments.

Effect on dry matter accumulation:

All treatments reduced the dry matter as measured at 40 days after treatment (Table 14). The high rate caused greater reduction in dry matter

Table 12. Effect of amitrol at low and high rates, applied morning, noon and evening, on the accumulation of dry matter of soybeans at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	45	103	174	301	100
Amitrol	2	morning	18	31	47	109	36
Amitrol	2	noon	11	17	19	42	14
Amitrol	2	evening	13	17	25	66	22
Amitrol	4	morning	11	22	25	48	16
Amitrol	4	noon	13	19	15	20	7
Amitrol	4	evening	9	13	11	26	9

Table 13. Effect of amitrol at low and high rates, applied morning, noon and evening, on percent of dry matter at harvest, weight of seeds and yields in bushels per acre of soybeans.

Treatment	Rate lbs/A	Time of application	% dry mat. at harvest grams	Weight of 100 seeds grams	Yield bu./A	Yield % of check
Check	-	-	83.0	13.8	62.8	100
Amitrol	2	morning	56.3	12.6	40.2	64
Amitrol	2	noon	42.1	12.1	29.5	47
Amitrol	2	evening	43.1	12.2	38.4	61
Amitrol	4	morning	41.4	12.5	34.6	55
Amitrol	4	noon	37.7	12.4	19.0	30
Amitrol	4	evening	40.9	13.0	32.4	52

Difference between means needed for significance when using R.E. (range of equality) at 5% level is 18.3 bushels per acre, and at 1% level is 24.0 bushels per acre.

Table 14. Effect of dalapon at low and high rates, applied morning, noon and evening, on the accumulation of dry matter of soybeans at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	45	103	174	301	100
Dalapon	1	morning	44	100	146	252	84
Dalapon	1	noon	41	92	109	211	70
Dalapon	1	evening	39	99	138	221	73
Dalapon	2	morning	38	82	104	186	62
Dalapon	2	noon	38	80	107	181	60
Dalapon	2	evening	36	65	91	155	51

Table 15. Effect of dalapon at low and high rates, applied morning, noon and evening, on percent of dry matter at harvest, weight of seeds and yields in bushels per acre of soybeans.

Treatment	Rate lbs/A	Time of application	% Dry mat. at harvest	Weight of 100 seeds	Yield bu./A	Yield % of check
			grams	grams		
Check	-	-	83.0	13.8	62.8	100
Dalapon	1	morning	70.7	12.4	31.7	50
Dalapon	1	noon	61.4	11.7	31.1	50
Dalapon	1	evening	65.0	11.7	33.6	54
Dalapon	2	morning	47.7	11.7	29.2	46
Dalapon	2	noon	45.2	10.7	20.9	33
Dalapon	2	evening	54.0	11.3	24.6	39

Difference between means needed for significance when using R.E. (range of equality) at 5% level is 18.3 bushels per acre, and at 1% level is 24.0 bushels per acre.

Table 16. Effect of 2,4-D, amitrol and dalapon at low and high rates on dry matter 40 days after treatment and seed yield of soybeans, in percent of check as influenced by time of application.

Treatment	Morning				Noon				Evening			
	Low		High		Low		High		Low		High	
	dry mat.	yield	dry mat.	yield	dry mat.	yield	dry mat.	yield	dry mat.	yield	dry mat.	yield
2,4-D	87	76	81	84	104	85	84	78	95	77	78	67
Amitrol	36	64	16	55	14	47	7	30	22	61	9	52
Dalapon	84	50	62	46	70	50	60	33	73	54	51	39

Fig. 5 Effect of amitrol at 2 pounds per acre, applied in the morning, on the maturity of Chippewa soybeans. Picture taken 95 days following treatment.

Fig. 6 Effect of amitrol at 2 pounds per acre, applied in the evening, on the maturity of Chippewa soybeans. Picture taken 95 days following treatment.

Fig. 5 Effect of amitrol at 2 pounds per acre, applied in the morning, on the maturity of Chippewa soybeans. Picture taken 95 days following treatment.

Fig. 6 Effect of amitrol at 2 pounds per acre, applied in the evening, on the maturity of Chippewa soybeans. Picture taken 95 days following treatment.

than low rates and loss of dry matter was greater from evening than from morning spraying.

Effect on yield of seed:

Yields were reduced by all treatments (Table 15). At the higher rate of application, plots sprayed in the morning yielded more than plots sprayed in the evening. This is directly related to the amount of dry matter produced in the early stages of growth (Table 16). Size of seed was reduced by all treatments; greater reduction resulting from the higher rates. Seed harvested from plants sprayed in the morning were somewhat larger than seed from plants sprayed in the evening. In general, size of seed was related to yield. Treatments made at noon delayed maturity the most.

CORN

The section on material and methods shows the rates of application of the 3 herbicides. However, due to rain following soon after the morning applications, replications 1 and 2 were resprayed the next day. Further complications were differences in soil fertility and the use of amounts of dalapon greater than the tolerance level for growth. Therefore, no data was collected from the plots treated with dalapon. Other data were confined to dry matter accumulation at 10 day intervals, brace root injury caused by 2,4-D and general observations of injury caused by amitrol. Tables 17 and 18 show the accumulations of dry matter under the herbicide treatments.

The relative humidities were 77, 57 and 46 percent for morning, noon and evening applications respectively. Temperatures were 54, 73 and 66°F for morning, noon and evening treatments. Neither relative humidity nor temperature showed any correlation with growth.

Injuries observed:

The usual injuries caused by 2,4-D developed within a few days. These included stem curvatures, leaf rolling and later brace root malformations. In general, plots which received 2,4-D applications had small stems, narrower and shorter leaves than unsprayed plots. Respraying replications 1 and 2 led to no increased injury. There was practically no injury from morning applications of 2,4-D to replications 3 and 4. Brace root injury was severe for all rates and times of applications of 2,4-D. This injury was least from morning and most from evening treatments (Figure 7).

Amitrol injury developed as a chlorotic condition within a few days. Greater injury resulted from treatments made in the evening, (Figures 8 and 9). The plants outgrew this condition as in the case of oats. Tasseling was delayed and brace roots were smaller than the brace roots of unsprayed plots.

Effect on dry matter accumulation:

Dry matter was reduced by the application of 2,4-D, but the data were erratic, (Table 17). Data regarding dry matter produced by plants sprayed with amitrol were very erratic and could not be correlated with time or rate of application (Table 18).

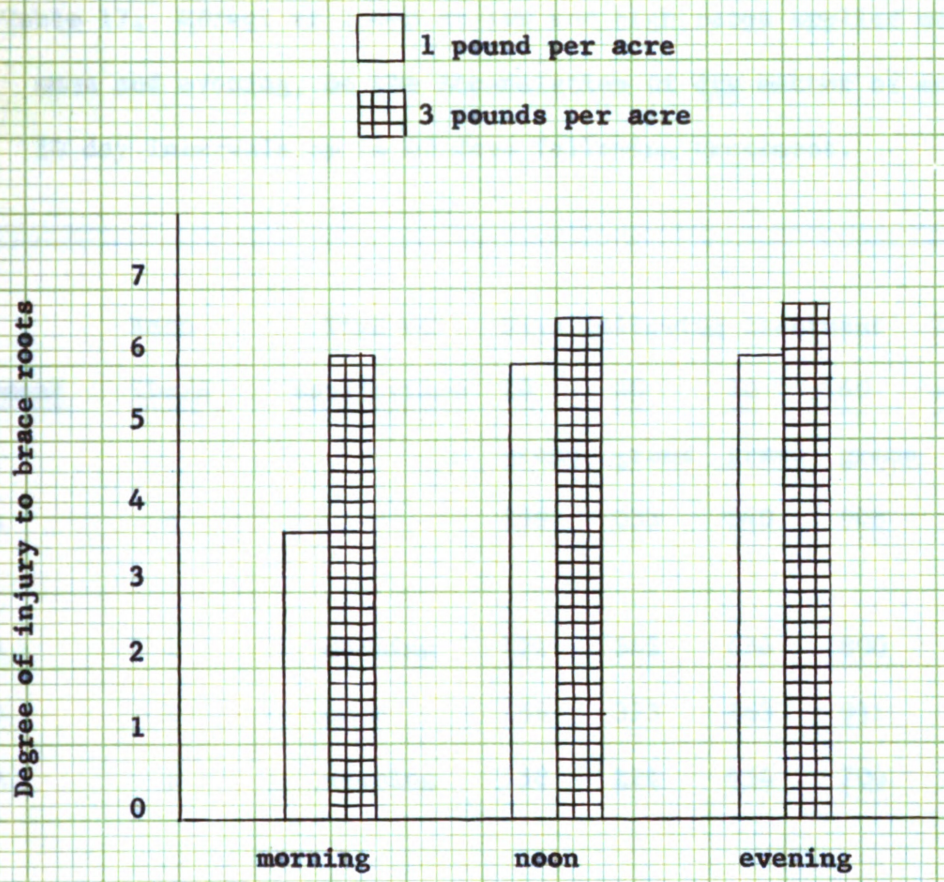


Fig. 7 Effect of 2,4-D at low and high rates, applied morning, noon and evening on the brace roots of corn. Evaluation made 86 days following treatment. Degree of injury rated from 1 to 10 in order of severity. Value given based on average of 25 consecutive plants in center rows of treated plots.

Table 17. Effect of 2,4-D at low and high rates applied morning, noon and evening, on the accumulation of dry matter of corn at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	158	333	840	908	100
2,4-D	1	morning	121	342	636	800	93
2,4-D	1	noon	156	313	863	931	103
2,4-D	1	evening	138	221	454	704	78
2,4-D	3	morning	151	296	613	863	95
2,4-D	3	noon	150	196	636	817	90
2,4-D	3	evening	139	300	613	863	95

Table 18. Effect of amitrol at low and high rates, applied morning, noon and evening, on the accumulation of dry matter of corn at 10 day intervals up to 40 days following treatment.

Treatment	Rate lbs/A	Time of application	Days following treatment 10	20	30	40	% of check at 40 days
			grams	grams	grams	grams	
Check	-	-	158	333	840	908	100
Amitrol	1	morning	181	390	908	1113	123
Amitrol	1	noon	175	255	613	936	103
Amitrol	1	evening	149	305	545	817	90
Amitrol	2	morning	111	216	523	704	78
Amitrol	2	noon	104	356	681	1044	115
Amitrol	2	evening	141	226	568	727	80

Fig. 8 Chlorosis in corn caused by morning application of amitrol at 1 pound per acre.

Fig. 9 Chlorosis in corn caused by evening application of amitrol at 1 pound per acre.

Fig. 8 Chlorosis in corn caused by morning application of amitrol at 1 pound per acre.

Fig. 9 Chlorosis in corn caused by evening application of amitrol at 1 pound per acre.


TRIAZOLE
1ª - 7 P.M.


TRIAZOLE
1ª - 6 A.M.

GENERAL OBSERVATIONS

2,4-D has been known to cause injury when applied to oats at the 2 and 3 leaf stage. Although these data indicate that 2,4-D actually stimulated the growth of oats, these rates would very likely have resulted in injury if spraying had been made earlier. Since stimulation of vegetative growth was greater when 2,4-D was applied in the evening, it seems reasonable to assume that injury also would have been greater from applications made at this time of day.

Amitrol when applied to soybeans at 2 and 4 pounds per acre, as in this experiment, resulted in too much injury, regardless of time of application. Rates of 1/2 and 1 pound per acre would have been more valuable in measuring the effect of time of application. On corn, rates of application of amitrol higher than those used in this experiment probably would be more satisfactory for measuring differences.

In the case of dalapon, rates used on soybeans and corn were too high. Rates of 1/2 and 1 pound per acre are suggested to show greater contrast in time of application.

SUMMARY

The effect of rates and times of application of 2,4-D, amitrol and dalapon on oats, soybeans and corn are summarized.

1. 2,4-D at 1 and 2 pounds per acre stimulated vegetative growth. Stimulation was greater from evening than from morning spraying.
2. Amitrol and dalapon reduced the length of panicles, number of panicles, number of kernels per panicle and yield. In general, evening treatments with amitrol were more injurious than morning treatments, while the reverse of this was true for dalapon. The effect of amitrol on yields could be predicted from injuries observed soon after spraying.
3. 2,4-D at 1/4 and 1/2 pounds per acre reduced the yields of soybeans. Evening treatments tended to be more injurious than morning treatments at the high rate of application as measured by maturity and yield.
4. Both amitrol and dalapon reduced yields of soybeans at rates used in this experiment. In general, evening treatments were more injurious. Both chemicals reduced size of seed.
5. 2,4-D applied to corn at 1 and 2 pounds per acre caused injury as shown by rolled leaves, crooked stalks and malformed brace roots. Evening applications were the most injurious.
6. Evening applications of amitrol on corn showed more visual injury than morning applications. However, plants outgrew the injury.

LITERATURE CITED

1. Aldrich, Richard J. Effect of 2,4-D on the growth and yield of oats grown under three levels of fertility. Agron. Jour. 50: 145 - 148. 1948.
2. Andersen, R.N. and Helgeson, E.A. Some effects of postemergence applications of dalapon to wild oats. Weed Jour. 4: 351 - 358. Oct. 1956.
3. Bakke, A.L. and Sylwester, E.P. As we fight weeds in 1948. Iowa Farm Sci. 2 (8) 7-8. 1948.
4. Bondarenko, D.D. and Willard, C.J. Amino triazole appears to give control of Canada Thistle. Ohio Farm and Home Research 42: (305) 1947.
5. Brown, D.A. Effect of 2,4-D on oats in 1952. (Abstract) Res. Rept. 9th. Ann. North Central Weed Control Conference. p. 74.
6. Buchholtz, K.P. Two years experience with 2,4-D in corn fields. Seed World 62: (3) 46. 1948.
7. Burrows, V.D. and Olson, P.J. Reaction of oats to 2,4-D butyl ester when applied at 20 different stages of growth (Abstract) Res. Rept. 9th. Ann. North Central Weed Control Conference. p. 74.
8. Danielson, L.L. and Schumacher, M.H. Experimental use of dalapon and natrin on certain transplanted vegetable crops. Proc. of 9th Ann. Northeastern Weed Control Conference 97 - 103. 1955.
9. Dearborn, C.H. Productivity of cultivated and uncultivated Golden Cross Bantam sweet corn weeded with post emergence sprays of 2,4-D. Proc. 3rd. Northeast States Weed Control Conference pp. 69 - 72.
10. Dearscheid, L.D., Straker, L.H. and Kratochvil, D.E. Differential responses of oat varieties to 2,4-D. Amer. Jour. Agro. 45: (1) 11 - 17. 1953.

11. Ellis, N.K. and Bullard, E.T. Varietal response of sweet corn to 2,4-D spray and the effect of different formulations of 2,4-D on yield. Proc. Amer. Soc. Hort. Sci. 51: 505 - 508.

12. Grigsby, B.H. and Churchill, B.C. Effects of 2,4-D on barley varieties. Michigan Agri. Exp. Sta. Quart. Bul. 30: (4) 448 - 451. 1948.

13. Hamner, C.L. and Tukey, H.B. Selective herbicidal action of midsummer and fall applications of 2,4-D. Bot. Gaz. 106: 232 - 245. 1944.

14. Hanson, J.R. and Freeman, J.F. Herbicidal tolerance of soybeans to post emergence sprays. (Abstract) Res. Rept. North Central Weed Control Conf. 8: 85 - 86. 1951.

15. Havis, J.R. and Sweet, R.D. The value of certain aromatic napthas and growth regulators as soil treatments for weed control in vegetables. Proc. Amer. Soc. Hort. Sci. 49: 325 - 331. 1947.

16. Hoffman, Otto L. Effect of various 2,4-D formulations on crop plants. Proc. 3rd. Ann. Meeting of the North Central Weed Control Conf. 95 - 97. 1946.

17. Kelly, Sally. The effect of temperature on the susceptibility of plants to 2,4-D. Plant Phy. 24: 534 - 536. 1949.

18. Linder, P.J., Brown, J.W. and Mitchell, J.W. Movements of externally applied phenoxy compounds in bean plants in relation to conditions favouring carbohydrates translocation. Bot. Gaz. 110: 628 - 632. 1948.

19. Marth, P.C. and Davis, F.F. Relation of temperature to the selective herbicidal effect of 2,4-D. Bot. Gaz. 106: 463 - 472. 1945.

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

21. Murray, Mary A. and Whiting, A.G. Effect of 2,4-D on root development in young corn plants.

22. Rice, Elroy L. Effect of various plant growth regulators on flowering in several crop plants. Bot. Gaz. 112: 207 - 213. 1951.

23. _____, Absorption and translocation of ammonium 2,4-D acetate by bean plants. Bot. Gaz. 109: 301-314. 1948.

24. Rodgers, E.J. Brittleness and response of corn to 2,4-D. Plant Phys. 27: (1) 153 - 172.

25. Rohrbaugh, L.M. and Rice, E.L. Effect of applications of sugar on the translocation of sodium 2,4-D by bean plants in the dark. Bot. Gaz. 111: 85 - 89. 1949.

26. Santelman, P.W. and Willard, C.J. The absorption and translocation of dalapon. Proc. 9th Ann. Northeastern Weed Control Conf. 21 - 29. 1955.

27. Shaw, W.C., Willard, C.J. and Bernard, R.L. The effect of 2,4-D on wheat, oats, barley. Ohio Agr. Exp. Sta. Res. Bul. 761. April 1955.

28. Slife, F.W. The effect of 2,4-D and several other herbicides on weeds and soybeans when applied as post emergence sprays. Weed Jour. 4: (1) 61 - 68. 1956.

29. Stahler, L.M. Tolerance of crop plants to spray solutions of 2,4-D and other selective herbicides. Proc. North Central Weed Control Conf. 2: 36 - 50. 1945.

30. Tam, R.K. Cooperative herbicidal value of 2,4-D and 2,4,5-trichlorophenoxyacetic acid on some herbaceous weeds, shrubs and trees under Hawaiian conditions. Bot. Gax. 109: 194 - 203. 1947.

31. Warren, G.F. and Hernandez, T.P. Weed control in certain vegetable crops with soil application of 2,4-D. Proc. Amer. Soc. Hort. Sci. 51: 515 - 525. 1948.

32. Waywell, C.G. The effect of herbicidal treatments on oats. Proc. 9th. Ann. Northeastern Weed Control Conf. 391 - 397. 1955.

33. Weaver, R.J. and Derose, H.R. Absorption and translocation of 2,4-D. Bot. Gaz. 107: 509 - 521. 1946.

34. Weaver, R.J., Swanson, C.P., Ennis, W.B. and Boyd, F.T. Effect of plant growth regulators in relation to stages of development of certain dicotyledonous plants. Bot. Gaz. 107: 563 - 568. 1946.

35. Wolfe, Dale E., Vermillion, Gertrude, Wallace, Arthur and Ahlgren, Gilbert H. Effect of 2,4-D on carbohydrate and nutrient element content and on rapidity of kill of soybean plants growing at different nitrogen levels. Bot. Gaz. 112: 186 - 197.