RESIDUE IN THE SOIL FOLLOWING ATRAZINE APPLIED AS A PREEMERGENT AND ITS EFFECT ON SUCCEEDING CROPS

by

JAMES ERNEST CONGROVE

B. S., Kansas State University, 1962

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

Approved by:

L. E. Anderson

Major Professor

TABLE OF CONTENTS

INTRODUCTION

The use of atrazine as a preemergent for controlling annual weeds in corn has created a problem involving the effect of residues on succeeding crops. Injury to susceptible crops following corn treated with atrazine has been observed. In rotations in which sensitive crops are included the use of atrazine may become hazardous.

The object of this investigation was to determine the effects of residues of atrazine on crops commonly grown in Kansas.

REVIEW OF LITERATURE

Atrazine is 2-chloro-4-ethylamino-6-isopropylamino-s-triazine. The material is a white, crystalline substance which is slightly soluble in water. The solubility of atrazine has been found to be near 70 ppm at 27°C. (1)

Atrazine has become well established as a selective preemergent herbicide for annual grass and broadleaf weed control in corn.

Corn plants are capable of metabolizing atrazine to products which are not injurious. (1,11) Other crops showing some tolerance are capable of metabolizing atrazine, but at a slower rate which permits the compound to accumulate to toxic levels. (1) Seeds of susceptible plants usually germinate but are killed shortly after emergence due to the uptake of atrazine through the roots. The first symptom of injury is marginal chlorosis. (14) When applying atrazine as a preemergent for weed control in corn it has been found advisable to consider the effect of residues in the soil on succeeding crops. (4)

Disappearance of herbicide residues from the soil involves a number of factors: vaporization, soil adsorption, leaching, chemical decomposition, photo-chemical decomposition, deactivation by microorganisms, removal by plants, and tillage. (3) The above factors are influenced by the nature of the compound, physical and chemical properties of the soil, amount of rainfall and leaching velocity, temperature and amount of chemical applied. (7)

Rodgers (12) in his work with triazines found that atrazine was inactivated more rapidly as temperatures increased to 45°C. He found that atrazine was inactivated in less than seven weeks during the summer but inactivation was markedly slowed when temperatures were below 30°C.

Talbert and Fletchall (20) applied two pounds of atrazine and simazine per acre in May, 1960. There was a rapid loss of the herbicide during the first three weeks after application. Rate of inactivation became slower through the summer and very little deactivation occurred during September and October.

The amount of rainfall and leaching velocity are factors which are considered important in loss of toxicity. Due to the slight solubility of atrazine it is not leached rapidly: however, leaching has been found important in dissipation when considering an extended period of time. (6)

Kuntz, et al. (9) found after applying two surface inches of water immediately after treatment that most of the atrazine remained in the top inch of soil. Following an application of 16 inches of surface water after treatment, growth reduction of oats sown in the top inch of soil continued to occur.

Burnside, et al. (6) found that atrazine was leached to the 12 to 18 inch soil depth after four months and to the 18 to 24 inch soil depth or greater after 16 months. A considerable amount of atrazine remained in the 3 to 24 inch soil depth after 16 months.

Behrens (3) stated that considerable amounts of atrazine may be adsorbed in soils with a high organic matter content. He stated that recent evidence indicates a deactivation of triazines by polysulfides or other electron rich compounds and that deactivation of atrazine by microorganisms is relatively slow.

Sheets and Shaw (16) in their investigation tested fourteen s-triazines in four different soils. Atrazine was found to be the most toxic compound to oats in all four soils. The four soils were Tifton loamy sand, Basket sandy loam, Cecil sandy loam and Sharkley clay. Atrazine was most toxic in Tifton sandy loam and least toxic in Sharkley clay.

Research with several crops concerning the effect of residues in the soil following applications of herbicides has been reported.

Behrens (2) after applying 2, 6 and 12 pounds of atrazine per acre in November, sowed flax, wheat, oats and planted soybeans the following spring. Percentage kills were estimated. Wheat, oats and soybeans were completely killed following the 6 and 12 pound rates while flax showed 73 and 83 percent reductions at 6 and 12 pounds respectively. The 2 pound rates severely reduced stands of wheat and oats but flax and soybeans were more tolerant.

Buchholtz (5) reported severe injury to oats on soil which had been treated with atrazine at 4 pounds per acre the previous year. No significant yield decrease was found with treatments of 1 and 2 pounds per acre.

Fink and Fletchall (8) seeded nine different forages in soil treated one year previously with atrazine at 1, 2 and 4 pounds per acre. The crops grown were orchardgrass, tall fescue, timothy, bromegrass, alfalfa, red clover, lespedeza, ladino clover and sweet clover. They found no effect on emergence for any species but reported stand reduction after the 2 and 4 pound applications. Tall fescue was most susceptible while timothy was injured least. Significant yield reductions occurred with all crops following the 2 and 4 pound rates. The 1 pound per acre rate reduced stands for all crops except tall fescue and Korean lespedeza.

Swader and Fletchall (19) substituted bluegrass for sweet clover in the above experiment. The 1 pound rate showed very little effect while the 2 pound rate caused considerable reduction of stand in ladino clover. The 4 pound rate caused severe reductions of stands in four species.

Schallock and Ilnicki (13) reported injury to ryegrass when seeded in corn at last cultivation when the corn had been treated with atrazine as a preemergent. No injury was observed when seeding was delayed until after corn harvest.

Ilnicki and Meggitt (10) investigating residual aspects of triazine compounds made 1, 2, 4, 6 and 8 pound per acre applications of simazine and atrazine. After initiating the experiment in 1959, the same applications on the same plots were made for three consecutive years. Rates of simazine at 4 pounds and above caused injury to susceptible crops after one year. Rates of 6 to 8 pounds produced severe injury. Successive applications of 2 pounds for three years also produced severe injury. Results with atrazine were similar but less severe.

Splittstoesser and Derscheid (18) reported severe injury to small grain when sown the year after application of 2 pounds per acre of atrazine.

Summarizing previous work with atrazine residues, results have shown varying degrees of tolerance among different species of plants. Recommended rates of 2 to 4 pounds have left residues injurious to susceptible species in some investigations. Loss of residues from the soil is dependent upon a number of factors which are variable.

MATERIALS AND METHODS

The investigation was conducted in 1963 at the Kansas State University Agronomy Farm, Manhattan, Kansas. The soil being an unnamed series, which is nearly level, poorly drained, alluvial silty clay loam with a light, silty clay calcareous subsoil.[1]

A flame cultivation test to control weeds in corn was conducted in the area in 1962. Ten pounds per acre of atrazine was applied May 5, 1962 as a preemergent to eliminate any weed factors in a portion of the area used in the flame test. The remainder of the area was not treated. In the 1963 residue investigation, the two areas were compared to determine the effect of atrazine residues remaining in the soil.

Total precipitation in 1962 after the atrazine was applied was near normal. There was a two week dry period after the atrazine treatment. A 4.74 inch rain on May 29 accounted for most of the precipitation in May. During the remainder of 1962, only one rain of more than 2 inches fell. Precipitation in 1963 was below normal each month resulting in extremely dry conditions during the growing season. Daily precipitation from May 1, 1962, through September 30, 1963, is included in table 1.

The area was plowed with a moldboard plow to an approximate depth of 9 inches in the fall of 1962. The soil was left in

[1]Dr. O. W. Bidwell, in personal communication.

Table 1. Precipitation record, Kansas State University Agronomy Farm, Manhattan, Kansas, May 1, 1962 to September 30, 1963.

	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
1		.39				.25	.03							.25			.08
2		.08			.01	.23	.02						.05				.23
3		1.25		.18		.27						.13					
4					.06						1.07						.01
5		.03	.02	1.33	.12				.09		.07		.02				
6		.22				1.40							.05		.02	.10	
7			.01														.02
8					.57												
9		.18			.34												
10					.72							.05		.08		.04	
11									.05		.24				.21		
12			.28						.09					.64	.51		
13			.46								.02		.50		.10	.02	
14																	
15			.38		.03								.07	.97	.02		
16							.56					.14	.08	.18			1.61
17													.38		.21	.09	
18			.03													1.06	
19	.22				.10		.05		.09		.16		.08	.21		.67	
20	.16		.18			.16		.01	.01				.23				
21	.32	.30			.15			.14	.03						.02		
22			.25		1.32			.02							.03		
23		1.14							.02								
24		.47		2.65									.06	.10			
25	.08	.34						.12					.35				.09
26													.04	.10			
27	.01						.57		.03			.49	.02				
28	.45		.75			.29						.01			.02	.03	
29	4.74				.93							.65	.13		.01		
30																	
31				.34	.21						.48				.02		
	5.93	4.40	2.86	4.50	4.56	2.65	1.23	.29	.41		2.04	1.47	2.06	2.53	1.17	2.01	2.09

this condition through the winter months. Prior to planting the various crops, the area was disced and harrowed.

The area was divided into 21 equal plots, 40 inches wide. The plots ran the entire length of the area. A random design with three replications was used in the experiment. Six crops occurring three times each, utilized 18 plots. The remaining three plots were not planted. The plots were in the same sequence in both the treated and untreated areas.

The crops were planted in two row plots with 40 inch spacings. One 40 inch quadrat for making weed counts was placed at random within each plot where a crop was not planted.

Table 2. Crops seeded, variety, date of planting and date of harvest.

Crop	Variety	Date of Planting	Date of Harvest
Soybeans	Clark	May 22	October 17
Castorbeans	Baker	May 21	November 7
Forage Sorghum	Atlas	May 22	September 9
Sudangrass	Greenleaf	May 22	September 10
Grain Sorghum	Midland	May 21	September 9
Sunflower	Advance	May 29	August 29

Oats and alfalfa were seeded in the spring but no yields were obtained due to the extremely dry conditions at sowing time which resulted in no alfalfa seedling survival and a poor stand of oats.

The plots were kept weed free during the growing season by cultivation and hoeing. Notes of observable injury were taken throughout the growing season.

A 40 foot section of one row was harvested from each plot. The above-ground portions of sunflower, forage sorghum and sudangrass were harvested, allowed to dry, then weighed to measure yield. Soybean, grain sorghum and castorbean yields were determined by seed weights.

Weed counts in each quadrat were made and the above-ground portions of the weeds were harvested and weighed in August.

To detect significant differences between means of the two treatments, the t-distribution for comparison of two randomized groups was utilized. Experimental error was determined by the average variation among the plots within the treatments. (17)

To determine the depth to which atrazine had leached, soil samples were obtained in May, 1963 and again in September. Samples were obtained with a one inch soil tube. Soil was taken from the 0 to 6, 6 to 12, and 12 to 18 inch soil depths in June and from the same depths plus an 18 to 24 inch depth in September. The samples were put in 4 inch pots and taken to the greenhouse where Kanota oats were grown as an indicator. The pots were watered daily by sprinkling. Atrazine injury to oats growing in the soil from various depths was observed.

Soil samples from 0 to 3, 3 to 6, and 6 to 9 inch soil depths were obtained in September, 1963 from the 1963 flame cultivation test where 10 pounds per acre of atrazine had again been applied as a preemergent. Kanota oats were grown for a bioassay and injury resulting from atrazine residues at the different soil depths was observed.

On September 25, nodule counts were made on soybeans to determine if atrazine residues affected nodulation. Twelve plants were selected from each replication in the treated area; four showing severe injury, four moderate injury and the remaining four plants having slight injury. The mean number of nodules on the four plants was reported. Nodules on four plants from each replication in the check area were counted and the mean number reported.

EXPERIMENTAL RESULTS

Atrazine residues resulted in early injury to sunflower, soybeans and castorbean. Marginal chlorosis was observed shortly after emergence while overall injury, in some instances, was sufficiently severe to reduce the stand. Other plants were stunted throughout the growing season; however, some plants appeared to be uninjured.

Yields gave indication that atrazine residues reduced stand for the above mentioned species. Information concerning yield and stand of the above species are reported in the following tables. Calculated t values and the table t values obtained from Snedecor's <u>Statistical Methods</u> (17) are included.

EXPLANATION OF PLATE I

General view of experiment (June, 1963). The area to the right was treated with ten pounds per acre of atrazine in 1962.

PLATE I

EXPLANATION OF PLATE II

Castorbeans were severely injured by soil residues. Weed growth in the treated and untreated quadrats was not significantly different.

PLATE II

EXPLANATION OF PLATE III

Leaf chlorosis of young castorbean plants injured by atrazine residue.

PLATE III

EXPLANATION OF PLATE IV

Note reduced stand of soybeans.
Forage sorghum and sudangrass
were uninjured by atrazine residue.

PLATE IV

EXPLANATION OF PLATE V

No apparent injury to forage or grain sorghum or sudangrass.

PLATE V

EXPLANATION OF PLATE VI

General view of experiment area, September, 1963.

PLATE VI

EXPLANATION OF PLATE VII

Oats seedlings in the center pots exhibit varying degrees of injury due to soil residue. The soil samples were taken in September, 1963.

PLATE VII

Table 3. Weight of sunflower plants in pounds per 40 foot row.

	Replication			
	1	2	3	$\bar{X}$
Untreated	30.3	28.5	17.6	25.5
Treated	0.0	10.3	0.4	3.6
				D = 21.9*[1]

Calculated t = 4.20 Table t = 2.78

Table 4. Seed weight of soybeans in pounds per 40 foot row.

	Replication			
	1	2	3	$\bar{X}$
Untreated	6.5	7.9	4.9	6.4
Treated	4.1	4.3	2.8	3.7
				D = 2.7*

Calculated t = 2.81 Table t = 2.78

Table 5. Seed weight (not hulled) of castorbean in pounds per 40 foot row.

	Replication			
	1	2	3	$\bar{X}$
Untreated	15.8	14.3	11.8	14.0
Treated	10.5	9.7	8.4	9.5
				D = 4.5*

Calculated t = 3.46 Table t = 2.78

[1]Asterisk denotes significance at .05 level, n.s. denotes non significance.

Table 6. Number of sunflower plants per 40 foot row.

	Replication 1	2	3	$\bar{X}$
Untreated	54	74	62	63.3
Treated	0	32	6	12.7
				D = 50.6n.s

Calculated t = 1.98   Table t = 2.78

Table 7. Number of soybean plants per 40 foot row.

	Replication 1	2	3	$\bar{X}$
Untreated	160	146	134	146.7
Treated	79	117	79	91.7
				D = 55.0*

Calculated t = 3.77   Table t = 2.78

Table 8. Number of castorbean plants per 40 foot row.

	Replication 1	2	3	$\bar{X}$
Untreated	37	35	30	34.0
Treated	19	24	28	23.7
				D = 10.3*

Calculated t = 3.12   Table t = 2.78

A t value greater than 2.78 indicated a significant difference at the .05 level between means of the two treatments.

The yield difference between means of the untreated and treated sunflower plots was 21.9 pounds. The calculated t value of 4.20 was significant. Stand reduction was non significant with a calculated t of 1.98. Considerable variation among replications reduced the value greatly.

A yield difference of 2.7 pounds between means of the treatments with soybeans was also significant. The calculated t value was 2.81. Soybean stand was also reduced significantly by atrazine residues. The t value was calculated at 3.77.

The calculated t value of 3.46 indicated a significant yield reduction of castorbeans in the treated plots. Stand reduction was also significant with a calculated t of 3.12.

Data obtained from soybean nodule counts is presented in table 9. The figures appearing in the table indicate the mean number of nodules observed on four selected plants. As the table indicates, there were twelve plants selected from each replication in the treated area and grouped into three classes of four according to degree of injury. Four plants were selected from each replication in the untreated area.

Table 9. Mean number of nodules observed on four soybean plants, September 25.

	Replication			
	1	2	3	$\bar{X}$
Untreated	71	100	61	77
Treated				
severely injured	1	6	4	3
moderately injured	39	19	18	25
slightly injured	72	58	60	63

Forage sorghum, sudangrass, and grain sorghum gave no indication of injury during the growing season. Yields of the above species were not significantly reduced by atrazine residues remaining in the treated area.

Information concerning yield of the above species is reported in the following tables. Calculated t values and the table t values at the .05 level of significance are given.

Table 10. Weight of sudangrass in pounds per 40 foot row.

	Replication			
	1	2	3	$\bar{X}$
Untreated	40.3	32.1	34.5	35.6
Treated	39.6	32.6	30.5	24.2
				D = 1.4n.s.

Calculated t = 0.38 Table t = 2.78

Table 11. Weight of forage sorghums in pounds per 40 foot row.

	Replication			
	1	2	3	$\bar{X}$
Untreated	74.2	73.6	71.3	73.0
Treated	71.0	79.0	65.8	71.9
				D = 1.1n.s.

Calculated t = 0.27 Table t = 2.78

Table 12. Seed weight of grain sorghum in pounds per 40 foot row.

	Replication			
	1	2	3	$\bar{X}$
Untreated	8.4	10.1	9.8	9.4
Treated	11.0	9.1	9.1	9.7
				D = 0.3n.s.

Calculated t = 0.04 Table t = 2.78

Broadleaf and grassy weeds emerged in the treated area. Weed counts made in the six quadrats placed at random in the two treatments showed no significant differences. Annual broadleaf weeds in the treated area appeared to be stunted during the early growing season. Rough pigweed, Amaranthus retroflexus was the predominant annual broadleaf. Annual grassy weeds predominantly crabgrass, Digitaria sp and foxtail Setaria sp showed no injury in the treated area.

The following tables include information on weed counts made in the two treatments. Calculated t and table t values are included.

Table 13. Number of annual broadleaf weeds per quadrat August 29.

	Replication			
	1	2	3	$\bar{X}$
Untreated	22	25	15	20.7
Treated	17	32	9	19.3
				D = 1.4n.s.

Calculated t = 0.19 Table t = 2.78

Table 14. Number of annual grassy weeds per quadrat August 29.

	Replication			
	1	2	3	$\bar{X}$
Untreated	15	13	15	14.3
Treated	21	2	9	10.7
				D = 3.6n.s.

Calculated t = 0.64 Table t = 2.78

Calculated t values indicated that atrazine residues did not reduce broadleaf or grassy weed stand significantly.

Table 15. Weight of annual weeds per quadrat August 29.

	Replication			
	1	2	3	$\bar{X}$
Untreated	34.1	22.2	22.8	26.4
Treated	27.9	18.9	17.4	21.4
				D = 5.0n.s.

Calculated t = 1.00 Table t = 2.78

The weight of annual weeds was less in all replications for the treated area but the difference in means between treatments was not significant at the .05 level.

Injury to Kanota oats grown on soil obtained from various soil depths in June, 1963 indicated atrazine residues concentrated at the 6 to 12 inch soil depth. Slight injury to oats grown on soil collected from the 0 to 6 and 12 to 18 inch depth was observed. Oats growing in soil from the 6 to 12 inches were killed by atrazine residues.

Soil obtained in September, 1963 from the 12 to 18 inch soil depth contained the highest concentration of atrazine at that date as indicated by severe injury to Kanota oats. Oats growing in soil collected from 0 to 12 and from the 18 to 24 inch depths were only slightly injured by atrazine residues.

DISCUSSION

Previous investigations of atrazine soil residues have indicated toxicity to susceptible crops following rates of 2 to 4 pounds per acre. Rates of 8 to 12 pounds per acre applied the previous year resulted in near complete kill of many crops. Based on this information the 10 pound rate used in this investigation was expected to cause considerable injury to the susceptible crops included.

Based on the results of this investigation it appears that monocotyledon crops are more tolerant than dicotyledons; however, in some cases certain broadleafs have been found to be more tolerant.

Although significant reductions in yield were found in soybeans, castorbean and sunflower, the yields were higher than anticipated in each crop. A number of factors may have been responsible for the relatively low toxicity of the atrazine residues in this investigation.

Following the atrazine application May 5, 1962, there was a period of two weeks before rain fell. Without moisture to leach it into the soil, considerable atrazine may have been lost through volatilization or photo-chemical decomposition.

Soil samples were not obtained in 1962 hence the depth of leaching at plowing time was not known. Since most of the rainfall came as light showers and with a soil of relatively high clay content, it is assumed that leaching may have been slow with most of the atrazine remaining near the surface. Inverting the soil by plowing to a depth of 9 inches obviously placed the residues at a greater depth from the surface. Precipitation through the winter months was below normal and leaching was probably retarded. From time of application to time of plowing only 5 rains of more than one inch fell, while during the 8 months from October 1 through May 31 only 10.15 inches of precipitation fell, including 2 rains more than one inch (table 2).

Oats grown in the greenhouse on soil obtained from various depths in the spring indicated atrazine residues were concentrated at the 6 to 12 inch depth which would verify the assumption that plowing placed the atrazine in that zone of the profile.

Loss of toxicity through soil adsorption, chemical decomposition and deactivation by soil microorganisms was not measured. It is known, however, that soils having a high clay content reduce toxicity of atrazine through adsorption. (3,16) One investigator (3) stated that decomposition of atrazine by microorganisms is slow. The amount of chemical decomposition which is influenced by chemical constituents of the soil may have been considerable in this investigation.

The soybean nodule counts indicate an indirect effect of atrazine on nodulation. It appears that nodulation is reduced due to the reduction of vigor in the soybean plant. Direct toxic effect of atrazine to the bacteria involved is unlikely.

Conclusions concerning loss of toxicity from residues are difficult to postulate from information obtained in this investigation. Since plants become more tolerant to atrazine as they grow, the fact that atrazine was located some depth from the surface may have been the primary reason why some plants of the susceptible crops were able to grow. Because the atrazine was at that depth, the plants were able to become established as seedlings and to grow for a period of time before being subjected to atrazine residues.

Based on results of this investigation, it appears that the varieties of forage sorghum, grain sorghum and sudangrass in this study can be grown following corn treated with atrazine. With experiment, other varieties of these same crops may be less tolerant. However, conditions differing from those in this experiment could result in significant reduction of yield.

The varieties of castorbean, soybean or sunflower included in this experiment were susceptible to atrazine. Growing these varieties following atrazine application should be avoided. Other varieties may have more tolerance.

Additional investigations concerning the effects of various soil and climatic factors and also cultural practices on atrazine residues need to be conducted. Tolerance to atrazine of various varieties of different species would be valuable information to the farmer.

SUMMARY

Based on experimental results it was found that residues from ten pounds per acre of atrazine applied the previous year caused the following:

1. Injury to young plants of soybeans, castorbean and sunflower.

2. Yields of soybeans, castorbean and sunflower were reduced significantly. Yields of forage sorghum, grain sorghum and sudangrass were not affected.

3. Fewer nodules were observed on soybean plants injured by atrazine residues. This was believed due to reduction of vigor of soybean plants.

4. Annual weed population was not reduced significantly.

5. Residues were concentrated at the 6 to 12 inch depth in June, 1963 and at the 12 to 18 inch depth the following September.

ACKNOWLEDGMENT

The author would like to express his sincere appreciation and thanks to his major advisor, Dr. L. E. Anderson, for suggesting the problem, his guidance throughout this investigation and for his critical reading and correction of the manuscript.

LITERATURE CITED

(1) Atrazine Technical Bulletin no. 63-1.
Geigy Agricultural Chemicals. Yonkers, New York. 1963.

(2) Behrens, R.
Relative residual phytotoxicity of simazine and 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (atrazine). Proc. NCWCC and WCWCC 16:103. 1959.

(3) Behrens, R.
Soil residues from herbicides. Ag. chemicals 17:34. 1962.

(4) Buchholtz, K. P.
Avoid those herbicide residues. Crops and Soils 15:15-16. April 1963.

(5) Buchholtz, K. P.
Responses of oats to residual triazine herbicides in the soil. Proc. NCWCC and WCWCC 16:87. 1959.

(6) Burnside, O. C., C. R. Fenster and G. H. Wicks.
Dissipation and leaching of monuron, simazine and atrazine in Nebraska soils. Weeds 11:209-213. 1963.

(7) Burschell, Peter and V. H. Freed.
The decomposition of herbicides in soils. Weeds 7: 157-161. 1959.

(8) Fink, Rodney J. and O. H. Fletchall.
Forage crop establishment in soil containing atrazine or simazine residues. Weeds 11:81-83. 1963.

(9) Kuntz, J. E., T. T. Kozlowski and R. R. Kilbury.
Leachability, movement and persistence of herbicides in forest nursery soils. Proc. NCWCC 17:12. 1960.

(10) Ilnicki, Richard D. and William F. Meggitt.
Some residual aspects in the use of triazine compounds for weed control. Abstracts WSA:46-47. 1961.

(11) Montgomery, Marvin and V. H. Freed.
The uptake, translocation, and metabolism of simazine and atrazine by corn plants. Weeds 9:231-237. 1961.

(12) Rodgers, Earl G.
Leaching of four triazines in three soils as influenced by varying frequencies and rates of simulated rainfall. Abstracts Proc. SWC:268. 1962.

(13) Schallock, D. A. and R. D. Ilnicki.
Herbicides: an effective weed control tool that must be used skillfully to prevent soil residue buildup. American Veg. Grower 10:20. 1962.

(14) Schneider, E. O.
Simazine and related triazine herbicides. Proc. NCWCC 15:11-12. 1958.

(15) Sheets, T. J., A. S. Crafts and H. Drewer.
Influence of soil properties on the phytotoxicities of the s-triazine herbicides. Jour. Agr. and Food Chem 10:458-462. 1962.

(16) Sheets, T. J. and W. C. Shaw.
Herbicidal properties and persistence in soils of s-triazines. Weeds 11:15-21. 1963.

(17) Snedecor, George W.
Statistical Methods, Fifth Edition. Iowa State University Press, Ames, Iowa. 85-92. 1956.

(18) Splittstoesser, W. E. and L. A. Derscheid.
Effects of environment upon herbicides applied preemergence. Weeds 10:304-307. 1962.

(19) Swader, J. H. and O. H. Fletchall.
Effect of several herbicide residues on the establishment of certain forage crops. Proc. NCWCC 19:129-130. 1962.

(20) Talbert, Ronald E. and O. H. Fletchall.
Rate of inactivation of atrazine and simazine in field plots as determined by bioassay techniques. Abstracts WSA:5. 1961.

RESIDUE IN THE SOIL FOLLOWING ATRAZINE APPLIED AS A PREEMERGENT AND ITS EFFECT ON SUCCEEDING CROPS

by

JAMES ERNEST CONGROVE

B. S., Kansas State University, 1962

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

Approved by:

L. E. Anderson
Major Professor

Injury to sensitive crops has been noted when planted in areas treated with atrazine the preceeding year. Previous investigators have found varying degrees of injury from atrazine residues under different climatic and soil conditions and with differing cultural practices employed. Among species of plants, a considerable range in degree of tolerance to atrazine is found.

A field study was conducted in 1963 to determine the effect of atrazine residues to crops which are grown in Kansas. In 1962, ten pounds per acre had been applied to provide a weed free area as part of a flame cultivation experiment with corn.

The crops grown included soybeans, sunflower, castorbean, grain sorghum, forage sorghum and sudangrass. They were planted in two row plots occurring at random, with three replications in both the treated and check areas. A t test was used to detect significant differences between the two treatments.

Young plants of castorbean, sunflower and soybeans showed signs of injury the year following atrazine application. No injury was noted in forage sorghum, grain sorghum or sudangrass. Yield reduction was significant in castorbean, sunflower and soybeans but not apparent in forage sorghum, grain sorghum or sudangrass.

Weed counts made in August from quadrats placed at random indicated atrazine residues did not reduce the annual broadleaf or grassy weed population significantly.

Fewer nodules were observed on soybean plants showing atrazine injury. This was believed due to reduction of vigor of soybean plants and not to direct toxic effect of the residues to the bacteria involved.

In a bioassay test, Kanota oats grown in soil samples obtained from various depths indicated atrazine residues were concentrated at the 6 to 12 inch depth in June, 1963, and at the 12 to 18 inch depth in September.

Under the conditions of this experiment, toxic residues were dissipated more rapidly than anticipated. Absence of rainfall for two weeks following application, lack of leaching rains during the summer of 1962, a relatively high clay content of the soil in addition to the fall plowing operation are believed to be conducive to these results.