RESIDUAL EFFECTIVENESS AND CONTACT TOXICITY OF SIX NEW SYNTHETIC INSECTICIDES TO GRASSHOPPERS

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by

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PREFACE

In June of 1949, the writer was assigned to work with Dr. Charles H. Brett as a laboratory and field assistant in the Entomology Department of Oklahoma Agricultural and Mechanical College.

Two new insecticides called Compound "497" and Compound "118" had been developed by the Julius Hyman Company of Denver, Colorado. An interest concerning their effectiveness for controlling grasshoppers as compared to some of the existing recommended insecticides, led to the research reported in this thesis.

The writer wishes to express his appreciation to the staff of the Entomology Department of Oklahoma Agricultural and Mechanical College for their helpful advice and criticisms and especially to Dr. Charles H. Brett, under whose supervision the experimental work was carried out. Dr. Brett has been a constant source of encouragement and guidance and has offered invaluable constructive criticisms in the writing of this paper. Dr. J. R. Dogger also offered many helpful suggestions. Dr. F. A. Fenton and Dr. R. G. Dahms gave excellent advice in the critical reading of this thesis.

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INTRODUCTION

Control of economic species of grasshoppers in Oklahoma has often been unsatisfactory with the use of poison baits. It has been the expressed hope of farmers and research workers that some of the newer organic insecticides would be more effective and economical.

The grasshopper compares with the boll weevil and chinch bug as three of Oklahoma's worst insect pests. Two of the most important economic species of grasshoppers in Oklahoma are the lesser migratory grasshopper, *Melanoplus mexicanus mexicanus* (Sauss.) and the differential grasshopper, *Melanoplus differentialis* (Thos.). These two species were used exclusively in the tests reported in this thesis.

Benzene hexachloride ($C_6H_6Cl_6$) (6)[1] is a compound known as 1,2,3,4,5,6-hexachlorocyclohexane. Developed in Great Britain by the Imperial Chemical Industries, Hawthorndale Laboratories, Jealotts Hill, under the supervision of Dr. O. B. Lean. Since the chlorine atoms may attach to the benzene structure in a number of ways, at least five different or insomeric benzene hexachlorides may form. The gamma isomer of the compound is generally recognized as being the active insecticide and it is the per cent of this isomer that is considered in all these experiments reported. It has been widely recognized as a grasshopper or locust poison. Brett and Rhoades (2) found that a dust containing 5 per cent gamma isomer, applied at the rate of 10 pounds per acre gave complete control of grasshoppers in alfalfa. Hill and Hixson (12) also had good results with benzene hexachloride in controlling grasshoppers in Nebraska in 1946.

Chlordane ($C_{10}H_6Cl_8$) (6) is a compound known as 1,2,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane. It is a colorless, odorless liquid with

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[1] Numbers in parentheses refer to Literature cited, Page 32.

a boiling point of 175°C. at 2 mm. pressure. It is soluble in many organic solvents, but insoluble in water. Miscible in deodorized kerosene, it decomposes in the presence of weak alkalies. Its volatility is intermediate between DDT and benzene hexachloride. It has been generally recommended for grasshopper control.

Another synthetic insecticide called toxaphene ($C_{10}H_{10}Cl_8$) has been developed by the Hercules Powder Company and tested to some extent in Montana (17). It is a mixture of isomers of octachloro-camphenes (6). Similar in action to DDT but with very adhesive residual films.

Parathion, ($C_{10}H_{14}O_5NPS$), an organic phosphate o, O-diethyl-O-p nitrophenyl thiophosphate has been recommended by some authors for grasshopper control. It has a high boiling point and a specific gravity of 1.26, is quite stable in normal waters and resists oxidation (6).

Several compounds have been isolated from the insecticide known as technical chlordane. Two of these which have shown particular promise as insecticides have been given the coined generic names of aldrin and dieldrin. Kearns (15) (1949) called them "II" and "III" for the want of a better name. Aldrin was called compound "118" by Julius Hyman Company, is 1, 2, 3, 4, 10, 10-hexachloro-1:4,5:8-diendomethano-1,4,4a,5,8,8a-hexa-hydronaphthalene with an empirical formula $C_{12}H_8Cl_6$. This nearly odorless compound is a white, crystalline solid, with a melting point of 100-103°C. It is very highly soluble in most organic solvents, but is insoluble in water. Dieldrin, an oxygenated deriviation of aldrin, resembles aldrin in most of its physical properties although it is somewhat less soluble in organic solvents. Its melting point is 173°C. It is stable to strong alkalies but decomposes in the presence of strong acids. Part of the work reported in this paper is a comparison of these new compounds with chlordane, toxaphene, parathion, and benzene hexachloride as stomach and contact toxins.

Effectiveness of Insecticides as Residual Toxicants

Benzene hexachloride has given good results on numerous occasions. Graham (9) reported almost 100 per cent mortality with benzene hexachloride in an orchard using an emulsion containing 0.5 per cent of the gamma isomer. The grasshoppers most numerous were Melanoplus differentialis (Thos). Kearns (14) tested acute oral toxicity to adult Melanoplus differentialis (Thos) by placing a drop of benzene hexachloride dissolved in an organic solvent, on the mouth of the individual grasshopper and holding it until the liquid was ingested. He concluded that the median lethal dosage per gram of body weight of benzene hexachloride lies between 5 and 10 micrograms of the gamma isomer and chlordane between 12.5 and 25 micrograms. It is evident from the volume of work reported on benzene hexachloride that most of the toxic action is derived from contact and the residual period of effectiveness is relatively short. Weinman and Decker (19) reported that benzene hexachloride shows less residual effect on Melanoplus femur-rubrum (Deg.) nymphs than either chlordane or toxaphene. On potted bean plants they found that chlordane was toxic for an appreciably longer time than either benzene hexachloride or toxaphene. Benzene hexachloride showed the shortest period of effectiveness. As a stomach poison, chlordane was approximately 2.5 times as effective as benzene hexachloride, and 7 times more active than toxaphene.

Griffith and King (11) sprayed and dusted citrus trees and introduced adult Schistocerca americana (Drury) into the cages that had been placed over the citrus trees. Toxaphene and chlordane exhibited significant residual toxicity for more than a week whereas benzene hexachloride and parathion showed little or no toxicity after 3 days. Gains and Dean (8) dusted cotton plants and enclosed approximately 35 nymphs of 3 species of grasshoppers in a cage with the cotton plants. Parathion and benzene hexachloride were the quickest acting materials, killing nearly 80 per cent of the population within 48 hours. Chlordane and toxaphene were slower acting poisons. In a similar test in 1947, Gains (7) found chlordane to be more toxic than either benzene hexachloride, benzene hexachloride-DDT, toxaphene or parathion.

Kearns (15) demonstrated that L.D.50 values for adult _Melanoplus differentialis_ (Thos.) show aldrin and dieldrin are approximately 6 times as toxic as chlordane as contact insecticides and are 3 or 4 times as toxic as chlordane as stomach poisons. Weinman and Decker (21) ran residual test in 1948, using chlordane, toxaphene, parathion, and aldrin. Aldrin was the only compound that showed any appreciable control after 10 days. Toxaphene at 2 pounds per acre was approximately as effective as chlordane at 1 pound per acre but slower in its action. Aldrin began to lose toxicity after 10-14 days and had no significant toxicity after 21 days even with 5 pounds per acre, which is 20 times that necessary to get control. Gains and Dean (8) were the first to report any results from dieldrin, in a field test. Dieldrin gave 100 per cent mortality against first and second instar nymphs of _Melanoplus differentialis_ (Thos.). They reported that dieldrin was superior as a residual insecticide to chlordane, toxaphene, benzene hexachloride, parathion, and aldrin. Butcher, Wilbur, and Dahm (4) found similar results with aldrin, chlordane, and parathion, each securing 100 per cent reduction in the grasshopper population which consisted of several common species found in Kansas. Parathion soon lost its toxicity.

Although Weinman and Decker (19) found a rather fast breakdown for toxaphene, Parker (17) made some rather extensive studies of the residual properties of toxaphene and reported that some was present for as long as 31 days after spraying with an oil emulsion. However, the toxaphene was present in chemical analysis and was not tested to see if it was still toxic to insects.

Temperature and humidity have an influence on the effectiveness of benzene hexachloride. Brett and Rhoades (2) obtained higher mortality at higher temperatures. Hill and Hixson (12) state that

> "Because benzene hexachloride remains effective in the field for at least 2 or 3 days, any grasshoppers escaping death at the time of dusting may later obtain a lethal dose when they return to the foliage to feed or rest. In one field observation 1.15 per cent and 5.0 per cent gamma benzene hexachloride dust were killing grasshoppers 6 days after application."

Effectiveness of Insecticides as Contact Toxicants

Benzene hexachloride and parathion appear to be much more effective to grasshoppers as a contact poison than as residual toxicants. Weinman, Decker and Bigger (20) placed adult <u>Melanoplus differentialis</u> (Thos.) in covered vegetation and then sprayed or dusted both the plants and the grasshoppers with benzene hexachloride, toxaphene, and chlordane. Benzene hexachloride showed more effective contact action than either chlordane or toxaphene. They also applied each toxicant by dissolving it in acetone and placing it on the metathoracic and first abdominal terga by means of a small wire loop. By measuring the quantity deposited on a glass slide it was possible to approximate the "milligrams per gram of hopper weight" necessary to kill the grasshopper. By this method they deducted that benzene hexachloride was approximately 1.75 times as toxic as chlordane and 62 times as toxic as toxaphene on adult <u>Melanoplus differentialis</u> (Thos.) as a contact poison.

Gains (7) dusted some nymphs and placed them in cages containing clean cotton plants. The nymphs were of several species but were mostly <u>Melanoplus differentialis</u> (Thos.). Benzene hexachloride proved to be the most effective material used, chlordane and parathion were more toxic than toxaphene. He concluded that benzene hexachloride acts more as a contact than as a stomach poison. In 1948 Gains and Dean (8) had similar results in that benzene hexachloride and parathion proved more effective as contact poisons than either toxaphene or chlordane.

Benzene hexachloride gives a quick "knockdown" of the grasshoppers. Petty (18) found that a high percentage of grasshoppers that were "knocked-down" by benzene hexachloride recovered upon removal from the sprayed surface. Weinman and Decker (19) state that the peak is reached in 24 hours and after that reinfestation from adjacent fields will begin.

Brett and Rhoades (2) suggest that parathion and benzene hexachloride kill largely by contact action and could be used as dust to an advantage. Weinman and Decker (21) reported parathion to be the most toxic of compounds tested for toxical application, being twice as toxic as "497" (dieldrin) which was the next most effective contact insecticide. The contact values of dieldrin, aldrin and benzene hexachloride were so close in their tests that the difference could have been due to experimental error.

The matter of temperature and humidity are very important factors to be considered, especially if the material to be used is parathion or benzene hexachloride. Much better results have been obtained when the temperature was relatively high. Brett and Rhoades (2) suggest that at higher temperatures the toxin is more volatile and also the activity of the grasshopper is greatly increased, thereby increasing the intake of toxicant. Jahn (13) proved this by experiments with the heartbeats of the differential grasshoppers. He found that the average rate varies from 20 beats per minute at 5°C. to 150 beats at 45°C. Near zero the heart slows to about 10 beats per minute and above 45°C. the rate continues to rise at least as high as 53°C.

Weinman and Decker (21) worked out the L.D. 50 values of these newer insecticides on adult Melanoplus differentialis (Thos.) grasshoppers as the following table shows:

Contact	1947	1948	Stomach	1947	1948
	Milograms per Kilograms body Wt.			Milograms per Kilograms body Wt.	
Parathion	0.7	0.7	Parathion	6.0	8.9
Dieldrin		1.4	Dieldrin		3.7
Aldrin		1.8	Aldrin		2.3
Chlordane	16.3	9.8	Chlordane	21.8	12.0
Toxaphene	73.9	61.0	Toxaphene	75.0	91.5

Kearns, Weinman and Decker (15) reported that the L.D.values vary quite a bit with respect to contact or stomach poisoning. They say:

"The L.D. 50 values for adult Melanoplus differentialis (Thos.) show that "II" (Aldrin) and "III" (Dieldrin) are approximately 6 times as toxic as chlordane as contact insecticides and are 3 or 4 times as toxic as chlordane as stomach poisons."

PROCEDURE

Tests on Residual Toxicity

Field-laboratory tests were made to measure residual toxicity. Grasshoppers for the first experiment were adult Melanoplus mexicanus mexicanus (Sauss.), of the first generation. They were caught in standard insect nets by sweeping the top of hairy vetch in an orchard near Perkins, Oklahoma, in the early part of June. The grasshoppers were brought to the laboratory and fed fresh alfalfa each day for more than two weeks before actual tests were started in order to insure a vigorous test population and allow all nymphs to mature. No differentiation was made as to sexes.

Grasshoppers were fed daily on green, succulent leafy alfalfa fresh from the field. It was washed before being placed in the cages. Bottoms of the cages were covered with newspapers to make cleaning easier and to prevent contamination of the cages when treated alfalfa was introduced into them.

In order to prevent the grasshoppers from escaping while feeding and cleaning the cages, a piece of light durable wallboard was sawed the approximate size of the openings and a hole cut out of the center large enough to allow a man's hand and arm to move in and out freely. Across this opening and on either side of the wallboard a portion of car tire inner tubing was fastened by thumb tacks. The inner tubing was cut across the diameter of the hole four times to insure easy passage of the hand and arm in and out of the cages and yet retain the grasshoppers within them. Approximately 25 individuals were placed in each cage. Two cages were used per test.

To facilitate using the insecticide at the recommended rate per acre, plots of alfalfa were measured off that contained 1/250th of an acre and the corresponding amount of toxicants per acre could be used. Six plots were measured off, three in a row to be used for dusts and alongside these, three in a row to be used for sprays. The plots were established in a uniform stand of green, succulent leafy alfalfa of the Oklahoma Common variety. Insecticides were carefully weighed on an analytical balance. Sprays and dusts of the insecticides were used at the following amount of toxicant per acre:

	Pounds Per Acre
Toxaphene..	2.0
Chlordane..	1.5
Benzene Hexachloride, Gamma isomer....................	0.6
Aldrin..	0.25
Dieldrin..	0.25

Dusts or wettable dusts were used with each insecticide except oil emulsion in the case of chlordane spray. Plots were sprayed and dusted July 7, 1949, near Stillwater, Oklahoma.

Once a cage of grasshoppers was fed treated alfalfa, they received only treated alfalfa until the termination of the experiment or until all individuals were dead. Both treated and untreated alfalfa was brought in from the field each day. Records were kept on each of the number which had died each day. The residual period was from the time of application of the insecticides to the alfalfa until a cage of grasshoppers started feeding on treated plants. Two cages were fed untreated alfalfa as a control.

The second series was conducted in a similar manner, using dusts and sprays of chlordane, benzene hexachloride, and toxaphene. Ten adult differential grasshoppers and approximately twenty lesser migratory grasshoppers were placed in each cage. Lesser migratory grasshoppers were, for the most part, adults or in the last instar at the time treated alfalfa was given them. They were second generation grasshoppers[1] and seemed to be somewhat smaller than those used in the first test. Alfalfa was dryer and vegetation in general was not so well foliated.

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[1] Often there is a second generation of lesser migratory grasshoppers in Oklahoma.

Tests on Contact Toxicity

A series of tests were run to demonstrate the effect of contact toxicity to adult differential grasshoppers, Melanoplus differentialis (Thos.). Insecticides used were chlordane, benzene hexachloride, toxaphene, aldrin and dieldrin. Starting at concentrations generally recommended for field use, concentrations were reduced by half each time the experiment was repeated until they reached very low toxicity. All materials were in dust form and were diluted with talc.

Ten adult differential grasshoppers which had been collected in a weedpatch near Stillwater, Oklahoma, and fed on untreated alfalfa until a healthy population was secure, were placed in a half-gallon fruit jar with a wire gauze lid. This had a small opening through which a glass tube could be inserted. Elbowed tubes from No. 6 glass tubing were used and 50 milligrams of the particular concentrations were measured out in each tube. Concentrations of insecticides in the initial test were: chlordane 15.0 per cent, toxaphene 20.0 per cent, benzene hexachloride 6.0 per cent, dieldrin 0.25 per cent, and aldrin 0.25 per cent. Two replicates were used in each test and two cages of untreated grasshoppers were used as a control.

A rubber bulb was fitted on one end of the elbowed glass tube and the other end inserted in the small hole at the top of the half-gallon jar which contained the grasshoppers. With one quick puff the insecticide was blown into the jar, forming a uniform cloud of dust, insuring even coverage on the grasshoppers. Grasshoppers were left in the jar for five minutes and then transferred to clean cages which contained fresh untreated alfalfa. Alfalfa was changed daily and the percentage of mortality noted at intervals of 1 hour, 2 hours, 4 hours, 8 hours, 16 hours, 32 hours, 60 hours, 90 hours and 130 hours.

In the first two series toxaphene was the only insecticide which did not kill 100 per cent in 32 hours. Cages used for control were rotated in each part of the test. No mortality was obtained. This was a check to detect possible contamination of cages. Their floors were covered with clean newspapers and thoroughly cleaned as each cage was vacated. A record of the relative humidity and temperature in the room was kept. Experiments were conducted from August 22, to September 27, 1949.

A temperature and humidity record was kept in the laboratory where the contact series was run and the temperature ranged from 68°F. to 90°F. and the humidity ranged from 34 per cent to 77 per cent.

RESULTS

Sprays Superior to Dusts

With the exception of benzene hexachloride all insecticides tested showed a definite superiority when used as sprays. Tables 1 through 7[1] show the superiority of chlordane sprays to dusts. Benzene hexachloride dusts caused approximately the same mortality rate as sprays when tested as a stomach poison (Table 4). Brett and Rhoades (2) suggested that benzene hexachloride could be used as a dust to an advantage. Weinman and Decker (20) are of the opinion that benzene hexachloride has a sharply defined threshold of toxicity as to temperature, however these workers did not determine these. Above these temperatures it is extremely effective and below which it is almost completely ineffective. At 50°F. to 60°F. Brett and Rhoades (2) obtained 74.5 per cent mortality with grasshoppers but at 83° to 92°F. 92 per cent mortality occurred. Weinman and Decker (19) found spray emulsions of chlordane were more effective than wettable powders. The difference between aldrin and dieldrin sprays and dusts was not as pronounced as with chlordane.

Residual Effectiveness of Dieldrin

Dieldrin caused approximately 62 per cent kill on grasshoppers that were not fed treated alfalfa until a 168-hour period had elapsed (Table 3). Aldrin did not cause such a high mortality rate as dieldrin at the end of a 336-hour period. Since some toxicity was still apparent, grasshoppers were started feeding on treated plants seven days later but no mortality was obtained. Aldrin gave very similar results to dieldrin so far as residual toxicity was concerned. Aldrin begins to lose its toxicity after about the 14th day according to Weinman and Decker (20).

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[1] There were two cages per treatment and the mortality figures for each cage are shown in the tables.

Relative Speed of Toxaphene Breakdown

Toxaphene loses its toxicity to grasshoppers rather fast. From 97 per cent mortality in one hour to 76 per cent mortality in 48 hours, the toxaphene spray decreased rapidly in toxicity as illustrated by Table 4. Table 5 shows about the same decrease in toxicity to differential grasshoppers. Tables 6 and 7 show that the same results that were obtained in experiments with differential grasshoppers reported by Brett and Darnell in 1948.[1] Also, they found that parathion breaks down faster than toxaphene so far as toxicity to the grasshoppers was concerned.

Factors Affecting Duration of the Residual Period

Higher insecticidal concentrations are usually required late in the season. There is insufficient evidence to state precisely why this is true but theories as to the age of the grasshopper and to the amount of food eaten have been advanced. In the writer's experiments alfalfa became drier and was not so well foliated as the season progressed.

Another factor that should be considered was the amount of rainfall on the plants after they had been sprayed and dusted. The alfalfa was treated August 12, 1949, and approximately 1/3 inch of rain fell before the 48-hour residual period had elapsed (Table 4). Thus it is possible that enough rain fell to reduce the effective residual period. However, on the first test begun July 7, 1/3 inch of rain fell on the alfalfa on July 9, but it did not seem to affect the toxicity of chlordane, aldrin, or dieldrin (Tables 1, 2, and 3). Weinman and Decker (21) obtained similar results.

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[1] Unpublished data from experiments made during the summer of 1949 by Dr. Charles H. Brett and Mr. Orval Darnell.

Acute Toxicity of Parathion, Chlordane and Dieldrin

In the residual tests parathion caused 100 per cent mortality after the 1-hour residual period but its effect dropped fast after 24 hours as shown by Table 6. Brett and Rhoades (2) obtained similar results with parathion and chlordane. After a 24-hour residual period dieldrin caused 100 per cent mortality in four days and chlordane 100 per cent mortality in five days (Table 1).

Mode of Action

Chlordane, toxaphone, aldrin and dieldrin seem to be equally effective as a stomach or a contact poison. They appear to kill by a reaction upon a certain body system, probably the nervous system. Whether they are considered a stomach or contact poison depends on the mode of entrance into the body of the insect. Most of the new synthetic insecticides are considered to be both. Tables 1 through 7 demonstrate examples of the grasshoppers receiving the majority of the toxin through the mouth and thereby are considered to be stomach poisons. Tables 8 through 12 demonstrate examples of the grasshoppers getting most of the toxic dose through the body integument and thereby are considered to be contact poisons, although some of the toxicity was probably due to a certain amount of fumigation action.

Benzene hexachloride is not so effective when used as a stomach poison as is shown in Tables 4, 5, 6, and 7. In contrast, Table 12 shows the high rate of mortality to differential grasshoppers even when used at such low concentrations as 0.75 per cent when applied directly to the insect's body.

Effectiveness of Kill at Low Concentrations

Dieldrin is effective at lower concentrations than any of the other insecticides tested. As seen in Table 9, dieldrin caused 95 per cent kill at 0.015 per cent concentration. Aldrin caused 85 per cent kill at 0.015 per cent concentration (Table 8). Chlordane was somewhat less effective at the low concentration, however, Table 10 shows that 70 per cent mortality was obtained at 0.8 per cent concentration. Toxaphene caused 55 per cent at 5 per cent and 95 per cent mortality at 10 per cent concentration. The contact tests shown in Tables 8 through 12 were conducted on healthy, vigorous adult differential grasshoppers.

Table 1. Period of residual toxicity to the lesser migratory grasshopper of dieldrin, aldrin, and chlordane as sprays and dusts on succulent alfalfa in the field. Treatment made July 7, 1949. Feeding of caged grasshoppers started 24 hours after treatment. Stillwater, Oklahoma.

Insecticide	Pounds per acre	Percent Mortality													
		Days on Treated Food													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dieldrin	0.25 lb. (spray)	52	83	96	100	-	-	-	-	-	-	-	-	-	-
		25	50	81	100	-	-	-	-	-	-	-	-	-	-
	0.25 lb. (dust)	27	62	65	73	81	81	85	89	89	96	96	96	96	96
		38	56	78	81	81	84	87	91	91	91	91	91	94	97
Aldrin	0.25 lb. (spray)	37	62	75	92	96	100	-	-	-	-	-	-	-	-
		32	58	71	78	81	90	93	97	100	-	-	-	-	-
	0.25 lb. (dust)	14	43	54	57	75	75	82	89	89	89	89	89	89	89
		52	65	82	91	96	96	96	96	100	-	-	-	-	-
Chlordane	1.5 lbs. (spray)	47	59	75	84	89	94	94	94	94	97	97	100	-	-
		25	45	67	74	77	83	93	93	93	93	97	97	97	97
	1.5 lbs. (dust)	4	13	22	30	39	43	43	52	52	52	56	56	61	61
		33	41	62	75	79	87	87	87	92	92	92	92	92	92

Table 2. Period of residual toxicity to the lesser migratory grasshoppers of dieldrin, aldrin, and chlordane as sprays and dusts on succulent alfalfa in the field. Treatment made July 7, 1949. Feeding of caged grasshoppers started 72 hours after treatment. Stillwater, Oklahoma.

Insecticide	Pounds per acre	Percent Mortality													
		Days on Treated Food													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dieldrin	0.25 lb. (spray)	19 36	35 46	64 53	74 60	87 76	93 86	96 90	96 93	96 93	96 93	96 93	100 93	- 96	- 96
	0.25 lb. (dust)	18 29	35 52	35 71	59 76	65 76	65 76	71 81	82 91	82 91	82 91	88 91	88 91	88 91	88 91
Aldrin	0.25 lb. (spray)	14 8	21 19	28 23	48 31	62 50	62 61	65 69	72 73	76 77	76 77	79 77	83 77	83 77	83 77
	0.25 lb. (dust)	19 10	26 21	42 24	55 37	58 65	58 69	61 69	67 72	67 75	74 75	78 75	78 83	81 86	81 86
Chlordane	1.5 lbs. (spray)	9 3	15 16	34 48	48 58	62 74	68 78	72 78	78 81	78 81	81 84	81 84	81 84	81 84	84 84
	1.5 lbs. (dust)	3 7	23 14	30 17	30 21	43 34	47 38	50 44	57 44	60 55	60 62	60 65	66 65	70 65	70 69

Table 3. Period of residual toxicity to the lesser migratory grasshopper of dieldrin, aldrin, and chlordane as sprays and dusts on succulent alfalfa in the field. Treatment made July 7, 1949. Feeding of caged grasshoppers started 168 hours after treatment. Stillwater, Oklahoma.

Insecticide	Pounds per acre	Percent Mortality													
		Days on Treated Food													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dieldrin	0.25 lb. (sprays)	0	20	40	60	70	70	70	70	70	70	70	70	70	70
		15	15	40	45	50	55	60	60	60	60	60	60	60	60
	0.25 lb. (dust)	20	30	40	50	60	60	60	60	60	60	60	60	60	60
		0	20	30	30	40	50	50	50	60	60	60	60	60	60
Aldrin	0.25 lb. (spray)	0	0	10	50	50	50	50	50	50	70	70	70	70	70
		0	11	11	33	56	56	56	67	67	67	67	67	67	67
	0.25 lb. (dust)	10	10	10	20	40	50	60	60	70	70	70	70	70	70
		0	10	10	30	30	40	50	50	60	60	60	60	60	60
Chlordane	1.5 lbs. (spray)	4	31	39	50	50	61	65	69	73	73	73	73	73	73
		0	9	14	18	25	25	27	27	27	36	54	59	59	63
	1.5 lbs. (dust)	0	12	15	27	27	33	36	39	39	42	52	52	54	54
		4	8	15	29	37	37	41	44	48	48	52	59	59	59

Table 4. Period of residual toxicity to the lesser migratory grasshopper of chlordane, gamma benzene hexachloride, and toxaphene as sprays and dusts on dry alfalfa with sparce foliage in the field. Treatment made August 12, 1949., Stillwater, Oklahoma.

Insecticide	Pounds per acre	Percent Mortality RESIDUAL PERIOD (Hours between Treatment of Plants and their Availability to Grasshoppers as Food) 1 Days on Treated Food							48 Days on Treated Food						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Chlordane	1.5 lbs. (sprays)	78 82	82 86	100 95	- 95	- 100	- -	- -	35 48	50 59	60 70	90 92	90 92	90 92	90 92
	1.5 lbs. (dust)	14 13	27 30	41 52	55 52	68 56	68 56	73 65	5 18	33 18	67 43	72 43	77 56	77 56	77 56
Gamma BHC	0.6 lb. (spray)	20 24	28 43	40 52	44 62	44 66	52 66	60 66	23 20	31 20	39 20	46 35	46 50	46 50	46 50
	0.6 lb. (dust)	41 5	65 16	82 26	82 36	82 36	82 36	82 36	14 33	24 38	24 52	33 62	33 62	33 62	33 62
Toxaphene	2.0 lbs. (spray)	59 61	77 83	100 94	- 94	- 94	- 94	- 94	27 27	41 54	54 54	59 63	72 81	72 81	72 81
	2.0 lbs. (dust)	26 38	46 62	47 81	52 86	52 95	52 95	63 95	35 36	35 45	40 45	40 45	50 45	50 45	50 45

Table 5. Period of residual toxicity to the differential grasshopper of parathion, chlordane, benzene hexachloride, and toxaphene as sprays and dusts on succulent alfalfa in the field. Dusts applied June 30, sprays applied July 28, 1948. Stillwater, Oklahoma.

Insecticide	Pounds per acre	Percent Mortality RESIDUAL PERIOD (Hours between Treatment of Plants and their Availability to Grasshoppers as Food)													
		1							48						
		Days on Treated Food							Days on Treated Food						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Parathion	0.2 lb. (spray)	50	71	85	100	-	-	-	7	14	50	50	50	50	50
	0.2 lb (dust)	25	70	72	77	77	77	77	0	0	0	0	0	0	0
Chlordane	1.5 lbs. (spray)	72	100	-	-	-	-	-	46	71	87	91	100	-	-
	1.5 lbs. (dust)	50	85	94	100	-	-	-	8	54	70	90	92	97	100
Benzene Hexachloride (gamma isomer)	0.6 lb. (spray)	20	40	60	80	80	80	80	0	5	5	10	44	44	44
	0.6 lb. (dust)	20	62	72	72	72	72	72	3	26	33	33	33	33	33
Toxaphene	2.0 lbs. (spray)	8	25	41	58	83	83	83	5	22	22	22	22	27	27
	2.0 lbs. (dust)	7	48	63	78	78	90	90	0	0	9	12	27	37	37

Table 6. Period of residual toxicity to the differential grasshopper of parathion, chlordane, benzene hexachloride, and toxaphene as sprays and dusts on succulent alfalfa in the field. Dusts applied June 30, sprays applied July 28, 1948. Stillwater, Oklahoma.

		Percent Mortality													
		RESIDUAL PERIOD (Hours between Treatment of Plants and their Availability to Grasshoppers as Food)													
		1							24						
Insecticide	Pounds per acre	Days on Treated Food							Days on Treated Food						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Parathion	0.2 lb. (spray)	50	71	85	100	-	-	-	7	14	50	50	50	50	50
	0.2 lb. (dust)	25	70	72	77	77	77	77	0	0	0	0	0	0	0
Chlordane	1.5 lbs. (spray)	72	100	-	-	-	-	-	46	71	87	91	100	-	-
	1.5 lbs. (dust)	50	85	94	100	-	-	-	8	54	70	90	92	97	100
Benzene hexachloride (gamma isomer)	0.6 lb. (spray)	20	40	60	80	80	80	80	0	5	5	10	44	44	44
	0.6 lb. (dust)	20	62	72	72	72	72	72	3	26	33	33	33	33	33
Toxaphene	2.0 lbs. (spray)	8	25	41	58	83	83	83	5	22	22	22	22	27	27
	2.0 lbs. (dust)	7	48	63	78	78	90	90	0	0	9	12	27	37	37

Table 7. Period of residual toxicity to the differential grasshopper of parathion, chlordane, benzene hexachloride, and toxaphene as sprays and dusts on succulent alfalfa in the field. Dusts applied June 30, sprays applied July 28, 1948, Stillwater, Oklahoma.

		Percent Mortality													
		RESIDUAL PERIOD (Hours between Treatment of Plants and their Availability to Grasshoppers as Food)													
		48							168						
Insecticide	Pounds per acre	Days of Treated Food							Days of Treated Food						
		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Parathion	0.2 lb. (spray)	0	0	0	0	33	33	33	0	0	0	0	0	0	0
	0.2 lb. (dust)	0	3	3	3	3	3	3	0	0	0	0	0	0	0
Chlordane	1.5 lbs. (spray)	12	50	87	100	-	-	-	0	14	22	22	22	22	22
	1.5 lbs. (dust)	0	8	23	34	52	52	52	0	0	0	0	7	10	10
Benzene hexachloride (gamma isomer)	0.6 lb. (spray)	11	11	20	20	20	20	20	0	0	0	0	0	0	0
	0.6 lb. (dust)	0	7	30	30	30	30	30	0	0	0	0	0	0	0
Toxaphene	2.0 lbs. (spray)	14	14	14	14	24	24	24	0	0	0	0	0	0	5
	2.0 lbs. (dust)	0	4	8	8	8	8	8	0	0	0	0	3	3	3

Table 8. Contact toxicity of Aldrin dust to adult differential grasshoppers.

Percentage of Toxicant	Affected or Dead	Percent Grasshoppers Affected or Dead								
		Hours after Treatment								
		1	2	4	8	16	32	64	90	130
.25	Affected	0	0	10	100	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
	Affected	0	10	40	70	80	100	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
.125	Affected	0	20	50	100	-	100	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
	Affected	0	0	30	80	100	-	-	-	-
	Dead	0	0	0	0	0	100			
.0625	Affected	0	0	30	80	90	100	-	-	-
	Dead	0	0	0	0	0	70	100	-	-
	Affected	0	0	20	50	80	100	-	-	-
	Dead	0	0	0	0	0	40	90	100	-
.031	Affected	0	0	0	0	40	90	100	-	-
	Dead	0	0	0	0	0	60	80	80	100
	Affected	0	0	0	30	60	100	-	-	-
	Dead	0	0	0	0	0	70	90	90	100
.015	Affected	0	0	0	0	0	20	50	60	70
	Dead	0	0	0	0	0	0	50	50	70
	Affected	0	0	0	0	10	70	80	100	-
	Dead	0	0	0	0	0	0	80	100	-
.007	Affected	0	0	0	0	0	0	20	30	30
	Dead	0	0	0	0	0	0	20	30	30
	Affected	0	0	0	0	0	10	30	40	40
	Dead	0	0	0	0	0	0	30	40	40
Check	Dead	0	0	0	0	0	0	0	10	20

Table 9. Contact toxicity of Dieldrin dust to adult differential grasshoppers.

Percentage of Toxicant	Affected or Dead	Percent Grasshoppers Affected or Dead								
		Hours after Treatment								
		1	2	4	8	16	32	64	90	130
.25	Affected	0	20	60	100	–	–	–	–	–
	Dead	0	0	0	0	0	100	–	–	–
	Affected	0	40	100	–	–	–	–	–	–
	Dead	0	0	0	0	0	100			
.125	Affected	0	10	70	90	100	–	–	–	–
	Dead	0	0	0	0	0	100	–	–	–
	Affected	0	10	60	90	100	–	–	–	–
	Dead	0	0	0	0	0	100	–	–	–
.62	Affected	0	0	60	90	90	100	–	–	–
	Dead	0	0	0	0	0	70	100	–	–
	Affected	0	0	30	80	90	100	–	–	–
	Dead	0	0	0	0	0	70	100	–	–
.31	Affected	0	0	0	40	70	100	–	–	–
	Dead	0	0	0	0	0	60	70	100	–
	Affected	0	0	0	40	80	100	–	–	–
	Dead	0	0	0	0	0	70	90	100	–
.15	Affected	0	0	0	0	20	60	100	–	–
	Dead	0	0	0	0	0	0	90	100	–
	Affected	0	0	0	0	60	90	90	90	90
	Dead	0	0	0	0	0	0	90	90	90
.007	Affected	0	0	0	0	0	10	40	40	40
	Dead	0	0	0	0	0	10	40	40	40
	Affected	0	0	0	0	10	10	50	50	50
	Dead	0	0	0	0	0	10	40	40	40
Check	Dead	0	0	0	0	0	0	0	10	20

Table 10. Contact toxicity of chlordane dust to adult differential grasshoppers.

Percentage of Toxicant	Affected or Dead	Percent Grasshoppers Affected or Dead — Hours after Treatment								
		1	2	4	8	16	32	64	90	130
.15	Affected	0	60	60	100	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
	Affected	0	30	100	-	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
7.5	Affected	0	10	30	90	100	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
	Affected	10	30	40	100	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
3.25	Affected	0	0	0	50	80	90	100	-	-
	Dead	0	0	0	0	0	40	90	90	100
	Affected	0	10	40	80	80	100	-	-	-
	Dead	0	0	0	0	0	50	100	-	-
1.625	Affected	0	0	10	40	50	70	80	80	80
	Dead	0	0	0	0	0	60	80	80	80
	Affected	0	0	0	10	40	80	80	90	100
	Dead	0	0	0	0	0	30	60	80	100
0.8125	Affected	0	0	0	0	10	20	80	80	80
	Dead	0	0	0	0	0	10	80	80	80
	Affected	0	0	0	0	0	40	60	60	60
	Dead	0	0	0	0	0	0	60	60	60
0.4162	Affected	0	0	0	0	0	40	60	60	60
	Dead	0	0	0	0	0	40	60	60	60
	Affected	0	0	0	0	0	40	40	50	70
	Dead	0	0	0	0	0	0	0	50	70
Check	Dead	0	0	0	0	0	0	0	10	20

Table 11. Contact toxicity of Toxaphene dust to adult aifferential grasshoppers.

Percentage of Toxicant	Affected or Dead	Percent Grasshoppers Affected or Dead								
		Hours after Treatment								
		1	2	4	8	16	32	64	90	130
20	Affected	0	0	0	20	60	70	-	-	-
	Dead	0	0	0	0	0	70	-	-	-
	Affected	0	0	0	40	80	100	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
10	Affected	0	0	0	40	70	90	-	-	-
	Dead	0	0	0	0	0	90	-	-	-
	Affected	0	10	20	60	80	100	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
5	Affected	0	0	0	0	0	0	60	70	70
	Dead	0	0	0	0	0	0	40	40	70
	Affected	0	0	0	0	0	20	40	50	0
	Dead	0	0	0	0	0	0	30	40	40
2.5	Affected	0	0	0	0	10	30	40	40	40
	Dead	0	0	0	0	0	0	30	40	40
	Affected	0	0	0	0	10	50	70	70	70
	Dead	0	0	0	0	0	30	50	60	60
1.25	Affected	0	0	0	0	0	20	20	20	20
	Dead	0	0	0	0	0	10	20	20	20
	Affected	0	0	0	0	10	20	50	50	50
	Dead	0	0	0	0	0	0	10	20	20
.625	Affected	0	0	0	0	10	10	10	20	20
	Dead	0	0	0	0	0	0	0	20	20
	Affected	0	0	0	0	0	0	10	10	10
	Dead	0	0	0	0	0	0	10	10	10
Check	Dead	0	0	0	0	0	0	0	10	20

Table 12. Contact toxicity of Benzene Hexachloride dust to adult differential grasshoppers.

Percentage of Toxicant	Affected or Dead	Percent Grasshoppers Affected or Dead								
		Hours after Treatment								
		1	2	4	8	16	32	64	90	130
6	Affected	100	-	-	-	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
	Affected	100	-	-	-	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
3	Affected	90	100	-	-	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
	Affected	80	100	-	-	-	-	-	-	-
	Dead	0	0	0	0	0	100	-	-	-
1.5	Affected	60	90	90	90	80	100	-	-	-
	Dead	0	0	0	0	20	80	-	-	-
	Affected	60	100	-	-	-	-	-	-	-
	Dead	0	0	0	0	30	100	-	-	-
.75	Affected	30	80	80	80	80	80	80	80	80
	Dead	0	0	0	0	0	80	80	80	80
	Affected	50	80	80	90	90	90	90	90	90
	Dead	0	0	0	0	0	90	90	90	90
.375	Affected	0	10	30	40	20*	20	20	20	20
	Dead	0	0	0	0	0	0	20	20	20
	Affected	0	20	70	70	60*	60	80	80	80
	Dead	0	0	0	0	0	60	80	80	80
.187	Affected	0	10	20	20	20	20	20	30	30
	Dead	0	0	0	0	0	10	20	30	30
	Affected	0	30	40	40	40	40	40	50	50
	Dead	0	0	0	0	10	20	40	50	50
Check	Dead	0	0	0	0	0	0	0	10	20

* Insects Recovered.

DISCUSSION

When using the insecticides chlordane, aldrin, dieldrin or toxaphene, good results were obtained when the alfalfa was green and succulent. After the alfalfa has dried up to some extent, and the vegetation is somewhat sparse, much lower mortality rates were noted in the experiments. With the knowledge of this fact the farmer might find it economically feasible to plant several rows of a quick-growing legume around the edge of his field and spray this early in the year with one of the above mentioned insecticides.

Benzene hexachloride dusts were slightly superior to sprays. This was in a definite contrast to the other insecticides in which the sprays were consistently superior to the dusts. In the contact tests, benzene hexachloride displayed a remarkably quick"knockdown." Usually there would be a 90-100 per cent "knockdown" in the benzene hexachloride cages within one or two hours. However, the grasshoppers were not actually considered dead until 32 hours after original poisoning. When the concentration of benzene hexachloride was as low as 0.3 per cent there were some grasshoppers that recovered after being affected for several hours. The relatively poor results obtained when benzene hexachloride was used as a residual insecticide and the excellent results when it was dusted directly on the grasshoppers, show the definite need of benzene hexachloride coming in actual contact with the grasshoppers.

Toxaphene gave good control for a short period but exhibited a rapid loss of toxicity at the end of 48 hours. It is definitely inferior to chlordane, aldrin and dieldrin, but because it is relatively inexpensive as compared to the other insecticides and is not very toxic to warm-blooded animals, it is used more extensively.

Dieldrin was somewhat superior to aldrin and chlordane both in speed of kill and residual toxicity. It showed a definite superiority both in residual effectiveness and contact toxicity. Chlordane was used at a much higher concentration than aldrin or dieldrin. Aldrin and dieldrin give a longer residual period of effective control than any of the other insecticides. One big advantage they have is the remarkably low concentrations at which they obtain excellent control.

If grasshoppers are treated along fence rows, ditches and the borders of fields and pastures soon after they have emerged, it should eliminate their migration from borders to the center of fields and crops. A striking example of this marginal feeding was observed by the author in an alfalfa field near Perkins, Oklahoma. The lesser migratory, Melanoplus mexicanus mexicanus (Sauss.), is capable of producing a second generation a year in Oklahoma which can do untold damage to crops.

In the event that plants are to be used for human or livestock consumption these organic insecticides probably should not be used unless a period of about a month in the field is allowed for the insecticides to break down. This again would be another very good reason for spraying grasshoppers early in the season. By combining the information on egg pod survey made by the Extension Service[1] and by carefully observing the population of young nymphs in the Spring, it should be possible to determine if it would be profitable to attempt to control them at this time.

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[1] Each Fall the Extension Service makes a thorough survey of the grasshopper egg pods.

SUMMARY

Comparisons were made of three insecticides recommended for grasshopper control with aldrin and dieldrin, two newly developed toxins. These tests were designed to demonstrate contact and stomach poisoning separately, as nearly as possible. Two of the most important economic species of grasshoppers in Oklahoma were used in the tests, namely, the differential grasshopper, _Melanoplus differentialis_ (Thos.) and the lesser migratory grasshopper, _Melanoplus mexicanus mexicanus_ (Sauss).

Tests demonstrating mostly the stomach poisoning effect were of the laboratory-field nature. Alfalfa was sprayed or dusted in the field and subject to weather conditions, then brought in and fed to caged grasshoppers. The tests showed that there was a definite relationship between the condition of the alfalfa and the effectiveness of chlordane. This was probably true of all of the insecticides tested with the possible exception of benzene hexachloride.

In these tests, dieldrin was somewhat superior to aldrin and chlordane, both in speed of kill and residual toxicity. Toxaphene caused good control for a short period but exhibited a rapid loss of toxicity at the end of 48 hours. Benzene hexachloride caused very low mortality rates in the test if 24 hours had elapsed before grasshoppers were exposed to the toxicant.

Indications of contact poisoning were shown by placing ten adult differential grasshoppers in a half-gallon fruit jar and dusting them with the insecticide. Grasshoppers were removed and placed in cages with fresh untreated alfalfa. Concentrations of the insecticides were started at the recommended strength and on each successive test the concentrations were halved. Benzene hexachloride caused good kills even when the concentrations were as low as 0.75 per cent. Dieldrin was superior to aldrin and chlordane. It caused 95 per cent mortality even as low a concentration as 0.015 per cent. Aldrin caused 75 per

cent mortality at 0.015 per cent concentration, and chlordane caused 70 per cent mortality at 0.8 per cent concentration.

Some of the grasshoppers recovered when the percentage of gamma isomer in benzene hexachloride was reduced to approximately 0.375 per cent. Also, the time required to affect grasshoppers was lengthened as the concentration of toxicant was cut down in the series.

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V I T A

Rex Bismarch Reinking was born at Wardville, Oklahoma, November 23, 1924. His secondary education was obtained at Limestone Gap, Oklahoma, where he graduated in June of 1942. Enrollment was made at Murray State School of Agriculture in September, 1942, where he was an Arts and Science Major. From June, 1943, until May, 1944, he worked on his father's farm. He entered the Army in May, 1944, where he served in the 95th Infantry Division, fighting in France, Belgium and Germany. He was discharged from the Army in April, 1946, and enrolled at Oklahoma Agricultural and Mechanical College in June, 1946. During the summers of 1947 and 1948 he was employed by Dr. D. E. Howell, of the Entomology Department, in experimental work with flies in barn sprays and control of horse flies. In August, 1949, he received the B. S. Degree from Oklahoma Agricultural and Mechanical College.

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