# A Two Year Study of Potential Resistance in the Adult Western Corn Rootworm in South Dakota

John M. Wirtz

# A TWO YEAR STUDY OF POTENTIAL RESISTANCE IN THE ADULT WESTERN CORN ROOTWORM IN SOUTH DAKOTA

BY

JOHN M. WIRTZ

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A TWO YEAR STUDY OF POTENTIAL RESISTANCE IN THE ADULT

WESTERN CORN ROOTWORM IN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser    Date

Head, Entomology-Zoology Department    Date

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# INTRODUCTION

The western corn rootworm *Diabrotica virgifera* Le Conte, and the northern corn rootworm *Diabrotica longicornis* Say, are major pests affecting corn in South Dakota. Jones (1968) considered the rootworm the number one corn pest in South Dakota and estimated that the rootworm caused fifty percent of all insect damage done to corn.

Prior to 1961 the northern corn rootworm was the predominant species causing damage in South Dakota. The western corn rootworm is presently the predominant species (Nearman, 1968).

Cultural and chemical control methods have been used to control corn rootworms in the past with varying degrees of success. Crop rotation, one of the first methods used (Forbes, 1915), has given some degree of control (Bigger, 1932).

With the increase in land values in the late 1940's farming practices changed considerably. It became necessary to continuously place a high value crop such as corn on the best soil. Corn on corn then became the common practice. A rapid increase in corn rootworm populations coincided with these practices (Jessen, 1970).

During this same period, following World War II, the feasibility of chemical control of corn rootworms was enhanced with the development of a new family of insecticides, the chlorinated hydrocarbons. From numerous tests in several states, aldrin and heptachlor became the recommended materials for corn rootworm control (Hill, Hixson and Muma, 1948), (Muma, Hill and Hixson, 1949), (Cox and Lilly, 1953), (Lilly, 1954), (Burkhardt, 1954), (Bigger and Blanchard, 1955), and (Apple, 1957).

The economic damage to corn by the rootworms and the cost of control have been high. The estimated total loss to farmers in South Dakota in 1968 was seven million dollars (Jones, 1968). The estimated total loss in 1969 was also seven million dollars (P. A. Jones, personal communication).

Although the loss attributed to rootworms has been high, the savings from use of recommended insecticides must be considered. In 1968, over 1,100,000 acres of corn were treated with rootworm insecticides. South Dakota farmers realized a savings of 800,000 bushels of corn above the cost of treatment. In 1969, an estimated 900,000 acres of corn were treated with corn rootworm insecticides. This treatment saved 1,500,000 bushels of corn above the cost of treatment (B. H. Kantack, personal communication).

Chlorinated hydrocarbon insecticides were used extensively until the early 1960's, when failures of aldrin and heptachlor occurred (Weekman, 1961). Other groups of insecticides including organophosphates and carbamates were tested and subsequently recommended. Ball and Weekman (1962) tested and recommended two organophosphates, diazinon and phorate, for use on corn rootworms.

With the subsequent use of large amounts of organophosphates the possibility of resistance comparable to that of the chlorinated hydrocarbons was anticipated. Ball (1968) reported a trend to resistance of corn rootworms to diazinon and phorate in Nebraska.

The study reported in this thesis was initiated in the summer of

1969 as a test model for an annual monitoring system of most rootworm insecticides used in South Dakota. The primary objective was to determine the $LD_{50}$'s of the recommended rootworm insecticides on western corn rootworm adults collected each year from several sites in the more intensive corn growing areas of the State. Comparison of the yearly $LD_{50}$'s should disclose if a trend towards resistance exists.

Only adults were used in this study since larvae were very difficult to collect from the field in any number and rearing techniques were time consuming and unsure. From tests which compared $LD_{50}$'s on larvae and adults, it has been concluded that if the adults were resistant the larvae were also resistant (Hamilton, 1966), (Brazzel, 1970).

# LITERATURE REVIEW

## Corn Rootworm Resistance to Insecticides

The first signs of failure of a chlorinated hydrocarbon insecticide at the recommended rate to control corn rootworms was noted in Nebraska in 1959 (Roselle, unpublished data). Failure of aldrin and heptachlor continued and became serious in 1960 and 1961 (Weekman, 1961).

In 1961, H. J. Ball and G. T. Weekman determined the $LD_{50}$ for certain insecticides on rootworm adults collected from two sites in Nebraska. One site consisted of a field in which rootworm control had been no problem; the second, a field in which resistance was suspected. Two chlorinated hydrocarbons, aldrin and heptachlor, and one organophosphate, diazinon, were tested. Suspected resistant adults from the first field required 100 times the dosage of aldrin or heptachlor to obtain an $LD_{50}$ as the dosage required for the rootworm adults from the field with no control problem. There was no significant difference in the $LD_{50}$ of diazinon from the two fields (Ball and Weekman, 1962).

Many reports of resistance were noted in the following years. Chlorinated hydrocarbon resistant northern corn rootworms were reported in South Dakota (Howe et al., 1963), in Illinois (Bigger, 1963), in Ohio (Blair et al., 1963), in Iowa (Hamilton, 1965), and in Wisconsin (Patel and Apple, 1966). Resistant western corn rootworms were reported in South Dakota (Howe et al., 1963), in Kansas (Burkhardt, 1963), and in Nebraska (Ball, 1962).

In 1963 a coordinated project was commenced to determine the resistance pattern for the western and northern corn rootworm in the north central States. The purpose was to determine the extent of the existing resistant populations. The highest level of resistance was reported in northwest Iowa, northern Kansas, and southeastern South Dakota. Aldrin and diazinon were used in this test. Diazinon was included as a comparison, as it was the organophosphate replacement for aldrin (Hamilton, 1965).

A five year study on the potential western corn rootworm resistance to two organophosphate insecticides was carried out in Nebraska from 1963-1967. The insecticides were diazinon and phorate. H. J. Ball summarized the data in 1968 and showed the mean $LD_{50}$ of rootworm adults collected in 1967 had increases of 66.1% for diazinon and 61.7% for phorate over the mean $LD_{50}$ of 1963. H. J. Ball also stated that these insecticides were still effective but the significant increase in $LD_{50}$ values indicated that poorer rootworm control might occur.

## CHEMICAL CONTROL TESTS

Several methods have been used to indicate the effectiveness of rootworm insecticides. The $LD_{50}$ laboratory test can be used in conjunction with one or several field tests to indicate the effectiveness of the formulation, the stability and the concentration of the insecticide needed, and the time and method of field application.

Larval counts, lodging, and yields were three of the early field tests used and were the basis for the original chlorinated hydrocarbon recommendations (Hill, Hixson, and Muma, 1948), (Cox and Lilly, 1953), (Lilly, 1954), and (Burkhardt, 1954).

Cox and Lilly (1953) included adult counts in their tests. Significant differences were noted between their treated areas and their untreated check.

Burkhardt (1954) reported delayed pupation of surviving larvae in the treated areas and suggested that the larvae had been retarded by the insecticides lindane, heptachlor and aldrin.

Weekman (1962) used a root rating analysis performed in mid-July and lodging counts as a means of determining rootworm damage.

Ball and Weekman (1962) initiated $LD_{50}$ tests on western corn rootworm adults in Nebraska. They indicated that some areas showed populations highly resistant to aldrin and heptachlor. Several suthors have used $LD_{50}$'s to determine possible resistance of both northern and western corn rootworms to chlorinated hydrocarbons or organophosphates, (Bigger, 1963), (Hamilton, 1965), (Blair et al., 1963) and (Patel and Apple, 1966).

Peters (1963) stated that plant lodging and yields, though widely used, are the most remote criteria for measuring the insect-plant relationship. Peters (1964) utilized root ratings and percent lodging correlated with yields and found both highly significant.

Eiben and Peters (1965) used the pounds of pull required to pull a single plant from the soil to evaluate varietal response to rootworm damage.

Ortman and Fitzgerald (1964) in determining varietal response of corn to rootworm damge utilized a root rating system.

Peters (1965) included rootworms per plant with lodging, root rating and yields to evaluate insecticides.

In South Dakota in 1964-1966 larval counts, root pulls, percent lodging and yields were used to determine performance of several insecticides at various rates (Nearman, 1968). Also in South Dakota in 1968-1969, extensive larval counts, root pulls, root rating and percent lodging were used in a similar study (Jessen, 1970).

The second conference on test methods for resistance in insects of agricultural importance has published a tentative test method for determining resistance to insecticides in *Diabrotica* species, (Brazzel, 1970). The procedure suggested by the committee on *Diabrotica* was very similar to that used by Ball and Weekman (1962), Ball (1968), and Hamilton (1966), with the addition of a solvent check.

# METHODS AND MATERIALS

## 1969

Several sites were established in South Dakota in August, 1969, for the collection of adult western corn rootworms. The sites were selected from known areas of high rootworm infestation. Several sites were selected so that fields with a wide range of previous insecticide use would be included in the study. The sites were located in the major corn growing areas of the state (Fig. 1).

Eight insecticides were tested in 1969. The insecticides are listed below with their chemical nomenclature:

| | |
|---|---|
| aldrin: | 1,2,3,4,10,10-hexachlor-1,4,5,8-diedomethano-1,4,4a,5,8,8a-hexahydronaphthalene |
| Bux®: | m-(1-ethylpropyl) phenyl methylcarbamate mixture (1-4) with m-(1-methylbutyl) phenyl methylcarbamate |
| diazinon: | 0,0-diethyl 0-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate |
| Dyfonate®: | 0-ethyl S-phenyl ethyphosphonodithioate |
| carbofuran: | 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate |
| Landrin®: | 3,4,5-trimethylphenyl methylcarbamate, 75%<br>2,3,5-trimethylphenyl methylcarbamate, 18% |
| Mocap®: | 0-ethyl S,S-dipropyl phosphorodithioate |
| phorate: | 0,0-diethyl S-(ethylthiomethyl) phosphorodithioate |

The above listed insecticides were applied topically to western corn rootworm adults at the following rates: 0.01, 0.05, 0.10, 0.50, 1.00, 5.00, and 10.00 micrograms actual insecticide per microliter of solution. The amount of solution applied to each insect was held constant at 1 uliter. Technical grade insecticides were used in all cases. Dilutions were made using acetone as the solvent.

## 1970

Three of the collection sites used in 1969 were selected for use in 1970. They included Yankton, Clay and Moody Counties (Fig. 1). Fourteen insecticides were tested in 1970. The insecticides are listed below with their chemical nomenclature:

| | |
|---|---|
| Bux: | m-(1-ethylpropyl) phenyl methylcarbamate mixture (1-4) with m-(1-methylbutyl) phenyl methyl-carbamate |
| Dasanit®: | 0,0-diethyl 0-(p-(methylsulfinyl) phenyl) phosphorothioate |
| diazinon: | 0,0-diethyl 0-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate |
| Dyfonate: | 0-ethyl S-phenyl ethyphosphonodithioate |
| carbofuran: | 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate |
| Landrin: | 3,4,5-trimethylphenyl methylcarbamate, 75%<br>2,3,4-trimethylphenyl methylcarbamate, 18% |
| Mocap: | 0-ethyl S,S-dipropyl phosphorodithioate |
| phorate: | 0,0-diethyl S-(ethylthiomethyl) phosphorodithioate |
| Gardona®: | 2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate |
| Imidan®: | 0,0-dimethyl S-phthalimidomethyl phosphorodithioate |
| NC 6897: | 2,2-dimethyl-1-1,3-benzodioxol-4yl-N-methyl carbamate |
| azinphos-methyl: | 0,0-dimethyl S(4-oxo-1,2,3-benzotriazin-3(4H)-ylmethyl) phosphorodithioate |
| Padan®: | 1,3-Bis(carbamoylthio)-2-(N,N-dimethyl-amino) propane |
| RE 12420: | 0,S-dimethyl N-acetyl phosphoramidothioate |

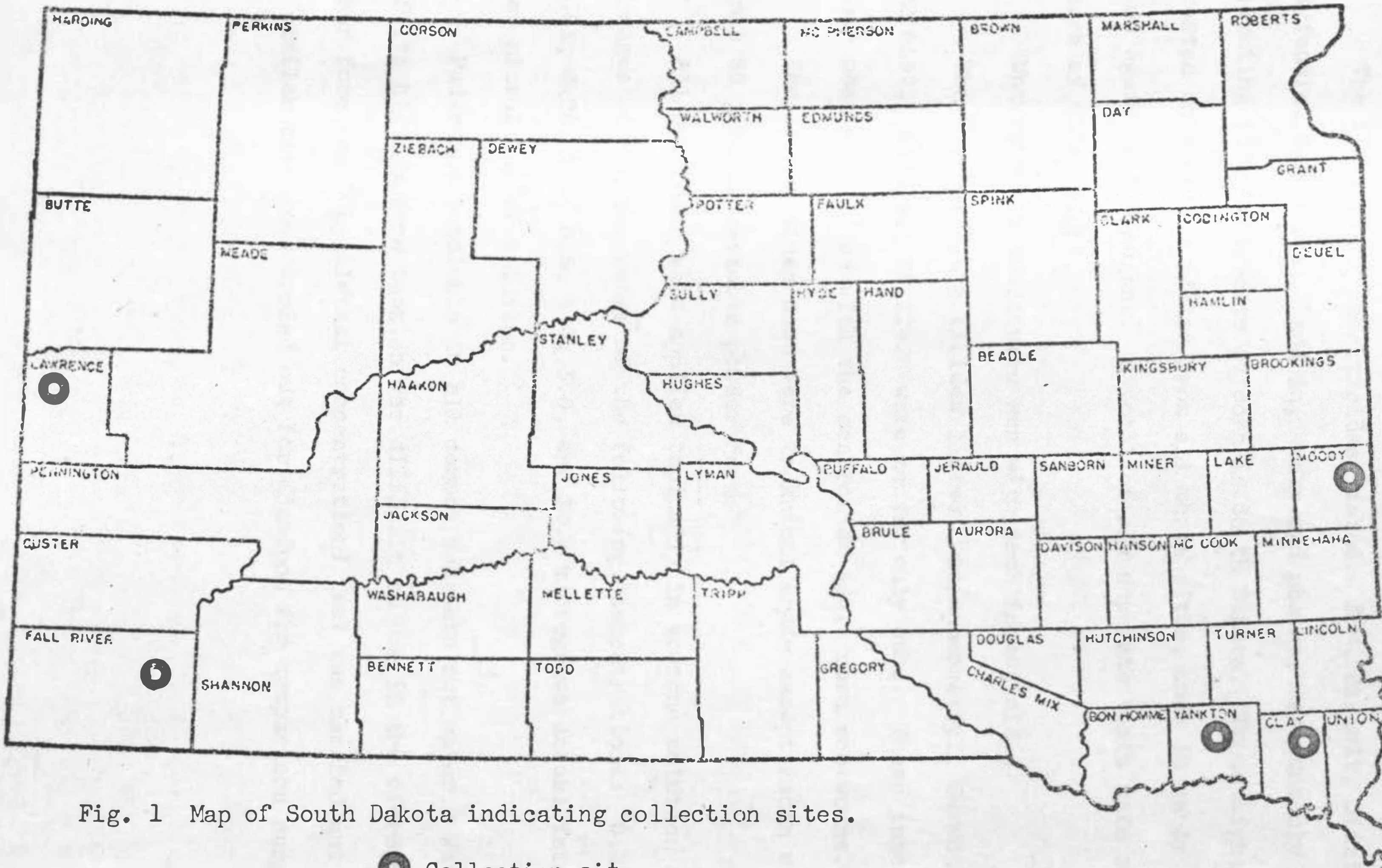


Fig. 1 Map of South Dakota indicating collection sites.

◉ Collection site

The first eight insecticides listed: Bux, Dasanit, diazinon, Dyfonate, carbofuran, Landrin, Mocap and phorate are commonly used as planting time treatments on corn in South Dakota. These eight were tested on rootworm adults from all three sites, once in early August and again in mid-August. A total of six separate tests were run for each of these eight.

Untreated controls were run with each insecticide.

The last six insecticides listed: azinphosmethyl, Gardona, Imidan, NC 6897, Padan and RE 12420 were tested only once. These insecticides have been associated with the control of adult corn rootworms.

The insecticides used were technical grade except Padan which was in a 50 percent wettable powder form.

All but Padan were applied topically in acetone solution at 1 uliter dosages within the range of the following concentrations: 0.001, 0.005, 0.01, 0.05, 0.1, 0.5, 1.0, 5.0, and 10.0 micrograms actual insecticide per microliter of solution.

Padan was insoluble in all common solvents but water. Water because of its high surface tension was difficult to use in the microapplicator. Therefore, an $LC_{50}$ (lethal concentration) test was carried out for Padan. A similar test was carried out for diazinon for camparison purposes.

## PROCEDURE

The rootworm adults used in the tests were collected from the selected sites with sweep nets and battery powered aspirators. The rootworms are first collected with the sweep nets and then removed from the nets with the power aspirator. Any coincidental insects caught in the sweep net can be bypassed with the aspirator. This procedure gives a homogeneous population of western corn rootworm adults.

The battery powered aspirator used consisted of a converted 12-volt car vacuum (Fig. 2). The vacuum bag that was standard with the car vacuum was replaced with a 2 3/4-inch diameter plastic tube with a screen covering one end. The open end of the tube was fitted to the head of the vacuum cleaner as the vacuum bag would normally be attached. The vacuum head was fitted with a small rubber tube to facilitate individual insect pickup (Fig. 3).

The power unit consisted of two 6-volt wet cell batteries connected in series to give 12 volts. The batteries were carried in a 10-inch plastic file card box. The unit was equipped with a volt meter and a jumper wire (Fig. 4,5,6). With the jumper wire plugged into a car cigarette lighter, the unit can be run for a prolonged period of time. It can also be charged in this manner.

The rootworms were transported and held in a 1 X 1 X 1 foot cage. Fresh silks and young ears of corn were used as food. Water was supplied by a petri dish containing a water soaked piece of gauze (Fig. 7). While in the laboratory the cages were kept in a special holding room with a temperature of 75-80° F and relative humidity of 40%.


Fig. 2 Converted Sears portable car vacuum.


Fig. 3 Break down of portable aspirator. a) Head b) Collection chamber c) Vacuum.

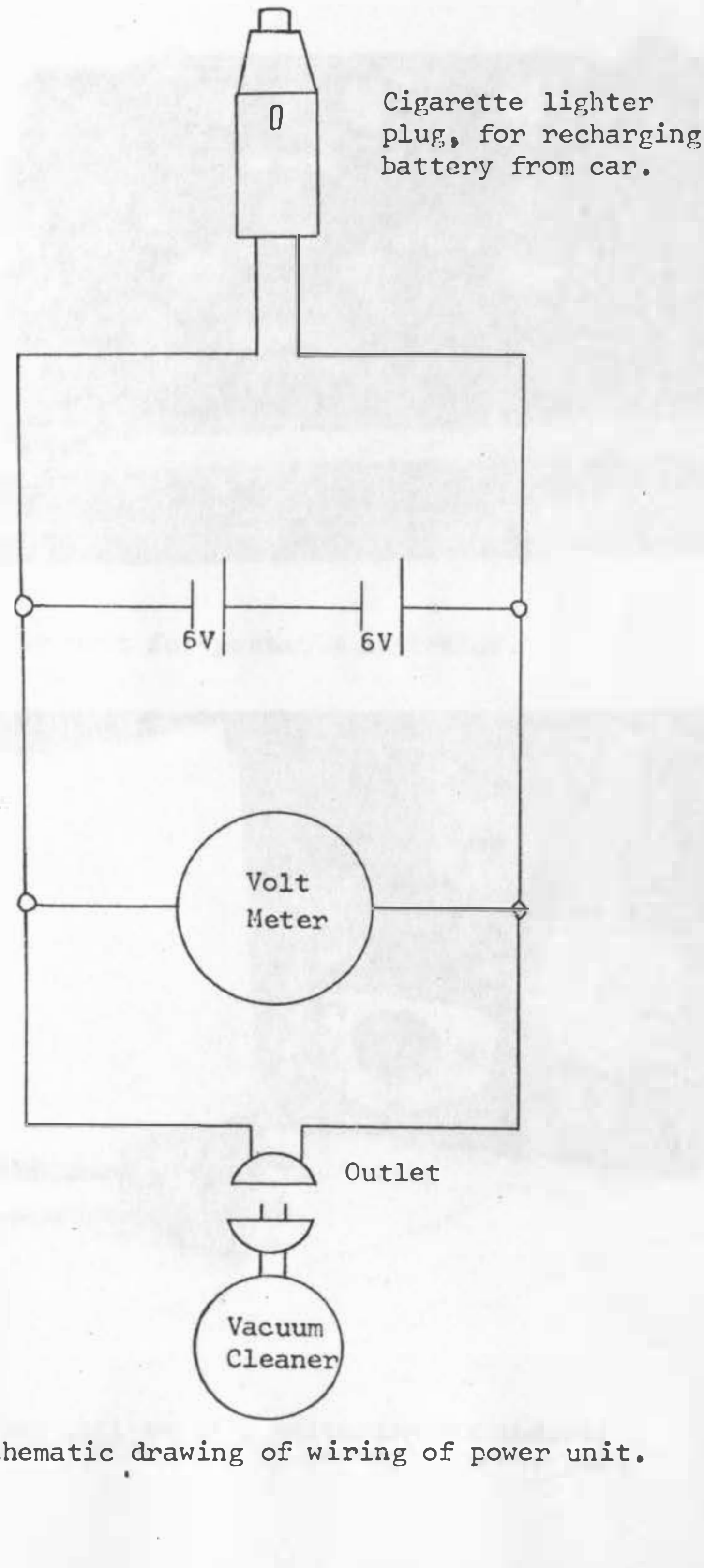


Fig. 4 Schematic drawing of wiring of power unit.

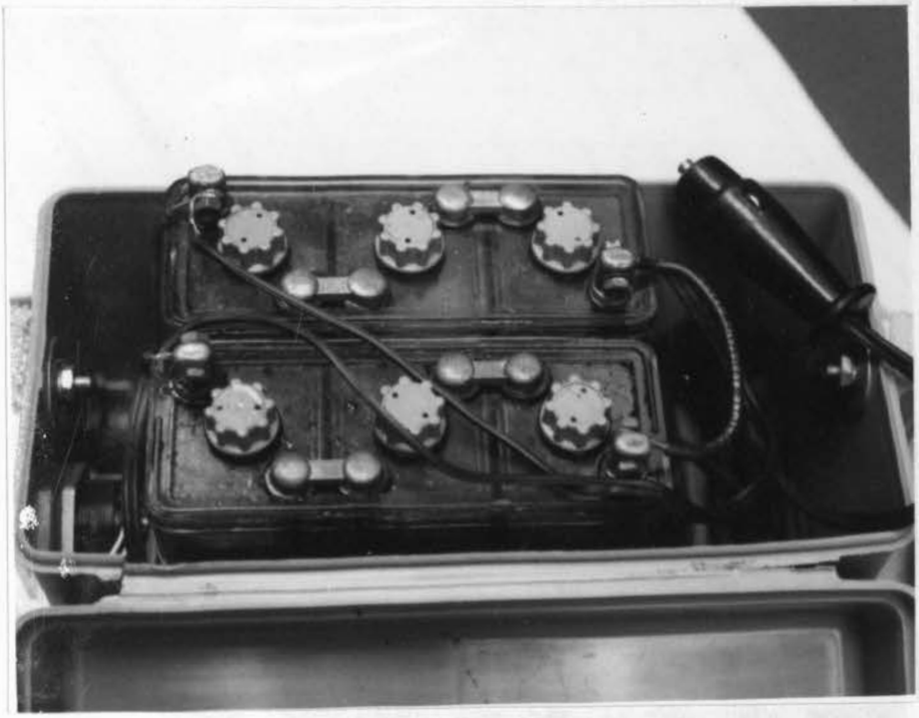

Fig. 5 Power unit for portable aspirator.

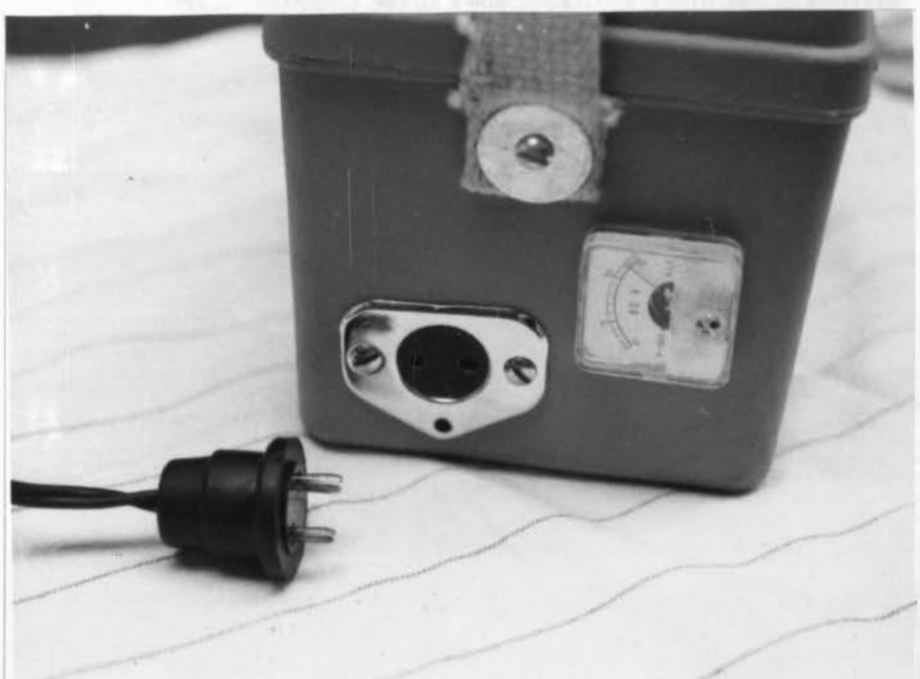

Fig. 6 Power unit showing voltmeter and outlet.

Fig. 7 Holding cage showing food and water.

Just prior to treatment the beetles for a test were removed from their cage and immobilized with $CO_2$ to facilitate handling.

Each individual beetle was treated separately with a microapplicator. The instrument maintained extreme accuracy with a repeatability of 1 uliter $\pm$ .02 uliter. The microapplicator was fitted with a 250 uliter Hamilton syringe with a 27-gauge needle (Fig. 8,9). This applicator was designed and built by E. W. Hamilton, toxicologist, Northern Grain Insects Research Laboratory. It is basically similar to that described by Hamilton and Dahm (1960).

When the applicator was activated for a single dose, a small drop appeared at the end of the needle. The abdomen of the rootworm beetle was then touched to the drop and the acetone-insecticide solution was immediately drawn onto the beetle. Working in this manner an individual can treat 2,000 - 2,500 beetles per day (Fig. 9).

An attempt was made to use water diluted insecticide in the micro-applicator, but this failed due to the high surface tension of water. The water-insecticide solution would cling to the needle rather than diffuse onto the beetle.

The beetles were manipulated in two ways; first in 1969 with a micro-vacuum pencil, second in 1970 with a forceps. The reasons for changing handling technique were speed and the possibility that the micro-vacuum pencil was removing a small amount of the insecticide upon application.

Each concentration of each insecticide used was replicated three times with 20 rootworms per replication. Only the concentrations of insecticide necessary to obtain a range of 0 to 100% kill were used.

Fig. 8 Microapplicator with syringe in place.

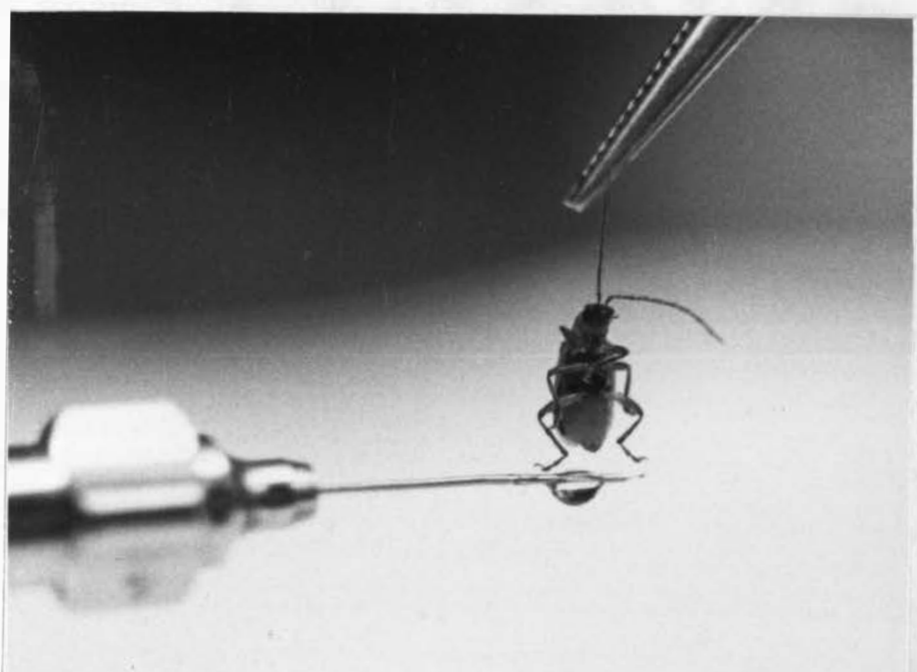

Fig. 9 Close-up of syringe and beetle about to be treated.

A control of three replicates of 20 each was included for each insecticide used.

Disposable 20 X 100 mm petri dishes were used to hold the treated rootworms. One replication of 20 beetles was placed in each petri dish. The rootworms were held for twenty-four hours at room temperature. No food or water was given the rootworms for this period. At the end of the twenty-four hours, the number dead was determined. A rootworm was considered dead if after being upset it did not actively try to right itself.

The procedure given was nearly identical to that given by the committee on Diabrotica of the second conference on test methods for resistance in insects of agricultural importance (Brazzel, 1970). The committee suggested a solvent control. Solvent controls were not used in this study, based on a study by Ball and Weekman (1962), who compared acetone and untreated controls and reported no significant difference.

$LC_{50}$'s were determined for Padan and diazinon. This was done by placing 1 ml aliquots of 1, 5, 10, 25, and 50 ug per ml insecticide solution on 9 cm filter paper and placing the filter paper in 20 X 100 mm petri dishes. One ml of the water-Padan solution thoroughly saturated the filter paper. Diazinon was diluted in acetone and placed on the filter paper in the same concentrations. The acetone was allowed to evaporate. One ml of water was then placed on each paper to compensate for the water present in the Padan solution. Both insecticides were replicated in the same manner as all previous insecticides. The beetles were held in the petri dishes for twenty-four hours. Then the number dead was determined.

The data collected were statistically analyzed using an electrical computer. Results were given in micrograms per microliter for both $LD_{50}$ and $LD_{90}$ with their fedicial limits. Micrograms per microliter can be converted directly to micrograms per insect in that the dosage for each insect was 1 uliter. The average weight of an adult western corn rootworm was calculated at .01 g. Using this figure micrograms per insect can be converted to micrograms per gram of insect tissue using a conversion factor of 100 (e.g. .022 ug/uliter = .022 ug/insect = 2.2 ug/g insect).

# RESULTS AND DISCUSSION

## 1969

All insecticides tested in 1969 possessed low $LD_{50}$'s on adult rootworms except aldrin. Aldrin, a chlorinated hydrocarbon, was expected to have a high $LD_{50}$ (Hamilton, 1966), (Table 1).

In many cases an actual $LD_{50}$ could not be calculated because of the limited dosage range used. Phorate and carbofuran are examples of this. The dosage range was expanded for tests run the following year. Also in some cases the computer could not calculate the $LD_{50}$ due to insufficient data. This occurred when the number dead from two adjacent concentrations jumped from nearly no kill to total kill. An example would be diazinon on beetles from Yankton County August 13, 1969 at .1 and .5 ug/insect. The .1 ug/insect concentration gave nearly no kill, the .5 ug/insect concentration gave total kill. In the above listed cases the $LD_{50}$ was stated as being less than the lowest concentration giving more than 50% kill.

In nearly all cases there was no significant difference between the first run in early August and the second run in early September.

Phorate and carbofuran proved to be the two most effective materials tested. In nearly all sites tested the $LD_{50}$'s fell below the lowest concentration used, .01 ug/insect. Phorate is an organophosphate and carbofuran is a carbamate.

Beetles from Yankton and Lawrence Counties possessed the highest $LD_{50}$'s for most insecticides tested. Yankton County is in the southern portion of the State where organophosphate and carbamate insecticides have been used extensively for several years. Lawrence County is an isolated corn growing area north of the Black Hills. This area has had a rootworm problem for years. Insecticides have been used here also. The prolonged use of insecticides in these areas was likely to produce some resistance. The 1969 data suggested that there was a trend toward a resistant beetle population in these areas (Fig. 10-12).

Table 1.--$LD_{50}$'s of eight insecticides tested on western corn rootworms from four sites in South Dakota in August and September, 1969.

| Insecticide | County | 1st run $LD_{50}$'s ug/uliter | 2nd run $LD_{50}$'s ug/uliter |
|---|---|---|---|
| Bux | Yankton | .022 | .029 |
| | Clay | .033b | |
| | Moody | .01 a | |
| | Lawrence | .045 | |
| Diazinon | Yankton | .155b | .10 b |
| | Clay | .01 a | .027 |
| | Moody | .05 a | |
| | Lawrence | .054 | |
| Dyfonate | Yankton | .100 | .074 |
| | Clay | .076 | .066 |
| | Moody | .081 | |
| | Lawrence | .129 | |
| Mocap | Yankton | .067 | .10 b |
| | Clay | .10 a | .079 |
| | Moody | .074 | |
| | Lawrence | .076 | |
| Landrin | Yankton | .05 a | .039 |
| | Clay | .049 | .020 |
| | Moody | .027 | |
| | Lawrence | .057 | |
| Phorate | Yankton | .01 a | .10 a |
| | Clay | .01 a | .009b |
| | Moody | .01 a | |
| | Lawrence | .011a | |
| Carbofuran | Yankton | .01 a | .01 a |
| | Clay | .01 a | |
| | Moody | .01 a | |
| | Lawrence | .01 a | |
| Aldrin | Lawrence | 10.00 a | |

a - less than the lowest concentration used.
b - confidence limits not valid.

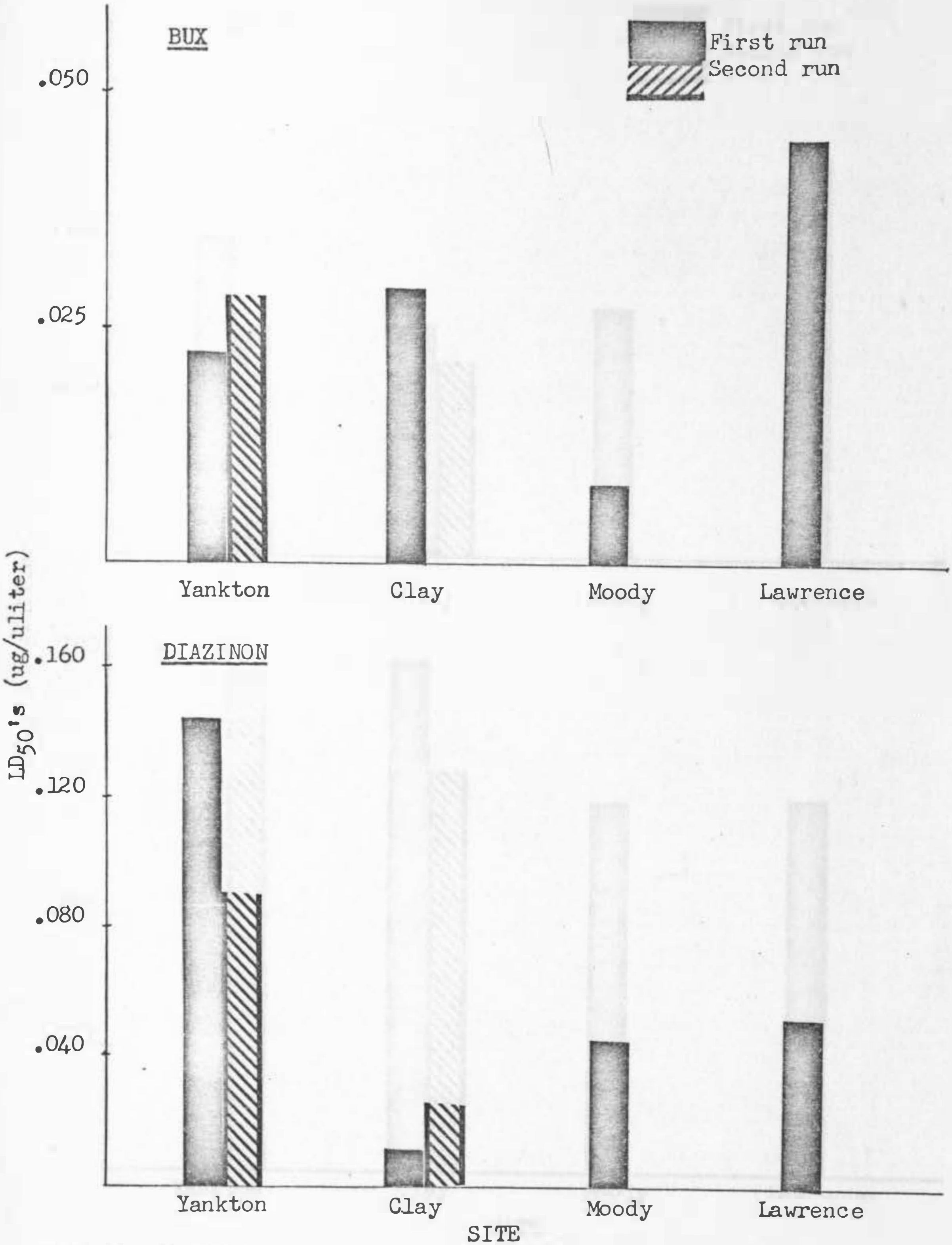


Fig. 10 $LD_{50}$'s of Bux and diazinon for adult western corn rootworms from four sites in South Dakota. The first run in August, 1969, the second run in September, 1969.

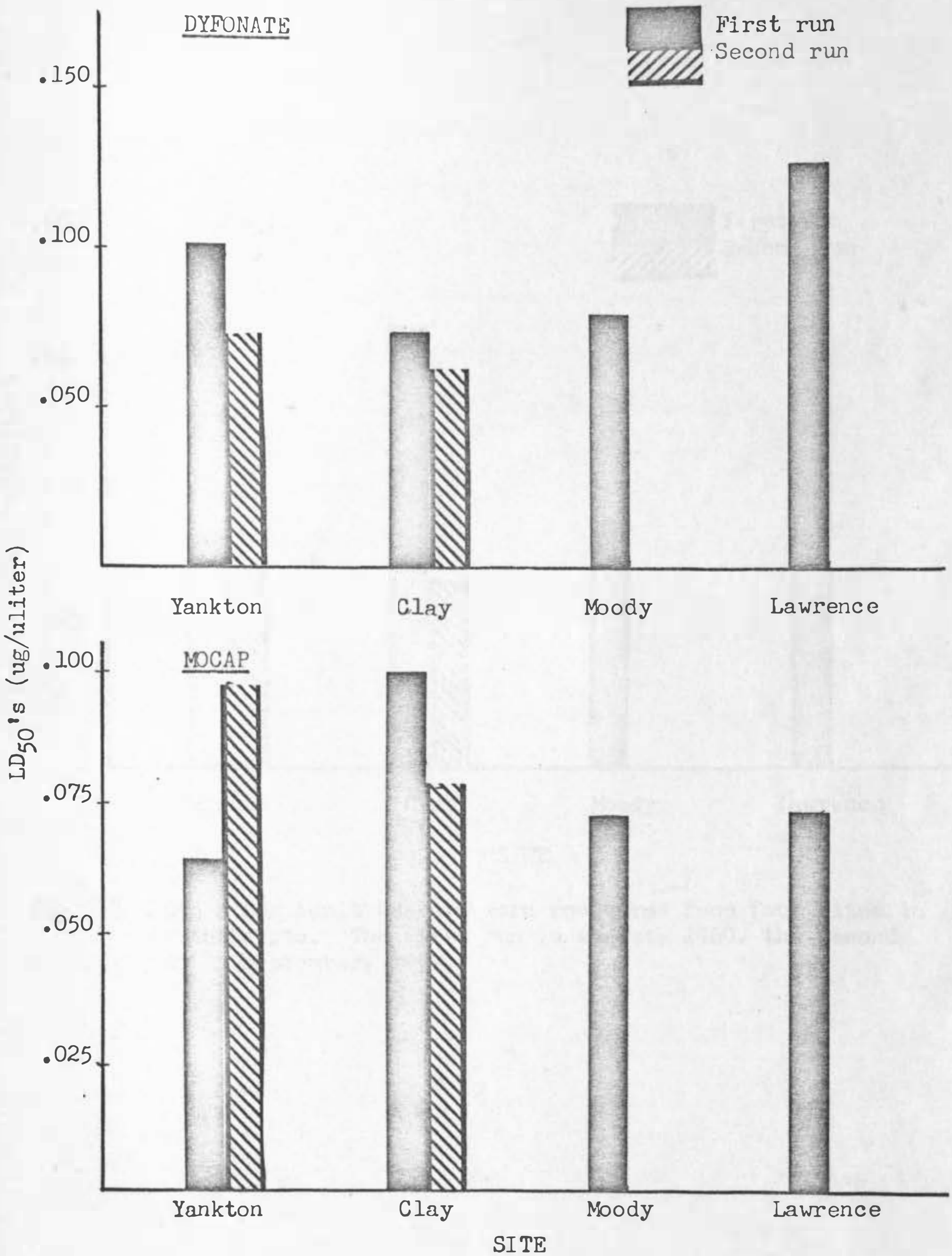


Fig. 11 $LD_{50}$'s of Dyfonate and Mocap for adult western corn rootworms from four sites in South Dakota. The first run in August, 1969, the second run in September, 1969.

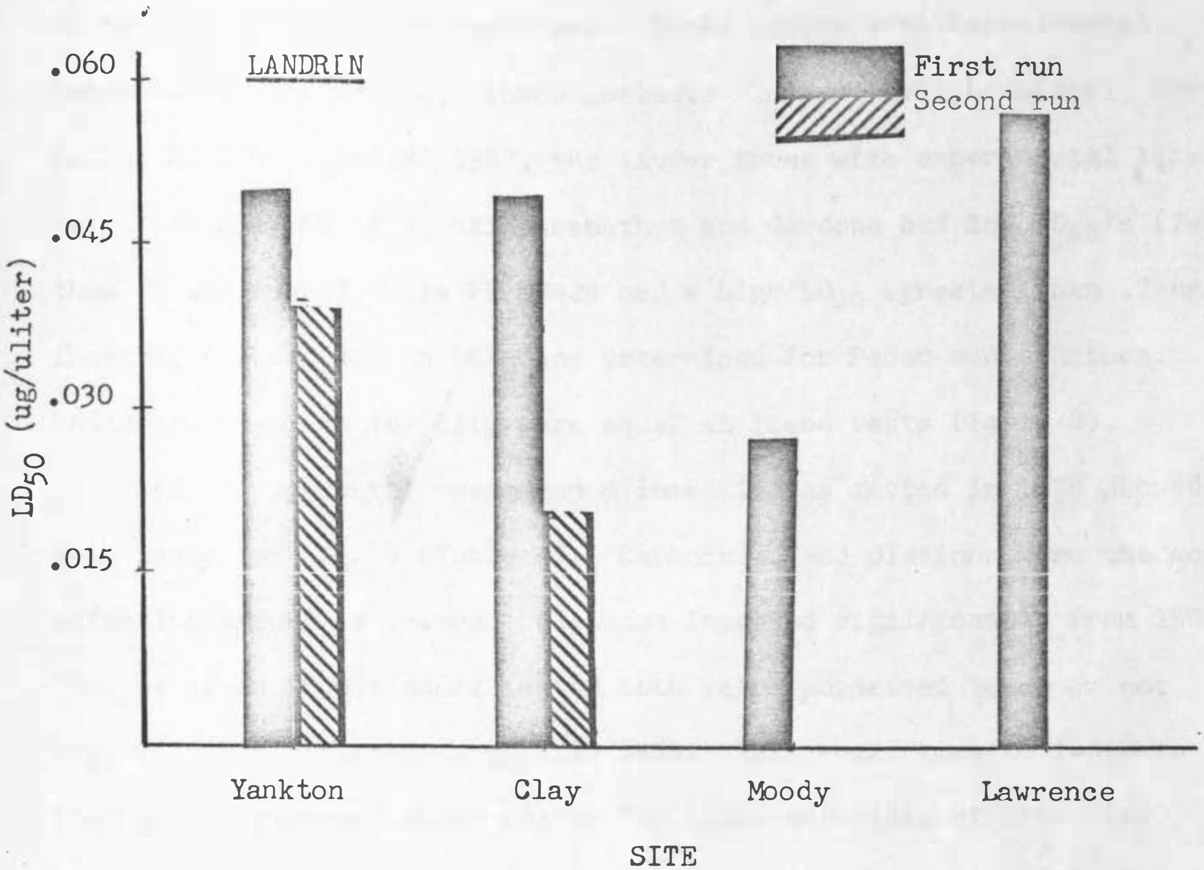


Fig. 12 $LD_{50}$'s for adult western corn rootworms from four sites in South Dakota. The first run in August, 1969, the second run in September, 1969.

1970

In 1970 three insecticides were tested that are not commonly used as soil insecticides on rootworms. Three others with experimental labels were also tested. These include: Imidan, azinphosmethyl, Gardona, Padan, RE 12420, and NC 6897, the latter three with experimental labels only. Imidan, NC 6897, azinphosmethyl and Gardona had low $LD_{50}$'s (less than .2 ug/insect) while RE 12420 had a high $LD_{50}$ (greater than .2 ug/insect), (Table 2). An $LC_{50}$ was determined for Padan and diazinon. Padan and diazinon toxicity were equal in these tests (Table 3).

All the presently recommended insecticides tested in 1970 showed relatively low $LD_{50}$'s (Table 4). Carbofuran and diazinon were the most effective materials tested. Diazinon improved significantly from 1969. Five of seven insecticides tested both years possessed lower or not significantly different $LD_{50}$'s in 1970. This would seem to indicate that no resistance problem exists for these materials at this time. These materials are: Landrin, carbofuran, Dyfonate, diazinon and Mocap. Bux and phorate showed significantly higher $LD_{50}$'s in 1970. There is a possible trend towards rootworm resistance to these materials. Both of these materials have been used extensively in South Dakota in the past several years.

In most of the insecticides tested there were consistently higher $LD_{50}$'s for rootworms from the southernmost site. This collection site was located in Yankton County (Fig. 13-16). These data were similar to data collected in 1969 (Fig, 10-12). Consistently higher $LD_{50}$'s for adults from this southern site indicated that a potential resistance

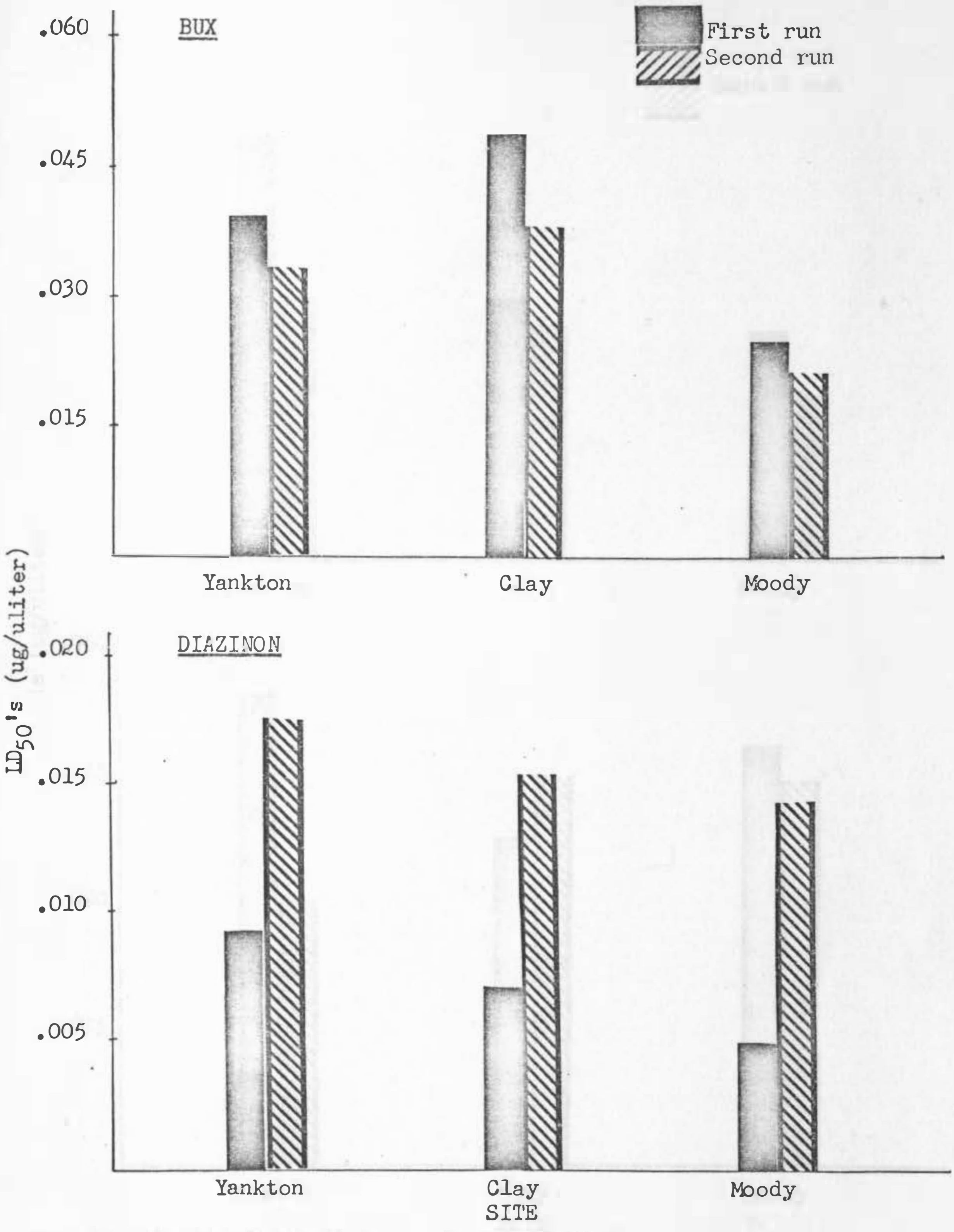


Fig. 13 $LD_{50}$'s of Bux diazinon for adult western corn rootworms from three sites in South Dakota. The first run in early August, the second run in mid August, 1970.

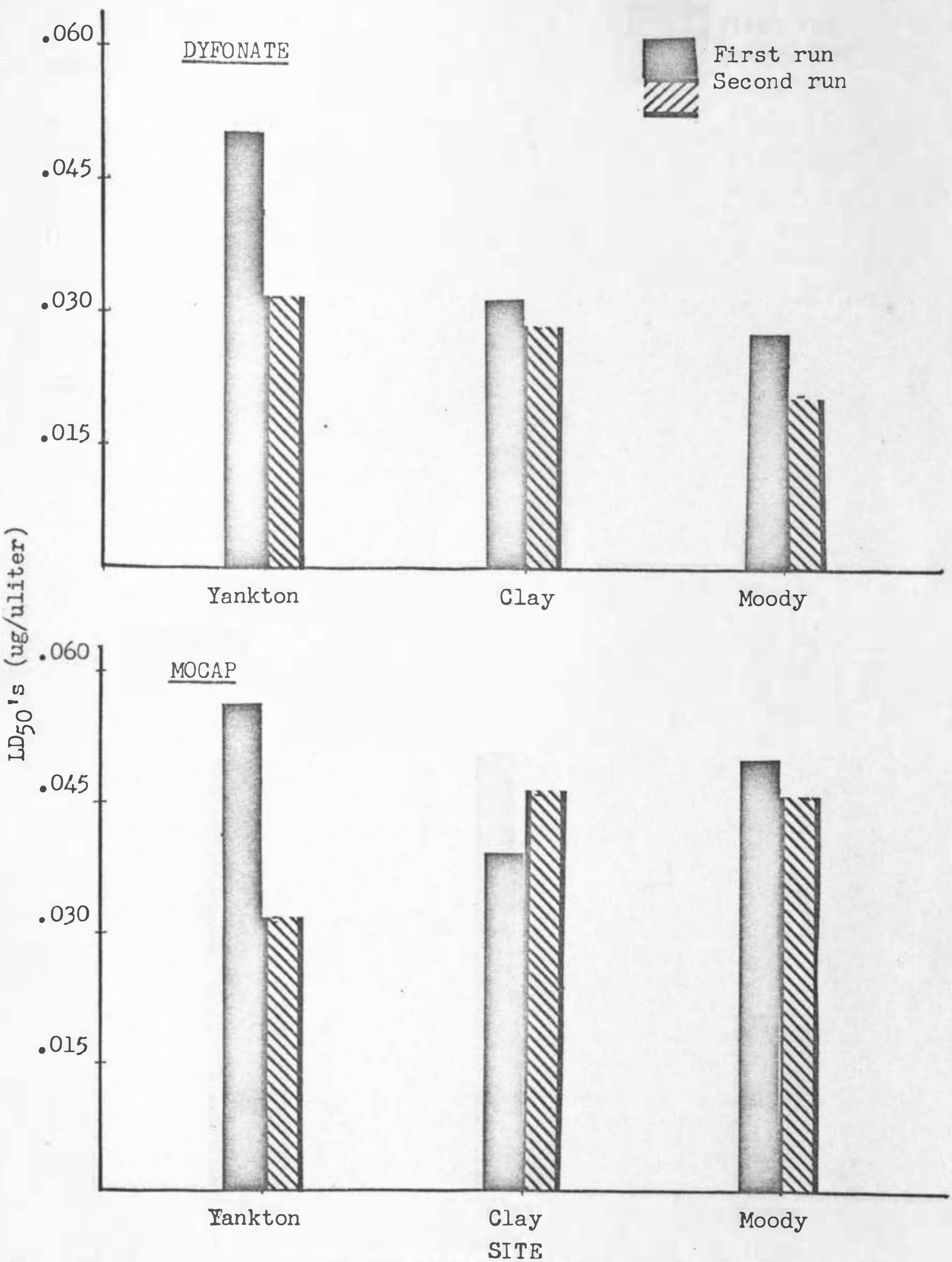


Fig. 14 $LD_{50}$'s of Dyfonate and Mocap for adult western corn rootworms from three sites in South Dakota. The first run in early August, the second run in mid August, 1970.

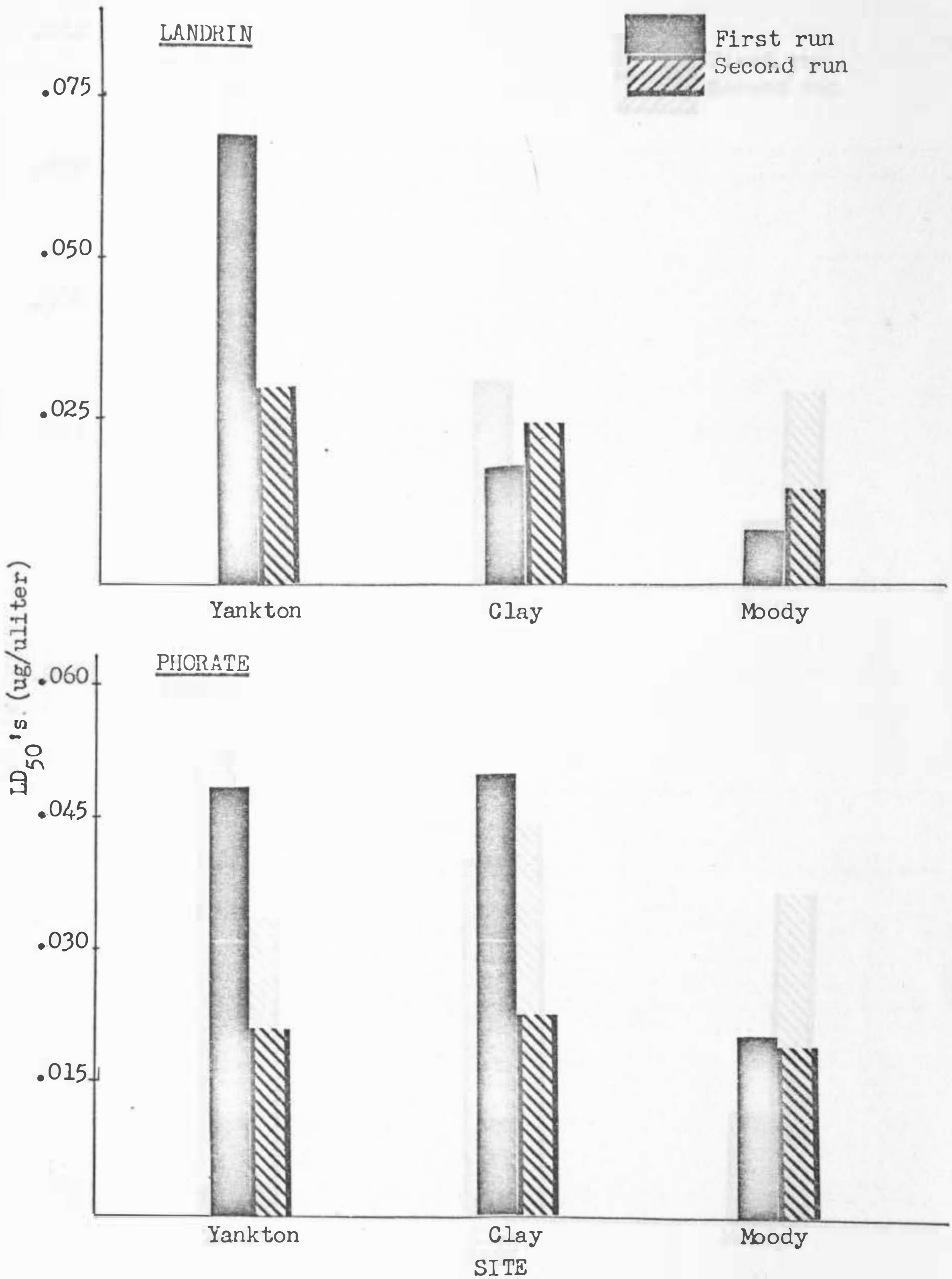


Fig. 15 $LD_{50}$'s of Landrin and phorate for adult western corn rootworms from three sites in South Dakota. The first run in early August, the second run in mid August, 1970.

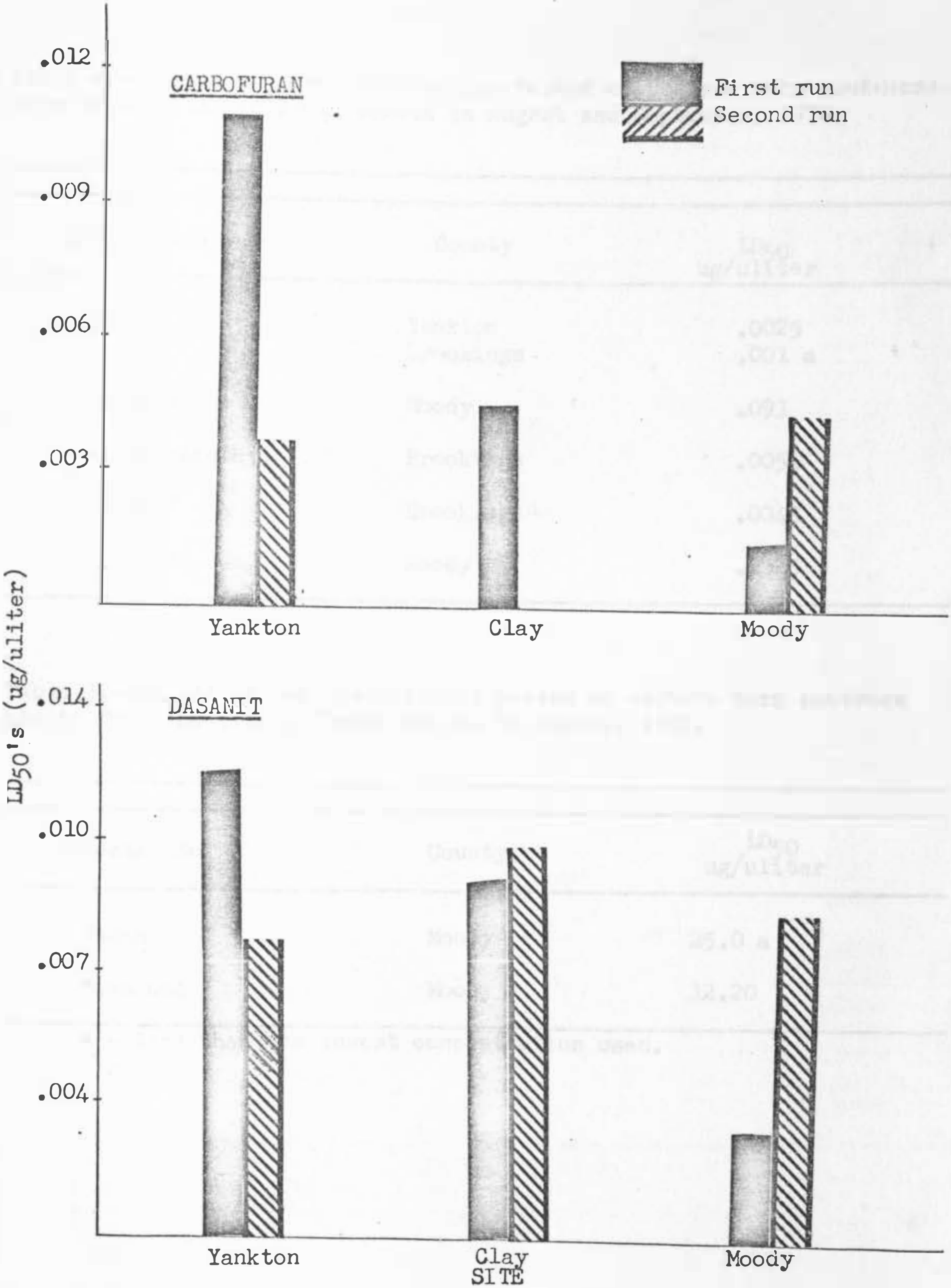


Fig. 16 $LD_{50}$'s of carbofuran and Dasanit for adult western corn rootworms from three sites in South Dakota. The first run in early August, the second run in mid August, 1970.

Table 2.--$LD_{50}$'s of five insecticides tested on western corn rootworms from three sites in South Dakota in August and September, 1970.

| Insecticide | County | $LD_{50}$ ug/uliter |
|---|---|---|
| Imidan | Yankton | .0025 |
| | Brookings | .001 a |
| Gardona | Moody | .093 |
| Azinphosmethyl | Brookings | .0056 |
| NC 6897 | Brookings | .0043 |
| RE 12420 | Moody | .2320 |

Table 3.--$LC_{50}$'s of two insecticides tested on western corn rootworm adults from one site in South Dakota in August, 1970.

| Insecticide | County | $LD_{50}$ ug/uliter |
|---|---|---|
| Padan | Moody | 25.0 a |
| Diazinon | Moody | 12.20 |

a - less than the lowest concentration used.

Table 4.—$LD_{50}$'s of eight insecticides tested on western corn rootworms from three sites in South Dakota in August 1970.

| Insecticide | County | 1st run $LD_{50}$'s ug/uliter | 2nd run $LD_{50}$'s ug/uliter |
|---|---|---|---|
| Bux | Yankton | .040 | .035 |
| | Clay | .053 | .040 |
| | Moody | .026 | .022 |
| Diazinon | Yankton | .01 b | .018 |
| | Clay | .0075 | .017 |
| | Moody | .0057 | .015 |
| Dyfonate | Yankton | .05 b | .034 |
| | Clay | .033 | .028 |
| | Moody | .028 | .023 |
| Mocap | Yankton | .057 | .032 |
| | Clay | .039 | .046 |
| | Moody | .05 b | .046 |
| Landrin | Yankton | .071 | .029 |
| | Clay | .018 | .026 |
| | Moody | .0089 | .014 |
| Phorate | Yankton | .05 b | .022 |
| | Clay | .05 b | .021 |
| | Moody | .023 | .020 |
| Carbofuran | Yankton | .011 | .0035 |
| | Clay | .0043 | .0042 |
| | Moody | .001 a | .0045 |
| Dasanit | Yankton | .012 | .0078 |
| | Clay | .0081 | .01 b |
| | Moody | .0035 | .0078 |

a - less than the lowest concentration used.
b - confidence limits not valid.

problem exists. These higher $LD_{50}$'s have no economic importance at this time, but there was an indication that there may be a problem in the future.

Again in 1970 as in 1969 there was no significant difference between the first run in early August and the second run in late August for the majority of insecticides tested.

# CONCLUSIONS

The $LD_{50}$ tests conducted in 1969-1970 have shown that all the common corn rootworm insecticides tested have low $LD_{50}$'s on adult western corn rootworms. Bux and phorate showed a significant increase in $LD_{50}$'s in 1970. If this trend continues it may become economically important. Diazinon on the other hand showed a significant decrease in $LD_{50}$ in 1970.

Aldrin, a chlorinated hydrocarbon, was tested in 1969 to confirm a previously determined resistance in the western corn rootworm. A very high $LD_{50}$ was determined, greater than 10 ug/insect.

Azinphosmethyl, Gardona, and Imidan, materials often used in aerial applications for adult corn rootworm control, were tested in 1970. All showed $LD_{50}$'s comparable with the commonly used soil insecticides tested in this study.

RE 12420, NC 6897 and Padan, all unregistered materials, were also tested in 1970. NC 6897 had a low $LD_{50}$ on adult rootworms which was comparable with the most effective materials tested in this study. RE 12420 on the other hand had a high $LD_{50}$ on adult rootworms well above all others tested except aldrin. Padan had a low $LC_{50}$ on adult rootworms which was comparable with that of diazinon.

$LD_{50}$'s on corn rootworm beetles collected from the Yankton County site were consistently higher than those from the other collection sites. Landrin, carbofuran, Dasanit and Mocap possessed significantly higher $LD_{50}$'s on adult rootworms from this site. This suggests that a potential resistance problem exists in this area. A few inconsistencies in the data collected in this study suggest some changes in procedure.

Definitely a longer period of study is suggested. Also, a more precise range of concentrations should be included for each individual insecticide. This could easily be done using the data from this study. With these changes more accurate and more detailed conclusions could be made. The use of adult $LD_{50}$'s minimizes dependence on insecticide failures in the field to first locate resistance to specific insecticides.

LITERATURE CITED

Apple, J. W. 1957. Reduced dosages of insecticides for corn rootworm control. J. Econ. Entomol. 50(1): 28-30.

Ball, H. J., and G. T. Weekman. 1962. Insecticide resistance in the adult western corn rootworm in Nebraska. J. Econ. Entomol. 55(4): 439-441.

Ball, H. J., and G. T. Weekman. 1963. Differential resistance of corn rootworms to insecticides in Nebraska and adjoining states. J. Econ. Entomol. 56(1): 553-555.

Ball, H. J. 1968. A five year study of potential western corn rootworm resistance to diazinon and phorate in Nebraska. J. Econ. Entomol. 61(2): 496-498.

Bigger, J. H. 1932. Short rotation fails to prevent attack of Diabrotica longicornis Say. J. Econ. Entomol. 25(2): 196-199.

Bigger, J. H. and R. A. Blanchard. 1955. Ecology and control of soil insects attacking corn in Illinois. J. Econ. Entomol. 48(3): 255-260.

Bigger, J. H. 1963. Corn rootworm resistance to chlorinated hydrocarbon insecticides in Illinois. J. Econ. Entomol. 56(1): 118-119.

Blair, B. D., C. A. Tripleharn, and G. W. Ware. 1963. Aldrin resistance in northern corn rootworm adults in Ohio. J. Econ. Entomol. 56(6): 894.

Brazzel, J. R. 1970. Second conference on test methods for resistance in insects of agricultural importance. Bull. Entomol. Soc. Amer. 16(3): 147-153.

Burkhardt, C. C. 1954. Chemical control of the western corn rootworm in Kansas in 1953. J. Econ. Entomol. 47(4): 691-696.

Burkhardt, C. C. 1963. Corn rootworm resistance and damage in Kansas-1962. Proc. Entomol. Soc. Am., North Central Branch. 18: 82-83.

Cox, H. C. and J. H. Lilly. 1953. Chemical control of the corn rootworm. J. Econ. Entomol. 46(2): 217-224.

Eiben, G. J., and D. C. Peters. 1965. Varietal response to rootworm infestation in 1964. Proc. Entomol. Soc. Amer., North Central Branch. 20: 83.

Forbes, S. A. 1915. Life history and habits of the northern corn rootworm Diabrotica longicornis. Ill. State Ent. Rept. 28: 80-86.

Hamilton, E. W. and P. A. Dahm. 1960. A versatile automatic micro-applicator. J. Econ. Entomol. 53(4): 853-856.

Hamilton, E. W. 1965. Aldrin resistance in corn rootworm beetles. J. Econ. Entomol. 58(2): 296-300.

Hamilton, E. W. 1966. $LD_{50}$'s for aldrin against resistant larvae and adults of western corn rootworm. J. Econ. Entomol. 59(2): 473-474.

Hill, R. E., E. Hixson, and M. H. Muma. 1948. Corn rootworm control tests with benzene hexachloride, DDT, nitrogen fertilizers and crop rotations. J. Econ. Entomol. 41(3): 392-401.

Howe, W. L., E. E. Ortman, and B. W. George. 1963. Observations of the northern and western corn rootworm in South Dakota. Proc. Entomol. Soc. Am., North Central Branch. 18: 83.

Jessen, J. I. 1970. Root pulls and ratings as an analysis of insecticide performance in the control of corn rootworms. South Dakota State University, Brookings. M.S. Thesis. 94 pp.

Jones, P. A. 1968. U. S. Dept. Agr., Plant Pest Control Div. Cooperative Economic Insect Report. 18(43): 1012-1028.

Lilly, J. H. 1954. Insecticidal control of corn rootworms in 1953. J. Econ. Entomol. 47(4): 651-658.

Muma, M. H., R. E. Hill, and E. Hixson. 1949. Soil treatments for corn rootworm control. J. Econ. Entomol. 42(5): 822-824.

Nearman, L. S. 1968. A three year insecticide control study on corn rootworms in South Dakota. South Dakota State University, Brookings. M.S. Thesis. 58 pp.

Ortman, E. E., and P. J. Fitzgerald. 1964. An evaluation of the performance of inbreds in the presence of a corn rootworm infestation. U. S. Dept. Agr., Grain and Forage Insects Research Branch. Special Report V-262. 40 pp.

Patel, K. K., and J. W. Apple. 1966. Chlorinated hydrocarbon resistant northern corn rootworm in Wisconsin. J. Econ. Entomol. 59(5): 522-525.

Peters, D. C. 1963. Economic life histories of corn rootworms in the corn belt. Proc. Entomol. Soc. Am., North Central Branch. 18: 79-81.

Peters, D. C. 1964. Recent results of soil insecticide tests in Iowa. Proc. Entomol. Soc. Am., North Central Branch. 19: 95-97.

Peters, D. C. 1965. Chemical control of resistant corn rootworms in Iowa. Proc. Entomol. Soc. Am., North Central Branch. 20: 58-61.

Weekman, G. T. 1961. Problems in rootworm control. Proc. Entomol. Soc. Am., North Central Branch. 16: 32-34.

Weekman, G. T. 1962. Corn rootworm control results - 1961. Proc. Entomol. Soc. Am., North Central Branch. 17: 46-48.