1960

A Study of Some Herbicides Applied Pre-emergence and the Influence of Rainfall Upon their Activity

Walter E. Splittstoesser

A STUDY OF SOME HERBICIDES APPLIED PRE-EMERGENCE AND THE INFLUENCE OF RAINFALL UPON THEIR ACTIVITY

BY

WALTER EMIL SPLITTSTOESSER

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Department of
Agronomy, South Dakota State
College of Agriculture
and Mechanic Arts

June, 1960

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

// Thesis Adviser

Head of the Major Department

ACKNOWLEDGEMENTS

The author wishes to acknowledge the guidance and encouragement of the Agronomy staff members; in particular, his adviser, Dr. Lyle Derscheid.

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INTRODUCTION

Weeds have been with man for countless years and it is evident that they will be with man for many more. As tillable land decreases and population increases, weeds will have to be controlled to insure the best land use.

Weeds are controlled by cultural, biological and chemical methods. Cultural practices are most widely used and generally the most practical. Biological control is useful only in specific areas. Chemical control of weeds was not a widely used method until the discovery of selective herbicides about 1900.

A group of chemicals now receiving much attention are the herbicides commonly called "pre-emergence chemicals." These chemicals are so named because of their time of application.

The possibility of controlling annual weeds by pre-emergence applications of herbicides on large acreages of corn without the aid of cultivation has stimulated a large amount of interest.

The objective of this study was to learn more about a relatively new group of herbicides used primarily as pre-emergence treatments in corn and how the control of annual weeds is influenced by the time and amount of rainfall that is received after the chemical is applied. These new chemicals are simazine[1] and atrazine[2].

It is hoped that these results will aid in developing more

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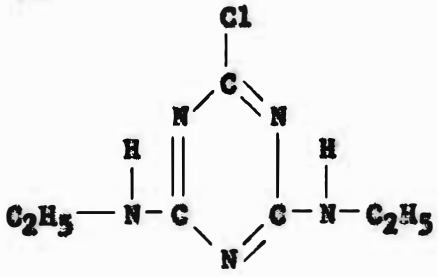
[1] 2-chloro-4,6-bis(ethylamino)-s-triazine.

[2] 2-chloro-4,6-bis(isopropylamino)-s-triazine.

practical uses for herbicides that are applied pre-emergence.

LITERATURE REVIEW

Simazine is 2-chloro-4,6-bis(ethylamino)-s-triazine and has the following structure (4):



This chemical was first released in 1956 (11). It is a white crystalline powder which is practically insoluble in water and only slightly soluble in certain organic solvents (13). The compound is comparatively nontoxic to humans (4).

Simazine was originally formulated as a 50 percent active ingredient wettable powder, but is now being formulated as an 80 percent active ingredient powder for spray applications. It is also formulated in pelleted form containing four percent active ingredient for granular applications. All rates of application are expressed in pounds of active ingredient of simazine per acre.

The exact amount of chemical needed to obtain satisfactory control of weeds has been influenced by the soil type. Fine textured soils have required more of the chemical than the coarse textured soils. Rogers (14) found that rates of four or eight pounds of simazine per acre were needed to obtain adequate control on muck soils. Bartley (3) reported that one pound per acre gave good control on sandy soils and eliminated 86 percent of the grassy weeds on clay loam soils. Other researchers (14, 15, 18) have also reported the need for rates up to

three and four pounds of simazine per acre on muck and clay soils to obtain the same amount of weed control as obtained with lower rates of one or one and one-half pounds per acre on sand and sandy loam soils.

Simazine remains in the soil for approximately six months when applied at the two-pound per acre rate (19). Schneider (18) reported that the residual action of simazine was probably not affected by soil microorganisms. The activity was reduced by absorption of the chemical by the soil colloids, leaching of the chemical from the root zone and various cultural practices.

Crop plants vary widely in their tolerance to simazine - corn appearing to be the most tolerant. Bartley (4) and Minarik (11) report that 16 pounds of simazine per acre gave no injury to corn. Fletchall (9), however, reports that corn yields from plots which received eight, four and two pounds of simazine per acre were 91, 95 and 106 bushels per acre, respectively, which indicated that higher rates injured the corn although no visible injury was evident. Anderson (1) cites data in agreement with Fletchall's. One pound of simazine per acre has injured oats, wheat, sorghum, soybeans and alfalfa (3, 4, 13).

On the other hand, some reports indicate that simazine has stimulated corn plants while also controlling weeds. Plants on treated plots were larger in size, greener in color and gave greater yields than those in weed-free untreated plots (3, 11).

At a two-pound per acre rate, no adverse effects were noticed upon the normal rotation crops which were planted one year later. At higher rates of application results were varied, depending upon the

rotation crop which was planted (19). Bayer (5) found no residual effect prior to or at the maturity of spring wheat or oats which were planted upon soil which received an application of four pounds per acre of simazine one year earlier. However, this author has observed severe injury to oats planted one year after an application of four pounds per acre of simazine. Rogers (16) found that four pounds per acre of simazine stunted soybeans planted one year later, while eight pounds per acre killed the soybeans.

Movement of simazine within the soil was very slight; therefore the chemical remains in the top one or two inches of soil where most weed seeds germinate (12).

Simazine did not penetrate the unbroken cuticle of leaves but was absorbed by roots (7, 18). Only a small portion of the chemical applied was absorbed but this was enough to obtain adequate control. Simazine gave a 50 percent inhibition of the Hill reaction at concentrations of 7×10^{-7} M while 2,4-D did not cause any significant inhibition at concentrations as high as 1×10^{-4} M (17).

Simazine labeled with radioactive carbon was absorbed in the same amounts by the roots of cucumbers, cotton, and corn, representatives of the very sensitive, medium and tolerant plants. However, the actual amount of simazine within corn and wheat plants varied greatly. Wheat plants contained 25 times as much herbicide as corn plants, indicating that corn metabolized the chemical. Corn produced radioactive carbon dioxide and the entire plant was radioactive indicating that the entire molecule was used (17).

Inhibition of the Hill reaction resulted in reduced carbohydrate formation and the typical death symptoms -- marginal chlorosis followed by necrosis which spread rapidly until death occurred (18).

At least one-half inch of rainfall in one shower was required to give satisfactory weed control. The exact amount of rainfall needed depended upon the rapidity of evaporation and the amount of soil moisture at the time of application (18). The rain leached the chemical into the soil where it was absorbed by young weed roots.

Freeman (10) found that two or four pounds of simazine per acre gave 100 percent control when heavy rains fell one week before the plots were sprayed at early post-emergence. When dry conditions prevailed for over a month after simazine was applied at two and three pounds per acre, less than 25 percent of the weeds were eliminated (8). Freakey (6) found that 0.41 inch of rain one week before treatment and 0.61 inch within the first week after treatment gave almost perfect control of weeds.

Derscheid (8) has reported results which indicate that not only the amount of weed control but also the rapidity of kill of weeds was associated with the time and amount of rainfall received after treatment. When 1.25 inches of rainfall fell the first week after simazine was applied at rates of two and four pounds per acre, respective weed elimination of 60 and 90 percent was obtained in two weeks. However, when only 0.06 inch of rainfall fell during the first two weeks after treatment, 1.5 inches fell the third week and 0.79 inch fell the fourth week after treatment, 90 and 95 percent, respectively, of the weeds were not

eliminated for over a month at both the two- and four-pound rates of simazine.

Atrazine is a trazine compound which is similar to simazine in crop tolerance and residual action. It is identical to simazine in structure except that an isopropylamino group is substituted for the ethylamino group on the number six carbon (2).

Atrazine is water soluble to 70 ppm, while simazine is water soluble to five ppm. This higher water solubility enables atrazine to move downward into the soil with less moisture than simazine and results in a shorter residual period (2). This shorter residual is an advantage when little moisture is received as less residual occurs the following year. The short residual is a disadvantage when much moisture is received, as weed control does not last the entire season.

MATERIALS AND METHODS

Greenhouse experiments were conducted during the winter of 1958-1959 using varying amounts of rainfall at several dates on flats treated with simazine or CDAA (2-chloro-N,N-diallylacetamide). Similar experiments were conducted in the field during the summer of 1959, and additional trials with simazine and atrazine were conducted in the greenhouse during the fall of 1959.

Greenhouse

During the winter of 1958-1959, three experiments were conducted. Four hundred green foxtail (Setaria viridis (Weigel) Hubb.) seeds, of which 46 percent were viable, were planted at a two-inch depth in four gallons of Vienna silt loam topsoil in each 20" x 14" x 4" flat. Simulated rainfall consisted of Brookings "tap" water being applied with a Sprayer Systems 8001E nozzle under 40 pounds of pressure. The nozzle was oscillated over three flats at one time applying an inch of rainfall to each flat in 44 minutes (32 oscillations). The apparatus used for applying the chemical and rainfall is shown in Figure 1.

In the first experiment during 1958-1959, five pounds active ingredient of 50 percent wettable powder of simazine were applied in 10 treatments of three replications of a randomized block. Preliminary experiments had indicated that a five-pound rate of simazine was the minimum effective rate under the existing experimental conditions.

Ten treatments were used in which nine were sprayed with simazine. The untreated flats and one treatment received one inch of

rainfall the day the flats were treated with simazine and one-fourth inch of rain semiweekly for four weeks. The remaining four pairs of treatments were divided into four treatments including incorporation and four without incorporation. One pair received one inch of rainfall one day before simazine was applied and one-fourth inch semiweekly for four weeks. The remaining three pairs received no rain before application of simazine. Each pair received one-fourth inch of rain semiweekly for four weeks except that one pair received one inch of rain seven days after simazine was applied, a second pair received the one inch 14 days after application, and the third pair received the same amount 21 days after application. In each case no rain was received for a week after the one-inch rain.

The chemical was incorporated into the soil by thoroughly mixing simazine into the top one inch of soil.

The number of living plants on each flat were counted at weekly intervals starting 15 days after application.

The second experiment was the same as the first experiment except that only one-half inch of rainfall was applied on the date that one inch was applied in the first experiment.

In the third experiment CDAA was applied at a five-pound rate instead of simazine. All other conditions were identical to the first experiment.

Greenhouse experiments were conducted after the field experiments were terminated the fall of 1959. Fifteen grams of foxtail seed were mixed with four gallons of soil for each 20" x 14" x 4" flat (25

Figure 1. A Greenhouse Experiment Showing the Simulated Rainfall Applicator in Operation

grams in eight gallons for 20" x 14" x 8" flats). The greenhouse sprayer was equipped with a Spraying Systems 8002E nozzle which applied one inch of rainfall in 22 minutes (16 oscillations).

The first greenhouse trial during 1959 was divided into three sections of five treatments of two replicates of a randomized block design. The first and third sections were similar to the first experiment during 1958-1959 and the second section was similar to the second experiment. Four pounds of active ingredient of 50 percent wettable powder of simazine were used in all three sections.

In the first section, five treatments were used in which four were sprayed with simazine. The untreated flats and one treatment received one inch of rainfall one day after the flats were treated with simazine and one-fourth inch of rain semiweekly for four weeks. The remaining three treatments received one-fourth inch of rain semiweekly for four weeks except that one treatment received one inch eight days after simazine was applied, a second treatment received the one inch 15 days after application and the third treatment received the same amount 22 days after application. In each case no rain was received for a week after the one inch rain.

Section two was similar to section one with the exception being that one-half inch of rainfall was applied at the same dates instead of one inch.

Section three was similar to section one, but the flats were four inches deeper (20" x 14" x 8").

In the second greenhouse trial during 1959, four pounds of active ingredient of simazine were applied in 10 treatments of three

replications of a randomized block design. Five of the treatments received one inch and five received one-half inch of rain seven days before simazine application. An untreated check was maintained in each rainfall level. Rainfall was received after application of simazine and was identical with the rainfall received in section one of the first 1959 experiment.

The third greenhouse trial in 1959 was divided into three sections of five treatments of two replicates of a randomized block. The first, second, and third sections were similar to the first, second, and first sections of the first 1959 experiment, respectively, except that the first section received two pounds of atrazine and the second and third sections received four pounds active ingredient of 50 percent wettable powder of atrazine per acre.

In each experiment the number of living plants was recorded at weekly intervals beginning one week after simazine or atrazine application.

Field

During the summer of 1959 four field experiments, called series, were conducted. The greenhouse rainfall applicator, as used in the greenhouse trials during the fall of 1959, was modified for applying simulated rainfall in the field. The apparatus used for applying the rainfall is shown in Figure 2.

The four series were laid out in a randomized block design and the chemical was applied on May 27, 1959. The experimental area was one mile northeast of Brookings on Vienna silt loam which had a severe

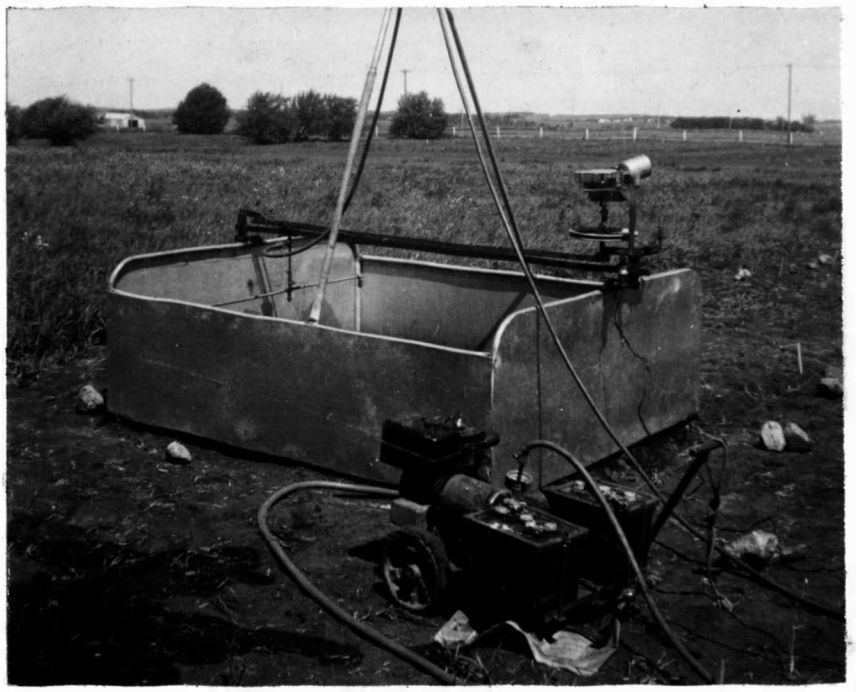


Figure 2. The Greenhouse Simulated Rainfall Applicator Modified for Field Use

The auxiliary unit in the foreground contained a gasoline engine powered water pump and a generator. The generator charged two batteries which powered a motor to oscillate the three-nozzle boom within the covered frame that prevented drift.

foxtail infestation. The plot size was five feet by six feet with four-foot alleys between replications. As stand counts of the foxtail plants were to be taken every week, a crop was not planted in the area. The experimental plot design of all series is shown in Figure 3.

The stand counts on all the field plots were made by counting all the living plants in three one-foot square areas. These counts were taken in the approximate center of each plot as Figure 4 illustrates.

To prevent natural rainfall from falling on the area, plots were covered during natural rains with a four mil polyethylene plastic sheet which was weighted down with rocks. Since plots were not covered except during natural rains, the recorded temperature under the plastic was very nearly the same as the air temperature and the effect of the covering was considered negligible. Figure 5 shows the covered field plots just after a rain.

The original four experiments were terminated at the end of 13 days as very few foxtail plants had emerged in either the treated or the untreated plots and the effect of rainfall during the first weeks could not be detected. The experiments were repeated on an area adjacent to the original using the same techniques for counting, plot design and natural rainfall prevention. However, the entire experimental area was seeded with 40 pounds of foxtail seed per acre. This insured seedlings during the first week after simazine application.

Series A was sprayed with two pounds per acre of simazine on June 23, 1959. Nine treatments were used in which eight were sprayed with simazine. The untreated plot received one-half inch of rainfall

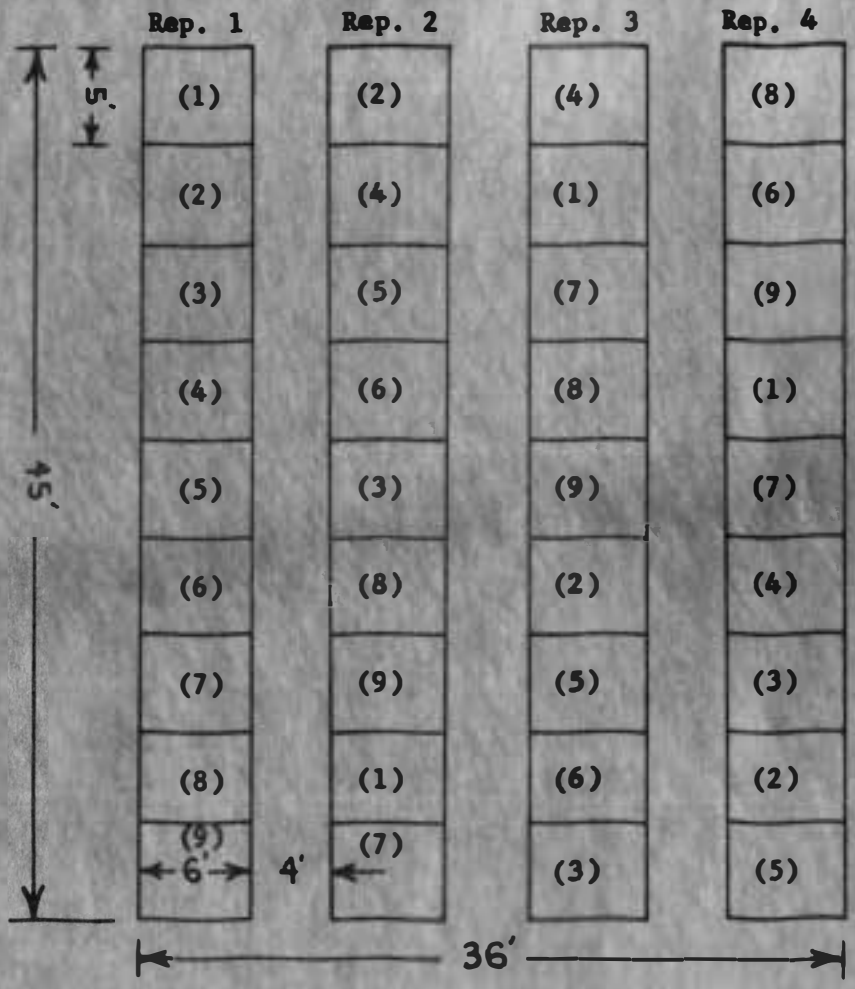


Figure 3. The Experimental Field Plot Design Using Nine Treatments Replicated Four Times

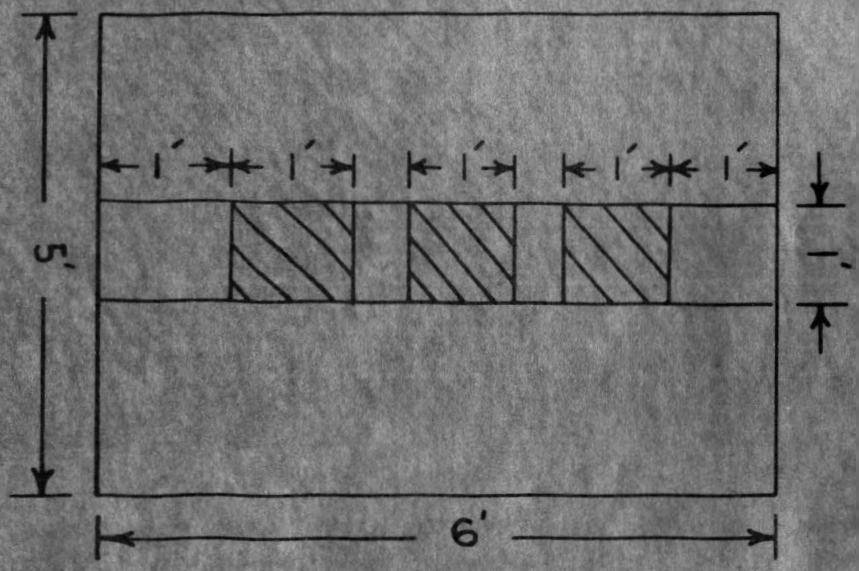


Figure 4. The Method Used for Taking Stand Counts on Field Plots with the Shaded Area Being Used for the Counts

Figure 5. Field Plots Covered with a Four-mil Polyethylene Plastic Sheet Just After a Rain

the day the other plots were treated with simazine and one-fourth inch of rain weekly for four weeks. The remaining four pairs of treatments were divided into four treatments including incorporation and four without incorporation. Each pair received one-fourth inch of rain semi-weekly for four weeks except that one pair received one-half inch of rain the day of application, a second pair received the one-half inch seven days after simazine application, a third pair received one-half inch 14 days after application, and the fourth pair received the same amount 21 days after application. In each case no rain was received for a week after the one-half inch rain.

The chemical was incorporated into the soil by disking twice with a five-foot disk operated at a depth of three to four inches.

Series B was similar to series A except that one inch of rainfall was applied, on the same rainfall dates, instead of one-half inch of rain.

Series C was similar to series A except that four pounds per acre of simazine were applied July 6 instead of two pounds per acre June 23.

Series D was similar to series B except that four pounds per acre of simazine were applied July 6 instead of two pounds per acre on June 23.

On August 17, after completion of the field results, samples of the top four one-inch layers of soil were taken from each plot of series D to study the depth of movement of simazine as indicated by damage to a susceptible crop.

The indicator plant used was Garry oats which gave 92 percent germination in germination tests. The various layers of soil were placed in separate paper cups. Twenty oats seeds were planted in each cup and were thinned to 10 plants per cup after 10 days. After 21 days the oats were harvested and the dry weight recorded for each cup.

RESULTS

Moisture influenced the effectiveness of pre-emergence applications of simazine and atrazine for foxtail control in greenhouse and field experiments. Death of the plants was the criterion used to determine amount of control. Where applicable, data were analyzed statistically by analysis of variance.

Greenhouse Experiments 1958-1959

The results of the first greenhouse trial which included the application of one inch of simulated rain at weekly intervals before and after treatment with five pounds per acre of simazine are given in Table I. The analysis of variance of foxtail stand counts taken 21 days after simazine application is given in Table II.

Sixty to 100 percent control of foxtail was achieved with all treatments. It was not directly established that mechanical incorporation of simazine had any influence on the stand of foxtail. However, when the chemical was not incorporated, flats receiving rainfall after simazine application contained significantly fewer weeds than those receiving rainfall before chemical treatment, and those receiving rainfall during the first 14 days after herbicide application contained significantly fewer weeds than those receiving rain 21 days after simazine treatment. When the chemical was incorporated, on the other hand, there appeared to be little effect on stand due to the date of rainfall.

The results of the second greenhouse trial which included the application of one-half inch of simulated rain at weekly intervals before

TABLE I. THE MEAN NUMBER OF FOXTAIL PLANTS ON PLATS TREATED WITH FIVE POUNDS PER ACRE OF SIMAZINE AND ONE INCH RAINFALL BEFORE AND AFTER SIMAZINE APPLICATION

Treatment no.	Pre-treatment[a] Rain[b] (Inches)	First week[a] Rain[b] (Inches)	Second week[a] Rain[b] (Inches)	Second week[a] Counts[c]	Third week[a] Rain[b] (Inches)	Third week[a] Counts[c]	Fourth week[a] Rain[b] (Inches)	Fourth week[a] Counts[c]
1[d]	0	1	1/4 & 1/4	179	1/4 & 1/4	178	1/4 & 1/4	176
2	0	1	1/4 & 1/4	24	1/4 & 1/4	16	1/4 & 1/4	12
3	1	1/4 & 1/4	1/4 & 1/4	156	1/4 & 1/4	97	1/4 & 1/4	74
4[e]	1	1/4 & 1/4	1/4 & 1/4	147	1/4 & 1/4	44	1/4 & 1/4	30
5	0	1/4 & 1/4	1	28	1/4 & 1/4	4	1/4 & 1/4	0
6[e]	0	1/4 & 1/4	1	50	1/4 & 1/4	10	1/4 & 1/4	0
7	0	1/4 & 1/4	1/4 & 1/4	163	1	67	1/4 & 1/4	4
8[e]	0	1/4 & 1/4	1/4 & 1/4	137	1	57	1/4 & 1/4	9
9	0	1/4 & 1/4	1/4 & 1/4	129	1/4 & 1/4	82	1	49
10[e]	0	1/4 & 1/4	1/4 & 1/4	108	1/4 & 1/4	31	1	19

a/ Rain pre-treatment received one day before simazine was applied; first week -- day of, and four days after application; second week -- 7 and 10 days after application; third week -- 14 and 17 days after application; fourth week -- 21 and 24 days after application.

b/ One inch rainfall applied first of two rainfall dates each week; 1/4 inch rainfall applied on each date.

c/ Means of three replications taken 7 days after 1 inch rain.

d/ Untreated.

e/ Incorporated.

TABLE II. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN TWENTY-ONE DAYS AFTER APPLICATION OF FIVE POUNDS PER ACRE OF SIMAZINE TREATED WITH ONE INCH OF RAIN AT WEEKLY INTERVALS

Source	df	MS
Replication	2	23
Treatments	9	8,801**
Incorporated and untreated vs. nonincorporated	1	10,427**
Incorporated, rain before vs. other incorporated	1	961
Incorporated, rain 2nd week vs. incorporated, rain 3rd and 4th week	1	392
Incorporated, rain 3rd week vs. incorporated, rain 4th week	1	171
Untreated vs. nonincorporated	1	54,859**
Nonincorporated, rain before vs. other nonincorporated	1	7,981**
Nonincorporated, rain 4th week vs. nonincorporated, rain 1st, 2nd and 3rd week	1	4,181**
Nonincorporated rain, 1st and 2nd week vs. nonincorporated rain, 3rd week	1	7
Nonincorporated rain 1st week vs. nonincorporated rain, 2nd week	1	228
Error	18	441

**Significant at 1% level.

and after treatment with five pounds per acre of simazine, are given in Table III. The analysis of variance of the foxtail stand count taken 21 days after application is given in Table IV.

All treatments achieved 20 to 80 percent control of foxtail. When the chemical was not incorporated, flats receiving rainfall before or on the date of simazine application contained significantly more weeds than other nonincorporated treatments. No other significant difference in stand was found among the treatments.

The third greenhouse trial used CDAA in place of simazine. This chemical has a high vapor pressure and volatilized readily throughout the entire greenhouse area. All plants, regardless of treatment, were subsequently killed at emergence due to these vapors.

Field Experiments 1959

Series A received two pounds of simazine per acre and the one-half inch rainfall level at weekly intervals. The results of this series are given in Table V. The analysis of variance of the foxtail stand count taken 28 days after chemical application is given in Table VI.

A significant F value was obtained for treatments, but no significant difference in stand was found between the untreated and the mean of treated plots. The incorporated plots contained a significantly higher number of plants than the plots which were not incorporated. No significant difference among nonincorporated treatments was found, but the incorporated treatment receiving rain the first week contained

TABLE III. THE MEAN NUMBER OF FOXTAIL PLANTS ON FLATS TREATED WITH FIVE POUNDS PER ACRE OF SIMAZINE AND ONE-HALF INCH RAINFALL BEFORE AND AFTER SIMAZINE APPLICATION

Treatment no.	Pre-treatment[a] Rain[b] (Inches)	First week[a] Rain[b] (Inches)	Second week[a] Rain[b] (Inches)	Second week[a] Counts[c]	Third week[a] Rain[b] (Inches)	Third week[a] Counts[c]	Fourth week[a] Rain[b] (Inches)	Fourth week[a] Counts[c]
1[d]	0	1/2	1/4 & 1/4	268	1/4 & 1/4	268	1/4 & 1/4	268
2	0	1/2	1/4 & 1/4	204	1/4 & 1/4	180	1/4 & 1/4	179
3	1	1/4 & 1/4	1/4 & 1/4	173	1/4 & 1/4	139	1/4 & 1/4	135
4[e]	1	1/4 & 1/4	1/4 & 1/4	124	1/4 & 1/4	98	1/4 & 1/4	74
5	0	1/4 & 1/4	1/2	182	1/4 & 1/4	97	1/4 & 1/4	94
6[e]	0	1/4 & 1/4	1/2	156	1/4 & 1/4	82	1/4 & 1/4	75
7	0	1/4 & 1/4	1/4 & 1/4	253	1/2	163	1/4 & 1/4	95
8[e]	0	1/4 & 1/4	1/4 & 1/4	195	1/2	105	1/4 & 1/4	58
9	0	1/4 & 1/4	1/4 & 1/4	151	1/4 & 1/4	85	1/2	51
10[e]	0	1/4 & 1/4	1/4 & 1/4	186	1/4 & 1/4	130	1/2	95

a/ Rain pre-treatment received one day before simazine was applied; first week -- day of and 4 days after application; second week -- 7 and 10 days after application; third week -- 14 and 17 days after application; fourth week -- 21 and 24 days after.

b/ One-half inch of rainfall applied first of two rainfall dates each week; 1/4 inch rainfall applied at each date.

c/ Means of three replicates taken 7 days after 1/2 inch rain.

d/ Untreated.

e/ Incorporated.

TABLE IV. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN TWENTY-ONE DAYS AFTER APPLICATION OF FIVE POUNDS PER ACRE OF SIMAZINE TREATED WITH ONE-HALF INCH OF RAIN AT WEEKLY INTERVALS

Source	df	MS
Replication	2	6,276
Treatments	9	59,857**
Untreated + nonincorporated vs. incorporated	1	28,075**
Incorporated, rain before vs. other incorporated	1	7
Incorporated, rain 2nd and 3rd week vs. incorporated rain 4th week	1	1,549
Incorporated, rain 2nd week vs. incorporated rain 3rd week	1	434
Untreated vs. nonincorporated	1	61,048**
Nonincorporated, rain before and 1st week vs. other nonincorporated	1	22,427*
Nonincorporated, rain 1st week vs. nonincorporated rain before	1	2,360
Nonincorporated, rain 2nd week vs. nonincorporated rain 3rd and 4th week	1	910
Nonincorporated, rain 3rd week vs. nonincorporated rain 4th week	1	2,904
Error	18	3,172

* Significant at 5% level.

**Significant at 1% level.

TABLE V. THE MEAN NUMBER OF FOXTAIL PLANTS ON SERIES A, AFTER TREATMENT WITH TWO POUNDS PER ACRE OF SIMAZINE AND ONE-HALF INCH OF RAINFALL

Treatment no.	First week[a]		Second week[a]		Third week[a]		Fourth week[a]	
	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]
1[d]	1/2	213	1/4	215	1/2	273	0	370
2	1/2	140	1/4	129	1/2	134	0	180
3[e]	1/2	180	1/4	212	1/2	246	0	344
4	1/4	23	1/2	61	1/2	101	0	159
5[e]	1/4	34	1/2	313	1/2	364	0	465
6	1/4	53	1/4	97	1/2	132	0	232
7[e]	1/4	9	1/4	97	1/2	336	0	400
8	1/4	61	1/4	59	1/2	138	1/2	243
9[e]	1/4	19	1/4	138	1/2	392	1/2	441

a/ Rainfall first week applied day of and 3 days after treatment; second week -- 7 and 10 days after treatment; third week -- 14 and 16 days after treatment; fourth week -- 21 days after treatment.

b/ One-half inch rainfall applied first of two rainfall dates each week; all plots received one-half inch rain 14 days after; 1/4 inch rainfall applied second of two rainfall dates.

c/ Means of 4 replicates taken 7 days after 1/2 inch rain.

d/ Untreated.

e/ Incorporated.

TABLE VI. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN TWENTY-EIGHT DAYS AFTER APPLICATION OF TWO POUNDS PER ACRE OF SIMAZINE AND ONE-HALF INCH OF RAIN AT WEEKLY INTERVALS

Source	df	MS
Replication	2	8,543*
Treatments	8	18,611**
Untreated vs. all others	1	3,085
Incorporated vs. nonincorporated	1	114,561**
Nonincorporated, rain 1st and 2nd week vs. nonincorporated rain 3rd and 4th week	1	5,160
Nonincorporated, rain 3rd week vs. nonincorporated rain 4th week	1	512
Nonincorporated, rain 1st week vs. nonincorporated rain 2nd week	1	10
Incorporated, rain 1st and 2nd week vs. incorporated rain 3rd and 4th week	1	14
Incorporated, rain 3rd week vs. incorporated rain 4th week	1	4,672
Incorporated, rain 1st week vs. incorporated rain 2nd week	1	20,876**
Error	16	1,330
Sampling error	54	2,250

* Significant at 5% level.

** Significant at 1% level.

significantly more plants than the incorporated treatment receiving rain seven days later. However, this treatment contained only seven percent less plants than the check, indicating that none of the treatments were satisfactory. Figure 6 shows this lack of control as seen 60 days after simazine application.

The results of series B which received two pounds per acre of simazine and one inch of rain at weekly intervals, are given in Table VII. The analysis of variance of the foxtail stand count taken 28 days after chemical treatment is given in Table VIII.

Significance for treatments were obtained although no significant difference in stand was found between the untreated and the mean of the treated. Series B, like series A, had a significantly greater stand on the incorporated than the nonincorporated plots. However, none of the treatments gave satisfactory control. Only two treatments gave over 50 percent control of foxtail. The chemical was not incorporated in either of these two treatments. The better of these received one inch of rainfall 14 days after application and gave 70 percent control. The other treatment received one-half inch of rainfall 14 days and one inch 16 days after application, and gave 63 percent control. As shown in Figure 6, no difference was noticeable among treated or between treated and the untreated plots 60 days after application.

Series C was devised in the event that insufficient chemical was applied on series A to obtain adequate control. The results of this experiment which received four pounds per acre of simazine and one-half inch of rain at weekly intervals, are given in Table IX. The analysis

Figure 6. Field Plots Fifty or Sixty Days After Application of Two or Four Pounds per Acre of Simazine When One-half or One Inch of Rainfall was Applied at Various Time Intervals

TABLE VII. THE MEAN NUMBER OF FOXTAIL PLANTS ON SERIES B AFTER TREATMENT WITH TWO POUNDS PER ACRE OF SIMAZINE AND ONE INCH OF RAINFALL

Treatment no.	First week[a] Rain[b] (Inches)	First week[a] Counts[c]	Second week[a] Rain[b] (Inches)	Second week[a] Counts[c]	Third week[a] Rain[b] (Inches)	Third week[a] Counts[c]	Fourth week[a] Rain[b] (Inches)	Fourth week[a] Counts[c]
1[d]	1	222	1/4	521	1/2	384	1/4	459
2	1	179	1/4	142	1/2	146	1/4	310
3[e]	1	391	1/4	357	1/2	403	1/4	614
4	1/4	34	1	129	1/2	130	1/4	223
5[e]	1/4	0	1	473	1/2	482	1/4	640
6	1/4	25	1/4	37	1	109	1/4	139
7[e]	1/4	1	1/4	163	1	477	1/4	482
8	1/4	20	1/4	54	1/2	111	1	170
9[e]	1/4	0	1/4	122	1/2	424	1	517

a/ Rainfall first week applied day of and three days after treatment; second week -- 7 and 10 days after treatment; third week -- 14 and 16 days after treatment; fourth week -- 21 days after treatment.

b/ One inch rainfall applied first of two rainfall dates each week with all treatments receiving one-half inch rain 14 days after; 1/4 inch rainfall applied second of two rainfall dates.

c/ Means of 4 replicates taken 7 days after 1 inch rain.

d/ Untreated.

e/ Incorporated.

TABLE VIII. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN TWENTY-EIGHT DAYS AFTER APPLICATION OF TWO POUNDS PER ACRE OF SIMAZINE AND ONE INCH OF RAIN AT WEEKLY INTERVALS

Source	df	MS
Replication	3	2,157
Treatments	8	47,857**
Untreated vs. all others	1	6,054
Nonincorporated vs. incorporated	1	331,938**
Nonincorporated, rain 1st and 2nd week vs. nonincorporated 3rd and 4th week	1	16,650
Nonincorporated, rain 3rd week vs. nonincorporated rain 4th week	1	640
Nonincorporated, rain 1st week vs. nonincorporated rain 2nd week	1	5,040
Incorporated, rain 1st and 2nd week vs. incorporated rain 3rd and 4th week	1	21,294*
Incorporated, rain 1st week vs. incorporated rain 2nd week	1	459
Incorporated, rain 3rd week vs. incorporated rain 4th week	1	778
Error	24	4,442
Sampling error	72	2,240

* Significant at 5% level.

**Significant at 1% level.

TABLE IX. THE MEAN NUMBER OF FOXTAIL PLANTS ON SERIES C AFTER TREATMENT WITH FOUR POUNDS PER ACRE OF SIMAZINE AND ONE-HALF INCH OF RAINFALL

Treatment no.	First week[a]		Second week[a]		Third week[a]		Fourth week[a]	
	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]
1[d]	1/2	390	1/4	483	1/4	429	1/4	392
2	1/2	337	1/4	371	1/4	347	1/4	379
3[e]	1/2	172	1/4	123	1/4	93	1/4	151
4	1/4	179	1/2	183	1/4	209	1/4	216
5[e]	1/4	118	1/2	171	1/4	132	1/4	159
6	1/4	129	1/4	115	1/2	231	1/4	266
7[e]	1/4	140	1/4	156	1/2	169	1/4	192
8	1/4	167	1/4	185	1/4	185	1/2	323
9[e]	1/4	90	1/4	60	1/4	92	1/2	111

a/ Rainfall first week applied day of and three days after treatment; second week -- 7 and 10 days after treatment; third week -- 14 and 16 days after treatment; fourth week -- 21 days after treatment.

b/ One-half inch rainfall applied first of two rainfall dates each week; 1/4 inch rainfall applied second of two rainfall dates.

c/ Means of 4 replicates taken 7 days after 1/2 inch rain.

d/ Untreated.

e/ Incorporated.

of variance of foxtail stand counts taken 28 days after simazine application is given in Table X.

The untreated plot contained significantly more plants than the treated plots. Plots in which the chemical was incorporated contained significantly fewer plants per plot than the nonincorporated plots. The nonincorporated treatment receiving rainfall the first week resulted in a significantly larger stand count than the nonincorporated treatment receiving rain seven days later. No other significant differences in stand were found on series C.

Throughout the entire counting period, the incorporated treatments gave better control than the nonincorporated treatments, but these treatments gave a significantly lower count than the check. Although the amount of foxtail control was significant, the nonincorporated treatments gave less than 51 percent control. All incorporated treatments gave more than 50 percent control at the end of 28 days with their average control being 69 percent. However, there was little control noticeable 50 days after application, as Figure 6 illustrates.

Series D received twice as much chemical as series A and B and received twice as much rainfall as series A and C. This series received four pounds per acre of simazine and one inch of rain at weekly intervals and should therefore give the best control. The results of this series are given in Table XI. The analysis of variance of the foxtail stand counts taken 28 days after simazine application are given in Table XII.

All plots which were incorporated contained fewer weeds than the

TABLE X. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN TWENTY-EIGHT DAYS AFTER APPLICATION OF FOUR POUNDS PER ACRE OF SIMAZINE AND ONE-HALF INCH OF RAIN AT WEEKLY INTERVALS

Source	df	MS
Replication	3	3,019
Treatments	8	17,370**
Untreated vs. all others	1	55,126**
Incorporated vs. nonincorporated	1	59,350**
Nonincorporated, rain 1st and 2nd week vs. nonincorporated rain 3rd and 4th week	1	2
Nonincorporated, rain 3rd week vs. nonincorporated rain 4th week	1	2,128
Nonincorporated, rain 1st week vs. nonincorporated rain 2nd week	1	17,441**
Incorporated, rain 1st and 2nd week vs. incorporated rain 3rd and 4th week	1	140
Incorporated, rain 1st week vs. incorporated rain 2nd week	1	425
Incorporated, rain 3rd week vs. incorporated rain 4th week	1	4,347
Error	24	1,937
Sampling error	72	736

**Significant at 1% level.

TABLE XI. THE MEAN NUMBER OF FOXTAIL PLANTS ON SERIES D AFTER APPLICATION OF FOUR POUNDS PER ACRE OF SIMAZINE AND ONE INCH OF RAINFALL

Treatment no.	First week[a]		Second week[a]		Third week[a]		Fourth week[a]	
	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]
1[d]	1	582	1/4	504	1/4	524	1/4	585
2	1	592	1/4	400	1/4	382	1/4	378
3[e]	1	252	1/4	206	1/4	176	1/4	199
4	1/4	523	1	447	1/4	328	1/4	343
5[e]	1/4	311	1	254	1/4	186	1/4	187
6	1/4	390	1/4	528	1	504	1/4	540
7[e]	1/4	385	1/4	350	1	335	1/4	356
8	1/4	411	1/4	428	1/4	397	1	494
9[e]	1/4	293	1/4	265	1/4	239	1	327

a/ Rainfall first week applied day of and three days after treatment; second week -- 7 and 10 days after treatment; third week -- 14 and 16 days after treatment; fourth week -- 21 days after treatment.

b/ One inch rainfall applied first of two rainfall dates each week; 1/4 inch rainfall applied second of each rainfall date.

c/ Means of 4 replicates taken 7 days after 1 inch rain.

d/ Untreated.

e/ Incorporated.

nonincorporated and the untreated plots. However, both the nonincorporated and incorporated treatments which received one inch of rain either the day of chemical treatment or seven days later, gave better control than the similar treatments which received one inch of rain either 14 or 21 days after simazine application. All nonincorporated treatments gave no significant difference in stand from the untreated plots.

The best control, 67 and 69 percent, was achieved by the incorporated treatments which received one inch of rain the day of chemical application, or seven days later. At the end of 50 days, however, this amount of control was unnoticeable as Figure 6 illustrates.

In a fifth experiment CDAA was applied pre-emergence instead of simazine. Four pounds per acre of CDAA were applied to the experimental area May 27. Various rates of rainfall and dates of application were planned for this experiment, but the plots were not covered that evening and by morning, 0.89 inch of natural rainfall had fallen on the entire area. Only one stand count was taken which was 12 days after application. This count indicated that over 90 percent of the foxtail plants were killed in the area in which the chemical was not incorporated into the soil, but less than nine percent were killed on the area in which the chemical was incorporated into the soil. The average stand counts of the untreated, incorporated and nonincorporated treatments are given in Table XIII.

The control of grassy weeds in the nonincorporated area of

experiment five was noted throughout the entire growing season. However, CDAA did not control the other weeds on these plots and by harvest the plots had an abundance of mustard, Russian thistle and kochia growing on them. The incorporated plots contained a dense growth of foxtail plants which probably prevented all other plants from growing. Figure 7 shows the contrast between the incorporated area with only foxtail plants and the nonincorporated area with few foxtail plants but an abundance of other weeds. This contrast between the incorporated and nonincorporated plots was also noted on simazine experiments which were abandoned due to insufficient weed emergence 12 days after chemical treatment. No stand counts were taken, but Figure 8 illustrates the same trend as was observed in the CDAA experiment.

After five inches of rainfall had fallen, samples of the top four one-inch layers of soil were removed from all plots of one replicate of series D. The dry weight of oats grown on these layers in the greenhouse are given in Table XIV. The oats grown on the upper two one-inch layers of simazine treated soil died, but that grown on the lower two one-inch layers gave approximately the same yield as the untreated. This indicated that the five inches of rainfall which had fallen had not moved the chemical below a two-inch depth.

Greenhouse Experiments 1959

The objectives of the 1959 experiments were to expand upon the 1958-1959 greenhouse results using conditions similar to field

Figure 7. Weed Stands on Plots Ninety-five Days After CDAA Application with Mechanical Incorporation (center) and No Incorporation (left and right)

Figure 8. Weed Stands on Plots Ninety-five Days After Simazine Application with Mechanical Incorporation (center) and No Incorporation (left and right)

TABLE XIII. THE MEAN NUMBER OF FOXTAIL PLANTS IN PLOTS OF UNTREATED, INCORPORATED AND NONINCORPORATED TREATMENTS TAKEN TWELVE DAYS AFTER 0.89 INCH OF RAINFALL HAD FALLEN ON THE AREA WHICH WAS TREATED WITH FOUR POUNDS PER ACRE OF CDAA JUST BEFORE THE RAIN

Treatment	Stand counts[a/]
Untreated	2,424 plants
Incorporated into soil	2,212 plants
Nonincorporated into soil	106 plants

a/ Foxtail plants per three square feet.

TABLE XIV. THE GRAM WEIGHT OF TEN GARRY OATS PLANTS WHICH WERE GROWN ON FOUR ONE-INCH LAYERS OF SOIL WHICH WAS TREATED WITH FOUR POUNDS PER ACRE OF SIMAZINE FORTY DAYS EARLIER

Treatment	Depth of Sample in inches	Replicate 1	Replicate 2
No simazine	0-1	0.197	0.198
No simazine	1-2	0.206	0.205
No simazine	2-3	0.200	0.200
No simazine	3-4	0.236	0.235
Treated soil	0-1	0.018[a/]	0.026[a/]
Treated soil	1-2	0.056[a/]	0.059[a/]
Treated soil	2-3	0.237	0.238
Treated soil	3-4	0.241	0.242

a/ All 10 plants were dead by harvest.

conditions and to gain some preliminary information about atrazine.

The results of the first experiment which received four pounds per acre of simazine and one or one-half inch of rain at weekly intervals, are given in Table XV. The analysis of variance of foxtail stand counts taken 29 days after application of simazine are given in Table XVI.

When one-half inch of rain was received, no significant difference in stand from the untreated occurred. However, one replicate of the treatment receiving one-half inch of rain one day after application gave 94 percent control. These treatments were less effective than those which included one inch of rain.

One inch of rainfall 1, 8, or 15 days after treatment with simazine gave excellent control of foxtail. However, rain one or eight days after treatment gave better control than that received 15 days after application. The flats receiving rainfall 15 days after application required a longer time interval to give control than the flats receiving rain 7 or 14 days earlier. The foxtail plants growing in flats four inches deep which received one inch of rainfall 21 days after simazine treatment were not injured.

All treatments on eight-inch deep flats achieved 80 to 100 percent control. However, flats that received one inch of rain 1, 8, or 15 days after simazine treatment contained significantly fewer weeds than those which received the same amount 21 days after treatment. The treatments on these eight-inch deep flats were, in general, more effective than the same treatments on the four-inch deep flats.

TABLE XV. THE MEAN NUMBER OF FOXTAIL PLANTS ON PLATS TREATED WITH FOUR POUNDS PER ACRE OF [illegible] AND VARIOUS RAINFALL TREATMENTS AFTER APPLICATION

Treatment no.	First week[a]		Second week[a]		Third week[a]		Fourth week[a]	
	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]	Rain[b] (Inches)	Counts[c]
1[d]	1	1,102	1/4 & 1/4	1,340	1/4 & 1/4	1,268	1/4 & 1/4	1,266
2	1	746	1/4 & 1/4	19	1/4 & 1/4	10	1/4 & 1/4	20
3	1/4 & 1/4	1,210	1	1,270	1/4 & 1/4	27	1/4 & 1/4	31
4	1/4 & 1/4	1,504	1/4 & 1/4	1,286	1	818	1/4 & 1/4	290
5	1/4 & 1/4	1,330	1/4 & 1/4	1,079	1/4 & 1/4	1,014	1	1,094
6[d]	1/2	1,383	1/4 & 1/4	1,255	1/4 & 1/4	1,206	1/4 & 1/4	1,253
7	1/2	1,647	1/4 & 1/4	767	1/4 & 1/4	679	1/4 & 1/4	680
8	1/4 & 1/4	1,437	1/2	1,322	1/4 & 1/4	1,221	1/4 & 1/4	1,210
9	1/4 & 1/4	1,802	1/4 & 1/4	1,262	1/2	1,261	1/4 & 1/4	1,210
10	1/4 & 1/4	1,387	1/4 & 1/4	1,290	1/4 & 1/4	1,275	1/2	1,224
11[e]	1	1,802	1/4 & 1/4	1,391	1/4 & 1/4	1,350	1/4 & 1/4	1,337
12[e]	1	571	1/4 & 1/4	2	1/4 & 1/4	7	1/4 & 1/4	2
13[e]	1/4 & 1/4	1,300	1	780	1/4 & 1/4	54	1/4 & 1/4	48
14[e]	1/4 & 1/4	1,736	1/4 & 1/4	137	1	70	1/4 & 1/4	59
15[e]	1/4 & 1/4	1,614	1/4 & 1/4	841	1/4 & 1/4	470	1	257

a/ Rainfall first week applied 1 and 5 days after treatment; second week -- 8 and 13 days after treatment; third week -- 15 and 19 days after treatment; fourth week -- 22 and 24 days after treatment.

b/ One inch or 1/2 inch rainfall applied first of two rainfall dates each week; 1/4 inch rainfall applied at each date.

c/ Means of 2 replicates taken 7 days after 1 or 1/2 inch rain.

d/ Untreated.

e/ Flats 8 inches deep.

TABLE XVI. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN TWENTY-NINE DAYS AFTER APPLICATION OF FOUR POUNDS PER ACRE OF SIMAZINE ON FOUR- AND EIGHT-INCH DEEP FLATS WHICH RECEIVED VARIOUS RAINFALL TREATMENTS

Analysis for four-inch deep flats receiving one inch of rainfall at seven-day intervals

Source	df	MS
Replication	1	14,213
Treatments	4	712,602**
Untreated vs. all others	1	1,316,238**
Rain 4th week vs. rain 1st, 2nd, and 3rd week	1	1,440,600**
Rain 3rd week vs. rain 1st and 2nd week	1	93,457**
Rain 1st week vs. rain 2nd week	1	110
Error	4	2,901

Analysis for four-inch deep flats receiving one-half inch of rainfall at seven-day intervals

Source	df	MS
Replication	1	85,748
Treatments	4	119,605
Error	4	199,609

Analysis for eight-inch deep flats receiving one inch of rainfall at seven-day intervals

Source	df	MS
Replication	1	1,255
Treatments	4	639,514**
Untreated vs. all others	1	2,481,534**
Rain 4th week vs. rain 1st, 2nd and 3rd week	1	72,930*
Rain 3rd week vs. rain 1st and 2nd week	1	1,519
Rain 1st week vs. rain 2nd week	1	2,070
Error	4	6,567

* Significant at 5% level.

**Significant at 1% level.

The results of the second greenhouse trial in which rainfall was applied before simazine application are given in Table XVII. They indicate that all treatments killed 100 percent of the weeds regardless of the amount of rain received after chemical treatment. Figure 9 shows these flats 10 days after treatment.

The flats receiving only one-half inch of rainfall seven days before simazine application showed no control of foxtail plants. This amount of rainfall did, however, stunt the foxtail plants for a short while. A second one-half inch of rainfall seven days after chemical treatment actually reduced the stand. Figure 10 shows the stunted plants at 10 days after simazine treatment. By 20 days after simazine treatment, these stunted plants had fully recovered and were the same size as the check.

In the third greenhouse trial during 1959, flats received two or four pounds per acre of atrazine and one or one-half inch of rain at weekly intervals. The results of this investigation are given in Table XVIII. The analysis of variance of the foxtail counts taken 35 days after application for two pounds per acre of atrazine and one inch of rain is given in Table XIX, four pounds and one inch in Table XX, and four pounds and one-half inch in Table XXI.

The final count showed that all the flats receiving two pounds per acre of atrazine and one inch of rain contained fewer foxtail plants than the untreated flats. The flats which received rainfall one or eight days after atrazine application had an equal number of weeds, but the number was significantly lower than that of flats which received rainfall 15 or 22 days after application. The treatment which did not

TABLE XVII. THE MEAN NUMBER OF FOXTAIL PLANTS ON FLATS AFTER APPLICATION OF FOUR POUNDS PER ACRE OF SIMAZINE WHEN RAINFALL WAS RECEIVED BEFORE AND AFTER APPLICATION

Treatment no.	Week before[a]	First week[a]		Second week[a]		Third week[a]
	Rain[c] (Inches)	Rain[c] (Inches)	Counts[d]	Rain[c] (Inches)	Counts[d]	Counts[d]
1[e]	1	1	1,425	1/4	1,283	1,283
2	1	1	374	1/4	55	0
3	1	1/4	713	1	30	0
4	1	1/4	465	1/4	56	0
5	1	1/4	496	1/4	43	0
6[e]	1/2	1/2	1,368	1/4	1,169	1,169
7	1/2	1/2	1,879	1/4	205	205
8	1/2	1/4	1,181	1/2	1,244	1,244
9	1/2	1/4	1,317	1/4	1,518	1,518
10	1/2	1/4	1,259	1/4	1,344	1,344

a/ Pre-treatment rainfall applied 7 days before treatment; first week -- 1 and 4 days after treatment; second week -- 8 and 13 days after treatment; third week -- none applied.

b/ All flats uniform in stand. Counts not taken.

c/ One inch or 1/2 inch rainfall applied first of two rainfall dates each week; 1/4 inch rainfall applied each of two rainfall dates each week.

d/ Means of 3 replicates.

e/ Untreated.

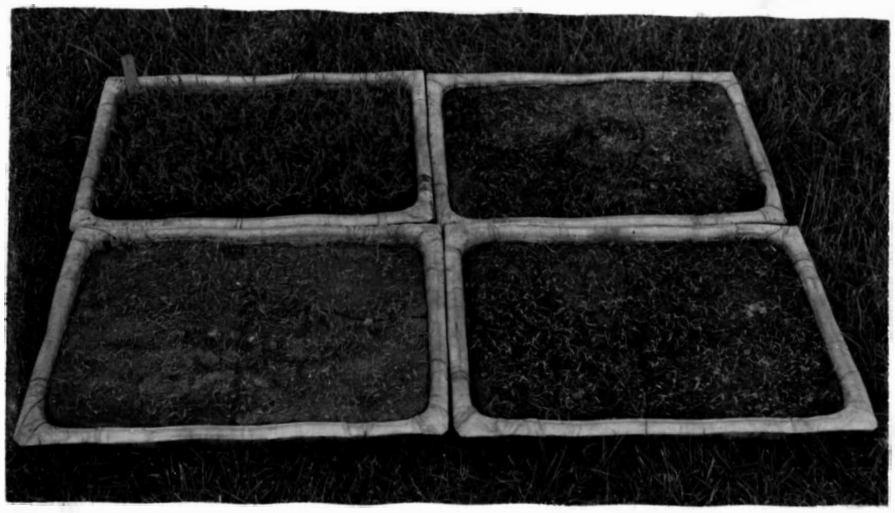


Figure 9. Simazine Treated Flats Showing Dead Foxtail Plants Which Received One Inch of Rainfall Seven Days Before Treatment (the check is in the upper left corner)

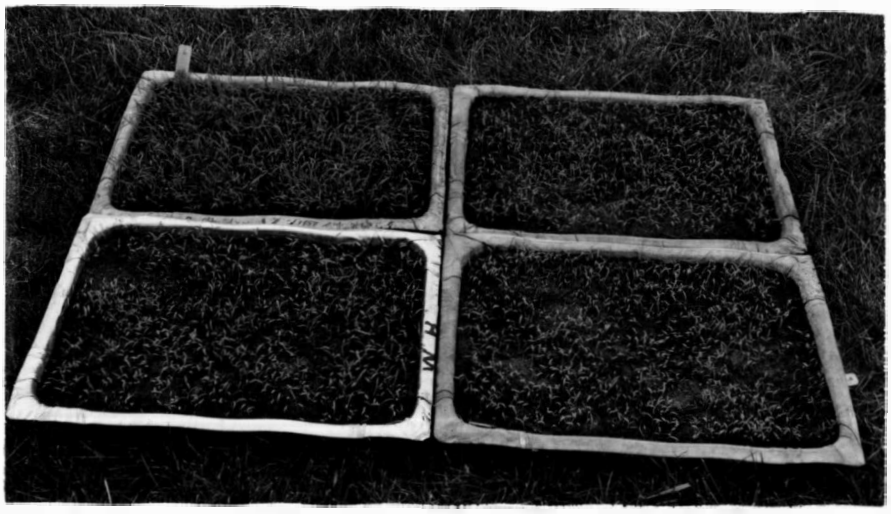


Figure 10. Simazine Treated Flats Showing Stunted Foxtail Plants Which Received One-half Inch of Rainfall Seven Days Before Treatment (the check is in the upper left corner)

TABLE XVIII. THE MEAN NUMBER OF FOXTAIL PLANTS ON FLATS AFTER TREATMENT WITH TWO OR FOUR POUNDS PER ACRE OF ATRAZINE AND VARIOUS RAINFALL LEVELS

Treatment no.	First week[a/] Rain[c/] (Inches)	Second week[a/] Rain[c/] (Inches)	Counts[d/]	Third week[a/] Rain[c/] (Inches)	Counts[d/]	Fourth week[a/] Rain[c/] (Inches)	Counts[d/]	Fifth week[a/] Rain[c/] (Inches)	Counts[d/]
1[g/]	1	1/8 & 1/8	1,423	1/8 & 1/8	1,084	1/8 & 1/8	1,162	1/8	1,097
2[f/]	1	1/8 & 1/8	139	1/8 & 1/8	11	1/8 & 1/8	16	1/8	16
3[f/]	1/8 & 1/8	1	1,116	1/8 & 1/8	18	1/8 & 1/8	18	1/8	15
4[f/]	1/8 & 1/8	1/8 & 1/8	1,410	1	972	1/8 & 1/8	199	1/8	72
5[f/]	1/8 & 1/8	1/8 & 1/8	1,408	1/8 & 1/8	1,054	1	902	1/8	875
6[g/]	1/8 & 1/8	1	1,440	1/8 & 1/8	1,220	1/8 & 1/8	1,243	1/8	1,209
7	1	1/8 & 1/8	110	1/8 & 1/8	63	1/8 & 1/8	66	1/8	63
8	1/8 & 1/8	1	955	1/8 & 1/8	8	1/8 & 1/8	5	1/8	4
9	1/8 & 1/8	1/8 & 1/8	1,285	1	259	1/8 & 1/8	21	1/8	10
10	1/8 & 1/8	1/8 & 1/8	1,395	1/8 & 1/8	655	1	572	1/8	96
11[g/]	1/8 & 1/8	1/8 & 1/8	1,458	1	1,327	1/8 & 1/8	1,306	1/8	1,290
12	1/2	1/8 & 1/8	1,232	1/8 & 1/8	492	1/8 & 1/8	351	1/8	340
13	1/8 & 1/8	1/2	999	1/8 & 1/8	67	1/8 & 1/8	83	1/8	72
14	1/8 & 1/8	1/8 & 1/8	1,412	1/2	594	1/8 & 1/8	80	1/8	51
15	1/8 & 1/8	1/8 & 1/8	1,349	1/8 & 1/8	1,077	1/2	1,048	1/8	246

a/ Rainfall first week applied 1 and 4 days after treatment; second week -- 8 and 13 days after treatment; third week -- 15 and 20 days after treatment; fourth week -- 22 and 26 days after treatment; fifth week -- 32 days after treatment.

b/ All flats uniform in stand.

c/ One-half inch or 1 inch of rainfall applied first of two rainfall dates each week; 1/8 inch of rainfall applied each of two rainfall dates each week.

d/ Means of two replicates taken 7 days after 1/2 inch or 1 inch rain. Fifth week counts taken 35 days after application.

g/ Untreated.

f/ Treated with 2 pounds per acre.

TABLE XIX. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN THIRTY-FIVE DAYS AFTER APPLICATION OF TWO POUNDS PER ACRE OF ATRAZINE WHEN ONE INCH OF RAINFALL WAS RECEIVED AT WEEKLY INTERVALS

Source	df	MS
Replication	1	12,461
Treatments	4	556,817**
Untreated vs. all others	1	1,162,128**
Rain 1st and 2nd week vs. rain 3rd and 4th week	1	419,528**
Rain 1st week vs. rain 2nd week	1	1
Rain 3rd week vs. rain 4th week	1	645,612**
Error	4	23,340

**Significant at 1% level.

TABLE XX. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN THIRTY-FIVE DAYS AFTER APPLICATION OF FOUR POUNDS PER ACRE OF ATRAZINE WHEN ONE INCH OF RAINFALL WAS RECEIVED AT WEEKLY INTERVALS

Source	df	MS
Replication	1	152
Treatments	4	546,635**
Untreated vs. all others	1	2,174,823**
Rain 1st and 2nd week vs. rain 3rd and 4th week	1	780
Rain 1st week vs. rain 2nd week	1	3,540
Rain 3rd week vs. rain 4th week	1	7,396
Error	4	1,617

**Significant at 1% level.

TABLE XXI. THE ANALYSIS OF VARIANCE OF FOXTAIL STAND COUNTS TAKEN FIFTEEN, TWENTY-TWO, AND THIRTY-FIVE DAYS AFTER APPLICATION OF FOUR POUNDS PER ACRE OF ATRAZINE AND ONE-HALF INCH OF RAINFALL AT WEEKLY INTERVALS

15 days after application

Source	df	MS
Replication	1	50,410
Treatment	4	67,172
Error	4	13,958

22 days after application

Source	df	MS
Replication	1	3,169
Treatment	4	520,671
Error	4	169,970

35 days after application

Source	df	MS
Replication	1	71,985
Treatments	4	524,593**
Untreated vs. all others	1	1,979,805**
Rain 1st and 2nd week vs. rain 3rd and 4th week	1	6,903
Rain 1st week vs. rain 2nd week	1	73,441
Rain 3rd week vs. rain 4th week	1	38,220
Error	4	14,713

**Significant at 1% level.

receive rainfall until 22 days after application gave significantly less control of foxtail than the treatment which included rainfall 15 days after application.

The flats which received four pounds per acre of atrazine and one inch of rainfall at varying time intervals, showed a high percentage of weed control. There appeared to be no differences due to the date that the rainfall was received.

The flats which received one-half inch of rainfall and four pounds per acre of atrazine did not show any significant differences in stand until the fourth week. The amount of control on these flats before this count was so variable between replicates and between treatments that the experimental error was large enough to render all treatments insignificant. However, the fifth week count showed that all flats contained fewer weeds than the untreated and that no difference in stand occurred among treatments.

DISCUSSION

The greenhouse trials conducted during 1958-1959 indicated that one inch of rainfall received before simazine application or within 21 days afterwards, gave good control of foxtail with or without mechanical incorporation of the chemical. However, without incorporation, treatments receiving rain within 15 days after application of the chemical gave better control. One-half inch of rainfall gave poor control when the chemical was not incorporated and gave only fair control when it was incorporated.

The greenhouse trials during 1959 did not include mechanical incorporation of the chemical. It was postulated that the effectiveness of simazine would vary if the foxtail seeds were mixed thoroughly throughout the soil in the flats instead of being planted at a depth of two inches as was done in the 1958-1959 experiments. These 1959 trials indicated that the depth of the seeds had no effect upon the amount of control when one inch of rainfall was received within eight days after simazine application. However, this amount was satisfactory but less effective when applied 15 days after chemical application and less effective than the 1958-1959 treatment which included one inch 15 days after application with the weed seeds planted at a two-inch depth. Treatments including rainfall 21 days after simazine application gave no control in 1959, while good control was achieved during 1958-1959. The treatments receiving one-half inch of rainfall in 1958-1959 gave essentially the same results as those which received this amount in 1959. Both of these one-half inch trials gave unsatisfactory

control.

The 1959 flats which received one-half inch of rainfall seven days before and again one day after simazine application, gave excellent control of foxtail. Foxtail plants which received one inch of rainfall before simazine treatment were dead 10 days after application.

The field results, however, did not completely support the greenhouse data. Throughout the entire growing season neither two nor four pounds per acre of simazine gave over 75 percent control of foxtail. By harvest time no control was noticeable. This lack of control may have resulted from the effect of the plastic sheet covering the plots during rains or resulted from the difference in climatic conditions between natural and artificial rainfall. The plots were covered only during natural rains and the temperature under the covering did not differ from the air temperature by more than a few degrees, but the climatic conditions under which artificial rainfall were applied were vastly different from natural conditions. The temperature was higher and the humidity lower when artificial rain was applied than when natural rains fell. The simulated moisture, therefore, evaporated much more quickly than under natural conditions.

Although the field experiments did not follow the greenhouse experiments entirely, the greenhouse results are in close agreement with those reported by Derscheid (8), Freeman (10) and Schneider (18). Other experiments[1] conducted under natural conditions in the same field as the field experiments gave the type of results that the greenhouse trials

[1]Derscheid, Lyle A. Unpublished data. 1959.

indicated. Therefore, because of the artificial environment, these field results may not be significant.

To obtain satisfactory control of foxtail with the use of simazine, it appeared necessary to have one inch of rain shortly before chemical application or within three weeks and preferably within two weeks afterwards. It is possible that moisture exerts its influence on the chemical in at least one of three ways: (1) by leaching it into the soil, (2) by keeping it in solution in the soil so that it may be absorbed by plant roots, or (3) a combination of both.

Flats which received one inch of rain before application of simazine had almost 100 percent control of foxtail, indicating that simazine diffused into the soil along a concentration gradient -- the highest concentration being at the surface.

Plants which received only one-half inch of rainfall before chemical application showed chemical injury but recovered. It is possible that this was insufficient moisture to leach a toxic amount of the chemical into the root zone. It is also possible that as the soil became dry, the moisture was insufficient to hold the chemical in solution for absorption by the roots. The first possibility seems more plausible as subsequent moisture caused the wilted plants to become turgid and recover. If toxic amounts of the chemical had been in the root zone, one would expect additional injury.

Likewise, mechanical incorporation improved the results both in the greenhouse and with the higher rate of chemical in the field, indicating that water served as the vehicle for moving the chemical into the soil.

It would appear that mechanical incorporation of the chemical could replace rainfall for moving the chemical into the soil. However, the poor field results were attributed to hot, dry conditions at the time of simulated rainfall and drier soil than under natural rainfall conditions. Therefore, it would seem that mechanical incorporation would replace rainfall only under adequate soil moisture conditions.

Although the results of this study and those of other workers (8, 10, 18) indicate that rainfall should be received within three weeks and preferably within two weeks after chemical application, the need for receiving rain at this early date is not clear. It is reasonable to believe that foxtail plants become more tolerant with age and that the normal amount of chemical applied pre-emergence in corn is not adequate to control these older plants. This is partially substantiated in this study by the fact that the longer the rain was delayed after chemical application the longer became the time interval required to give control.

It becomes apparent that this chemical is useful when applied pre-emergence for control of annual weeds in corn in areas where rainfall is adequate and timely. In subhumid areas such as South Dakota, its usefulness is limited. Rainfall data for the years 1950 to 1959 indicate that the chemical would have been effective six years out of the ten at Brookings, five or six years at Canton, three to five years at Gettysburg, four to six years at Menno, five or six years at Redfield, and four or five years at Watertown.

Atrazine applied at the four-pound rate gave excellent results when as little as one-half inch of rainfall was received one, two, or

three weeks after chemical application, indicating that less moisture is needed to activate this chemical. This would seem logical as atrazine is 14 times (70 vs. 5 ppm) more water soluble than simazine. It would appear that atrazine would be more useful in subhumid areas.

SUMMARY AND CONCLUSIONS

Experiments were conducted in 1958 and 1959 to determine the effect of rainfall upon the control of foxtail with simazine and atrazine. Two rates of rainfall were used in the greenhouse and in the field with two rates of the chemicals. Rainfall was applied at various times ranging from seven days before application of the chemicals to as late as 21 days after application of the chemicals. The effect of the rainfall was determined by reduction in stand of foxtail plants.

The following conclusions were derived:

1. Water serves as the vehicle by which simazine, and probably atrazine, moves into the soil. In wet soil this movement is along a concentration gradient while in dry soil it is by leaching.

2. Pre-emergence applications of four pounds per acre of simazine are effective for controlling foxtail if the chemical is applied to wet soil, or if one inch of rain falls within 15 days after chemical application, or if one-half inch falls within one or two days after application. Fair to good results are obtained when one inch of rain falls during the third week.

3. Proper mechanical incorporation of the chemical reduces the need for rainfall if soil moisture is adequate but is not a complete substitute.

4. Simazine moves downward in the soil very slowly. In Vienna silt loam, five inches of natural rainfall moves toxic quantities to a depth of two inches.

5. Atrazine is more soluble in water than simazine. Pre-emergence

applications of two to four pounds per acre are effective for controlling foxtail if one-half inch of rain falls within 15 days after chemical application. Fair to good results are obtained when similar amounts of rain fall within the third week.

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