SOIL PARAMETERS INFLUENCING HERBICIDAL ACTIVITY AND PERSISTENCE OF RAMROD, CDAA, AND BENSULIDE

By

ROBERT MARION HODGDEN

Bachelor of Science

Oklahoma State University

1965

Submitted to the faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
July, 1967

SOIL PARAMETERS INFLUENCING HERBICIDAL ACTIVITY AND PERSISTENCE OF RAMROD, CDAA, AND BENSULIDE

Thesis Approved:

J. Q. Lynd
Thesis Adviser

Paul W. Santelmann

D. D. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

The author is grateful to Oklahoma State University for the use of its facilities and to the faculty for its leadership and training throughout the course of this study.

An expression of appreciation is extended to my major adviser, Dr. J. Q. Lynd, for his counsel and assistance, and to the members of my graduate committee, Dr. P. W. Santelmann and Dr. Eddie Basler.

The author is very thankful to his wife, Aurora, for her patience and encouragement during his graduate work and to his parents, Mr. and Mrs. Walter N. Hodgden, for their assistance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The agricultural revolution in the United States continues to demand higher and higher production levels from agronomic crops. Hand in hand with increased production, crop protection from action of pests and pathogenic organisms must be intensified.

Familiar examples of harmful organisms include the microbial pathogens controlled with bactericides, fungicides, etc., and insects controlled with insecticides. Equally important are the weedy higher plants as crop competitors. Losses caused by weeds in the United States are equal to the combined losses from insects and disease. Annually, losses due to the presence of weeds in the United States represent an estimated 5 billion dollars (1).

The traditional method of weed control in the past was by mechanical methods, but modern trends are towards chemical weed control. The amount of crop land treated with weed killers in 1949, had more than doubled in 1959, at which time more than 50 million acres were being treated anually. In 1965 more than 500,000 acres of agronomic crops, range lands, and turf grasses were treated with herbicides in Oklahoma (25).

Though chemical weed control is a sizable industry, many associated problems remain in question. Many herbicide applications to agronomic crops are made by application of herbicides to the soil. Soils, with their many varying chemical and physical properties, present many problems which affect the efficiency and persistence of herbicides.

The experiments in this study were attempts at establishing correlations between the soil properties, texture, organic matter, and fertility status, and the phytotoxicity and persistence of 2-chloro-N-isopropylacetanilide (Ramrod), 2-chloro-N,N-diallylacetamide (CDAA), and N-(beta-O, O-diisopropyl-dithiophosphorylethyl)-benzene sulfonamide (Bensulide).

LITERATURE REVIEW

CDAA, chloro-N, N-diallylacetamide, and Ramrod, 2-chloro-N-isopropylacetanilide, are amide herbicides. Much has been reported in the literature concerning CDAA and other amides, but little work with Ramrod, a new herbicide, has been reported to date.

Isenberg et al., (17) in 1951 reported that maleic hydrazide (not an amide, but classed with amides because of similar properties) injured plants primarily through partial inhibition or inactivation of one or more of the dehydrogenases. Also in 1951, work by Darlington and McLeish (8) showed that maleic hydrazide disrupted plant mitotic processes. Low concentrations of maleic hydrazide resulted in chromosome breakage while high maleic hydrazide concentrations completely stopped mitosis. Later work by Canvin and Friesen (6) confirmed that CDAA is also a mitotic poison. In barley roots, mitotic inhibition was directly proportional to CDAA concentration.

Soil organic matter seems to be the most important soil factor affecting herbicide activity (23). Correlation coefficients for herbicide activity and soil organic matter content were found to be .991 and .91 for Monuron (24) and CDAA (27), respectively. Upchurch and Mason (27) report that approximately 5 times as much herbicide was required for toxicity at 20% organic matter to be equal to toxicity at 5% organic matter. This was generally true for all 12 of the soil incorporated herbicides that were studied. Upchurch et al., (28) in 1966 report, however, that CDAA activity and soil organic matter content are not always correlated. Various soil organic matter levels between 3 and 40% had no effects on CDAA activity, but soil organic matter levels below 3% had erratic effects on CDAA activity. Apparently, in soils with less than 3% organic matter, few adsorption sites are available to bind CDAA and losses due to volatilization are large. Upchurch et al., (28) believe poor results with CDAA on wet soils to be due to occupation of adsorption sites by water allowing CDAA volatility losses to increase. Gantz and Slife (12) also found high soil moisture levels to shorten the toxicity period of CDAA.

Soil texture has been reported to be influential in controlling CDAA activity. Sheets (22) found a 2.9 fold difference between the effective concentration for a clay and silt loam soil. Leaching studies (12) show CDAA to be much more mobile in sandy soils than in finer texture soils.

Crafts in 1939 (7) found nitrogen additions to the soil to lower the toxicity of chlorate. In 1949, Ishaque (18) reported on the relation of mineral elements to 2,4-D toxicity. He found additions of ammonium nitrate, sodium phosphate, potassium carbonate, calcium phosphate, and magnesium sulphate all increased 2,4-D injury to shoots, but decreased injury to roots. Phosphorus was most significant in reducing root injury. Work by Bingham and Upchurch (4) has shown that phosphorus additions reduce the toxicity of Diuron to cotton and ryegrass while nitrogen and potassium additions have little effect. Upchurch and Mason (27) found soil phosphorus and CDAA toxicity to be negatively correlated, but calcium and CDAA toxicity were highly correlated. Negative correlation was found between phosphorus levels and Diuron toxicity by Upchurch et al. (28) in 1966. Upchurch et al. (26)

in 1963 reported that Amitrole toxicity increased with phosphorus additions while CIPC, Dalapon, and EPTC toxicities were not highly influenced by phosphorus additions.

Soil nutrient levels affect herbicide effectiveness, but herbicides also affect nutrient absorption. Voight (30) and Kramer (19) both have found pesticides to reduce phosphorus accumulation in pines.

Volatilization of CDAA from the soil is the primary means of detoxification. Studies (9) have shown that 90% or more of applied CDAA can volatilize within 24 hours from low organic matter soils. Volatilization was reduced to 60% in 24 hours with a soil containing 5% organic matter. Microbial detoxification of CDAA apparently does not take place (5). Persistence of CDAA in soils at phytotoxic levels is very short. Sheets (22) found 160 p.p.m. of CDAA to be reduced to nonphytotoxic levels in three months.

Ramrod has shown a high degree of specificity for annual grassy weeds at rates of 3 to 5 p.p.m. (2).

Bensulide, N(beta-O, O-diisopropyl-dithiophosphorylethyl)-benzene sulfonamide, is a relatively new herbicide, first appearing in the literature in 1963 (10). The herbicide is unique in that it is an aliphatic acid containing nitrogen, phosphorus, and sulfur. No information is available concerning the toxic mechanism of Bensulide. However, herbicides of a particular class tend to have similar modes of action by which they are toxic to plants.

Other aliphatic acids, Dicamba, TCA, and Dalapon, apparently exert toxicity to plants by interfering with the pathway of pantothenate formation (13, 14, 15, 29). Pantothenate is a constituent of coenzyme A and thus occupies a central position in the metabolism of all organism. Biosynthesis of pantothenate (13) results from the combination of pantoate with beta-alanine. Pantoate is formed from alpha-ketoisovalerate.

Hilton et al., (14) in 1958 reported that chloro-substituted propionic and isobutyric acids toxicity could be eliminated by an exogenous supply of beta-alanine. This suggested that aliphatic acid herbicides interfere with pantothenate synthesis. In vitro studies by Hilton et al., (15) in 1959 showed Dalapon did compete with pantoate for a site on the enzyme of synthesis for pantothenate. Unchlorinated aliphatics were found to block the utilization of beta-alanine in *Escherichia coli*, while chlorinated aliphatic acid derivatives inhibit pantothenate production by competing with pantoate. Hilton (13) in 1965 succeeded in pinpointing the reactions inhibited by several aliphatics. Propionate was found to prevent the formation of pantothenate from beta-alanine, salicylate stopped the conversion of alpha-ketoisovalerate to ketopantoate, Dicamba blocked the conversion of ketopantoate to pantoate, and Dalapon prevented the formation of pantothenate from pantoate.

Bensulide's most important use at the present time is as a turf herbicide. Applications of 7.5 to 10 p.p.m. of Bensulide have resulted in greater than 90% control of crabgrass without serious injury to turfgrasses (10, 11, 20). Bensulide applications at the time of turf establishment have resulted in injury to bluegrass, fescue, and bentgrass, but no injury resulted with turf establishment 2 months after application time (3).

Bensulide persists in the soil for long lengths of time. A 7.5 p.p.m. application gave 49% crabgrass control one year later and 10%

crabgrass control two years later (20).

Bensulide phytotoxicity was shown to be strongly influenced by soil organic matter additions (21). High carbon-nitrogen and medium carbon-nitrogen ratios of organic additions greatly reduced Bensulide toxicity while high nitrogen-low carbon organic additions did not appreciably affect phytotoxicity.

The phytotoxicity of Bensulide was found to be strongly affected by soil texture (21). As soil texture was made coarser, the phytotoxicity of Bensulide greatly increased.

Bensulide phytotoxicity was greatly reduced by all additions of nitrogen, phosphorus, and sulfur applied alone or in combinations (16). The most effective treatment in reducing Bensulide phytotoxicity was a 1:1:1 ratio of nitrogen, phosphorus, and sulphur.

MATERIALS AND METHODS

This study was conducted in the laboratory. Herbicidal activity was evaluated with bioassay procedures using plants grown in 8.9 X 8.9 cm. plastic pots under artificial light supplied by white and Gro-lux sources at an intensity of 500 f.c. Herbicide solutions were applied to the soil surface except where soil incorporation was specified. Herbicide formulation of 2-chloro-N-isopropylacetanilide (Ramrod) was a 65% a.i. wettable powder, formulation of 2-chloro-N, N-diallylacetamide (CDAA) was 429.5 g/l a.i. emulsifiable liquid, and formulation of N-(beta-O,O-diisopropyl-dithiophosphorylethyl)-benzene sulfonamide (Bensulide) was a 62.9% a.i. emulsifiable liquid.

Experiments in this study were conducted with Eufaula sand, a Typic Quarzipsamment, and with Brewer clay loam, a Typic Argiustoll. Analyses of these soils are shown in Table I.

Foxtail millet, Setaria italica (L) Beauv., and grain sorghum, Sorghum vulgare Pers. were used as bioassay plants. Growth periods were 10 days for foxtail millet and 7 days for grain sorghum. Herbicide activity was evaluated by weighing aerial portions of the plants after drying at 100° C for 24 hours.

Organic Matter Experiments

Organic matter studies were conducted on Eufaula sand with three levels of organic matter additions, 1%, 2%, and 3%. The organic matter additive was prepared by mixing equal portions of finely ground

TABLE I

CHARACTERISTICS OF EUFAULA AND BREWER SOILS

	Eufaula	Brewer
% Sand	90.0	27.1
% Silt	7.0	44.6
% Clay	3.0	29.3
% Organic Matter	0.5	3.1
% Total Nitrogen	0.04	0.11
Cation Exchange Capacity*	2.7	14.6
Exchangable Cations*		
Calcium	1.1	9.5
Magnesium	0.9	3.1
Potassium	0.3	0.5
Available Phosphorus**	6.8	6.4
pH	5.7	6.3

*milliequivalents per 100 grams soil (1N ammonium acetate)

**pounds per acre (.025 N HCl)

alfalfa leaves (2.4% N) and wheat straw (.39% N). Four herbicide levels at each organic matter level were used in all combinations in a 4 X 4 factorial.

The Ramrod experiment with organic matter was bioassayed with grain sorghum. Herbicide levels were 0, 2, 3, and 4 p.p.m. The CDAA organic matter study was also bioassayed with grain sorghum. Levels of CDAA were 0, .25, .5, and 1.0 p.p.m.

Texture Studies

Soil texture was manipulated by mixing various proportions of silica sand with Brewer clay loam soil. The finest soil texture was Brewer clay loam soil. Coarser soil textures were prepared by mixing Brewer soil and silica sand in 3:1, 1:1, and 1:3 ratios. Four levels of herbicide were used with each soil texture.

Ramrod texture experiments were bioassayed with three successive crops of foxtail millet, each having a growth period of ten days. There was no interval between crops. Ramrod levels were 0, 2, 4, and 6 p.p.m.

Texture experiments with CDAA were bioassayed with grain sorghum. The CDAA levels of 0, 1, 2, and 3 p.p.m. were mixed throughout the soil.

Fertility Studies

The influence of nitrogen and phosphorus levels and ratios upon Ramrod and CDAA phytotoxicity were evaluated with Eufaula soil. Nitrogen levels added to the soil were 0, 50, 100, and 200 p.p.m., and phosphorus levels were 0, 25, 50, 100, and 200 p.p.m.

Nitrogen-phosphorus combinations added to the soil included ratios of 4:1 (200 p.p.m. N, 50 p.p.m. P), 2:1 (200 p.p.m. N, 100 p.p.m. P), 1:1 (100 p.p.m. N, 100 p.p.m. P), 1:2 (100 p.p.m. N, 200 p.p.m. P), and 1:4 (50 p.p.m. N, 200 p.p.m. P). All fertility additions were mixed into the soil. Nitrogen and phosphorus sources were ammonium nitrate and calcium monobasic phosphate, respectively.

Influence of soil nitrogen and phosphorus upon Ramrod and CDAA phytotoxicity was evaluated with grain sorghum. Ramrod and CDAA rates were 3 p.p.m. and .25 p.p.m., respectively.

Persistence Studies

Ramrod, CDAA, and Bensulide* applications were made to Eufaula soil. Soil moisture levels were raised to approximately field capacity and the soils were then allowed to incubate for various lengths of time until bioassay was made.

Periods of incubation for Ramrod were 0, 1, 2, 3, and 4 weeks. Bioassay with foxtail millet was made at the one week intervals. Ramrod rates were 0, .5, 1, 2, and 4 p.p.m.

CDAA activity was bioassayed with foxtail millet after incubation periods of 0, 1, 2, and 3 weeks. CDAA rates were 0, 1, 2, 4, and 6 p.p.m.

Bensulide incubation periods were 0, 4, 8, 12, and 16 weeks. At the end of each incubation period, Bensulide activity was bioassayed with grain sorghum. Bensulide rates were 0, 4, and 8 p.p.m.

---

* Herbicide was soil incorporated.

RESULTS AND DISCUSSION

Data of these experiments are presented graphically and also in tables in the Appendix. Graphic figures present the data as % of the check, the checks equaling 100%

The influence of soil organic matter additions upon Ramrod effectiveness is shown in Figure 1 and Table III. Additions of organic matter resulted in highly significant reductions in the phytotoxicity of Ramrod to grain sorghum. The addition of 3% organic matter to Eufaula soil completely eliminated the phytotoxicity of Ramrod at the highest herbicide level, 4 p.p.m. Interaction between Ramrod and organic additions was significant at the 1% level.

CDAA toxicity as influenced by soil organic matter additions exhibited a trend similar to that of Ramrod. Figure 2 and Table IV show highly significant increasing reductions in the phytotoxicity of CDAA as the level of organic matter was increased. CDAA and organic matter interacted significantly. These results are in contrast with results showing CDAA to not be well correlated with organic matter content of soils containing less than 3% organic matter (28).

Soil texture manipulations were not effective in changing Ramrod phytotoxicity to foxtail millet, Table II. Failure to detect a correlation between soil texture and Ramrod phytotoxicity may have been due to the high sensitivity of foxtail millet to the herbicide. Foxtail millet growth weights did not gradually decrease in response to increased Ramrod levels, but either grew normally or were killed

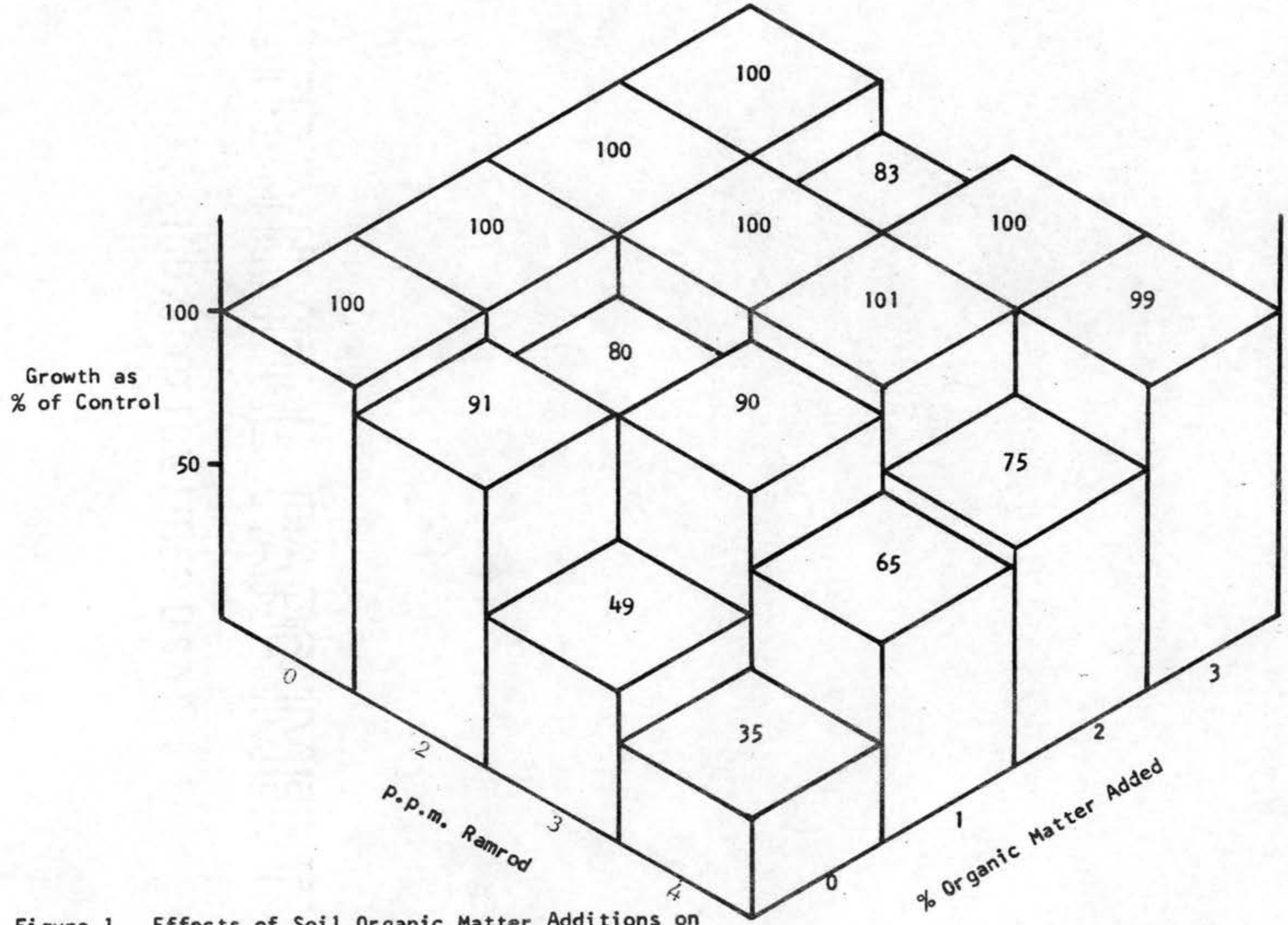

Figure 1. Effects of Soil Organic Matter Additions on Ramrod Phytotoxicity to Grain Sorghum.

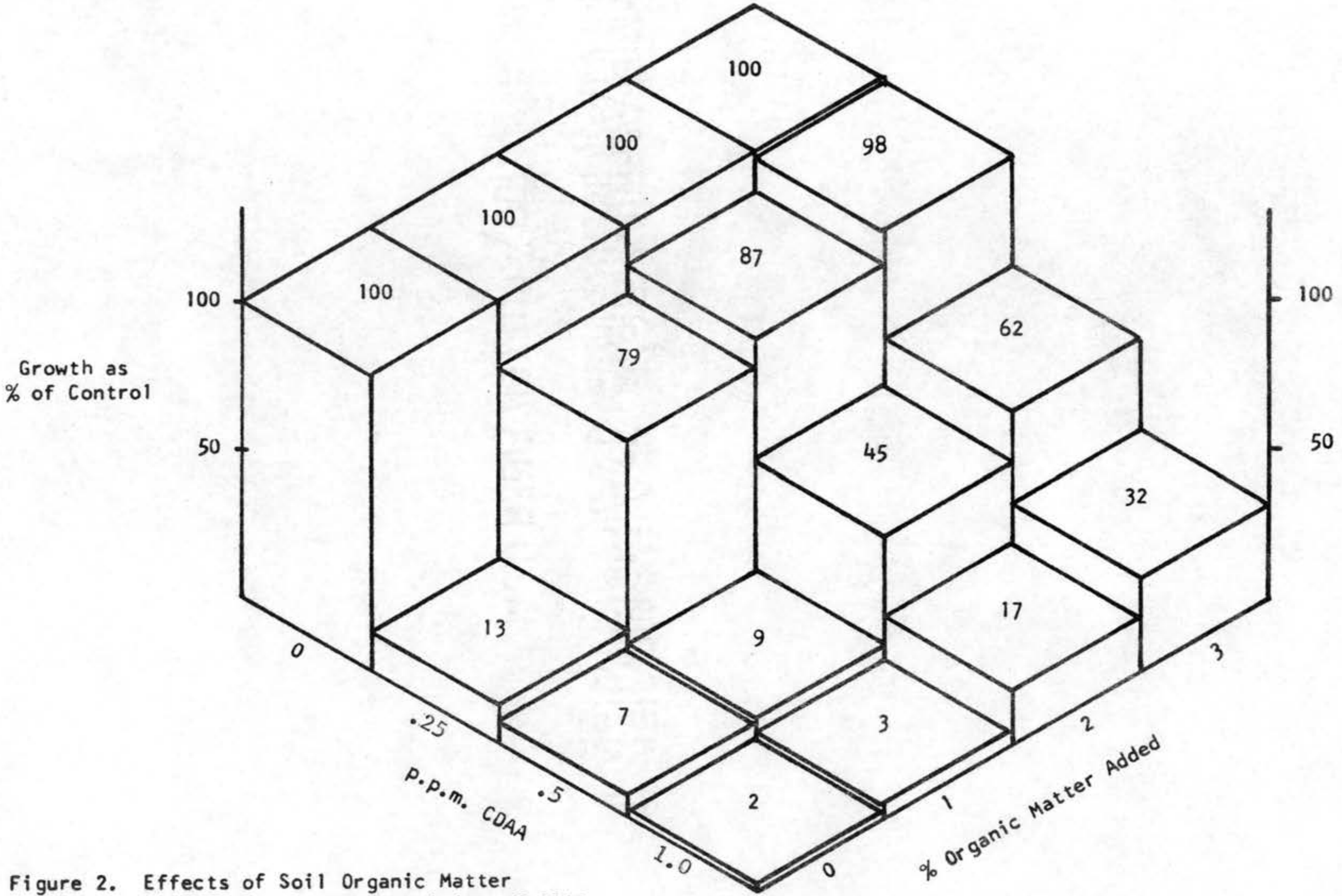

Figure 2. Effects of Soil Organic Matter Additions on Phytotoxicity of CDAA to Grain Sorghum.

TABLE II

EFFECTS OF SOIL TEXTURE ON RAMROD PHYTOTOXICITY TO FOXTAIL MILLET

Crop	p.p.m. Ramrod	Foxtail Millet Growth*				
		Brewer	B.+¼Sand	B.+½Sand	B.+3/4Sand	Σ
1	0	.070	.088	.071	.088	.317
	2	0	0	0	0	0
	4	0	0	0	0	0
	6	0	0	0	0	0
2	0	.276	.133	.098	.104	.611
	2	.056	.087	.042	.068	.253
	4	.001	0	0	.002	.003
	6	0	0	0	0	0
3	0	.314	.321	.307	.339	1.281
	2	.271	.238	.270	.255	1.034
	4	.216	.174	.190	.179	.759
	6	.138	.147	.171	.210	.666
	Σ	1.342	1.188	1.149	1.245	4.924

*Weight in grams (sum of 3 replications).

at emergence. No analytical procedures were performed on these data.

CDAA phytotoxicity was not affected by soil texture manipulations (Figure 3 and Table V). As soil texture became coarser, fewer adsorption sites were available for herbicide retention. The coarser soil textures in this experiment may have allowed CDAA to accumulate in the pot bottoms or rise to the soil surface and be lost through volatilization.

Ramrod phytotoxicity was strongly influenced by the nitrogen and phosphorus status of Eufaula soil (Figure 4 and Table VI). Increases in nitrogen levels of the soil resulted in increases in the phytotoxicity of Ramrod to grain sorghum.

Phosphorus additions of 25 and 50 p.p.m., resulted in decreased Ramrod toxicity. Additions of 100 and 200 p.p.m., of phosphorus, however, appeared to increase phytotoxicity.

Very large differences in Ramrod phytotoxicity were found between the various nitrogen and phosphorus ratios. Nitrogen-phosphorus levels of 2:1 and 1:4 resulted in large reductions in Ramrod toxicity, and 1:1 and 1:2 ratios resulted in large phytotoxicity increases. Results of fertility-herbicide experiments are expressed as percents or ratios and were not statistically analyzed. Coefficients of variation indicate the experiments were of dependable precision.

Nitrogen additions increased the phytotoxicity of CDAA in a manner similar to results with Ramrod (Figure 5 and Table VII). All phosphorus levels increased CDAA toxicity, but the levels of phosphorus and toxicity reductions seem to have no correlation. These results are in agreement with those of Upchurch and Mason (27).

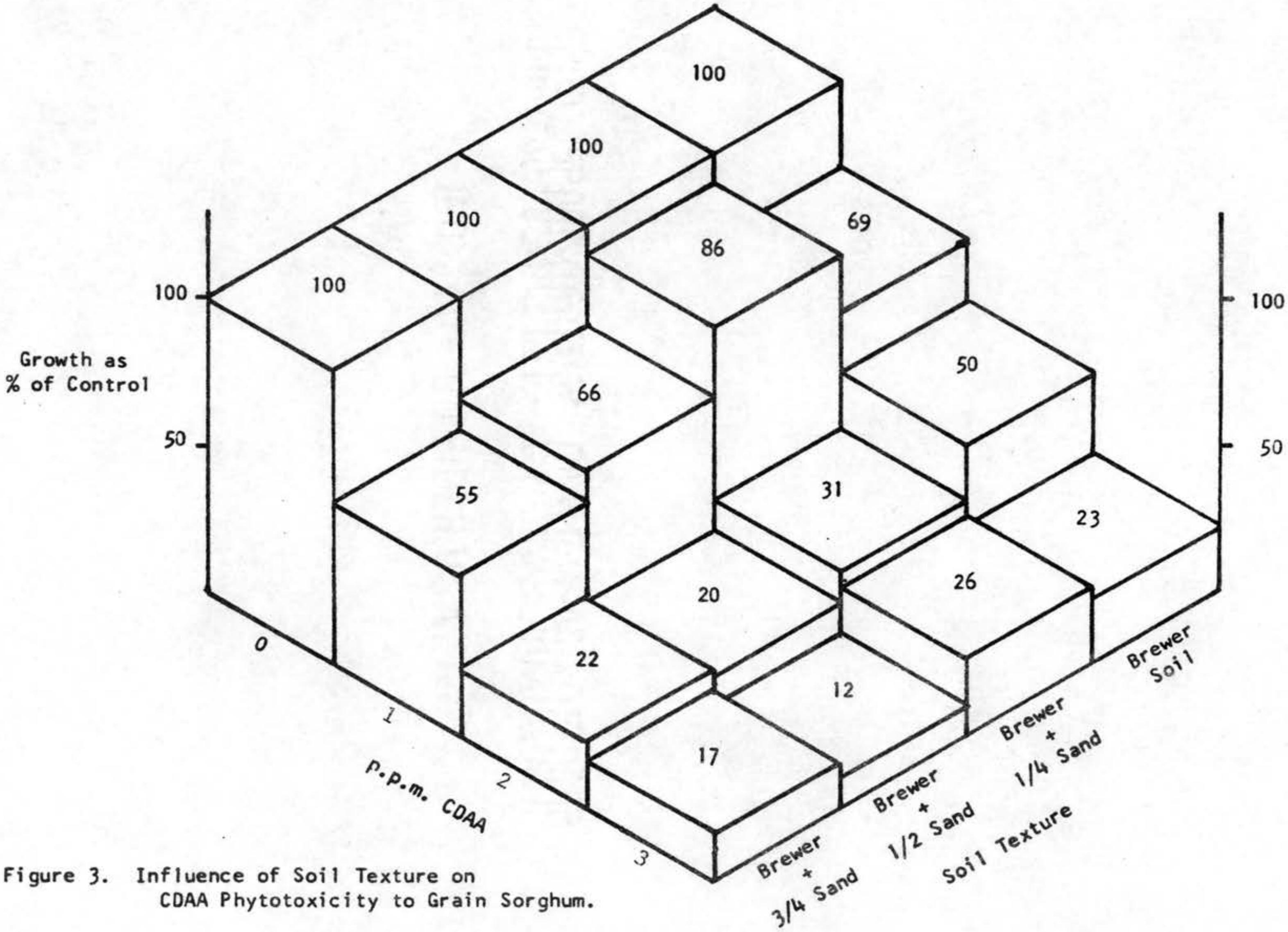

Figure 3. Influence of Soil Texture on CDAA Phytotoxicity to Grain Sorghum.

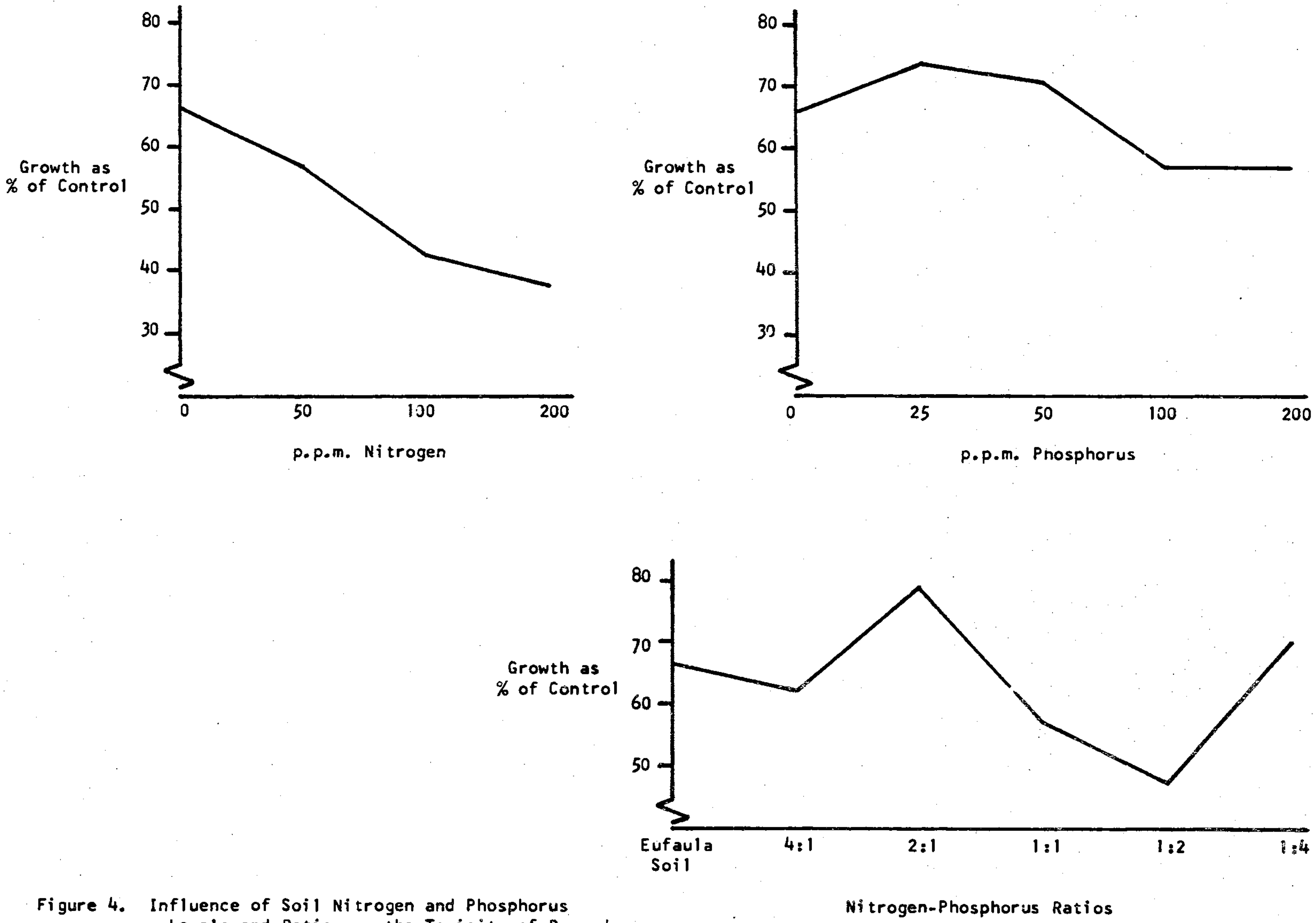

Figure 4. Influence of Soil Nitrogen and Phosphorus Levels and Ratios on the Toxicity of Ramrod to Grain Sorghum.

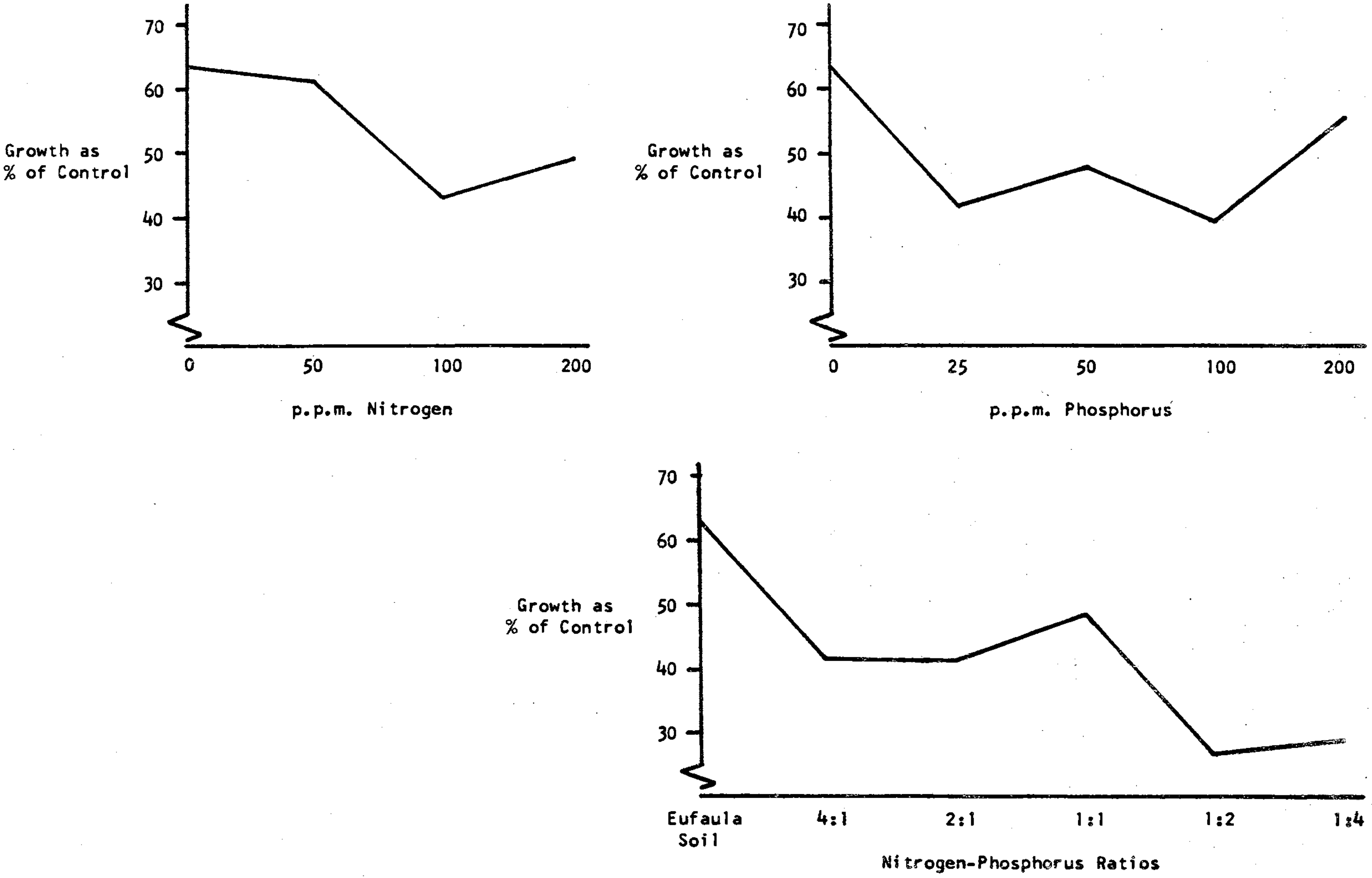

Figure 5. Influence of Soil Nitrogen and Phosphorus Levels and Ratios on the Toxicity of CDAA to Grain Sorghum.

Generally, additions of nitrogen and phosphorus increased the phytotoxicities of Ramrod and CDAA. These results are in sharp contrast with results showing Bensulide phytotoxicity to decrease with nitrogen, phosphorus, and sulfur additions.

Evaluation of the length of time the three herbicides persist in soils at phytotoxic levels is shown in Figure 6 and Table XIII (Ramrod), Figure 7 and Table IX (CDAA), and Figure 8 and Table X (Bensulide). Both Ramrod and CDAA exhibited relatively short periods of residual activity. Ramrod levels up to 4 p.p.m. were not phytotoxic to foxtail millet after 4 weeks, and CDAA levels up to 6 p.p.m. were not phytotoxic three weeks after application. Bensulide remained at phytotoxic levels much longer than did Ramrod and CDAA. Four p.p.m. of Bensulide were no longer phytotoxic to grain sorghum after 12 weeks and 8 p.p.m. did not appear to be toxic after 16 weeks. Bensulide remained at phytotoxic levels for much shorter periods of time in this study than in the study of Lewis and Lilly (20) which was done in the field. Optimum temperature and soil moisture conditions during incubation may have increased microbial degradation of Bensulide and shortened the residual period. Slower microbial degradation rates would be expected under field conditions where microbial activity is low during unfavorable moisture and temperature conditions. Evidence, however, showing that Bensulide is microbiologically degraded is not available. Persistence studies were not statistically analyzed.

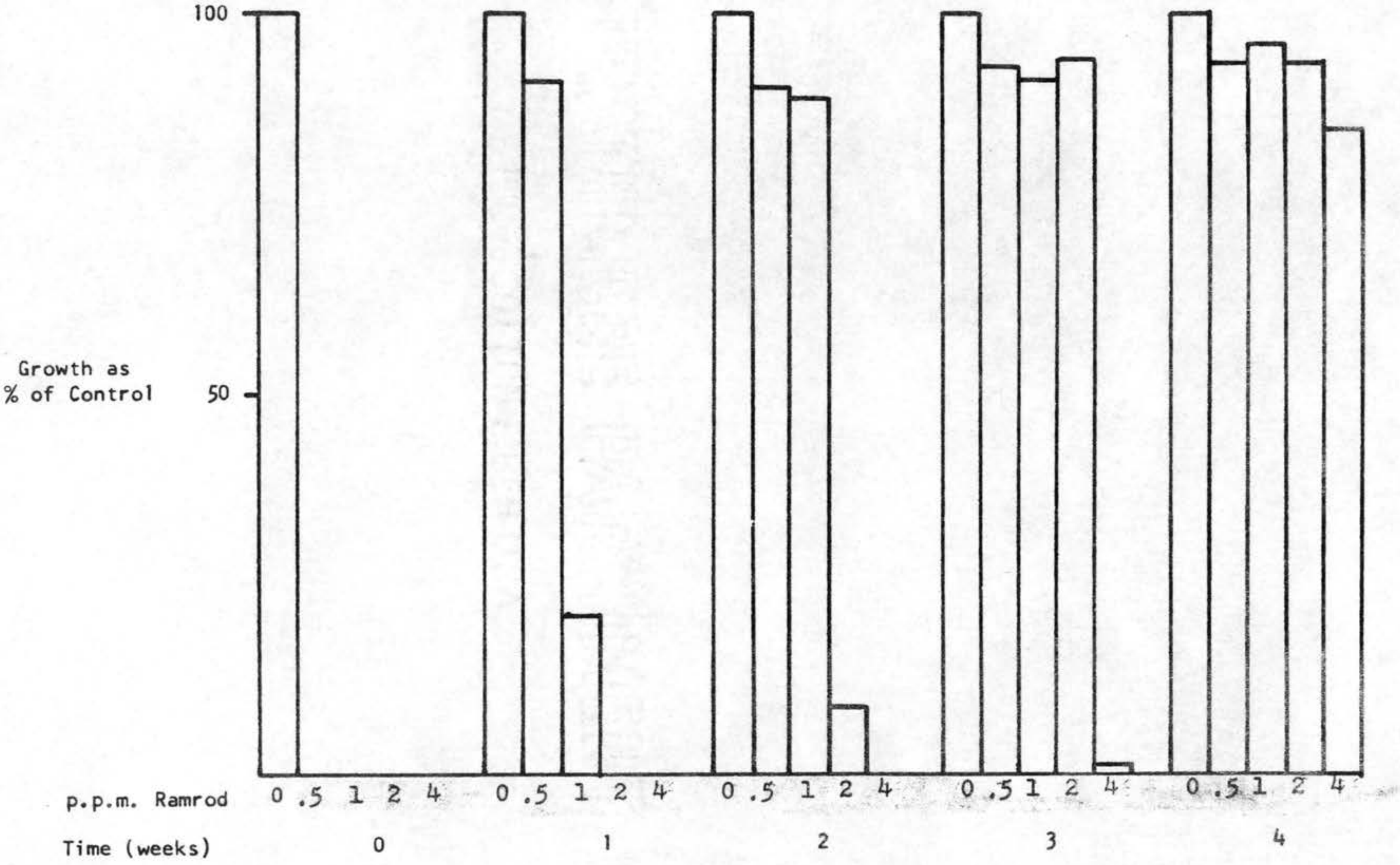

Figure 6. Toxicity of Ramrod to Foxtail Millet as Affected by Length of Time Between Application to the Soil and Bioassay.

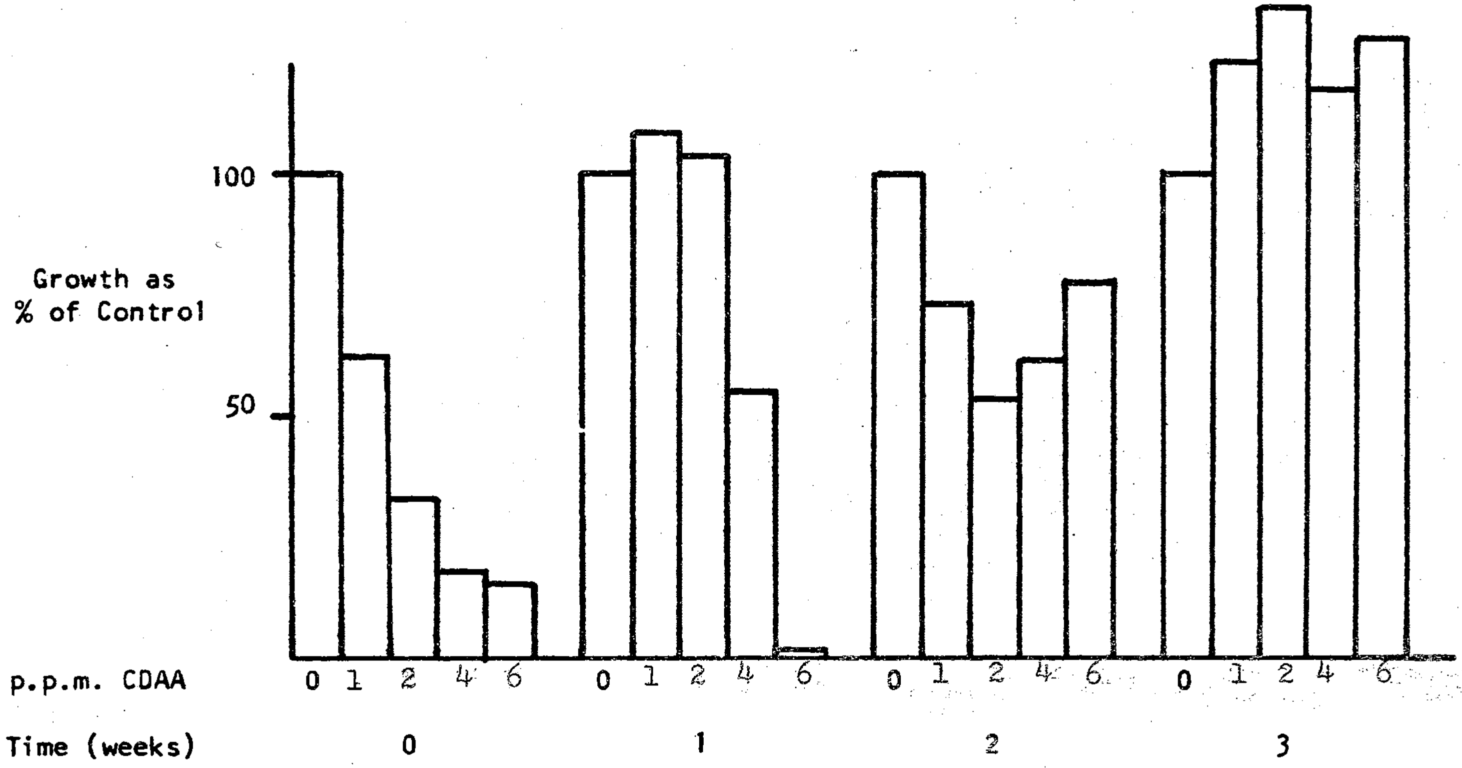

Figure 7. Toxicity of CDAA to Foxtail Millet as Affected by Length of Time Between Application to the Soil and Bioassay.

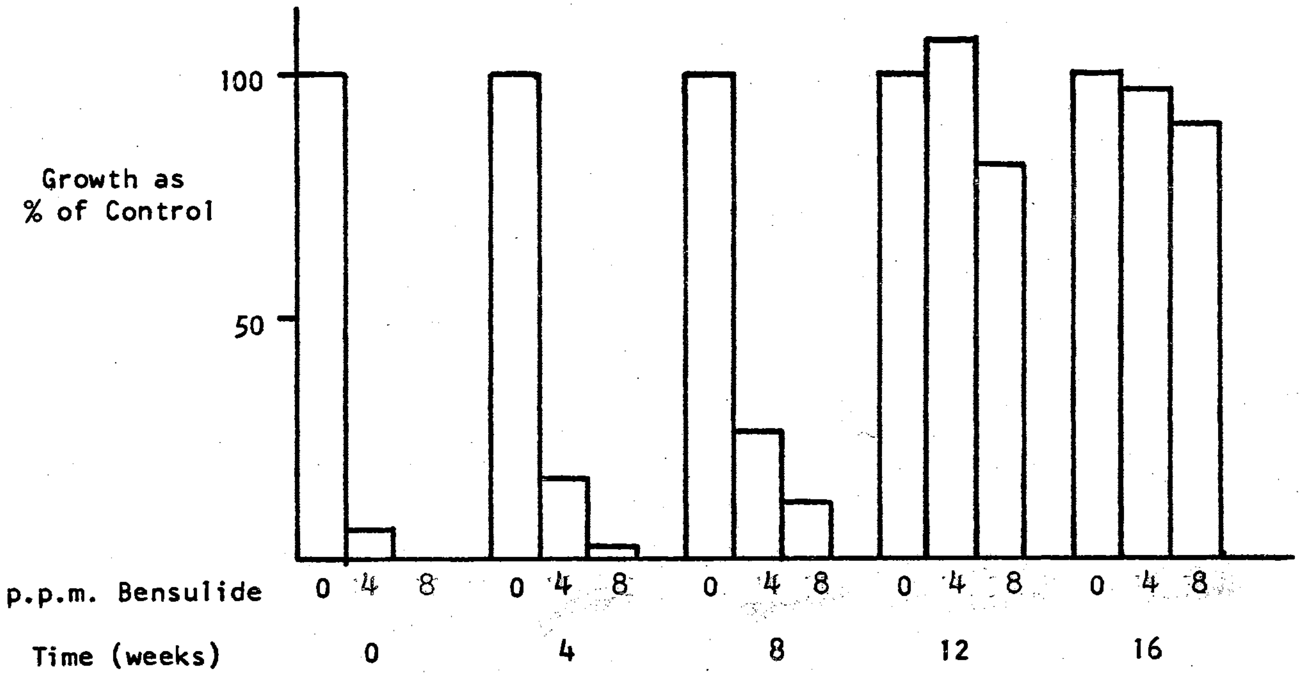

Figure 8. Toxicity of Bensulide to Grain Sorghum as Affected by Length of Time Between Application to the Soil and Bioassay.

SUMMARY AND CONCLUSIONS

The objective of these experiments was to evaluate the influence of soil organic matter, soil texture, and soil fertility upon the phytotoxicity of Ramrod and CDAA. The length of time Ramrod, CDAA, and Bensulide persist in the soil at phytotoxic levels was also determined. Treatments were made to Brewer and Eufaula soils and herbicide activity was bioassayed with either foxtail millet, Sertaria italica (L) Beauv., or grain sorghum, Sorghum vulgare Pers.

The effectiveness of Ramrod and CDAA was strongly influenced by the organic matter content of the soil. Decreases in phytotoxicity were proportional to the amount of organic matter added to the soil.

Ramrod and CDAA effectiveness was not influenced by soil texture.

Ramrod phytotoxicity was increased proportionally to the amount of nitrogen added to the soil. Additions of 25 and 50 p.p.m. of phosphorus resulted in small phytotoxicity reductions, but phytotoxicity was increased at higher phosphorus levels. Nitrogen-phosphorus ratios of 2:1 and 1:4 decreased Ramrod phytotoxicity and nitrogen-phosphorus ratios of 4:1, 1:1, and 1:2 increased Ramrod phytotoxicity. All nitrogen and phosphorus fertility additions increased CDAA phytotoxicity, but phytotoxicity increases were not correlated with the amount of nitrogen or phosphorus added. Phytotoxic residuals of Ramrod and CDAA remained in the soil for short lengths of time, approximately three or four weeks. Bensulide, with a longer residual period, remained at phytotoxic levels for twelve to sixteen weeks.

LITERATURE CITED

1. Agricultural Research Service. Losses in Agriculture. U. S. Dept. of Agr. Handbook No. 291, 120 p. 1965.

2. Anonymous, CP 31393 - Selective Herbicide for Experimental Use. The Monsanto Company. January 1965.

3. Bingham, S. W. and R. E. Schmidt. Crabgrass control in turf. Proc. Southern Weed Conf. 17: 113-122. 1964.

4. Bingham, S. W. and R. P. Upchurch. Some interactions between nutrient level (N, P, K, Ca) and diuron in the growth of cotton and Italian ryegrass. Weeds 7: 167-177. 1959.

5. Bounds, Harold C. and Arthur R. Colmer. Detoxification of some herbicides by Streptomyces. Weeds 13: 249-252. 1965.

6. Canvin, D. T. and G. Friesen. Cytological effects of CDAA and IPC on germinating barley and peas. Weeds 7: 153-156. 1959.

7. Crafts, A. S. The relation of nutrients to toxicity of arsenic, borax, and chlorate in soil. J. Agr. Res. 58: 637-671. 1939.

8. Darlington, C. D. and John McLeish. Action of maleic hydrazide on cells. Nature 167: 407-408. 1951.

9. Deming, J. M. Determination of volatility losses of C^{14} CDAA. Weeds 11: 91-96. 1963.

10. Dewald, C. L., L. W. Francher, and B. H. Lake. Betasan-a promising new herbicide for use on turf. Proc. Southern Weed Conf. 16: 110-114. 1963.

11. Duich, J. M., B. R. Fleming, A. E. Dudeck, and G. J. Shoop. 1963 crabgrass control results in Pennsylvania. Proc. Northeastern Weed Control Conf. 18: 507-509. 1964.

12. Gantz, R. L. and F. W. Slife. Persistence and movement of CDAA and CDEC in soil and tolerance of corn seedlings to these herbicides. Weeds 8: 599-606. 1960.

13. Hilton, J. L. Inhibition of pantothenate biosynthesis by substituted benzoic acids. Weeds 13: 267-271. 1965.

14. Hilton, J. L., L. L. Jansen, and W. A. Gentner. Beta-alanine protection of yeast growth against the inhibitory action of several chlorinated aliphatic acid herbicides. Plant Physiol. 33: 43-45. 1958.

15. Hilton, J. L., J. S. Ard, L. L. Jansen, and W. A. Gentner. The pantothenate-synthesizing enzyme, a metabolic site in the herbicidal action of chlorinated aliphatic acids. Weeds 7: 381-396. 1959.

16. Hodgden, Robert and Charles Harms. Soil fertility levels governing Bensulide phytotoxicity to Digitaria sanguinalis. Agronomy Abstract, American Society of Agronomy Meetings. August, 1966.

17. Isenberg, F. M. R., M. L. Odland, H. W. Popp, and C. O. Jensen. The effect of maleic hydrazide on certain dehydrogenases in tissues of onion plants. Science 113: 58-60. 1951.

18. Ishaque, M. Studies on the relation of mineral elements to the effect of 2,4-D on rice. Proc. Southern Weed Conf. 2: 63-64. 1949.

19. Kramer, P. J. Effects of respiration inhibitors on accumulation of radioactive phosphorus by roots of loblolly pine. Plant Physiol. 26: 30-36. 1951.

20. Lewis, W. N., and J. Paul Lilly. Retreatments of pre-emergence and postemergence crabgrass herbicides and their residual effects on the establishment of three turfgrasses. Proc. Southern Weed Conf. 19: 161-167. 1966.

21. Lynd, J. Q., C. E. Rieck, and P. W. Santlemann. Soil components determining Bensulide phytotoxicity. Agron. J. 58: 508-510. 1966.

22. Sheets, T. J. Effects of soil type and time on the herbicidal activity of CDAA, CDEC, and EPTC. Weeds 7: 442-448. 1959.

23. Sheets, T. J., A. S. Crafts, and H. R. Drever. Influence of soil properties on the phytotoxicities on the s-triazine herbicides. J. Agr. and Food Chem. 10: 458-462. 1962.

24. Sherburne, H. R., and V. H. Freed. Adsorption of 3 (p-chlorophenyl)-1, 1-dimethylurea as a function of soil constituents. J. Agr. and Food Chem. 2: 937-939. 1954.

25. Southern Weed Conference - Research Report. Economic data on losses due to weeds, 172-200. 1965.

26. Upchurch, R. P., G. R. Ledbetter, and F. L. Selman. The interaction of phosphorus with the phytotoxicity of soil applied herbicides. Weeds 11: 36-41. 1963.

27. Upchurch, R. P., and D. D. Mason. The influence of soil organic matter on the phytotoxicity of herbicides. Weeds 10: 9-13. 1962.

28. Upchurch, R. P., F. L. Selman, D. D. Mason, and E. J. Kamprath. The correlation of herbicidal activity with soil and climate factors. Weeds 14: 42-49. 1966.

29. van Oorschot, J. L. P., and J. L. Hilton. Effects of chloro substitutions on aliphatic acid inhibitors of pantothenate metabolism in *Escherichia coli*. Arch. Biochem. Biophys. 100: 289-294. 1963.

30. Voight, G. K. The effect of fungicides, herbicides, and insecticides on the accumulation of phosphorus by *Pinus radiata* as determined by the use of P^{32}. Agron. J. 46: 511-513. 1954.

APPENDIX

TABLE III

SOIL ORGANIC MATTER AMENDMENT EFFECTS ON RAMROD PHYTOTOXICITY TO GRAIN SORGHUM

	Grain Sorghum Growth* Percent Organic Matter Added				
p.p.m. Ramrod	0	1	2	3	Σ
0	.198	.192	.232	.221	.843
2	.180	.154	.233	.184	.751
3	.097	.174	.235	.222	.728
4	.069	.125	.174	.218	.586
Σ	.544	.645	.874	.845	2.908

Treatment F = 13.2**, Organic Matter F = 32.9**,

Herbicide F = 17.1**, Organic Matter X Herbicide = 2.6**

C. V. = 14%

*Dry weight in grams (sum of 3 replications).

**Significant at .01 level.

TABLE IV

EFFECTS OF SOIL ORGANIC MATTER AMENDMENTS ON CDAA PHYTOTOXICITY TO GRAIN SORGHUM

p.p.m. CDAA	Grain Sorghum Growth* Percent Organic Matter Added 0	1	2	3	Σ
0	.230	.256	.222	.204	.912
.25	.030	.203	.193	.199	.625
.50	.015	.024	.101	.126	.266
1.0	.005	.007	.037	.066	.115
Σ	.280	.490	.553	.595	1.918

Treatment F = 25.17**, Organic Matter F = 16.29**

Herbicide F = 94.48**, Organic Matter X Herbicide = 5.69**,

C.V. = 27%

*Dry Weight in Grams (sum of 3 replications).

**Significant at .01 level.

TABLE V

INFLUENCE OF SOIL TEXTURE ON CDAA PHYTOTOXICITY TO GRAIN SORGHUM

	Grain Sorghum Growth Soil Texture Manipulations				
p.p.m. CDAA	Brewer	B.+¼Sand	B.+½Sand	B.+3/4Sand	Σ
0	.108	.101	.113	.098	.420
1	.075	.087	.075	.054	.291
2	.054	.031	.023	.022	.130
3	.025	.026	.014	.017	.082
Σ	.262	.245	.225	.191	.923

Herbicide F = 30.62** Texture F = 1.18 (n.s.)

Herbicide X Texture F = 0 (n.s.) C.V. = 37%

---

*Dry weight in grams (sum of 3 replications).

**Significant at .01 level.

n.s. = not significant at .05 level.

TABLE VI

PHYTOTOXICITY OF RAMROD TO GRAIN SORGHUM AS INFLUENCED BY LEVELS AND RATIOS OF NITROGEN AND PHOSPHORUS

Fertility Treatment (ppm)		Grain Sorghum Growth* Herbicide Treatment		Percent of Check**
Nitrogen	Phosphorus	0	3 ppm Ramrod	
0	0	.297	.198	66.6
50	0	.323	.186	57.5
100	0	.345	.148	42.9
200	0	.244	.094	38.5
0	25	.286	.212	74.1
0	50	.326	.229	70.2
0	100	.330	.188	57.0
0	200	.301	.173	57.5
200	50	.263	.164	62.4
100	50	.228	.181	79.4
100	100	.327	.188	57.5
50	100	.360	.171	47.5
50	200	.296	.222	75.0

C.V. = 25%

*Dry weights in grams (sum of 4 replications).

**Ratio of untreated to treated sums.

TABLE VII

INFLUENCE OF NITROGEN AND PHOSPHORUS LEVELS AND RATIOS ON CDAA PHYTOTOXICITY TO GRAIN SORGHUM

Fertility Treatment (ppm)		Grain Sorghum Growth* Herbicide Treatment		Percent of Check**
Nitrogen	Phosphorus	0	.25 ppm Randox	
0	0	.319	.201	63.0
50	0	.336	.206	61.3
100	0	.342	.150	43.9
200	0	.290	.143	49.3
0	25	.360	.150	41.7
0	50	.363	.171	47.1
0	100	.338	.134	39.6
0	200	.336	.185	55.1
200	50	.255	.105	41.2
100	50	.331	.137	41.4
100	100	.347	.166	47.8
50	100	.322	.117	36.3
50	200	.303	.116	38.3
C.V. = 27%				

*Dry weights in grams (sum of 4 replications).

**Ratio of untreated to treated sums.

TABLE VIII

INFLUENCE OF SOIL INCUBATION TIME ON TOXICITY OF RAMROD TO FOXTAIL MILLET

Weeks of Incubation	Foxtail Millet Growth* Ramrod Levels (p.p.m.)					
	0	.5	1	2	4	Σ
0	.388	0	0	0	0	.388
1	.422	.387	.088	0	0	.897
2	.243	.219	.215	.020	0	.697
3	.538	.498	.486	.508	.005	2.035
4	.245	.228	.236	.229	.209	1.147
Σ	1.836	1.332	1.025	.757	.214	5.164

*Weight in grams (sum of 3 replications).

TABLE IX

INFLUENCE OF SOIL INCUBATION TIME ON THE PHYTOTOXICITY OF CDAA TO FOXTAIL MILLET

Weeks of Incubation	Foxtail Millet Growth* CDAA Levels (p.p.m.) 0	1	2	4	6	Σ
0	.090	.056	.030	.016	.014	.206
1	.085	.092	.088	.048	.009	.322
2	.078	.058	.042	.048	.062	.288
3	.062	.077	.084	.073	.080	.376
Σ	.315	.283	.244	.185	.165	1.192

*Weight in grams (sum of 3 replications).

TABLE X

INFLUENCE OF SOIL INCUBATION TIME ON THE PHYTOTOXICITY OF BENSULIDE TO GRAIN SORGHUM

Weeks of Incubation	Grain Sorghum Growth* Bensulide Levels (p.p.m.) 0	4	8	Σ
0	.179	.011	0	.190
4	.184	.030	.003	.217
8	.185	.049	.021	.255
12	.179	.191	.145	.515
16	.192	.184	.173	.549
Σ	.919	.465	.342	1.726

*Weight in grams (sum of 3 replications).

VITA

ROBERT MARION HODGDEN

Candidate for the Degree

of

Master of Science

Thesis: SOIL PARAMETERS INFLUENCING HERBICIDAL ACTIVITY AND PERSISTENCE OF RAMROD, CDAA, AND BENSULIDE

Major: Agronomy

Biographical:

Personal Data: Born in Enid, Oklahoma, October 24, 1943, the son of Walter N. and Norma Hodgden.

Education: Graduate of Enid Memorial High School in 1961; received the Bachelor of Science degree from Oklahoma State University in Agronomy in August, 1965; graduate study at Oklahoma State University from September, 1965 to July, 1967.

Experience: Reared on a farm and worked on farms during summers of undergraduate training; Graduate Research Assistant in the Agronomy Department of Oklahoma State University from February, 1966 to June, 1967.

Member of: American Society of Agronomy, Crop Science Society of America, International Soil Science Society.