THE RELATION OF TEMPERATURE IN THE SUSCEPTIBILITY OF GRASSHOPPERS TO SYNTHETIC INSECTICIDE DUSTS

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PREFACE

In the spring of 1946, the writer was assigned to work with Dr. Charles H. Brett as a Research assistant in the Oklahoma Agricultural Experiment Station.

Tests were made using synthetic insecticide dusts for controlling grasshoppers in the field. Interest in this method of control and the many possibilities it offered, lead to the research reported in this thesis. It was evident that temperature was one of the important influencing factors. It was decided after consultations with Drs. C. H. Brett and F. A. Fenton to study the effect of temperature in the susceptibility of grasshoppers to synthetic insecticides.

The writer gratefully acknowledges his indebtedness to the staff of the Entomology Department of the Oklahoma Agricultural and Mechanical College for their valuable suggestions and criticisms, more particularly to Dr. C. H. Brett, under whose supervision the experimental work was carried on, and who later offered many helpful criticisms in the writing of this thesis; to Dr. F. A. Fenton who was a source of much encouragement and advice on the writing of this paper; and to Prof. G. A. Bieberdorf who made many helpful suggestions and criticisms.

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INTRODUCTION

Throughout the history of man, grasshoppers or locusts have been reported injuring his crops. It would be difficult to say when he first met the "locust problem", but it surely happened in the dawn of agriculture. The Bible and the writings of the ancient Babylonians, Egyptians, and Greeks contain references to the dreaded locusts as pests of agriculture. Until the last century a losing battle has been fought.

The injury done by grasshoppers is a continual and ever-present loss. The general public usually becomes aware of grasshoppers or other insects only when they increase to devastating numbers. During the period from 1856 to 1880 the Missouri Valley was ravaged by swarms of the Rocky Mountain Locusts or Migratory Grasshoppers (2)[1]. Since that time grasshoppers have been a recurring problem in the Central and Western states with an almost continual campaign being waged against them.

Outbreaks in Oklahoma are usually local. Urbahns (11) records four serious outbreaks in Oklahoma territory since it was opened to settlement in 1889. Grasshopper infestations were severe throughout the central and west central portion of the state in 1912 and 1913 and again in 1919.

In 1924 a serious outbreak occurred in the western part of the state, followed by another in the southwestern portion in 1925. The last statewide outbreak of importance occurred during the years 1936 to 1938, thousands of acres of cotton, corn and alfalfa, many shade and fruit trees, and large quantities of truck and garden plants were destroyed.

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[1] Numbers in parenthesis refer to Literature cited, Page 34.

The attempted control measures of grasshoppers have been many and varied. Some of these such as planting poisonous plants, making noises, and innoculation with diseases and parasites have proved ineffectual. Those that are more or less successful are cultural practices, trapping, poison baits, spraying and dusting. The one most often used in America up to the present time is that of spreading poisoned baits. In alfalfa poisoned baits have been unsatisfactory, due to dense vegetative growth and difficulty of getting baits on the ground. Complete kills are seldom obtained, and persistent baiting has been necessary in order to reduce infestations sufficiently to guarantee harvest of at least a partial crop of hay or seed.

Poisoned baits were first used in 1878 when the United States Entomological Commission (9) reported several experiments with a mixture of Paris green and flour as bait for locusts. Experiments with bran-arsenic mash for the control of grasshoppers in the San Joaquin Valley, California, were reported by Coquillet (3) in 1886. This mash consisted of bran, arsenic, sugar, and water, the sugar being added to make the arsenic adhere to the flakes of bran. Molasses was soon substituted for sugar. Jackson (6) in 1894 referred to the successful use, in Colorado, of a bait consisting of bran, Paris green, and some old molasses or other cheap substance to make it stick together. High temperatures in Oklahoma generally have complicated the effective use of baits, leaving much to be desired.

Dusts and sprays were previously used in grasshopper control but in recent years they have been almost entirely supplanted by poisoned bait. The introduction of the new synthetic insecticides, DDT, benzene hexachloride, chlordane or 1068, 3956, an aryl alkyl thianophosphate, or 3422, which are highly toxic to insects, together with new methods of insecticide distribution have turned attention again to the use of dusts and sprays in grasshopper control.

Benzene Hexachloride was developed in Great Britian (10) by the Imperial Chemical Industries, Hawthorndale Laboratories, Jealotts Hill, under the supervision of Dr. O. B. Lean. This insecticide has been reported to be effective against a wide range of insects. Slade (10) reported it to be extremely toxic to locusts. He states,

> A small quantity of dust containing the crude material was sieved on a bench on one side of a room in which were housed cages containing locusts. All these locusts subsequently died. Furthermore, after scrubbing the cages, vacuum cleaning the walls, and washing the floors, fresh locusts placed in cages also died. It was not until the room had been redecorated and the cages again scrubbed that breeding of the locusts could be resumed.

Other workers have had excellent results with benzene hexachloride dust in the control of grasshoppers. Brett and Rhoades (1) found that a dust containing 5 percent gamma isomer, applied at the rate of 10 pounds per acre gave complete control of grasshoppers in alfalfa. Hill and Hixson (4) also had good results, using benzene hexachloride in tests conducted in Nebraska during the summer of 1946, in controlling the following four species of grasshoppers: Melanoplus differentialis (Thos.) M. femur-rubrum (Deg.) M. bivittatus (Say) and M. mexicanus mexicanus (Sauss.). Dust application with an airplane was not as effective as with a power duster.

Chlordane or 1068 was first discussed in 1945 by Drs. Kearns, Ingle, and Metcalf (7). They found in their tests that this product exhibited a high order of toxicity to a wide range of insects. Their report shows a comparison of the toxicity of chlordane, DDT, and benzene hexachloride on several species. In Table 9 of their report the mortality at the end of 24 hours using emulsions of 2 percent DDT was 30 percent, 1 percent chlordane, 70 percent, and 0.5 percent gamma benzene hexachloride, 100 percent, as a stomach poison on the differential grasshopper, Melanoplus differentialis (Thomas).

A synthetic insecticide known as chlorinated camphene or 3956 has been tested in Montana, Arizona, and California (5). In Montana a 20 percent dust and an emulsion spray applied at the rate of 4 pounds per acre gave 95 and 97 percent kills respectively. In Arizona the average kill, in two tests with 20 pounds per acre of a dust containing 10 percent of chlorinated camphene, was 69 percent in one day and 88 percent in three days. In California tests, dosages of 2 to 8 pounds of 20 percent dust per acre gave 100 percent kill in six days.

A new synthetic insecticide, developed by the American Cyanamid Company of New York, known as an aryl alkyl thianophosphate or 3422 was tested for the first time by the Oklahoma Agricultural Experiment Station on the two-lined grasshopper, Melanoplus bivittatus (Say) June 13, 1947. A 91 percent kill was obtained with 2 percent dust applied at the rate of 20 pounds per acre.

Research reported upon in this thesis was carried on from June, 1946 to July, 1947. It has been concerned principally with the suscepti-

bility of the most important economic species of grasshoppers to the new synthetic insecticides and a correlation of this susceptibility with temperatures, both in the laboratory and in the field.

METHODS OF PROCEDURE

Adults of the differential grasshopper, Melanoplus differentialis, the two-lined grasshopper, M. bivittatus, and the lesser migratory grasshopper, M. mexicanus were collected in the field during October, brought into the laboratory and used as a source of egg supply. These adult grasshoppers were kept in screen cages. Four-ounce jars, filled with sand, were placed in each cage. The females deposited their eggs readily. After these jars had sufficient numbers of eggs in them, they were removed from the cages and placed in an electric refrigerator, at a temperature of about 40 degrees Fahrenheit, for a period of 10 days to 2 weeks. They were then placed in an incubator. Newly hatched nymphs were transferred from the incubator to rearing cages and fed head lettuce. Some tests were made with grasshoppers collected directly from the field.

The chemicals used in laboratory tests were in the dust form containing benzene hexachloride, chlordane or 1068, 3956, DDT and 3422. Those that were used in field tests were benzene hexachloride, chlordane or 1068, 3956, and 3422[2].

In the laboratory tests, 10 grasshoppers were placed in a two quart fruit jar. A piece of screen wire was cut and fitted into the

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[2] For the sake of conformity and to avoid confusion, the names for the chemicals used in this thesis will be BHC for benzene hexachloride, chlordane for 1068, 3956 for Chlorinated Camphene and 3422 for an aryl alkyl thianophosphate.

ring of the fruit jar and used as a cover. The screen had a small hole about the size of a lead pencil in it to allow a small glass tube to enter the jar for applying the dust. The glass tube was heated and curved in the middle and had a rubber bulb on one end. Dust was weighed, put into the glass tube, and allowed to settle in the curve to prevent loss. The open end of the tube was placed in the opening in the screen cover. One vigorous squeeze of the rubber bulb at the other end of the tube forced all the dust into the jar in one puff. This gave good coverage on the grasshoppers. The grasshoppers were allowed to stay in the jar for a five-minute period. They were then transferred to a screen cage where head lettuce was available and placed in the constant temperature compartments. These compartments were designed and built by Brett (2). The four different temperatures used in these tests were 100°F., 90°F., 80°F., and 70°F. Observations were made at 2, 4, 8, 24, 48, and 72-hour intervals. For some of the insecticides observations were made at the end of longer periods. Fifty milligrams of dust were used in each treatment. Each test was replicated 10 times.

In field tests the dusts were applied with a Root Model Y-2, six-row power duster. This machine was mounted on a two-wheel trailer and drawn behind a "Jeep". Dusts used in the field tests during the spring of 1946 (1) were prepared in a series of concentrations of gamma isomer by diluting with talc, a preparation which was technical BHC containing 10 percent of the gamma isomer. The chlordane dusts were prepared by impregnating talc with the technical concentrate. These tests were made in alfalfa fields where the plants were about 15 inches high and nearly

ready to cut. The dust for each treatment was applied at the rate of 10 pounds per acre over 2.5 acre plots. Treatments were made at three different times and in two different localities. Records were taken in the dusted plots between 6 to 8 hours after application and again between 24 to 30 hours after. A square yard frame was placed on the ground at random and two observers counted all affected[3] and dead grasshoppers within the area. Such counts were replicated 10 times in each plot.

Dusts used in field tests during the spring of 1947 were prepared by the John Powell Chemical Company and The American Cyanamid Company. They were applied with the power duster previously described. Ten percent gamma BHC was applied at the rate of 50 pounds per acre. Five percent gamma BHC was applied at the rate of 10 pounds per acre. Ten and twenty percent 3956 were each applied at the rate of 40 pounds per acre. One and two percent 3422 were each applied at the rate of 20 pounds per acre. These tests were made along irrigation ditches which were covered with dense vegetation. Records were taken in the dusted plots between 4 to 5 hours after application, 8 to 9 hours after, 24 to 25 hours after and again 6 days after.

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[3] Grasshoppers were considered to be affected when they stumbled about showing loss of coordination accompanied by peculiar nervous tremors.

THE SUSCEPTIBILITY OF GRASSHOPPERS TO SYNTHETIC INSECTICIDES AT CONSTANT TEMPERATURES OF 100°F., 90°F., 80°F. and 70°F. IN THE LABORATORY

Adult Differential Grasshoppers, Melanoplus differentialis (Thomas).

Grasshoppers collected in the field and treated with 4 percent gamma BHC and placed in a temperature compartment held at 100°F. were all affected by the end of two hours. Seventy percent were affected at 90°F., 40 percent at 80°F., and 40 percent at 70°F. At the end of 4 hours the percentage of affected grasshoppers was 60, 90, 60, and 60 for the temperatures ranging from 100°F. to 70°F. respectively. The percentage of kill was 40, 10, 0, and 0. At the end of 8 hours the range for affected grasshoppers was 20, 60, 100, and 100 percent. The percentage of mortality was 80, 40, 0, and 0. All of the individuals at 100°F. and 90°F. were dead at the end of 24 hours. At 80°F. 90 percent were dead and 10 percent had recovered after 24 hours. At 70°F. 80 percent were dead and 20 percent had recovered after 24 hours. All of the recovered individuals were gravid females. These were placed in cages where they deposited viable eggs. Grasshoppers hatched from these eggs were reared successfully. (See tables 1, 2, 3, and 4)

This test shows the BHC dust to have a rapid effect upon the grasshoppers which is first evidenced by peculiar tremors with loss of coordination. The speed of the action is proportional to the concentration of the gamma isomer and increases in temperature. At the lower temperatures a greater period of time is required before symptoms develop.

Fewer of the grasshoppers are killed and the percentage of those affected which can recover is increased. Recovered grasshoppers showed no apparent after effects.

The pronounced temperature relationships when using BHC are apparently due to a considerable extent to fumigating action. Fifty milligrams of BHC dust were placed in the bottom of a two quart jar. Ten grasshoppers were placed in another two quart jar which was inverted over the first, open end to open end. A screen wire between the two jars prevented the grasshoppers coming in direct contact with the dust. At temperatures of 100°F., 90°F., 80°F., and 70°F. the range for affected grasshoppers was 100, 100, 80, and 50 percent, respectively, at the end of 8 hours. The range of kill was 100, 100, 80, and 70 percent, respectively, at the end of the 24 hour period.

Grasshoppers treated with 10 percent chlordane and placed in temperature cabinets held at 100°F., 90°F., 80°F., and 70°F. showed no effects until the end of 4 hours, at which time 40 percent were affected at all temperatures. At the end of 8 hours percentage of affected grasshoppers ranged 80, 80, 70, and 70 respectively, and the range of mortality was 20, 20, 10, and 10 percent respectively. At the end of 24 hours there was a 70 percent kill at 100°F. with 60 percent kill for 90°F., 50 percent for 80°F., and 50 percent for 70°F. The 48 hour reading gave 80, 80, 70, and 70 percent killed respectively. The 72 hour reading showed 20 percent recovery and an 80 percent kill at all temperatures.

Results obtained with chlordane show it to be slower in action and less toxic to grasshoppers than BHC, also there is not as much of

a temperature effect as with BHC. Chlordane gave about the same percentage of recovery and kill at all temperatures.

Grasshoppers treated with 20 percent DDT showed no effects until the end of 24 hours when a 10 percent kill was recorded at 90°F. with 20 percent at 80°F. and 70°F. None was affected or killed at 100°F. The 48-hour reading showed 10 percent kill at 100°F., 20 percent at 90°F. and 40 percent at 80°F. and 70°F. At the end of 72 hours 30, 30, 40, and 50 percent were killed at 100°F., 90°F., 80°F., and 70°F., respectively. Observations made over a period of 14 days showed no further mortality.

In contrast to BHC, DDT shows its greatest toxic effect on grasshoppers at the lower temperatures. DDT is much slower in action. None of the grasshoppers was killed until at the end of 24 hours. Grasshoppers treated with DDT did not twitch spasmodically before dying.

Grasshoppers treated with 3956 showed no effects until at the end of 4 hours when 50, 50, 20, and 10 percent were affected at 100°F., 90°F., 80°F., and 70°F. respectively. One hundred percent mortality was obtained at the end of 48 hours with temperatures of 100°F. and 90°F. Seventy-two hours were required for complete kill at 80°F. At 70°F. 90 percent were killed and 10 percent recovered.

This test showed 20 percent 3956 to be less toxic to grasshoppers than 4 percent gamma BHC and somewhat intermediate between BHC and chlordane. At 100°F. and 90°F. it required 48 hours for complete kill. Seventy-two hours were required at 80°F. At 70°F. there was 90 percent kill and 10 percent recovery.

Adult Migratory Grasshoppers Melanoplus mexicanus mexicanus (Sauss.).

Grasshoppers reared in the laboratory were treated with 4 percent gamma BHC and placed in compartments held at constant temperatures of 100°F., 90°F., 80°F., and 70°F. At the end of two hours the grasshoppers were 100, 90, 70, and 50 percent affected, respectively. The percentage affected in 4 hours for the temperature series was 50, 80, 90, and 80 respectively, with a mortality of 50, 20, 0 and 0 percent. The 8-hour reading showed 10 percent affected and 90 percent dead at 100°F., 60 percent affected and 40 percent dead at 90°F., 80 percent affected and 20 percent dead at 80°F., and 90 percent affected and 10 percent dead at 70°F. All grasshoppers were dead at the end of 24 hours except those at 70°F. where there was a 20 percent recovery.

This test shows the BHC dust to have a more rapid effect upon the migratory grasshoppers than it does the differential grasshopper. Concentration of the gamma isomer and an increase in temperature affects and kills the migratory grasshoppers more quickly. No recovery was recorded at the higher temperatures. Those which recovered at the lower temperatures showed no apparent after effects. (See tables 5, 6, 7, and 8)

Grasshoppers treated with 10 percent chlordane and placed in the series of controlled temperature compartments, showed 30 percent affected in 2 hours at 100°F. and 90°F., with 10 percent affected at 80°F. and 90°F. The 4 hour reading gave 70, 70, 50, and 50 percent affected respectively, with no mortality being recorded. At the end of 8 hours 70, 80, 70, and 70 percent were affected and 30, 20, 10, and 0 percent

dead. The 24 hour reading showed 40 percent affected and 60 percent dead at 100°F., 50 percent affected and 50 percent dead at 90°F., 50 percent affected and 50 percent dead at 80°F., and 60 percent affected and 40 percent dead at 70°F. At the end of 48 hours there were 20 percent affected and 80 percent dead at 100°F., with 30 percent and 70 percent dead at 90°F., 80°F., and 70°F. In 72 hours 90 percent mortality and 10 percent recovery was recorded for 100°F., while 80 percent mortality and 20 percent recovery was recorded for the other three temperatures. Observations made over a period of 14 days showed no further mortality.

These tests show the lesser migratory grasshopper to be more susceptible than the differential grasshopper to chlordane. Both species show a greater susceptibility to BHC than to chlordane. At the higher temperatures only about one-half the time is required to get a complete knockdown using BHC as with chlordane, and about one-third the time for a complete kill. At the lower temperatures this period of time is less pronounced.

Grasshoppers treated with DDT showed no effects until the end of 24 hours when a 20 percent kill was recorded for all four temperatures. The 48-hour reading showed 30 percent kills for 100°F. and 90°F., with 40 percent kills for 80°F. and 70°F. At the end of the 72 hour period 30 percent were killed at 100°F., 40 percent at 90°F. and 80°F., and 50 percent at 70°F. Observations made over a period of 14 days showed no further mortality.

These tests show the lesser migratory grasshopper to be more susceptible to DDT than the differential grasshopper. Both species are more

susceptible to BHC and chlordane than to DDT. In comparison with BHC and chlordane, DDT shows a greater toxic effect at the lower temperatures.

Grasshoppers treated with 3956 showed 30, 30, 20, and 10 percent affected at 100°F., 90°F., 80°F. and 70°F. respectively. No mortality was recorded until the end of 8 hours when 70, 80, 80, and 80 percent were affected and 30, 20, 10, and 10 percent were dead respectively. One-hundred percent were dead at the end of 48 hours for 100°F., 90°F., and 80°F. It required 72 hours to obtain 100 percent kill at 70°F.

These tests show the lesser migratory grasshopper to be more susceptible to 3956 than the differential grasshopper. Both species show greater susceptibility to BHC than to 3956, but less to chlordane and DDT. Toxic action is faster and more complete at the higher temperatures in a manner similar to that of BHC and chlordane.

Nymphs of the Two-Lined Grasshopper, Melanoplus bivittatus (Say).

Third, fourth and fifth instar nymphs collected in the field, treated with 5 percent gamma BHC and placed in temperature compartments held at 100°F. and 90°F. were all affected at the end of two hours. Ninety percent were affected at 80°F., and 80 percent at 70°F. At the end of four hours the percentage of grasshoppers affected was 40, 60, 80, and 80 respectively for the temperature series ranging from 100°F. to 70°F. The percentage of kill was 60, 40, 20 and 20 respectively. At the end of eight hours the range for affected grasshoppers was 10, 30, 50, and 70 percent respectively. The percentage of mortality was 90, 70, 50, and 30. All of the individuals were dead in all treatments at the end of 24 hours. (See tables 9, 10, 11 and 12)

Grasshoppers treated with 3956 and placed in temperature compartments held at 100°F. and 90°F. each showed 10 percent to be affected at the end of 2 hours. None was affected at 80°F., or 70°F. At the end of 72 hours all individuals were dead in all treatments.

These tests show the nymphal stages to be very susceptible to 3956, but more especially at temperatures of 100°F. and 90°F., although 100 percent mortality was recorded at all temperatures in 72 hours after treatment, they were affected more quickly at the higher temperatures.

All grasshoppers treated with 2 percent 3422 and placed in a temperature compartment held at 100°F. were affected at the end of 2 hours. Ninety percent were affected at 90°F., and 80°F., and 80 percent at 70°F. At the end of 4 hours the percentage of affected grasshoppers was 30, 50, 60, and 80 for the temperatures ranging from 100°F. to 70°F. respectively. The percentage of kill was 70, 50, 40, and 20. At the end of 8 hours the range of affected grasshoppers was 0, 0, 10 and 20 percent. The percentage of mortality was 100, 100, 90, and 80. All grasshoppers were dead by the end of 24 hours.

Grasshoppers treated with 1 percent 3422 were 80 percent affected at the end of 2 hours at 100°F., 80 percent at 90°F., 60 percent at 80°F. and 50 percent at 70°F. At the end of 4 hours the percentage of affected grasshoppers was 60, 80, 90, 100 for the temperatures ranging from 100°F. to 70°F., respectively. The percentage of kill was 40, 20, 10, and 0. At the end of 8 hours the range of affected grasshoppers was 30, 40, 50, and 70 percent. The percentage of mortality was 70, 60, 50, and 30. At the end of 48 hours 10 percent of the individuals in each treatment held

at 100°F., 90°F., and 80°F. had recovered, while 20 percent of the individuals had recovered at 70°F.

From the results of these tests, 2 percent 3422 dust shows great promise in controlling grasshoppers. A quicker kill was recorded than with any other insecticide used.

The 1 percent 3422 dust did not give satisfactory control. A large percentage of recovery was recorded in both laboratory and field tests.

Adult Two-Lined Grasshoppers, Melanoplus bivittatus (Say).

Grasshoppers collected in the field, treated with 4 percent gamma BHC and placed in a temperature compartment held at 100°F. were all affected by the end of 2 hours. Eighty percent were affected at 90°F., 50 percent at 80°F. and 40 percent at 70°F. At the end of 4 hours the percentage of affected grasshoppers was 60, 80, 60, and 60 for temperatures ranging from 100°F. to 70°F., respectively. The percentage of kill was 40, 20, 10, and 0. At the end of 8 hours the range for affected grasshoppers was 30, 60, 80, and 100 percent with a kill of 70, 40, 20, and 0 percent. All of the individuals at 100°F. and 90°F. were dead at the end of 24 hours. At 80°F. 90 percent were dead and 10 percent had recovered after 24 hours. At 70°F. 80 percent were dead and 20 percent had recovered after 24 hours.

The results in this test were essentially the same as those obtained using BHC at the same temperatures on the differential grasshopper. This was also true in tests using chlordane, DDT, and 3956 as is shown in tables 13, 14, 15, and 16.

Results in this test show adult Melanoplus bivittatus grasshoppers to be less susceptible to BHC and 3956 at all temperatures than were the nymphal stages.

Table 1. Comparative Tests using BHC, Chlordane, DDT and 3956 at a Constant Temperature of 100°F. on Adults of the Differential Grasshopper, Melanoplus differentialis (Thomas).

Formulation	Percentage of Grasshoppers																	
	Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A[1]	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	100	0	0	60	40	0	20	80	0	0	100	0	-	-	-	-	-	-
Chlordane 10%	0	0	0	40	0	0	80	20	0	30	70	0	0	80	20	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	30	0
3956 20%	0	0	0	50	0	0	90	0	0	20	80	0	0	100	0	-	-	-

Table 2. Comparative Tests using BHC, Chlordane, DDT and 3956 at a Constant Temperature of 90°F. on Adults of the Differential Grasshopper, Melanoplus differentialis (Thomas).

Formulation	Percentage of Grasshoppers																	
	Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A[1]	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	70	0	0	90	10	0	60	40	0	0	100	0	0	100	0	-	-	-
Chlordane 10%	0	0	0	40	0	0	80	20	0	40	60	0	20	80	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	10	0	0	20	0	0	30	0
3956 20%	0	0	0	50	0	0	80	0	0	20	80	0	0	100	0	-	-	-

[1]Explanation of letters used.

A - Percent of grasshoppers affected.
D - Percent of grasshoppers dead.
R - Percent of grasshoppers recovered.

Table 3. Comparative Tests using BHC, Chlordane, DDT and 3956 at a Constant Temperature of 80°F. on Adults of the Differential Grasshopper, Melanoplus differentialis (Thomas).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	40	0	0	60	0	0	100	0	0	0	90	10	0	90	10	0	90	10
Chlordane 10%	0	0	0	40	0	0	70	10	0	50	50	0	30	70	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	40	0	0	40	0
3956 20%	0	0	0	20	0	0	40	0	0	50	50	0	30	70	0	0	100	0

Table 4. Comparative Tests using BHC, Chlordane, DDT and 3956 at a Constant Temperature of 70°F. on Adults of the Differential Grasshopper, Melanoplus differentialis (Thomas).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	40	0	0	60	0	0	100	0	0	0	80	20	0	80	20	0	80	20
Chlordane 10%	0	0	0	40	0	0	70	10	0	50	50	0	30	70	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	40	0	0	50	0
3956 20%	0	0	0	0	0	0	40	0	0	50	50	0	20	80	0	0	90	10

Table 5. Comparative Tests using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 100°F. on Adults of the Lesser Migratory Grasshopper, Melanoplus mexicanus mexicanus (Sauss.).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	100	0	0	50	50	0	10	90	0	0	100	0	0	100	0	-	-	-
Chlordane 10%	30	0	0	80	0	0	70	30	0	40	60	0	20	80	0	0	90	10
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	30	0	0	30	0
3956 20%	30	0	0	50	0	0	70	30	0	10	90	0	0	100	0	0	100	0

Table 6. Comparative Tests using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 90°F. on Adults of the Lesser Migratory Grasshopper, Melanoplus mexicanus mexicanus (Sauss.).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	90	0	0	80	20	0	60	40	0	0	100	0	0	100	0	-	-	-
Chlordane 10%	30	0	0	70	0	0	80	20	0	50	50	0	30	70	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	30	0	0	40	0
3956 20%	30	0	0	60	0	0	80	20	0	10	90	0	0	100	0	0	100	0

Table 7. Comparative Tests using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 80°F. on Adults of the Lesser Migratory Grasshopper, Melanoplus mexicanus mexicanus (Sauss.).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	70	0	0	90	0	0	80	20	0	0	100	0	0	100	0	0	100	0
Chlordane 10%	10	0	0	50	0	0	70	10	0	50	50	0	30	70	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	40	0	0	40	0
3956 20%	20	0	0	50	0	0	80	10	0	20	80	0	0	100	0	0	100	0

Table 8. Comparative Tests using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 70°F. on Adults of the Lesser Migratory Grasshopper, Melanoplus mexicanus mexicanus (Sauss.).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	50	0	0	80	0	0	90	10	0	20	80	0	20	80	0	0	80	20
Chlordane 10%	10	0	0	50	0	0	70	0	0	60	40	0	30	70	0	0	70	30
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	40	0	0	50	0
3956 20%	10	0	0	40	0	0	80	0	0	30	70	0	10	90	0	0	100	0

Table 9. Comparative Tests Using BHC, 3956 and 3422 at a Constant Temperature of 100°F. on Nymphs of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 5% Gamma	100	0	0	40	60	0	10	90	0	0	100	0	-	-	-	-	-	-
3956 20%	10	0	0	70	0	0	90	0	0	70	30	0	10	90	0	0	100	0
3422 2%	100	0	0	30	70	0	0	100	0	0	100	0	-	-	-	-	-	-
3422 1%	80	0	0	60	40	0	30	70	0	10	90	0	0	90	10	0	90	10

Table 10. Comparative Tests Using BHC, 3956 and 3422 at a Constant Temperature of 90°F. on Nymphs of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 5% Gamma	100	0	0	60	40	0	30	70	0	0	100	0	0	100	0	-	-	-
3956 20%	10	0	0	100	0	0	100	0	0	40	60	0	10	90	0	0	100	0
3422 2%	90	0	0	50	50	0	0	100	0	0	100	0	-	-	-	-	-	-
3422 1%	80	0	0	80	20	0	40	60	0	10	90	0	0	90	10	0	90	10

Table 11. Comparative Tests Using BHC, 3956 and 3422 at a Constant Temperature of 80°F. on Nymphs of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 5% Gamma	90	0	0	90	10	0	50	50	0	0	100	0	0	100	0	-	-	-
3956 20%	0	0	0	70	0	0	90	10	0	40	60	0	0	90	0	0	100	0
3422 2%	90	0	0	60	40	0	10	90	0	0	100	0	0	100	0	-	-	-
3422 1%	60	0	0	90	10	0	50	50	0	10	90	0	0	90	10	0	90	10

Table 12. Comparative Tests Using BHC, 3956 and 3422 at a Constant Temperature of 70°F. on Nymphs of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 5% Gamma	80	0	0	80	20	0	70	30	0	0	100	0	0	100	0	0	100	0
3956 20%	0	0	0	80	0	0	100	0	0	50	50	0	10	90	0	0	100	0
3422 2%	80	0	0	80	20	0	20	80	0	0	100	0	0	100	0	-	-	-
3422 1%	50	0	0	100	0	0	70	30	0	20	80	0	20	80	0	0	80	20

Table 13. Comparative Tests Using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 100°F. on Adults of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	100	0	0	60	40	0	30	70	0	0	100	0	-	-	-	-	-	-
Chlordane 10%	0	0	0	40	0	0	80	20	0	30	70	0	0	80	20	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	30	0
3956 20%	0	0	0	50	0	0	100	0	0	30	70	0	0	100	0	-	-	-

Table 14. Comparative Tests Using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 90°F. on Adults of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	80	0	0	80	20	0	60	40	0	0	100	0	-	-	-	-	-	-
Chlordane 10%	0	0	0	40	0	0	90	10	0	40	60	0	20	80	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	30	0	0	30	0
3956 20%	0	0	0	50	0	0	90	10	0	20	80	0	0	100	0	-	-	-

Table 15. Comparative Tests Using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 80°F. on Adults of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	50	0	0	60	10	0	80	20	0	0	90	10	0	90	10	-	-	-
Chlordane 10%	0	0	0	40	0	0	70	0	0	50	50	0	30	70	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	40	0	0	40	0
3956 20%	0	0	0	30	0	0	50	0	0	50	50	0	20	80	0	0	100	0

Table 16. Comparative Tests Using BHC, Chlordane, DDT, and 3956 at a Constant Temperature of 70°F. on Adults of the two-lined grasshopper, Melanoplus bivittatus (Say).

Formulation	Percentage of Grasshoppers Hours After Treatment																	
	2			4			8			24			48			72		
Dusts	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R	A	D	R
BHC 4% Gamma	40	0	0	60	0	0	100	0	0	0	80	20	0	80	20	0	80	20
Chlordane 10%	0	0	0	30	0	0	70	0	0	50	50	0	0	70	0	0	80	20
DDT 20%	0	0	0	0	0	0	0	0	0	0	20	0	0	40	0	0	40	0
3956 20%	0	0	0	0	0	0	40	0	0	50	50	0	20	80	0	0	90	10

THE SUSCEPTIBILITY OF GRASSHOPPERS TO SYNTHETIC INSECTICIDES IN THE FIELD

1946 Tests.

Severe outbreaks of grasshoppers in alfalfa fields of Northwestern Oklahoma during the spring of 1946 afforded an opportunity to make field tests of synthetic insecticides applied as dusts. During these tests the temperature ranged from 80°F. to 95°F. There was a wind velocity of 2 to 3 miles per hour at the time of application. Grasshoppers were estimated to average between 35 and 40 per square yard. About 70 percent were Melanoplus differentialis, 10 percent Melanoplus bivittatus and 20 percent Melanoplus mexicanus mexicanus and Melanoplus femur-rubrum.

Excellent control was obtained with 5 percent gamma BHC dust, applied at the rate of 10 pounds per acre. Sixty-four percent of the grasshoppers were killed 6 to 8 hours after application and in every test except one, 100 percent kill was recorded at the end of 24 hours. This particular test recorded only an 85 percent kill with a 15 percent recovery at the end of 24 hours. Lesser percentages of gamma BHC did not give favorable results. (Table 17)

Extent of control was directly proportional to the concentration of gamma isomer for the same sample preparation. There was variation between different sample preparations. It appears that one-half to one pound of gamma isomer per acre, depending upon the preparation, will give satisfactory control.

Chlordane was unsatisfactory as a 10 percent dust applied at the rate of 10 pounds per acre for controlling grasshoppers in the field. At the end of 24 hours, only 7.7 percent of the grasshoppers were killed. Five percent dust killed 3.7 percent of the grasshoppers. (Table 17)

1947 Tests.

In the spring of 1947, field tests were again made in Northwestern Oklahoma using synthetic insecticides as dusts. During these tests the temperature was between 50°F.-60°F. at the time of application. The wind velocity was 10-20 M.P.H. Treatments were made along heavily weeded irrigation ditches.

Ten percent gamma BHC applied at the rate of 50 pounds per acre gave 98 percent kill at the end of 8 hours. No affected grasshoppers were observed at the 24-hour period and at the end of six days the area was destitute of grasshoppers. None had migrated into the treated area.

Five percent gamma BHC, applied at 10 pounds per acre, did not give as good control as it did the previous year. This was probably due to lower temperature and greater wind velocity at the time of application. The temperature and wind velocity for the 1946 test was 80°F.-95°F. and 2-3 M.P.H., respectively as compared to 50°F.-60°F. and 10-20 M.P.H., respectively for the 1947 tests. At the end of the 24 hour period, in the 1947 tests, there was a 74.5 kill recorded with approximately the same reading at the end of 6 days. Migrations of grasshoppers had begun moving into the plots at the six-day reading.

There was little difference between the control obtained with 20

percent and 10 percent 3956 dusts applied at the rate of 40 pounds per acre. More grasshoppers were affected at the end of six days after application in the plots treated with 20 percent 3956 than were in the plots treated with the 10 percent 3956. The 3956 was the only insecticide used that was still toxic at the end of 6 days.

Tests using two percent 3422, applied at the rate of 20 pounds per acre gave excellent results in the field, a 92 percent kill being recorded at the end of 3 hours. This percentage of kill did not increase appreciably at the 24 hour or 6 day reading. Grasshoppers had begun moving in the treated plots at the 6 day reading.

Tests using 1 percent 3422 applied at the rate of 20 pounds per acre showed it to be unsatisfactory in the control of grasshoppers in the field. There was a very high percent of recovery with this concentration. The above results are shown in table 18.

The field tests show a 2 percent concentration of 3422 to be a very promising insecticide for controlling grasshoppers. It caused a high percent of kill more quickly than any of the other insecticides used.

Table 17. Grasshopper control in alfalfa using Benzene Hexachloride and Chlordane applied at 10 pounds per acre.

Concentration wt/wt	Hours after application	
Benzene Hexachloride (Percentage of gamma isomer)	6-8	24-30
	Average Percentage Mortality	Average Percentage Mortality
5.0	64.0	100.0
4.0	50.0	84.0
2.0	30.0	57.0
0.5	1.0	22.0
0.1	0.0	7.0
Chlordane		
10.0	0.0	7.7
5.0	0.0	3.7

Table 18. Control of nymphs of the two-lined grasshopper, Melanoplus bivittatus, using dusts, applied with a six-row crop duster in heavily weeded irrigation ditches. Temperature 50°F.-60°F. Wind velocity 10-20 M.P.H. Gate, Oklahoma, June 13, 1947.

Insecticide	Pounds per Acre (Dust)	Percentage of Grasshoppers per Square Yard											
		Time in Hours after Treatment											
		4			8			24			144		
		U[1]	A	D	U	A	D	U	A	D	U	A	D
BHC 10 percent gamma	50	3	91.7	5.3	0	2	98	0	0	100	0	0	100
BHC 5 percent gamma	10	16.5	73.5	10	10	17.7	72.3	17.5	8	74.5	24	0	76
3956 20 percent	40	60.7	39.3	0	36.6	31.3	32.1	30.7	47.2	22.1	9	2	89
3956 10 percent	40	58.5	41.5	0	16.2	44.8	39	18.8	46.7	34.5	16.2	.7	83.1
3422 2 percent	20	14.1	22.3	63.6	1	7	92	1.7	7.3	91	6.4	.2	93.1
3422 1 percent	20	57.1	42.9	0	39.6	49.2	11.2	81.6	10.4	8	88	0	12

[1]Explanation of letters
U - unaffected grasshoppers. A - affected grasshoppers. D - dead grasshoppers.

DISCUSSION

A review of the literature up to the present time revealed no quantitative work as having been done concerning the relation of temperature in the susceptibility of grasshoppers to these synthetic insecticides.

Some of these insecticides show considerable increase in their toxic effect at high temperatures. DDT was more effective at the lower temperatures.

Greater toxic action at high temperature may be partially due to fumigation. This action was more pronounced with BHC and 3422 than with chlordane and 3956. Tests with BHC showed very definite fumigating action.

When gases are released from chemicals, high temperatures speed up the rate of release. Grasshoppers are also more active in high temperatures. Uvarov (12) states that the influence of temperature plays an important part in the respiratory movements of grasshoppers. The number of movements per minute are increased in proportion with the number of degrees increase in temperature. These movements increase from an average of 5.9 per minute at a temperature of 9.5°C. to 26.6 per minute at a temperature of 26.6°C.

Krogh (8) studied the composition of the air in the tracheal system of the hind leg of a grasshopper and found that the oxygen percentage may be as high as 20 percent during rest but after exhausting muscular exercise it is reduced to 5 percent.

When insecticides act as fumigants they will give off more gas at high temperatures and since grasshoppers are more active and have

a smaller amount of oxygen in their tracheal system the respiratory movements are faster in order to replace the oxygen. Thus, if the insecticide is applied at high temperatures more of the toxic gas will be taken in to replace oxygen than when grasshoppers are comparatively inactive at low temperatures.

DDT does not act as a fumigant. It is slow in its action and is taken up by absorption through the fatty tissues. The grasshoppers are sluggish at low temperatures and the rate of metabolism is slower. Perhaps this reduces the rate at which DDT is eliminated and thus allows a lethal concentration to be more quickly reached.

A good contact dust for grasshopper control should act quickly in order that further damage by the insects may be prevented. Residual qualities are desirable for continuing the control throughout a hatching period or to kill grasshoppers which migrate into the area. Low toxicity to warm blooded animals is very important and low cost in the application of the insecticide is of prime importance. Not all of these features are fully realized as yet in any of the synthetics but a great step forward has been made in grasshopper control.

SUMMARY

Laboratory and field tests were made with synthetic insecticide dusts to compare their relative toxicity to adults and nymphs of the differential grasshopper, Melanoplus differentialis; the two-lined grasshopper, M. bivittatus; and the lesser migratory grasshopper, M. mexicanus mexicanus.

Grasshoppers were placed in constant temperature compartments held at 70°F., 80°F., 90°F., and 100°F. to measure the effect of temperature in the susceptibility of the insects to the different synthetic insecticides.

Benzene hexachloride showed a very definite temperature relationship. Insects treated with 4 or 5 percent gamma BHC and placed in the 100°F. compartment were affected and killed more quickly than with any of the other insecticides except 2 percent 3422. There was no recovery of the grasshoppers, once they became affected, however, a recovery was recorded at the lower temperatures with a greater period of time being required before grasshoppers become affected. The nymphal steges were more susceptible than adults, also the lesser migratory grasshopper, M. mexicanus mexicanus, was more susceptible to the insecticide than the differential grasshopper, M. differentialis, or the two-lined grasshopper, M. bivittatus.

From the results obtained in both laboratory and field tests, it appears that 5 percent gamma BHC is an effective insecticide for controlling grasshoppers, when used as a dust at 10 pounds per acre.

Tests were made in the Laboratory and in the field with chlordane or 1068 dust. This material shows only a slight temperature relationship, being more toxic at the higher temperatures. Chlordane showed a greater toxicity to the nymphal stages than to the adults and also was more toxic to the migratory grasshopper than to the other two species used. This synthetic was less effective in its control of grasshoppers, when used as 10 percent dust, than was the 5 percent gamma BHC dust.

DDT in contrast to the other synthetics used, showed a more toxic effect at the lower temperatures. A higher percentage of kill being obtained at 70°F. than at 100°F. DDT did not appear to be a very effective material for controlling grasshoppers. Nymphs were more susceptible to DDT than were adults.

Chlorinated camphene or 3956 appeared to be an effective insecticide for the control of grasshoppers. It acted more slowly, however, than BHC. At least 72 hours were required for complete kill with 20 percent 3956 as compared with 24 hours to obtain complete kill with 5 percent BHC. Once the grasshoppers became affected with 3956, they did not recover as in some instances when BHC or chlordane were used.

An aryl alkyl thianophosphate known as 3422, used as a 2 percent dust, gave effective control of grasshoppers more quickly than any other insecticide used in laboratory or field tests. Within 8 hours after treatment, all insects were dead in the 100°F. compartment. Twenty-four hours were required for complete kill at 90°F., 80°F., and 70°F. None of the affected grasshoppers recovered. Ninety-three and one tenth percent of them were killed in a field test with dust at 20 pounds per acre.

One percent 3422 dust was not satisfactory in its control. A large percentage of the affected grasshoppers recovered both on laboratory and field tests. Only 12 percent were killed in a field test with dust applied at 20 pounds per acre.

LITERATURE CITED

(1) Brett, Charles H. and W. C. Rhoades.
Grasshopper control in alfalfa with Hexachlorocyclohexane dust. Jour. Econ. Ent. 39 (5): 667. Oct., 1946.

(2) Brett, Charles H.
Interrelated effects of food, temperature, and humidity on the Lesser Migratory Grasshopper, Melanoplus mexicanus mexicanus (Saussure). Okla. Agri. Exp. Sta. Tech. Bul. T-26. Feb., 1947.

(3) Coquillet, D. W.
Report on the locusts of the San Joaquin Valley, California. U. S. Comm. Agr., Ann. Rpt.: 289-303. 1885-86.

(4) Hill, Roscoe E. and Ephriam Hixson.
Hexachlorocyclohexane dusts and fogs to control grasshoppers. Jour. Econ. Ent. 40 (1): 137-38. Feb., 1947.

(5) Hinman, E. J. and F. T. Cowan, Et Al.
New insecticides in grasshopper control. E-722: 18. May, 1947.

(6) Jackson, H. B.
Destructive locusts in Colorado. U. S. Dept. Agr., Div. Ent., Insect Life: 32-34. 1894.

(7) Kearns, C. W., Lester Ingle, and Robert Metcalf.
A new chlorinated hydrocarbon insecticide. Jour. Econ. Ent. 38 (6): 661-68. Dec., 1945.

(8) Krogh, A.
The composition of the air in the tracheal system of insects. Skand. Arch. Physiol. 29: 29-36. 1913.

(9) Riley, Packard, and Thomas.
First Report, United States Entomological Commission on the Rocky Mountain Locust.: 401-03. 1877-78.

(10) Slade, R. E.
The gamma isomer of hexachlorocyclohexane (gammexane), an insecticide with outstanding properties. Chemistry and Industry (40): 314-18. Oct., 1945.

(11) Urbahns, T. D.
Grasshopper control in the Pacific States. U.S.D.A. T. Bul. 1140: 4. 1920.

(12) Uvarov, B. P.
Locusts and Grasshoppers. A handbook for their study and control. Imperial Bureau of Entomology. William Clowes and Sons. London and Beccles.: 1928.

Typist--Mary Jo Barr