CONTACT AND STOMACH TOXICITY OF FIVE

INSECTICIDES TO GRASSHOPPERS

By

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INTRODUCTION

History and Importance of Grasshopper Toxins

Wakeland (20)[1] states that practical grasshopper control
was almost impossible until 1885 when wet bran bait was first
used in the United States. This bait method of control went on
for many years, undergoing many changes and improvements until
1946, when the chlorinated hydrocarbons were first used as insecti-
cides against grasshoppers.

In 1946 benzene hexachloride, chlordane, and toxaphene were
applied in the form of dusts and sprays and were found to give
satisfactory results. This new method of controlling grasshoppers
became widely known and expanded rapidly. Today the old arsenic
bait method is seldom recommended. Instead, where baits are
desirable, the Bureau of Entomology and Plant Quarantine (17)
recommends some of the new chlorinated hydrocarbons to replace
arsenicals in the bait.

In the past the amount of insecticide required to control
grasshoppers was measured in pounds per acre. Today our new
toxins are so potent that only ounces per acre are needed. Aldrin,
one of the new grasshopper toxins, gives excellent control of
grasshoppers at dosages of two ounces per acre in a spray. Such
low dosages per acre have cut the cost of grasshopper control to
such an extent that it is now economical to control grasshoppers
in many places where it was considered too costly in the past.

The possible damage that grasshoppers can do is shown in the

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[1]Numbers in parentheses refer to "Literature Cited," Page 38.

Julius Hyman Newsletter, May 1949, which states that, "grass-hoppers consume green forage roughly eight times as fast in pro-portion to their weight as beef animals on a good range." It also makes the statement that, "a grasshopper will eat its own weight in green food in about 16 hours." It is easy to see why grasshoppers are a serious pest when not controlled. The Julius Hyman Newsletter, July 1949, mentioned Melanoplus bivittatus (Say) reaching a density of 150 per square yard. This occurred in a South Dakota wheat field. Bishopp (1) states that 3 million acres in Canada were treated with aldrin for grasshopper control at the low cost of 70 cents per acre. It is apparent why grass-hopper control with our new insecticides can save so many dollars.

Description of Insecticides Tested

Aldrin is a chlorinated hydrocarbon. The commercial form, according to Hyman (10), contains not less than 95 percent 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethano-naphthalene. The other 5 percent consists of related chlorinated hydrocarbons. The empirical formula for the principal chemical is $C_{12}H_8Cl_6$. Aldrin is a whitish, crystalline solid. The melting point of the commercial product is not less than 90°C and in a pure state melts at 101-102°C. According to Hyman (11) it is soluble in most organic solvents, but is insoluble in water. Brown (4,p.12) states that aldrin is stable when in contact with alkalies, as well as hydrated metallic chlorides. Decker (5) shows that when aldrin is applied to plants it is about the same as chlordane in residual effectiveness, but is less residual than DDT. Aldrin when warmed,

according to Brown (4, p. 12), produces a mild piney odor but is nearly odorless under normal conditions.

Aldrin was developed by the Julius Hyman Company during 1948. It was not approved by the U.S.D.A. for grasshopper control until August 1950. Wakeland (20) states that aldrin was extensively tested by the Canadians as a grasshopper toxin before it was approved in this country. Today it ranks as good if not better than any of the widely used grasshopper toxins.

Dieldrin is an oxygenated derivative of aldrin. The commercial form contains, according to Hyman (12), not less than 85 percent 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene. Similar chlorinated hydrocarbons comprise the remaining 15 percent. The principal chemical has the empirical formula $C_{12}H_8OCl_6$. Dieldrin is a whitish crystalline solid and is almost odorless. Hyman (12) gives the following information about dieldrin. Its melting point is 172-175°C. and for the commercial product not less than 150°C. Like aldrin, dieldrin is stable to alkalies. Although it is decomposed by strong acids, it is stable to acids normally encountered in the agricultural field. It is insoluble in water.

Dieldrin was developed in 1948 by the Julius Hyman Company. It is more toxic to grasshoppers than aldrin, and has been approved for the control of cotton insects which includes grasshoppers. The cost of dieldrin is considerably more than that of aldrin, which along with its long residual quality may keep it from becoming the most widely used grasshopper toxin. Information concerning an experiment comparing the residual action of dieldrin

with that of DDT is discussed in the Julius Hyman Newsletter, January 1949. Seven weeks after application dieldrin retained 65 percent of its insecticidal activity, while the activity of DDT was completely lost.

Heptachlor is a chlorinated hydrocarbon which was developed by the Velsicol Corporation. Its chemical name is 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene. The empirical formula is $C_{10}H_5Cl_7$. Heptachlor is a white, crystalline solid having a melting point of 92-94°C. It is moderately soluble in most organic solvents and is insoluble in water. This compound is almost odorless. In the presence of strong alkalies and pro-bably also when exposed to certain metallic halides, according to Kearns (14), it slowly decomposes with the liberation of hydro-chloric acid. Weinman (21) shows the residual action of heptachlor to be less than that of aldrin. Its toxicity to grasshoppers, both as a contact and stomach poison, approaches that of aldrin.

All of the following information concerning EPN 300 was taken from Du Pont (6). EPN 300 is an organic phosphonate with the chemical name Ethyl p-nitrophenyl thionobenzenephosphonate. The pure compound is crystalline. Its melting point is 36°C. It is soluble in most common organic solvents, but only slightly soluble in water. Technical EPN is a dark amber liquid having a specific gravity of 1.27 at 25°C.

EPN is considered to be residual but its residual life is short when compared to DDT. It is compatible with most commonly employed insecticides, including the sulfur fungicides, but its residual life is greatly reduced when used with bordeaux mixture.

EPN 300 was developed by Du Pont and Company. It is still mostly in the experimental stage. As a grasshopper toxin it looks promising, especially where a short residual period is desired.

The following information describing compound 1189 and compound 1367 is cited from a letter sent by General Chemical Division, Allied Chemical and Dye Corporation, dated October 22, 1951.

The chemical name for compound 1189 is 2,3,3a,4,5,6,7,7a,8,8-decachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene-1-one. General Chemicals now has a derivative of compound 1189, designated for the present as compound 1367. Its exact structure has not been determined. Compound 1367 appears to be equal to compound 1189 as a stomach poison, but it has considerably more contact action. In tests conducted by General Chemicals compound 1367 has compared quite favorably with aldrin and dieldrin against grasshoppers in laboratory and small scale field tests.

Insecticides Compared as Stomach Poisons

Chlordane was not used for comparison in this experiment, though the toxicity of chlordane to grasshoppers is well known. In discussing other experiments chlordane will frequently be compared with other grasshopper toxins.

From tests conducted using adult _Melanoplus differentialis_ (Thos.), Kearns (14) in determining L.D. 50 values found aldrin, dieldrin and heptachlor to be from three to four times as toxic as chlordane when used as stomach poisons. In a comparison of aldrin, dieldrin and heptachlor using adult _Melanoplus differen-_

tialis (Thos.), Weinman (21) concluded that aldrin is more toxic as a stomach poison than either chlordane, heptachlor or dieldrin. His table shows the L.D. 50 values which were compared on Melanoplus differentialis (Thos.) using milligrams per kilogram of body weight, with the following results: chlordane 12.0, heptachlor 4.4, aldrin 2.3, dieldrin 3.7.

In contrast to this Mitchener (15) concluded the following results when he compared aldrin with dieldrin. Dieldrin and aldrin were sprayed on cabbage leaves and fed to three important economic species of grasshoppers. Dieldrin at the rate of 2 ounces to 40 Canadian gallons of water, gave better kills than aldrin at the rate of 4 ounces to 40 Canadian gallons of water.

In comparing aldrin to chlordane the U.S. Department of Agriculture (17) recommends 2 ounces of aldrin or $\frac{1}{2}$ pound of chlordane per 100 pounds of wet bait to successfully control grasshoppers. This assumes aldrin to be four times as effective as chlordane as a stomach poison. Brett (3) also found aldrin to be about four times as toxic as chlordane. This was based on tests conducted where fourth, fifth and sixth instars of Melanoplus differentialis (Thos.) were fed treated alfalfa leaves.

Insecticides Compared as Contact Poisons

Kearns (14) determined the L.D. 50 values of aldrin, dieldrin, heptachlor and chlordane using adult Melanoplus differentialis (Thos.). He found aldrin, dieldrin and heptachlor to have six times the toxicity of chlordane when used as contact poisons. Weinman (21) in determining the L.D. 50 dosage on adult Melanoplus differentialis (Thos.) using milligrams per kilogram of body

weight lists the following: chlordane 9.8, heptachlor 1.6, aldrin 1.8, dieldrin 1.4. He claims the small difference between aldrin and dieldrin could easily have been due to experimental error. According to laboratory tests conducted by Gains (8) on grasshopper nymphs, aldrin and dieldrin were found to be equally effective as contact poisons. Reinking (16,p.28) compared the contact toxicity of aldrin and dieldrin by dusting adult differential grasshoppers in half-gallon fruit jars. His conclusion was that dieldrin was superior to aldrin.

Insecticides Compared in the Field

Gains (7) used first and second instars of _Melanoplus differentialis_ (Thos.) to compare dusts with sprays in the field. As would be expected dieldrin was more toxic to the nymphs than chlordane or aldrin. Aldrin at 0.42 pound per acre as a dust gave 98.1 percent kill the first day, and the same 3 days later. Chlordane at 0.84 pound per acre used as a spray gave 86.9 percent kill the first day and 96.0 percent kill 3 days later. Dieldrin at 0.25 pound per acre applied as a dust gave 100 percent kill the first day, while aldrin in the same concentration and also as a dust gave 68.6 percent kill the first day, and 96.1 the third day. All materials were more effective when applied as sprays than as dusts.

Gains (8) using grasshopper nymphs compared compound 1189, chlordane, aldrin and dieldrin in field tests. Compound 1189 and chlordane applied at 1.5 pounds per acre as dusts caused 98 percent reduction at the end of 9 days. Chlordane and compound 1189 gave about the same control from 2 to 14 days. Aldrin and

dieldrin applied at 0.3 pound per acre gave complete control and compared with chlordane and compound 1189 at one pound per acre. In contrast to the general rule of sprays being more effective than dusts, compound 1189 spray did not prove as effective as the dust.

Insecticides Compared as to Speed of Kill

Reinking (16) found dieldrin to be faster in speed of kill than either chlordane or aldrin. Weinman (21) concluded that heptachlor is faster acting than aldrin.

Residual Qualities

Weinman (21) conducted an experiment to determine the residual qualities of aldrin and heptachlor. In his test he used various instars and adults of several economic species of grasshoppers. He concluded that of the two, aldrin and heptachlor, aldrin has the longest residual effect. Heptachlor began to lose its effectiveness after four days, even at a dosage of 4 ounces per acre. Aldrin residues began to lose effectiveness after ten to fourteen days. After twentyone days there was no appreciable toxicity even from the residue on plants sprayed with 5 pounds per acre, which is about 20 times the amount necessary to give control.

Mitchener (15) sprayed aldrin and dieldrin on cabbage and oat leaves and fed them to three important economic species of grasshoppers. Dieldrin was effectively toxic for approximately eleven days on oats and cabbage, while aldrin was similarly effective for approximately five days, but only on cabbage.

In an experiment where caged adult _Melanoplus mexicanus mexi-_

canus (Sauss.) were fed green alfalfa one week after spraying,
Reinking (16,p.28) concluded that dieldrin is more residual than
aldrin or chlordane. The residual action of the toxins could have
been affected by rain which fell during the experiment.

Decker (5) reports that under heavy rain, chlordane appeared
to be much more resistant to being washed off than aldrin or
dieldrin.

According to Gains (9) simulated rain will reduce the action
of aldrin sprays more than it will dieldrin. In the Hyman News-
letter, October 1950, an experiment controlling grasshoppers in
Montana is discussed. The residual action of aldrin was more
pronounced at higher dosages and during cool weather. Residual
kills were less with dusts than with sprays.

Factors Regulating Required Dosages

According to Hyman (13) the most effective time to apply
aldrin is just after hatching. As the grasshoppers grow and dis-
tribute themselves, Brett (2) says the effectiveness of the in-
secticide is gradually lost; more insecticide per acre is
necessary and more acres must be covered to acquire good control.
After grasshoppers reach the adult stage they can fly great
distances and are more resistant to insecticides.

Hyman (13) recommends, under moderate infestation, aldrin at
2 ounces per acre as a spray and 3 ounces per acre as a dust. The
spray is more effective and therefore requires a lower rate of
application than the dust.

Temperature is an important factor in the effectiveness of an
insecticide in the field. Brett (2) through experiment found that

with most insecticides an increase in temperature caused an increase in the rate of kill and often the percent of kill. Hyman (13) says "best results are obtained when aldrin insecticides are applied during periods when temperature is high enough to insure grasshopper activity."

The type vegetation is important in regulating the success of grasshopper control. Brett (2) mentions that if an insecticide is residual and is good as a stomach poison, it is usually more effective where infestations are on succulent plants rather than dry plants with little foliage. The Bureau of Entomology and Plant Quarantine (17) recommends higher dosages of the toxins when the vegetation is tall and dense.

Toxicity of Insecticides to Range Animals

The U.S.D.A. (17) warns that feed contaminated with aldrin or chlordane should not be fed to dairy animals or to animals being finished for slaughter. They say that according to experiments, animals fed forage contaminated with amounts of these toxins used to control grasshoppers will not visibly impare the health of the animals. These toxins are readily stored in the fat of the animals, which makes the meat or milk unfit for human consumption.

Some experiments to determine the extent that these insecticides are stored in the animal fat, and their toxic effects on the animals were conducted at Kerville, Texas (19). In one experiment the animals were fed the insecticides at dosages of 10 p.p.m. This low dosage was used because of the small amounts of these toxins required for control of forage insects, and the low residue on the forage that may be anticipated. Sheep and cattle accumulated 40 to

50 p.p.m. of aldrin in their fat in 56 days, but contamination did
not appreciably increase during another 8 weeks of feeding.
Calves and sheep stored 10 to 15 p.p.m. of chlordane in their fat
in 56 days, which did not increase during continued feeding of
the insecticide.

The cattle which were fed aldrin made a higher net gain,
gained a higher percentage of their initial weight and used fewer
pounds of feed to produce each pound of gain than those fed chlor-
dane and those fed no insecticide. The cattle fed chlordane pro-
duced about the same results as those fed uncontaminated feed.
This situation was just the reverse with sheep. Sheep fed aldrin
did poorly in converting food to meat. Those fed chlordane did
about the same as those fed insecticidally free food.

In another experiment, cattle and sheep were fed 25 p.p.m.
of aldrin, dieldrin and chlordane. Chlordane deposits in the fat
were not as great and were eliminated much more rapidly than were
aldrin and dieldrin. Aldrin and dieldrin were about equal in
their extent of contamination of the fat, and the rate they were
eliminated. All three insecticides caused very poor food utiliza-
tion in a 56 day test.

The Bureau of Entomology and Plant Quarantine (18) conducted
some experiments using horses. Dieldrin and aldrin each were fed
to a single horse. The dosage was 25 mg./kg., given as wettable
powders. Dieldrin proved toxic but not lethal. Aldrin produced
very mild symptoms of poisoning. Chlordane was fed to one horse
at a dosage of 45 mg./kg. The horse developed clinical symptoms
of marked but not lethal character.

PROCEDURE

Tests With Stomach Poisons

The grasshoppers used for all of the stomach toxicity tests were collected near Kingfisher, Oklahoma. This was a unique place from the standpoint of average grasshopper density. It was undoubtedly a reservoir for many species of grasshoppers from which they could move to other areas if and when favorable conditions developed. This place had a density of grasshoppers much greater than any other place that could be located in central Oklahoma at that time. The spring and summer of 1951 were particularly bad for grasshoppers because of the excessive moisture, making it difficult to locate enough for experimental purposes. This grasshopper paradise was pretty well hidden, being located several miles from a paved road. The topography was slightly rolling, and the soil very sandy. The vegetation consisted of weed fields bordered with oak woods (Plates I and II). The pasture was being grazed and none of the area had been plowed recently. There was a pond in a low area near where the grasshoppers were collected.

A good variety of vegetation was present for the grasshoppers to feed on. Some of the dominant weeds shown on Plate II, Figures 1 and 2, were umbrella-plant (Eriogonum annua), Heterotheca subaxillaris, broom-snakeroot (Gutierrezia dracunculoides), Aplopappus ciliatus, starwort (Aster sp.), rutabaga (Brassica sp.), and Croton sp. Pokeweed (Phytolacca sp.) is shown on Plate I, Fig. 2. Plate I, Fig. 1, shows some unidentified thistle which reached 3 to 4 feet in height. The weeds growing near the oak woods margin had a dense growth of grass among them. The dominant grass was bermuda

(*Cynodon dactylon*), but there was enough burgrass (*Cenchrus* sp.) to make it uncomfortable for the hands at times.

The various species of grasshoppers included several in the family Tettigoniidae and many in the family Acrididae. The economic species consisted of *Melanoplus differentialis* (Thos.), *Melanoplus bivittatus* (Say), *Melanoplus femur-rubrum* (De Geer), *Melanoplus mexicanus mexicanus* (Sauss.) and *Schistocerca americana* (Drury). The differential grasshopper was the dominant species.

The grasshoppers were collected with standard insect nets and placed in small screen cages. Fresh succulent leaves such as poke were added to the cages so they could continue to feed and also to help shade them from the sun. At the time of the first collection which was made the last of June, very few adult grasshoppers were present. The differentials were mostly third, fourth and fifth instars. Of all the species, the most desired one, the differential grasshopper, was the most difficult to collect. The individuals of this species would jump or fall from weeds most readily, or migrate into some humanly impermiable vegetation. The adult differentials were the heaviest on pokeweeds which were shaded by oak trees. This was particularly true at the time of the second collection which was the last of July.

The grasshoppers collected were heavily parasitized, especially the nymphs collected during the last of June. The dominant parasite at this time was a round worm belonging to the subclass Gordiacea, which became less prevalent as the grasshoppers reached the adult stage. The larva of a fly was the most common form of

parasitism among the adults collected during the last of August.

It was impractical to obtain collections consisting of only differential grasshoppers. Many individuals were needed and there was a limited time to collect them. In an effort to get as good a collection of specimens as possible, the grasshoppers were kept for several days before the tests were begun. Death occurred to many of the parasitized and injured individuals during this time, as well as to some of the more undesirable species that could not seem to stand cage life.

The most common species used in the tests was the differential. The developmental stage of this grasshopper is given at the bottom of each table. The grasshoppers were fed fresh lettuce daily until the time of the test. For each test fresh alfalfa or lettuce was dipped in water emulsions of the toxicants. The dipped plants used in each test and the percentage concentrations of the 5 chemicals used are listed on Tables I, II, and III. Untreated alfalfa and lettuce were used in the checks.

The insecticides were carefully weighed on an analytical balance and mixed with water measured by a graduate cylinder. Each test was made twice, including the checks.

Parasitism caused the death of several individuals in the treated groups, which made it necessary to determine the percent effective control by the use of Abbott's formula.

The cages used for the tests were one foot square and eight inches high with the front and back made of inch wood and screen wire on the sides. While feeding the grasshoppers and cleaning the cages it was at first difficult to keep the grasshoppers from

escaping. This situation was cured by using a piece of stiff wallboard the size of the door openings with a large enough hole in it to permit free movement of a man's arm. The hole in the wallboard was covered on both sides with pieces of a car inner tube. Each section of rubber was cut 4 ways along the diameter of the hole making enough flaps to keep a close fit around the person's arm or hand passing in and out of the cages. This contraption was made by a former student who had worked with grasshoppers.

Due to the residual nature of most of the chemicals used, a constant guard was kept against contamination of the cages. After the plants were dipped in the toxic emulsions, the excess water was permitted to drain off on paper towels, before they were placed in the cages. The drained plants were then placed on two paper towels in the bottom of each cage. After each experiment the inside of each cage was washed with soap and hot water.

During the entire experiment it was difficult to determine when the grasshoppers should be considered dead. A quick look at many individuals would indicate that they were dead, but if punched they would start moving a leg or two, or their mouthparts. Most of them in this condition were dead for all practical purposes. For the purpose of accuracy each grasshopper that appeared dead was punched with a pencil and if any part of it moved including its mouthparts, it was considered alive.

Tests With Contact Poisons

The grasshoppers used for contact tests were all adult _Melano-_

plus differentialis (Thos.). These grasshoppers were collected during the last of August in and on the northwest side of Stillwater, Oklahoma. Only a few isolated weed patches contained enough grasshoppers to warrant collecting them, and in those few patches they were frequently very numerous. It was almost impossible to collect the grasshoppers during the heat of the day by any method; however they were collected with fair success in the early morning. The easiest collection was made during and right after a cool rain. The rain lowered their body temperature, making them slow and reluctant to jump. They were all collected by hand and pushed through a slot in a paper sack which was sealed at the top with two paper clips.

There were three plants which seemed to be preferred by the grasshoppers. These were lambs quarters (Chenopodium sp.) sunflower (Helianthus sp.), and giant ragweed (Ambrosia sp.). Of these three, lambs quarters seemed to be the most preferred.

The same five chemicals tested as stomach poisons were compared as contact poisons. The concentrations used were 1.0, 0.5 and 0.25 percent. Attaclay was used as a diluent for the 0.25 percent concentration tests (Table IV), and pyrophyllite for the tests at 1.0 and 0.5 percent concentration, (Tables V and VI).

Each test was conducted by placing 10 adult differential grasshoppers in a half-gallon fruit jar with a screen wire lid. The lid, which was made by replacing the cover part of the fruit jar lid with wire, had a small hole in it through which a glass tube could be inserted. A piece of No. 6 glass tubing about 8 inches long and bent to an angle of about 120° was filled with 50

milligrams of the particular concentration for each insecticide.
A rubber bulb fitted with valves allowing air to pass in one end
of it and out the opposite end was attached to the elbowed glass
tubes with a piece of rubber tubing. The glass tubes were in-
serted in the wire lids and with one puff the insecticide was
blown into the jar. The grasshoppers which were in the path of
the dust received more insecticide than the others; however,
suspension of the dust in the jars was good. Continual movement
of the grasshoppers helped keep the dust in suspension, resulting
in good coverage. The grasshoppers were left in the jars for five
minutes and then transferred to the cages described in the
procedure on stomach tests. They were fed fresh lettuce during
the remainder of the test. The percentage mortality was recorded
at intervals shown on Tables IV, V and VI. The last recording
was made 96 hours after treatment instead of 72 hours shown on
the stomach tests.

Ovicide Tests

If it were possible to treat the soil containing grasshopper
egg pods and either prevent them from hatching or kill them just
after hatching, considerable money and effort could be saved in
grasshopper control. In an attempt to find a toxin that could be
used in economical concentrations against grasshopper eggs in the
field, the following test was conducted.

Adult female differential grasshoppers were collected at the
same place, in the same manner, and at approximately the same
time as described in the procedure for contact tests. These
female grasshoppers were placed in a cage and were fed fresh

lettuce.

The cage was approximately 2 feet long, 2 feet high, and 18 inches wide, and had screen on the sides and top, with plywood on the ends and bottom. A tray about 2 inches deep was filled with sterile sand and placed in the cage as a place for the grasshoppers to deposit their eggs. The sand was kept moist by adding distilled water so the egg pods would not become dehydrated. Twice during the egg deposition period the pods were removed and placed in glass jars containing moist sand and then cooled at approximately 40°F. for about 3 weeks. The purpose of cooling the eggs was to break their diapause.

A cardboard box 22 inches high, 2 feet long and 21 inches wide was remodeled into an incubator for the eggs. Holes for 36 paper cups were cut in the top of the box so that about two thirds of each cup would extend into the box. A thermostat located in the center and just below the cups regulated two electric heating units at the base of the box. Two thermometers were placed in the cups so that the temperature could be watched. The thermostat was set to hold the temperature at 30°C., but due to poor insulation it varied from 28°C. to 33°C. The sand in the cups was kept moist by the daily addition of water.

Insecticides used in the test were aldrin, dieldrin, heptachlor and chlordane. The first part of the ovicide test consisted of placing egg pods into cups containing treated sand at concentrations of 1 and 0.5 percent. Two egg pods placed in their normal position in each cup were covered with the treated sand, leaving only their spongy ends exposed at the surface.

The remainder of the egg pod test was conducted by dipping the egg pods into water emulsions of the insecticides. The insecticides were diluted to 1 percent by volume. Each egg pod was dipped in the toxic emulsion for 5 minutes and then placed on a paper towel to dry. One dipped egg pod for each toxin was placed in a wax coated paper cup and covered with sterile sand.

The rest of the test consisted of breaking up a single egg pod for each toxin and dipping its contents into the same water emulsion used for the pods, thus allowing each egg to become directly exposed to the toxin. The eggs were removed from the emulsion after 5 minutes, placed on paper towels to dry and then covered with sand in a paper cup.

Each cup was replicated twice for the entire experiment. A check was set up by using 4 egg pods in sterile sand, each pod being placed in a different cup.

Plate I.

Figure 1.

Figure 2.

Plate II.

Figure 1.

Figure 2.

RESULTS

Results With Stomach Poisons

Aldrin and dieldrin were used as standards of comparison for the other 3 toxins.

As is shown on Table I, heptachlor at a concentration of 1.0 percent was about the same in its speed of kill as aldrin at a concentration of 0.25 percent. During the first 8 hours heptachlor at 1.0 percent and aldrin at 0.25 percent were both faster acting than dieldrin at 0.25 percent, but after 24 hours dieldrin showed a higher mortality rate than either heptachlor or aldrin. When heptachlor, aldrin and dieldrin were compared at 0.25 percent, dieldrin gave the highest kill at the end of 16 hours, and for the remainder of the test.

On Table II aldrin, dieldrin and heptachlor are compared at 0.06 percent concentration. Heptachlor was as effective in its speed of action and total kill as aldrin and dieldrin. Heptachlor was a little faster acting on alfalfa than on lettuce. In contrast to this, dieldrin was faster in its action on lettuce. Aldrin gave about the same results on alfalfa and lettuce.

When heptachlor was diluted to a concentration of 0.03 and 0.015 percent it was definitely inferior to aldrin and dieldrin at the same concentration. Figures found on Table III show that heptachlor didn't give 100 percent mortality at either concentration for a period of 72 hours. Aldrin and dieldrin both gave 100 percent mortality at the end of 72 hours, and in every instance but one in 48 hours. The toxic effects of aldrin and dieldrin were so close at both concentrations they could be considered

equal at these dilutions and according to this test. This is not
in complete agreement with Weinman (21) who found aldrin to be
superior to dieldrin as a stomach poison.

EPN 300 at 1.0 and 0.25 percent concentration (Table I) was
faster acting than any of the other materials tested. At the end
of the first 4 hours 34 percent of the grasshoppers feeding on al-
falfa treated with 0.25 percent EPN were dead, while those feeding
on alfalfa treated with 0.25 percent dieldrin had only a 4 percent
mortality. After 48 hours dieldrin and EPN both at 0.25 percent
caused 100 percent mortality. At 1.0 percent EPN killed 46 percent
of the grasshoppers in 4 hours. EPN at 1.0 percent was only
slightly quicker than dieldrin at 0.25 percent in making a complete
kill.

A comparison of EPN 300 with aldrin and dieldrin at 0.06
percent concentration (Table II), shows EPN again with its fast
action, but only killing about 25 percent of the grasshoppers in
8 hours; none of them being dead in 4 hours. Aldrin and dieldrin
gave little or no kill at the end of 8 hours. After 24 hours EPN,
aldrin and dieldrin caused about the same percent mortality. EPN
produced 100 percent mortality in 72 hours on alfalfa but failed
to do so on lettuce, and therefore failed to equal aldrin and
dieldrin in effectiveness.

Like heptachlor, EPN 300 shows its inferiority to aldrin and
dieldrin as a grasshopper toxicant when compared at low concentra-
tions. EPN at a concentration of 0.03 and 0.015 percent (Table
III) was not significant in its speed of kill and fell far short
of giving 100 percent mortality in 72 hours.

Compound 1189 acted differently than the other toxins in one respect. Referring to Table I, compound 1189 gave a better kill at 0.25 percent concentration than at 1.0 percent. This could possibly have been due to a repellent action caused by the higher concentration. With a concentration of 0.25 percent, compound 1189 was a little faster acting than dieldrin and aldrin, and like aldrin and dieldrin, gave 100 percent mortality.

Compound 1189, when diluted to 0.06 percent concentration (Table II), gave about the same results on alfalfa as aldrin and dieldrin, but failed in one test to kill all of the grasshoppers feeding on treated lettuce.

Table III comparing the toxicants at the low levels of 0.03 and 0.015 percent places compound 1189 below dieldrin and aldrin in effectiveness. Compound 1189 did not produce 100 percent mortality in any of the 4 tests, and ranked about the same in toxicity as heptachlor.

Results With Contact Poisons

Aldrin and dieldrin were used as a comparison for the other 3 toxins in the contact tests.

Heptachlor was very close in its effect to aldrin at 1.0 percent (Table V) and 0.25 percent (Table IV), however at 0.25 percent heptachlor gave a 10 percent greater mortality than aldrin. In contrast, aldrin gave 20 percent greater mortality than heptachlor when compared at a concentration of 0.5 percent. It is possible the diluent attaclay was responsible for aldrin being inferior to heptachlor at the concentration of 0.25 percent. At a 1.0 percent concentration (Table V) heptachlor and aldrin were

almost identical in their speed of kill and percent mortality. They both produced 100 percent mortality at the end of 72 hours. The effectiveness of dieldrin was superior to the other 4 toxins tested. These results compare favorably with those of Weinman (21) who compared the L.D. 50 dosages on adult differential grasshoppers already discussed under "Insecticides Compared as Contact Poisons."

At a concentration of 0.25 percent EPN 300 had little effect as a contact poison, giving only 13 percent effective control (Table IV). At 0.5 percent, EPN showed considerable improvement, giving an effective control of 75 percent (Table VI). Looking at Table VI, it appears that EPN was slightly faster acting for the first 24 hours than dieldrin. Actually at the end of 8 hours, 80 percent of the grasshoppers that had been treated with EPN showed only minor signs of life, while 90 percent of those treated with dieldrin were almost lifeless. The period of time after the grasshoppers were down until death was some shorter for EPN than for dieldrin. EPN gave the same results as heptachlor at 0.5 percent, which was less than that of aldrin. EPN, even at 1.0 percent (Table V), fell below aldrin, dieldrin and heptachlor in effect, by failing to produce 100 percent mortality.

From all indications, compound 1189 had no contact action. Table IV shows 1189 at 0.25 percent having the same percent mortality as the checks. Unlike the other insecticides, compound 1189 did not give any better results at the higher concentration of 0.5 percent (Table VI). Instead, the mortality was nil for both replicates which again was identical to the checks mortality.

Even at the highest concentration of 1.0 percent (Table V), 1189 produced only 22 percent effective control. This low percentage could have partially been due to experimental error. If any of the grasshoppers died from 1189, it was probably from stomach action. They were observed cleaning the toxic dust from their legs with their mandibles.

Method of Kill

All of the materials tested except compound 1189 definitely acted as both stomach and contact poisons. Aldrin, dieldrin and heptachlor likely function primarily as nerve toxins. According to Brown (4,p.322), these toxins affect the respiratory rate of roaches. Aldrin and dieldrin both show a latent period of 2-3 hours after injection, followed by a rapid respiration increase to a high peak. Heptachlor shows only a slight latent period, the rise being gradual and less pronounced. EPN 300 being an organic phosphate probably functions as an anticholinesterase. The destruction of cholinesterase results in the addition of acetylcholine, eventually causing a complete block of nerve transmission.

Results of Ovicide Tests

On December 8, four weeks after incubation started, 16 grasshoppers hatched in one of the checks. They were confined to the cup by a piece of screen wire inserted in the cup, but were placed in another cage immediately after they were discovered. Even though the young grasshoppers were active in the cup, they died soon after being placed in the cage. Three days later on December 11, 13 hatched in a cup containing sand treated with 1 percent

chlordane. None of this hatch ever became active enough to jump, and all died while still in a pale, unsclerotized condition. All of the other eggs including the other three checks failed to hatch.

From all indications the grasshoppers that hatched in the checks died from the insecticide fumes from the treated cups. The fact that the grasshoppers hatching in the 1 percent chlordane never became active might indicate that soil treatment in the spring would help control the newly hatched nymphs. There is no definite explanation as to why so many of the eggs failed to hatch; however it is possible that their diapause was not broken.

Table I. Grasshopper toxins; a comparison of five different materials as stomach poisons*. July 4, 1951.

Material Tested	Concentration Percentage	No. of grass-hoppers	Percent Mortality (hrs.)						Percent Mortality (average)	Effective Control (percent)
			4	8	16	24	48	72		
Heptachlor	1.0	25	12	16	44	56	100	100	100	100
"	1.0	17	6	12	24	53	100	100		
Heptachlor	0.25	13	0	0	23	54	61	100	100	100
"	0.25	26	8	8	19	27	35	100		
Dieldrin	0.25	13	8	8	30	70	100	100	100	100
"	0.25	20	0	5	25	55	100	100		
Aldrin	0.25	7	0	14	28	71	100	100	100	100
"	0.25	10	20	20	20	40	70	100		
EPN 300	1.0	42	52	69	93	93	100	100	100	100
"	1.0	15	40	53	87	93	100	100		
EPN 300	0.25	32	34	40	47	97	100	100	100	100
"	0.25	12	33	58	58	66	100	100		
Compound 1189	1.0	18	5	11	45	57	90	94	97	96
"	1.0	20	0	10	30	45	100	100		
Compound 1189	0.25	15	0	40	66	100	100	100	100	100
"	0.25	26	7	7	42	92	100	100		
Check		18	0	0	11	28	39	55	29	0
"		23	0	4	4	4	4	8		

*Differential grasshoppers (3rd, 4th, 5th instars) were fed fresh alfalfa which had been dipped in the toxic emulsions.

Table II. Grasshopper toxins; a comparison of five different materials as stomach
poisons* at 0.06 percent concentration. July 29, 1951.

Material Tested	Dipped Plants	No. of grass- hoppers	Percent Mortality (hrs.)							Percent Mortality (average)	Effective Control (percent)
			4	8	12	16	24	48	72		
Heptachlor	lettuce	13	0	15	15	23	77	100	100	100	100
"	"	15	0	0	33	33	80	100	100		
Heptachlor	alfalfa	14	0	0	36	64	86	100	100	100	100
"	"	14	0	7	57	57	79	100	100		
Dieldrin	lettuce	14	0	21	36	50	86	100	100	100	100
"	"	14	0	0	43	43	50	100	100		
Dieldrin	alfalfa	14	0	0	14	29	57	93	100	100	100
"	"	14	0	0	0	0	50	100	100		
Aldrin	lettuce	13	0	0	15	31	76	100	100	100	100
"	"	16	0	0	19	31	50	100	100		
Aldrin	alfalfa	15	0	7	27	60	73	93	100	100	100
"	"	14	0	0	43	43	79	100	100		
EPN 300	lettuce	12	0	25	25	33	58	83	92	92	86
"	"	13	0	23	31	46	54	92	92		
EPN 300	alfalfa	12	0	17	33	33	75	92	100	100	100
"	"	14	0	36	57	57	79	100	100		
Compound 1189	lettuce	16	0	0	0	0	0	63	94	97	95
"	"	12	0	8	8	25	33	83	100		
Compound 1189	alfalfa	17	0	0	35	35	59	100	100	100	100
"	"	15	0	0	13	13	53	100	100		
Check	lettuce	14	0	2	5	7	16	21	31	36	0
"	alfalfa	14	0	1	4	6	14	27	41		

*Differential grasshoppers (5th and 6th instars and adults) were fed on fresh alfalfa
and lettuce which had been dipped in the toxic emulsions.

Table III. Grasshopper toxins; a comparison of five different materials as stomach poisons*. August 8, 1951.

Material Tested	Concentration Percentage	No. of grass-hoppers	Percent Mortality (hrs.)							Percent Mortality (average)	Effective Control (percent)
			4	8	12	16	24	48	72		
Heptachlor	0.03	21	0	0	4	18	48	76	80	74	55
"	0.03	19	0	0	5	10	21	68	68		
Heptachlor	0.015	23	0	0	13	17	56	91	91	94	90
"	0.015	25	0	4	4	16	32	80	96		
Dieldrin	0.03	23	0	13	13	65	82	100	100	100	100
"	0.03	29	0	20	31	76	93	100	100		
Dieldrin	0.015	27	0	0	14	37	89	100	100	100	100
"	0.015	27	0	3	26	52	96	100	100		
Aldrin	0.03	43	2	9	21	42	83	100	100	100	100
"	0.03	28	0	3	40	50	90	100	100		
Aldrin	0.015	36	3	3	33	60	94	100	100	100	100
"	0.015	31	0	13	29	45	68	84	100		
EPN 300	0.03	48	0	17	17	38	52	67	71	78	59
"	0.03	25	4	8	20	28	36	84	84		
EPN 300	0.015	41	0	4	10	20	54	78	78	75	57
"	0.015	29	0	7	24	31	60	72	72		
Compound 1189	0.03	26	0	4	8	11	11	46	80	88	79
"	0.03	24	0	4	21	33	46	90	96		
Compound 1189	0.015	20	0	0	5	5	15	35	75	78	59
"	0.015	35	0	3	9	17	31	63	80		
Check		32	0	3	9	13	25	38	40	42	0
		23	0	0	0	0	4	17	43		

*Differential grasshoppers (5th and 6th instars and adults) and mixed grasshopper species.

Table IV. Grasshopper toxins; a comparison of five different materials as contact poisons at 0.25 percent concentration*. August 25, 1951.

Material Tested	Percent Mortality (hrs.)							Percent Mortality (average)	Effective Control (percent)
	4	8	16	24	48	72	96		
Heptachlor	0	0	0	0	0	30	40		
"	0	0	0	10	20	40	60	50	38
Dieldrin	0	0	10	20	60	90	90		
"	0	0	0	0	30	60	70	80	75
Aldrin	0	0	0	0	20	20	40		
"	0	0	10	30	30	40	40	40	25
EPN 300	0	0	0	0	10	10	20		
"	0	0	10	10	30	30	40	30	13
Compound 1189	0	0	0	10	40	40	40		
"	0	0	0	0	0	0	0	20	0
Check	0	10	10	10	10	10	20		
"	0	0	10	10	10	20	20	20	0

*Differential grasshoppers adults were dusted with the toxic materials in one half gallon jars for five minutes; removed and fed fresh lettuce for the duration of the test.
Ten grasshoppers were used in each test.

Table V.   Grasshopper toxins; a comparison of five different materials as contact
poisons at 1.0 percent concentration*.   August 30, 1951.

Material Tested	Percent Mortality (hrs.)							Percent Mortality (average)	Effective Control (percent)
	4	8	16	24	48	72	96		
Heptachlor	0	0	10	60	100	100	100	100	100
"	0	0	20	40	90	100	100		
Dieldrin	0	0	40	100	100	100	100	100	100
"	0	10	10	60	100	100	100		
Aldrin	0	0	0	50	100	100	100	100	100
"	0	0	0	40	90	100	100		
EPN 300	0	10	40	90	90	90	90	95	94
"	0	10	40	90	100	100	100		
Compound 1189	0	0	0	10	10	10	40	30	22
"	0	0	0	0	0	0	20		
Check	0	0	0	0	0	10	10	10	0
"	0	0	0	0	0	10	10		

*Adult differential grasshoppers were dusted with the toxic materials in one half
 gallon jars for five minutes; removed and fed fresh lettuce for the duration of the
 test.
Ten grasshoppers were used in each test.

Table VI. Grasshopper toxins; a comparison of five different materials as contact poisons at 0.5 percent concentration*. September 6, 1951.

Material Tested	Percent Mortality (hrs.)							Percent Mortality (average)	Effective Control (percent)
	4	8	16	24	48	72	96		
Heptachlor	0	0	10	30	60	60	70	75	75
"	0	0	10	30	40	70	80		
Dieldrin	0	0	20	40	100	100	100	100	100
"	0	0	20	20	80	100	100		
Aldrin	0	0	0	20	70	100	100	95	95
"	0	0	0	30	40	60	90		
EPN 300	0	0	10	50	70	70	70	75	75
"	0	0	30	80	80	80	80		
Compound 1189	0	0	0	0	0	0	0	0	0
"	0	0	0	0	0	0	0		
Check	0	0	0	0	0	0	0	0	0
"	0	0	0	0	0	0	0		

*Adult differential grasshoppers were dusted with the toxic materials in one half gallon jars for five minutes; removed and fed fresh lettuce for the duration of the test.
Ten grasshoppers were used in each test.

DISCUSSION

It is apparent from this experiment that of the 5 toxins tested, only dieldrin might replace aldrin as the most effective grasshopper toxin. Dieldrin is superior to aldrin both as a contact and a stomach poison, however this difference may not be great enough to overshadow some advantages of aldrin. The cost of aldrin is less than dieldrin. Of the two, dieldrin has the longest residual period. Too long a residual period could interfere with such things as harvesting and grazing.

It is doubtful if heptachlor will ever become a widely used grasshopper toxin. Even though it approaches aldrin as a contact poison, it is inferior as a stomach poison. In order for heptachlor to become more widely used than aldrin, it would have to be considerably below aldrin in cost, as more heptachlor per acre would be required to give the same degree of control.

If EPN 300 is ever applied as a grasshopper toxin, it will likely be used only in special situations. For example, if a very short residual period were desired EPN could be of some use. If some insect was being controlled with EPN and grasshoppers were present and doing damage, EPN could work on both insects. EPN would also be good if a very rapid knockdown was desired. For general grasshopper control, too high a concentration of EPN would be necessary for economy, and its residual period would be too short.

According to this experiment, compound 1189 could never be a dependable grasshopper toxin. The effect of 1189 as a stomach poison is good but not outstanding; however as a contact poison

it has no effect at concentrations that could be applied economically in the field. The other grasshopper toxins tested function as contact poisons as well as stomach poisons.

SUMMARY

Three tests were conducted comparing the stomach toxicity of
heptachlor, EPN 300, and compound 1189 with aldrin and dieldrin,
using the differential grasshopper Melanoplus differentialis
(Thos.). The grasshoppers ranged in age from third instar nymphs
to adults. For one test alfalfa and lettuce were dipped into
emulsions of the toxic materials and allowed to dry. For the
other tests, only alfalfa was used. The dipped plants were placed
in a cage and fed to the grasshoppers.

In the test where lettuce and alfalfa were used, the dipped
lettuce was more toxic in more instances than the dipped alfalfa.
At the higher concentrations EPN 300 was the fastest acting and
gave good results; however at the lowest concentration it gave
poor results. Aldrin and dieldrin were superior to the other
toxins and were about the same in effect, dieldrin being some-
what the best. Heptachlor and compound 1189, like EPN, failed
to give 100 percent mortality at the lowest concentration. Hep-
tachlor was the most effective of the three compared with aldrin
and dieldrin.

Tests showing contact toxicity were conducted by placing ten
adult differential grasshoppers in a half-gallon fruit jar and
dusting them with the insecticide. The grasshoppers were removed
from the jars after 5 minutes, placed in cages and fed fresh
lettuce. Concentrations of insecticides used were 1.0, 0.5, and
0.25 percent. Diluents used were attaclay at 0.25 percent and
pyrophyllite at 1.0 and 0.5 percent. Dieldrin was superior in
all tests to the other materials, being the only one that pro-

duced a complete kill at 0.5 percent. Aldrin and heptachlor
were similar in results. EPN 300, like aldrin, dieldrin and
heptachlor, gave 100 percent mortality at 1.0 percent. Except
at the lowest concentration, EPN was about as effective as
aldrin and heptachlor. Compound 1189 showed so little indica-
tion toward contact action, that it should be considered in-
effective as a contact poison.

For the ovicide test, egg pods were collected by placing
adult female differentials in a cage and letting them deposit
their eggs in a tray filled with moist sand. The egg pods were
refrigerated for 3 weeks to break their diapause. Insecticides
used were aldrin, dieldrin, heptachlor and chlordane. The first
part of the test consisted of placing egg pods in paper cups con-
taining treated sand. In the second part of the test egg pods
were dipped in toxic emulsions, then placed in cups of sterile
sand. The third part of the test consisted of breaking up the
egg pods and dipping the eggs into toxic emulsions, then burying
the eggs in cups of sterile sand.

An incubator was constructed by cutting holes in a box.
Paper cups were placed in the holes. The box was heated by two
electric heating units, and the temperature was controlled by a
thermostat. The eggs were kept moist during incubation.

Only two egg pods hatched. One pod in a check hatched in 4
weeks, but the insects soon died, probably from insecticide fumes
from adjacent cups. A pod in 1 percent chlordane treated sand
hatched but were never active like those in the check, and all
died.

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