EVALUATION OF SOME NON-HAZARDOUS INSECTICIDES AND REPELLENTS FOR THE CONTROL OF STORED GRAIN INSECT PESTS

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PREFACE

This thesis is an evaluation of some non-hazardous insecticides and repellents for the control of major pests of stored grains.

A total number of fourteen such chemicals was tried against four different grains. Many of them proved very effective as toxicants and repellents.

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INTRODUCTION

Insect pests constitute one of the most important hazards to stored grains and grain products man has been facing since, perhaps, the dawn of civilization. Evidence indicates that serious insect pests of storage that confront men today were prevalent in ancient times. Supplies of grains stored in the Egyptian tombs as early as 169 B.C., were found infested with the insects that are common pests of today. (Cotton 1956).

To protect the grains from the ravages of the insect pests, different methods and materials have been employed by man at different times. In early days the primitive man made use of sand and some aromatic plant products as grain protectants by mixing them with the grains. Exposure to sun radiation was one of the most effective of the ancient methods and is still used in some parts of India to kill the insect infestation in stored grains. (Pruthe 1949).

Until recently a great number of other materials, such as finely divided silica gel, rock phosphate, precipitated chalk, magnesium oxide, aluminium oxide, and other local materials like flints, feldspar, quartz, sulphus, and ashes, have been used to prevent the losses through the feeding activities of these pests.

In his struggle for extermination of his insect enemies, man has devised a large number of chemical weapons of which the greater numbers are relatively recent developments. These include organic hydrocarbons, phosphatic compounds, and dozens of inorganic and organic fumigants. Many of these chemicals have proved remarkably effective in controlling the insects infesting the stored grains and are in the fore front so far as the protection of grains is concerned.

The high yields and wide distribution of grains over the world in the last few decades have undoubtedly extended the insect breeding zone. Consequently the problem of insect control in storage has fundamentally become more complicated and more extensive. The losses caused by the insects are still alarmingly high. According to the United Nations Food and Agriculture Organization Survey made in 1947, the loss due to the insect pests was found to be as great as 12,945,000 tons of food products annually. In the United States alone the losses have been estimated at 300 million bushels worth more than 500 million dollars yearly at 1951 price levels. This tremendous loss due to the insects in storage is a big challenge to the entomologists of the world.

As already stated the progress, in the development of insecticides and the knowledge of their reactions, is spectacular in the very recent years. These insecticides, particularly, the organic synthetics, have attained a greater degree of complexity. Their excessive and indiscriminate use, specifically on food products, has created a potential health hazard that is unique in character and scope.

Taking into account, the heavy annual losses caused by these insects, and the chemical hazards involved in their control, it is essential that some more non-hazardous grain protectants be found. Such grain protectants should essentially be safe to seeds and have long residual toxicity against the insects. It was solely to meet this demand, that the present study was undertaken.

A total of fourteen non-hazardous chemical materials having low order of mammalian toxicity were tested as toxicants and repellents in dust formulations and through jute bags impregnation.

Four insect species of the stored products pests namely rice weevils, granary weevils, confused flour beetles, and sawtoothed grain beetles, were selected as test insects for this investigation.

Phytotoxocity of the dusts used in three different grains was ascertained through germination tests.

CHAPTER II

REVIEW OF LITERATURE

Fletcher and Ghosh (1920) stated that oil, lime sand, and leaves of some aromatic plants repelled the stored grain insects. Harris (1938) found that wood ash at 1 part per 30 parts of grain and lime at 1 part per 50 parts of grains gave a good control of the insects infesting stored products. Laudani (1954) proved that pyrenone at 1 part per 500 parts grains protected the grains against the weevils.

Parkins (1944) proved that quartz particles of 1.8 micron were more effective then those averaging 0.5 micron. Alexander et el. (1944) stated that particle size below 10 micron adhered well to the grains and the body of the insects. David (1951) noted in his studies, that particles above 15 micron do not adhere to each other and to the insect bodies. Parkins (1944) recommended the use of flints, feldspar, and limonite quartz against weevils and sawtoothed grain beetle. Darling (1947) made a study on some inert dusts and found that kaeolin and eucalyptus wood ashes might give a good degree of control. Cotton and Frankfield (1949) reported that silica aerogel at 0.05% as dust gave 100 per cent kill of confused flour beetles. Grandori (1950) reported efficacy of bentonite against stored grain insect pests at 200 gms per 100 k gms of grain. Cotton and Ashley (1952) reported that finely divided silica, rock phosphate, magnesium oxide killed the insects when mixed directly with the grains. Grandori (1955) showed that Italian bentonite containing 26% silica and 65% mont morrilomite controlled insects in stored wheat.

Dove (1947) showed that pyrethrins synergised with piperonyl butoxide were very effective against grain insects. Beekley (1948) noted pyrethrum treatment of wheat proved effective for 8½ months against rice weevils at one pound of 100% dust per bag. Watts (1950) found that 0.9% piperonyl butoxide and 0.08% pyrethrins in the ratio of 1.5 gave 100% mortality of rice weevils within a week at 1 gm per 100 gms of wheat. He also proved that pyrethrin (0.08%) alone could give 97% kill and piperonyl butoxide singly gave only 11% kill after a month. Pingale (1953) stated that piperonyl butoxide (0.8%) and pyrethrins (0.05%) when impregnated on jute bags provided protection against lesser grain beetles. Chiang (1953) found that ryania gave low kill compared to DDT and parathion dusts.

Nakujuna (1952) noticed that rice weevil was controlled effectively by treating the bags with 1% lindane. Swain (1952) discovered that rice weevil in sorghum can be controlled by spraying the top layer with lindane. Atkinson and Grear (1953), Cotton et al. (1944) used soft paper towel bags and Kraft-bag and impregnated them with 10% solution of DDT in acetone. Later in 1945, they found that Kraft paper bags treated with 8.5% solution of DDT in carbon tetrachloride offered greater resistance to insect penetration than cotton twill bags impregnated with aldrin, dieldrin, BHC, endrin, isodrine, and lindane at 1% dilution, and found it effective against rice weevils for about six months. Jewett (1951) impregnated cotton bags with 10% dilution of DDT in carbon tetrachloride and found it effective against insects infesting the stored grains for about 18 months. Atkinson (1955) showed that pure BHC 1-1.25% and DDT 1.5% gave protection against stored grain insect pests. Parkins (1956) recommended use of lindane at 1 p.p.m. against weevils in peas and beans. Kockum (1953) stated that lindane 0.4% and pyrethrin at 8 ozs. per 9 cubic feet controlled the rice weevil and angoumois moth in corn. Radeleff (1952) stated that methoxychlor does not tend to be stored in animal body like DDT. Barnes (1953) noted that methoxychlor does not produce any poisoning effects on nervous system when given to animals. Lemmon (1953) classified methoxychlor as one of the safest insecticides that may be applied without any danger to animals.

Brett (1953) noted that malathion 5% dust gave good results against bean beetle in storage. McGregor (1954) studied the effects of dipterex on cattle grubs and proved that it was safe and effective when applied as a systemic. Lindgren et.al. (1954) showed that malathion and chlorthion dusts at 1 P.P.M. and 2 P.P.M. killed rice weevils and granary weevils in 10 days. Kulash (1956) stated that 1% malathion, 1% lindane, sprayed on inside of twill bags checked the increase of rice weevil for six months. Sivil (1956) proved that 1% dilution of malathion, parathion, chlordane did not allow marked increase of stored grain pests for 6 months in heavy cloth bags.

Graham (1922) stated that the optimum temperature for most insects is in the vicinity of 26°C. Back and Cotton (1924) found that the granary weevil is more resistant than rice weevil in the temperature zone of 32 - 60°F. Bodenheimer (1927) made a study on the rice weevil and granary weevil and showed that the former develops more rapidly at a higher temperature and the latter at low temperature. Schavardt (1934) noted that moisture contents of 11 - 17% are most favorable to larval development of stored grains insects. Anderson (1938) proved that neither rice weevils nor granary weevils could reproduce below

below 53 - 60°F. Richards (1947) placed the lower limit for oviposition at 68°F. Cotton and Frankfield (1953) noted that the rate of reproduction of the granary weevil and rice weevil was highest at 80°F., and 14% moisture level. Below 9% moisture there was no breeding of these weevils. Willux (1952) studied the effects of moisture contents of wheat on different insects and found that at 9% moisture level survival was generally low for the rice weevil and the granary weevil. At 11% moisture, survival of the rice weevil was greater than the sawtoothed grain beetles. Sawtoothed beetles were more susceptible to toxicant than rice weevils at all temperature levels. For breeding of sawtoothed grain beetle, cracked grain is essential. Turney (1957) has proved that little or no reproduction of sawtoothed grain beetle was obtained on clear rough rice with 12% moisture.

Parkins (1953) stated that an insect was considered dead if it neither moved spontaneously nor responded to slight pressure. Later in 1956, he noted that an insect was considered knocked down if it lay on its back unable to regain its normal position and did not respond to any reflex action when touched with a brush. David (1956) stated that all living beetles usually fold their legs against their bodies, whereas in case of dead insects, they were more or less stretched out.

CHAPTER III

MATERIALS AND METHODS

1. Test Insecticides

The test insecticides selected for this study belong to two different groups, namely: (a) Botanicals, including Pyrenone and Ryania and (b) Modern Synthetics, including C & C 7744, Dow ET-14, R 55, R 441 V. C. rodent repellent, etc.

From the brief account of these materials given below, it will be clear that all of them carry a very low order of mammal toxicity and that there is little potential danger to public health in their use as grain protectants against insect pests of stored grain. The LD 50 expressed in each case is based upon oral dosage to white rats.

Pyrenone: It is a trade name given to a compound of pyrethrins synergised with piperonyl butoxide in the ratio of 1:9 by weight. Pyrethrins are non-toxic to man and animals, when applied at the recommended dosage level. The LD 50 is 200 mg/kg.

Ryania: The active principle in ryania is Ryanodine ($C_{24}H_{35}NO_9$) which has LD 50 of the order of 1200 mg/kg and has a comparatively longer residual toxicity.

C & C 7744: ($C_2H_4NO_2$) It is a product of the Carbide Carbon Chemicals Company. The chemical contains neither phosphorus nor chlorine and has a broad spectrum of activities. It possesses a rapid killing action and has a good residual toxicity. It is stable to hydrolysis, ultra violet light rays and thermal decomposition. LD 50 is 2000 mg/kg.

Dipterex: $(C_5H_4PO_3Cl_3)$ It has LD 50 in the order of 450-500 and is stable at room temperature but decomposes on heating.

Dow ET-14: It is a new chemical used extensively for fly control and is a complex organic phosphatic compound. It has extremely low order of mammalian toxicity. LD 50 is 2500 mg/kg.

Malathion: $(C_{10}H_{19}O_6PS_2)$ It is an organo phosphate with low order of mammalian toxicity. LD 50 is 1162 mg/kg and it does not tend to store in the body.

Methoxychlor: $(C_6H_{15}O_2Cl_3)$ is a chlorinated hydrocarbon closely related to DDT but is far less toxic to mammals and does not store in the body tissues like DDT. It is stable to heat and resistant to oxidation, ultra-violet rays and carries long residual effectiveness. LD 50 is 6000 mg/kg.

Lindane: $(C_6H_6Cl_6)$ is gamma isomer (99% or more) of technical benzene hexachloride. It has no danger as a chronic or cumulative toxicant. Its LD 50 is 125 mg/kg.

Perthane: $(C_{18}H_{20}Cl_2)$ is also a chlorinated hydrocarbon having LD 50 of 5000 mg/kg. It is non-phytotoxic and stable under ordinary environmental conditions.

R 11: (2, 3, 5, less 2-butalene, tetrahydro furfural) is less toxic than pyrethrins and acute oral. LD 50 is 2.5 gm/kg. R 55 and R 441 are closely related to R 11.

V. C. rodent repellent which is a new chemical was supplied by Virginia Carolina Chemical Company. It has a very low mammalian toxicity.

Except for ryania and pyrenone, the test insecticides were prepared as 10% dust formulations from wettable powders, concentrates, and calculated amounts of attaclay. The thorough mixing of the two ingredients in each case was obtained by using the Standard Ball Mill (Fig. 2).

The materials selected for jute bag impregnation included R 11, R 55, R 441, pyrenone, malathion, Dipterex, methoxychlor, lindane, and perthane at 1% concentrations.

2. Test Insects

Four destructive and common species of stored grain insects were used for the experimental work. They included:

(a) Rice weevil - Sitophilus oryza (L.)
(b) Granary weevil - S. granarius (L.)
(c) Confused flour beetle - Tribolium confusum (Duv.)
(d) Sawtoothed grain beetle - Oryzaephilus surinamansis (L.)

Stock cultures of these species were received from Dr. D. A. Wilbur, Professor of Entomology, Kansas State College, Manhattan, Kansas, and were reared separately on suitable culture media at 80°F. constant temperature and 14% grain moisture level.

3. The Preparation of Grains

Three different types of food grains namely: wheat, corn, and grain sorghums, were selected as host grains for evaluating the various test materials. The grains were obtained from a local market. First of all, they were cleaned and carefully examined for possible insect infestation. The cleaned grains then were tested for their moisture content with Steinlite Electric Moisture Tester and adjusted to the level of 14% by adding distilled water to the grain (Fig. 1).

The quantity of distilled water required to raise the moisture contents of a given weight of grains was calculated by the formula:

$\left(\frac{100-A}{100-B} - 1\right)$ x weight in grams.

A = actual moisture contents of the grains
B = moisture contents desired

Sufficient quantities of the host grains at desired moisture contents were kept separately in air tight one-gallon glass jars.

4. Treatment of the Grains

Non-replicated preliminary tests were conducted against all the test insect species at three different exposures of one day, three days, and six days, to determine the level of dosages of those insecticides that are relatively new to this field. On the basis of these preliminary tests, C & C 7744, 10%; Dipterex, 10%; Dow ET-14, 10%; malathion, 10%; methoxychlor, 10%; and ryania, pure, were incorporated with enough of the host grains at two levels of dosage of 1/1000 and 1/10,000 (1 part in 1000 parts of grain and 1 part in 10,000 parts of grains) each excepting ryania which was mixed at 1/500 and 1/1000 levels.

The mixing of the insecticidal dusts in the grains was done on the Standard Ball Mill for 10 - 15 minutes for each treatment. By this method it is possible to secure a reasonably uniform distribution of the insecticides in the grains within a short period of time.

The treated grain samples of each treatment were stored separately in air tight large glass jars. These jars were labelled showing the name of the insecticide and the level of dosage.

5. Experimental Arrangement

The entire field of study was divided into three major groups given below.

(a) Repellency tests
(b) Toxicity tests
(c) Jute bag impregnation tests

(a) <u>The repellency tests</u>

The repellency tests were conducted in an insect proof apparatus (Fig. 4) which is a modification of the one described by Laudani (1954). The construction of such an apparatus eventually depends upon the number and nature of test materials to be tried. Laudani (1954) designed a laboratory apparatus for determining the repellent action of pyrethrins when incorporated with grains. The above apparatus was designed to reduce the possibility of fumigation effects from the various dusts. C & C 7744, dipterex, malathion, Dow ET-14, methoxychlor as 10% dust at 1/1000 and ryania and pyrenone as pure dusts at 1/500 were tested against each insect species.

The treated grain was placed in small paper cups which could hold 150 gms. of grains. They were completely filled with treated grain so that an insect might easily contact it and could enter or leave the cup without any difficulty. The cups were labelled accordingly and arranged in the wooden box in the circular fashion so that all of them may be equidistant from the point of insect liberation. Two check cups containing untreated grains were included in each of these tests. Each treatment was represented by single cup. One hundred and fifty weevils were taken from the culture jar with hand aspirator and placed in an empty cup and after about one half hour of rest, were liberated at the center of the box. The screened top was fixed and lights were turned off to simulate normal conditions for the insect activities inside the box. After about three hours, when 80-85% of the insects had entered the cups, the lids were placed on all the cups to stop entry or exit of any insects. The numbers of dead and alive insects were counted in each cup by screening them from the grains. Three tests were made for each insect species under similar environmental conditions.

Similar tests were carried out against the confused flour beetles and sawtoothed grain beetle. In a later test two other repellents, R 11 as 12.5% dust and V. C. rodent repellent 40% at 1/1000, were studied in a similar way. In this test, however, each chemical was replicated five times.

(b) Toxicity Tests

The insecticidal experiments were carried out in all the three grains, wheat, corn, and grain sorghums, to evaluate various chemical dusts as grain protectants against the four species of the test insectides.

One pint glass jars, having reversable rubber ring lids were selected for these tests. Each one was labelled as to show insecticide, dosage and replicate.

Lots of 150 gms. of wheat grains, treated with six chemical dusts, namely: C & C 7744, Dipterex, Dow ET-14, malathion, methoxychlor as 10% dusts at 1/1000 and 1/10,000 levels of dosage and ryania 100% dust at 1/500 and 1/1000 levels, were placed in the proper jars. Each treatment was replicated six times with three checks.

These jars were made air tight to avoid any loss of moisture from the grains by placing the lid in a position so that the rubberised sealing ring touches the jar rim.

To eliminate any possibility of interaction of the materials, each treatment was kept in a separate shelf of a wooden rack as shown in the fig. 5. Before the actual liberation of the insects, the lid on the jars were inverted, thereby permitting a limited amount of air to enter the jars. This arrangement enabled the insects to respire normally and reduced loss of grain moisture to the minimum. Fifty insects, composed of 15 rice weevils, 10 granary weevils, 10 confused flour beetles, and 15 sawtoothed grain beetles, were introduced in each experimental jar with the help of a hand aspirator. The insecticidal effects of the various dusts against these insects were studied at three different exposure periods. For each exposure, two treated jars of each treatment and two untreated checks were examined for the insect mortality.

The first examination was made after one day's exposure by screening the insects from grain of each jar and counting the dead and living insects.

As most of the stored grains insects are apt to simulate death, special care was taken in distinguishing the dead insect from the living ones. In this study, the insects showing any movement were counted as living. It may be mentioned here that, out of the four species studied in this paper, the T. confusum (Duv.) did not simulate death. Rice weevils, granary weevils and sawtoothed grain beetles were generally found to feign death, but nevertheless, no real difficulty was encountered in distinguishing the dead and live insects during this investigation. It was observed that after about one half minute all living insects species which simulate death were on their legs or moving their limbs if knocked down on their back.

Similar examinations were made on three days and six days exposure in the wheat grain.

To determine the efficency of these insecticidal dusts in different types of grains, the insecticidal tests were repeated in grains of corn and sorghums, with malathion, Dow ET-14, and C & C 7744 10% dusts at 1/1000 dosage level. Each insecticide in each grain was replicated six times and its effects on insects mortality studied at three exposure levels of one day, three days, and six days under the similar environmental conditions obtaining for insecticidal tests in wheat. The number of dead and living insects were counted after one day, three days and six days exposures in each grain.

(c) Jute Bag Impregnation Tests

Small sacklets of jute about 6" x 4" which could hold about 250 gms. of wheat grains were dipped in 1% dilutions of C & C 7744, Dipterex, malathion, methoxychlor, perthane, lindane, pyrenone, R 11, R 55, and R 441 and dried in the shade.

Each insecticide was replicated three times and was studied at three exposure periods of one day, two weeks, and two months.

The tests were run in the wooden box used for the repellency tests. The treated sacklets, three for each treatment, as mentioned before, were filled with 250 gms. of untreated and cleaned wheat grains. The sacklets were arranged in the wooden box apart from each other. The mouths of the sacklets were closed before liberating the insects.

Approximately 300 insects consisting of rice weevils and confused flour beetles in about equal number were introduced at the center of the box which was then made insect tight by fixing the screen top and was allowed to remain undisturbed for the first examination. After each examination the same sacklets were again filled up with untreated grains for subsequent observations and arranged in like manner.

The insects from grains in the bags were screened off and the number of dead and alive insects was counted in each sample.

Fourteen days after the bags were treated, they were again filled a third time and exposed to insect attack for a period of 72 hours.

CHAPTER IV

GERMINATION TESTS

Samples of wheat, corn and sorghum, treated with 10% dusts of C & C 7744, Dipterex, Dow ET-14, malathion, methoxychlor at 1/1000 and of 100% ryania dust at 1/500 and one check for each grain were tested for the germination.

CHAPTER V

RESULTS AND DISCUSSION

(a) Repellency Tests

Table 1 shows that ryania and pyrenone 100% dusts at 1/500 gave the best results as repellents against rice weevils. The other insecticidal dusts like C & C 7744, Dow ET-14, dipterex, malathion showed only a small degree of repellency. Methoxychlor as 10% dust exhibited slight to moderate repellency to the weevils. Ryania and pyrenone (Table 2) similarly protected the grains against the confused flour beetle, T. confusum at 1/500 dosage level while the other materials gave about the same results as in table 1.

As shown in table 3, these dusts when used against the sawtoothed grain beetle gave about the same degree of repellency as demonstrated in two previous tests. Most of these materials in the repellency tests because of their low mammalian toxicity and also because they had never been tried in this field.

Pyronone has been found to be good repellent against such pests and was included in the tests to act as standard of comparisons. It is clear from the data presented in the tables 1, 2, and 3 that ryania is as good a repellent as pyrenone at 1/500 dosage level.

R 11 as 12.5% dust and V.C. rodent repellent (Table 4) posses the repellency, but, of these two materials, R 11 has given remarkably good results at 1/1000.

Being comparatively non hazardous these materials, especially R 11, appear to have a good promise for protecting grains on farms and in other small storage facilities.

(b) Toxicity Tests

Data presented in table 5 show that malathion, Dow ET-14 and dipterex were the most outstanding materials causing 70-97% mortality at 1/1000 rate. At 1/10,000 these materials were comparatively less effective and gave only 25-90% kill. C & C 7744 at 1/1000 caused mortality to the test insects ranging from 50-90%. At 1/10,000 dosage level, the kill was poor and ranged from 33-80%. Dipterex 10% was more effective and effected 75-97% kill at 1/1000 and 25-82% at 1/10,000. The effect of ryania and methoxychlor at 1/1000 and 1/500 respectively, was almost the same on the four insects and brought about 43-57% of kill.

At three days' exposure (Table 6) malathion at 1/1000 proved most effective by causing 100% of all the four species. At 1/10,000 it killed 100% of sawtoothed grain beetles and 80-97% of the other test insects. Dipterex and Dow ET-14 at 1/1000 gave almost equal results by causing mortality from 85-100%. At 1/10,000 Dow ET-14 surpassed dipterex and effected 30-97% kill of different insects as against 25-60% caused by dipterex at the same dose. C & C 7744 10% at 1/1000 killed 100% of sawtoothed grain beetles and about 80% of the other three species. At 1/10,000 it caused 60-100% of mortality. Ryania and methoxychlor at 1/1000 and 1/500 proved about equally good against the weevils and caused 100% kill of sawtoothed grain beetle and about 70% of confused flour beetles. At 1/10,000 they proved poor against all the species especially the weevils.

Table 7 shows that malathion, dipterex, Dow ET-14, and C & C 7744 at 1/1000 caused total mortality of the four species. At 1/10,000 dosage level also malathion affected 100% kill in the test insects. C & C 7744, dipterex, Dow ET-14, caused total mortality of 68%, 78%, and 85% respectively. Methoxychlor and ryania at their lower doses did not prove very effective.

The toxicity of malathion, Dow ET-14 and C & C 7744 as 10% dusts at 1/1000 was studied against the four insect species in corn and sorghum grains (Tables 8, 9, 10) and tables 11 and 12. It was revealed that their toxic effects in these two grains was almost equal to the effects in wheat on three different exposures (Tables 5, 6, 7).

From the results obtained in the toxicity tests, it is evident that in general, confused flour beetle adults were considerably more resistant to a majority of the insectidal dusts. Fortunately, however, the two weevil species were found to be largely susceptible and saw-toothed grain beetle was the most susceptible to these toxicants.

The total mortality of the four species caused by the different chemicals as dusts at the higher doses ranged from 96-100% at six days exposure (Fig. 6).

In the insecticidal tests, securing of uniform mixture of the dusts can be a very real problem in practice when seed mixing machines, tumbling drums, etc., are not readily available. In such exigencies the mixing can easily be done by making use of shovels or any other suitable implement available at the farm. This can be done by applying the dust to the top layer of grain and then working it in by means of the implement.

(c) Jute Bag Impregnation Tests

Data presented in table 13 show that R 11, R 55, R 441, perthane, and pyrenone proved to be excellent repellents and gave about 100% protection against rice weevils and confused flour beetles. The protection offered by malathion and lindane against the two species was almost the same ranging from 96-100%. Methoxychlor appeared to have less repelling action, but it gave 93-94% protection against the rice weevil and the confused flour beetle respectively. Dipterex gave 82-90% protection against rice weevils and confused flour beetles respectively.

Table 14 shows that after two weeks, R 11, R 55, R 441, perthane, and pyrenone proved very good repellents and kept the grains free from infestation up to 93-100% against both the species. Malathion, lindane and methoxychlor proved more protective than repellents and gave protection against the insects ranging from 85-100%. Dipterex gave better results as protective (93-95%) than as repellent (75-89%).

In table 15, the data presented show that after two months R 11, R 55, R 441, perthane, and pyronone protected the grains against rice weevils (94-100%) and confused flour beetles (96-98%). Malathion, lindane and methoxychlor proved more protective and less repelling to both the species and gave encouraging protection ranging from 88-98%. Dipterex appeared to be a fair grain protectant against both the species (73-92%).[1]

1. The repellency percentage in tables 13, 14, and 15 was arrived at by comparing the total numbers of dead and living insects with the number in the check. The protection percentage was determined by comparing the number of living insects with the corresponding check.

From the results obtained in these tests, it is rather evident that these materials gave a fair to good protection to grains. R 11, R 55, R 441, pyrenone and perthane gave an excellent account as repellents and the others such as malathion, methoxychlor, lindane and dipterex gave quite encouraging performances as protectants.

The method of jute impregnation has many advantages over the other methods of controlling stored grain insect. First, the grain is kept free from insect infestation; second, it is more economical; and third, the numbers of application are low. It is highly useful in controlling insect pests of flour with which chemicals cannot safely be mixed.

Table 16 indicates that wheat treated at the higher dosage with C & C 7744, dipterex, Dow ET-14, malathion, and methoxychlor as 10% dust and ryania as 100% dust had 5-61% of germination as compared to 50% in check.

Corn and sorghum grain treated with C & C 7744, Dow ET-14, malathion at 1/1000 showed 38-45% germination compared with 40-42% on the checks.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The object of this investigation was to evaluate some non-hazardous grain protectants against the insect pests of stored grain. Dust formulation of C & C 7744, Dow ET-14, dipterex, malathion, methoxychlor, and ryania having a very low order of mammalian toxicity, were selected and applied directly to grains as 10% dusts at two different levels of dosages of 1/1000 and 1/10,000, except the ryania 100% dust which was applied at 1/500 and 1/1000. The insecticidal effects of these chemical dusts were studied against four species of major insect pests of stored food products, namely rice weevil, Sitophilus oryza (L.), granary weevil, Sitophilus granarius (L.), confused flour beetles, Tribiolium confusum (Duv.) and sawtoothed grain beetle, Oryzaephilus surinamensis (L.). These chemicals were studied at three exposure periods of one day, three days, and six days in wheat, corn, and grain sorghums.

Repellency tests with all the above named dusts and V.C. rodent repellent 40%, R11 12.5%, and pyrenone 100% were carried out at their higher dose as mentioned before. R 11 as 12.5% dust, V.C. rodent repellent at 40%, and pyrenone were tried at 1/1000 and 1/500 respectively against the rice weevil, confused flour beetle, and sawtoothed grain beetle in wheat grains in an insect tight enclosure for different exposures.

Some new materials like R 11, R 55, R 441, perthane along with dipterex malathion, methoxychlor, pyrenone, and perthane were studied as grain protectants by impregnating them on small jute bags at 1% dilutions. The protective values of these materials were studied over the exposure periods of one day, two weeks, and two months, against the rice weevil and the confused flour beetle.

From the data presented on the protective and insecticidal values of different treatments tried, ryania and R 11 as 12.5% dust proved good repellents. Malathion, C & C 7744, Dow ET-14, methoxychlor, dipterex at 1/1000 killed all adults of all the test insects within a week. Ryania was as good as methoxychlor.

In jute bag impregnation tests, it was revealed that R 11, R 441, R 55, perthane and malathion at 1% concentration gave complete protection to grain against two of the most prevalent and injurious species of the test insects, i.e. rice weevils and confused flour beetles for two months.

In view of the results achieved in the foregoing experiments, it is concluded that:

1. Ryania 100% dust and R 11 as 12.5% dust have proved excellent repellents against the rice weevils, confused flour beetles, and saw-toothed grain beetle, when incorporated with the grains at 1/500 and 1/1000 respectively.

2. C & C 7744, Dow ET-14, dipterex, methoxychlor at 1/1000 failed to qualify as repellents against any of the test insects.

3. Malathion, C & C 7744, dipterex, Dow ET-14 as 10% dusts at 1/1000, and malathion at 1/10,000 effected 100% kill of all the species within a week.

4. Methoxychlor 10% dust at 1/1000 killed all the test insects but T. confusum (85%) within a week.

5. Ryania 100% dust at 1/500 killed essentially all insects within one week's exposure.

6. At the lower level of dosage (1/10,000 except ryania at 1/1000), all the insecticidal dusts killed the sawtoothed grain beetle. However, with the exception of malathion, they did not eliminate the other species.

7. That the insecticidal effectiveness of a material did not vary greatly when used in different grains.

8. R 11, R 55, R 441, perthane, malathion, pyrenone, dipterex, lindane, and methoxychlor at 1% dilution, when impregnated in jute bags, gave a good protection to grains against the four species of the test insects.

9. None of the test dusts had any adverse effect on germinating power of wheat, corn, and grain sorghums.

In the author's opinion further studies, in the evaluation of the toxicants group at different grain moisture levels and at different room temperatures might add to the pesticidal values of these materials for varying environmental conditions.

BIBLIOGRAPHY

Anderson, D. L. 1938. Effects of Temperature on Rice Weevil and Granary Weevil. Bul. Ent. Res. 31:1-7.

Alexander, P. F. et al. 1944. Innert Dust Insecticides. Ann. Appl. Biol. 31: 143-149.

Apt.A. 1952. Evaluation of Dusts and Sprays for the Protection of Shelled Corn from Insect Attack - U. S. D. A. Agriculture Research Service Ent. Research Br. E875: 25 p.

Atkins, J. and E. M. Grear, 1953. Storage of Flour in Jute Bags treated with Insecticides. Journal Science Food and Agr. 4: 155-160.

________, 1938. Stored Grain Pests. U. S. D. A. Farms.Bul. 1260: 47 p.

Back, E. A. and R. T. Cotton, 1923. Biology of Sawtoothed Grain Beetle. Jour. Agr. Res. 33: 435-542.

Balzer, A. I. 1947. Insect Pests of Stored Rice and Their Control. U. S. D. A. Farmers Bul. 1906: 26 p.

Barnes, D. F. 1953. Toxicity of DDT to Animals. Jour. Econ. Ent. 45: 750-751.

Beekley, I. A. 1948. Protection of Grains Against Weevils. Jour. Agr. Res. 31: 221-229.

Bodenheimer, F. 1923. Ecology of Pests. Zeitschr Angrew Ent. 1: 1-80.

Brett, C. H., et al. 1953. Mexican Bean Beetle Control with Malathion. Journal of Economic Entomology 46: 912-913.

Bushland, R. C. 1952. Toxicity of Insecticides to Livestock. Agriculture Year Book. 1952: 276-283.

Gann, F. R. 1955. Biological and Economic Problems of Stored Grains Entomology. Ann. Appl. Biol. 42: 98-103.

Chapman, R. N. 1921. Insect Infesting Stored Food Products. Minn. Expt. Sta. Bul. 198: 38 p.

Chiang, H. C. 1953. Effects of Ryania and DDT on Some Pests. Jour. Econ. Bul. 46: 273-283.

Collins, W. E. and N. King. 1953. A Modified Technique for Laboratory Evaluation of Contact Insecticides. Jour. Econ. Ent. 46: 51-53.

Conolly, C. R. 1952. Insecticides. Pest Cont. 20 (5) : 24.

Cotton, R. T. 1920. Rice Weevil - Sitophilus oryza. Jour. Agr. Res. 20: 409-422.

________ 1926. Granary Weevil. U. S. D. A., Tech. Bul. 1393: 36p.

________ 1938. Control of Insects Attacking Grains in Farm Storage. U. S. D. A. Farms Bul. 1811: 14p.

________ et al. 1944. Protection of Food and Seed from Insect Attack. Jour. Econ. Ent. 37: 384-388.

________ and J. C. Frankfield, 1945. Protecting Seed from Insect Attack. U. S. D. A. Bul. Ent. Pl. Quar. Cir., No. 677: 15p.

________ 1948. Stored Products Insects. U. S. D. A. Cir. No. 720: 72-75.

________ and Wallace Ashley, 1952. Insect Pests of Stored Grain and Seeds. U. S. D. A. Year Book. 1952: 629-639.

________ et al. 1949. Insect Proofing Cotton Bags. U. S. D. A. Bul. Ent. Pl. Quar. E 783: 19p.

Dahms, R. A. 1955. Methods of Treating Sorghum Selfing Bags for Insect Control. Jour. Econ. Ent. 48: 569-572.

David. W. 1948. Factors Influencing the Action of Dust Insecticides. Bul. Ent. Res. 41: 1-57.

Deong, E. R. 1956. Chemistry and Uses of Pesticides. 2nd Ed. 350p. Reinbold Publishing Corporation, N. Y.

Dean, G. A. 1913. Mill and Stored Grain Pests. Kan. Agr. Expt. Sta. Bul. 189: 139-236.

Doane, R. W. 1919. Weevils in Australian Wheat in California. Jour. Econ. Ent. 12: 308-311.

________ 1924. The Control of Insects in Cereal Food. Jour. Econ. Ent. 17: 549-572.

Dove, W. E. 1954. How to Protect Stored Wheat. Jour. Econ. Ent. 48: 569-572.

Eden, W. G. 1953. Control of Rice Weevil in Corn. Jour. Econ. Ent. 46: 1105-1107.

________ 1954. Control of Corn Earworm and Stored Grain Insects. Jour. Econ. Ent. 47: 1124-1126.

Fletcher, T. B. and Ghosh, C. C. 1920. Stored Grain Pests. Proc. 3rd. Ent. Meeting. Pusa 2: 712-761.

Good, N. E. 1936. The Flour Beetle of <u>Genus</u> <u>Triliolium</u>. U. S. D. A. Tech. Bul. 498: 1-58.

Graham, C. E. 1922. Studies in Insect Ecology. Amer. Naturalist. 32:289-297.

Grandori, R. 1955. Protection and Disinfestation of Wheat Through Non-toxic Substances. Trans. IX, Internatl. Cong. of Ent. 1951, Vol 1: 849-853.

Gray, H. E. The Biology of Flour Beetles. Mill Production 13: 7, 18-22.

Guy, H. F., 1937. Investigation of Organic Compounds as Insecticides. Ent. Del. Agr. Exp. Sta. Tech. Bul. 19: 5-60.

Hall, D. W. 1955. Problem of Food Storage in Tropical Territories. Ann. Appl. Biol. 42: 85-97.

Harris, W. V. 1936. Insects Injurious to Food Products. Bul. Ent. 28: 485-488.

Hewlett, P. S. 1952. Piperonyl-butoxide as a Synergistic for Pyrethrins. Bul. Ent. Res. 42: 293-309.

Herrick, G. W. J. 1926. Insect Injurious to Household. U. S. D. A. Tech. Bul. 1405-31p.

Hierholzer, O. 1953. A Simple Method of Obtaining Test Insect of Equal Vitality. Any Schadlingsk. 24(11): 165-167.

Horsfall, J. L. and F. C. Bishop, 1952. Safe Use of Insecticide. U. S. D. A., Agr. Year Book 1952: 271-275.

Howe, R. W. et al. 1952. Control Measures Against Insects Attacking Ground Nuts. Bul. Ent. Res. 43: 259-279.

______ 1956. Effects of Temperature and Relative Humidity on Rate of Development and Mortality of <u>Tribolium</u> sps. Ann. Appl. Biol. 42: 356-368.

Jacks, H. 1951. Control of Weevils Damaging French Beans and Corn in Storage. Bul. Ent. Res. 42: 159-163.

Jewett, H. H. and F. A. Price, 1951. Protection of Stored Grain from Insects by Bag-Impregnation. Ky. Agr. Exp. Sta. Bul. 571: 8p.

Kockum, S. 1952. Protection of Col. Maize Stored in Cribs. S. Afr. Jour. of Agr. 19:69:73. Abstracted in R. A. E. (A) 39: 227.

Kulash, M. W. 1956. Treated Corn Bags to Control Rice Weevil in Corn. Jour. Econ. Ent. 49: 64-65.

Krijgsman, B. J. and T. Longbeck, 1951. Contact Toxicity and Real Toxicity. Bul. Ent. Res. 42: 135-143.

Lemmon, C. H. 1953. Toxicity of Organic Insecticides to Livestock. Bul. Ent. Res. 46: 19-25.

Laudani, H. and G. R. Swank. 1954. A Laboratory Apparatus for Detecting Repellency of Pyrethrin. Jour. Econ. Ent. 47: 1104-1107.

Lindgren, D. L. et al. 1953. Beetles in Stored Dates. Hilgardia 22: 97-117.

__________ 1954. Malathion, Chlorthion for Control of Insects Infesting Stored Grain. Jour. Econ. 47: 705-706.

Lloyd, C. J. 1952. Insecticidal Tests Against Potato Tuber Moth. Jour. Econ. Ent. 44: 613-614.

MacDonald, H. 1956. Study on Toxic Hazards of Pesticides to Man. World Crops 8: 370-371.

Michelbaker, A. E. and D. P. Furman. 1951. Control of Household Insect Pests. Calif. Agr. Exp. Sta. Cir. No. 172: 23-25.

Oxley, T. A. 1955. Grain Storage in East Africa. Bul. Ent. Res. 48: 71-89.

Nakujuna, N. 1952. Grain Protection in Storage. Bul. Ent. Res. 45: 25-30.

Parkin, E. A. 1944. Control of Granary Weevil with Finely-divided Mineral Dusts. Ann. Appl. Biol. 31: 84-88.

__________ 1953. The Susceptibility to DDT dust of Coleoptera Infesting Stored Products. Bul. Ent. Res. 44: 439-445.

__________ 1955. Progress in the Control of Insects Infesting Stored Food Stuffs. Ann. Appl. Biol. 42: 104-111.

__________ 1956. Insecticidal Tests for the Protection of Stored Peas and Beans. Bul. Ent. Res. 46: 625-641.

Pelly, R. and L. S. Kockum. 1955. Experiments on Grain Protection with Insecticides. Bul. Ent. Res. 45: 295-311.

Pingale, S. V. 1953. Impregnation of Jute Bags with Insecticides for Protecting Stored Food Products. Indian Jour. Ent. 15: 343-351.

Radeleff, R. D. 1950. Acute Toxicity of Chlorinated Insectide. Jour. Econ. Ent. 43: 358-364.

Rusin, N. N. 1953. Organoleptic Properties of Food Products Treated with DDT and BHC. Gigiena i sanit. 2: 27-32. Abstracted in Chem. Abs. 47(3): 7725d. 1953.

Shadd, C. K. and R. T. Cotton, 1949. Storage of Small Grains and Shelled Corn. U. S. D. A. Farms Bul. 2000: 30p.

Shafer, G. D. 1915. How Contact Insecticides Kill Insects. Mich. Agr. Exp. Sta. Tech. Bul. 21: 67p.

Solomon, M. E. 1955. The Power of Survival of Storage Pest under Winter Condition. Bul. Ent. Res. 46: 311-354.

Starris, K. J. 1956. Some Effects of Insecticides. Jour. Econ. Ent. 48: 549-555.

Stinger, A. et al. 1955. Insecticidal Activity and Chemical Constitution Analogues and Isosteres of DDT. Ann. Appl. Biol. 43(3): 366-387.

Sturgeon, L. 1952. Losses Caused by Stored Grain Insect Pests. Pest Control, 20: 12, 14, and 16.

Svik, F. P. 1956. Treated Cloth Bags to Control Rice Weevil in Corn. Jour. Econ. Ent. 49(1): 64-65.

Turney, H. H., 1957. Some Effects of Cracked Grains on the Reproduction of Sawtoothed Grain Beetle. Jour. Kan. Ent. Soc. 30(1): 6-8.

Vanova, S. V. et al. 1951. A New Preparation for Insect Eradication in Grains. Sentv. Chem. 1-641. Abstracted in Chem. Abs. 47: 8959f. 1951.

Watts, C. N. 1950. Piperonyl butoxide and Pyrethrins to Control Rice Weevil. Jour. Econ. Ent. 47: 706-707.

White, G. D. 1952. Experiments in Preventing the Build-up of Insects in Newly Harvested Wheat. U. S. D. A. Bur. Ent. and Pla. Quar. E850: 19p.

Whitehead, F. E. 1944. Insect Population of Farm Wheat Bins and Experiments in their Control. Proc. Okla. Acad. Sci. 24: 29-34.

Wilbur, D. A. 1952. Effects of Moisture Contents of Wheat on Toxicity of Insecticidal Dusts. Kan. Ent. Soc. 25: 121-125.

Wilbur, D. A. 1952. Effects of Pyrethrum and Piperonyl Butoxide when Applied to Wheat. Jour. Econ. Ent. 45: 913-920.

__________ 1954. Effects of Certain Protectants on Wheat Germination. Jour. Econ. Ent. 47: 706-707.

__________ 1955. Grain Protectants on the Farm. Kan. Agr. Exp. Sta. Cir. No. 323: 34-35.

Yoeman, A. H. 1952. Radient Energy and Insects U. S. D. A. Agr. Year Book 1952: 411-421.

Brawn, A. W. A. 1951. Insect Control by Chemicals. Chapters I-VII 141p. John Wiley and Sons Inc. N. Y.

Cotton, R. T. 1956. Insects Pests of Stored Grain and Grain Products. Rev. Ed. Burgess. Publishing Co. Minneapolis 15, Minn.

Chapman, R. N. 1931. Animal Ecology. Chapters I-IV. 155p. McGraw Hill Book Co. Inc. N. Y.

Fenton, F. A. 1952. Field Crop Insects. Chapters II-IV, Macmallen, Co. N. Y.

Erear, E. H. 1948. Chemistry of Insecticides, Fungicides and Herbicides. 2nd Ed. Pts. II and III, 789p. D. von Nostrand Co. Inc. New York.

_________ 1952. Chemistry of Pesticides. D. von Nostrand Co. Inc. N. Y. 510p.

Metcalf, R. L. 1955. Organic Insecticides: Their Chemistry and Mode of Action. Chapters III and XI, 105p. Interscience Publication. Inc. N. Y.

Oxley, St. A. 1948. The Scientific Principles of Grain Storage 321p. The Nothern Publishing Co. Ltd. Liverpool.

Rose, C. J. 1955. Crop Protection 229p. Leonard Hill Ltd. Lovelon.

Shepard, H. H. 1951. The Chemistry of Insecticides. Chapters V and VII and X and XIII, 170p. Hill Book Co. Inc. N. Y.

Wardle, R. H. 1923. The Principles of Insect Control. Chapters VI - VIII, 98p. University Press, Manchester.

Wardle, R. H. 1931. The Problem of Applied Entomology. Part I: 1-229. McGraw and Hill Book Co. Inc. N.Y.

TABLE I

REPELLENT AND LETHAL ACTION OF VARIOUS INSECTICIDAL DUSTS AGAINST RICE WEEVILS

S. No.	Treatment	No. of Insects found in different treatments					
		I Test		II Test		III Test	
		Dead	Alive	Dead	Alive	Dead	Alive
1	Pyrenone pure at 1 pt. in 500 pts. grains	1	1	-	3	1	3
2	Ryania 10% at 1 pt. in 500 pts. grains	1	3	1	4	2	2
3	Methoxychlor 10% dust at 1 pt. in 1000 pts. of grains	5	10	7	11	4	14
4	C & C 7744 10% dust at 1 pt. in 1000 pts. grains	8	10	11	7	9	9
5	Dow ET-14 10% dust at 1 pt. in 1000 pts. grains	10	12	11	13	10	8
6	Dipterex 10% dust at 1 pt. in 1000 pts. grains	9	8	10	7	11	10
7	Malathion 10% dust at 1 pt. in 1000 pts. grains	14	9	16	9	15	13
8	Checks (untreated) (average)	-	26	-	31	-	29

Temperature - 69°

TABLE II

REPELLENT AND LETHAL ACTION OF VARIOUS INSECTICIDAL DUSTS AGAINST CONFUSED FLOUR BEETLE

S. No.	Treatment	No. of Insects found in different treatments					
		I Test		II Test		III Test	
		Dead	Alive	Dead	Alive	Dead	Alive
1	Pyrenone pure at 1/500	-	2	-	2	-	-
2	Ryania pure at 1/500	-	3	-	2	-	1
3	Methoxychlor 10% at 1/1000	2	9	5	8	4	7
4	C & C 7744 10% dust at 1/1000	1	12	1	14	2	10
5	Dow ET-14 10% at 1/1000	2	11	1	12	3	8
6	Dipterex 10% at 1/1000	8	6	7	6	4	9
7	Malathion 10% at 1/1000	8	2	11	3	10	5
8	Checks (untreated) (average)	-	21	-	18	-	19

1/1000 = 1 pt. of dust in 1000 pts. of grains
1/500 = 1 pt. of dust in 500 pts. of grains

TABLE III

REPELLENT AND LETHAL ACTION OF VARIOUS DUSTS
AGAINST SAWTOOTHED GRAIN BEETLE

S. No.	Treatment	No. of Insects found in different treatments					
		I Test		II Test		III Test	
		Dead	Alive	Dead	Alive	Dead	Alive
1	Pyrenone pure at 1/500	0	0	0	0	0	1
2	Ryania pure at 1/500	0	0	0	1	0	1
3	Methoxychlor 10% at 1/1000	8	5	5	7	6	6
4	C & C 7744 10% at 1/1000	9	11	8	10	10	7
5	Dow ET-14 10% at 1/1000	7	6	7	8	9	6
6	Dipterex 10% at 1/1000	9	2	11	2	8	4
7	Malathion 10% at 1/1000	16	2	15	3	14	4
8	Check (untreated) (average)	-	24	-	22	-	27

1/500 and 1/1000 = 1 pt. of dust in 500 and 1000 pts. grains

TABLE IV

REPELLENT AND LETHAL ACTION OF VARIOUS DUSTS
AGAINST RICE WEEVIL AND CONFUSED FLOUR BEETLE

S. No.	Treatment	Raps	No. of Insects found in different treatments			
			Rice Weevil		Confused flour beetle	
			Alive	Dead	Alive	Dead
	R 11 12.5% dust at 1/1000	1	3	0	0	0
		2	2	0	0	0
		3	1	0	1	0
		4	1	0	0	0
		5	1	0	0	0
	V. C. Rodent Repellent 10 %	1	4	0	3	0
		2	2	0	0	0
		3	2	0	1	0
		4	3	0	3	0
		5	4	0	2	0
	Checks (untreated)	1	19	0	16	0
		2	15	0	15	0
		3	16	0	17	0

1/1000 = 1 pt. dust in 1000 pts. grains

TABLE V

INSECTICIDAL EFFECTS OF VARIOUS DUSTS IN WHEAT ON DIFFERENT INSECTS AFTER ONE DAY'S EXPOSURE

		Mortality Percentage			
Formulations	Dosage	Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
Malathion 10%	1/1000	77	80	55	97
	1/10000	63	70	50	80
Dow ET-14 10%	1/1000	70	75	55	97
	1/10000	43	35	24	90
Dipterex 10%	1/1000	57	65	35	97
	1/10000	25	8	9	82
C & C 7744 10%	1/1000	57	50	55	90
	1/10000	33	35	30	80
Ryania (pure)	1/500	47	45	40	57
	1/1000	20	25	15	26
Methoxychlor 10%	1/1000	43	35	30	50
	1/10000	30	24	18	24
Check	untreated	0	0	0	0

Grain moisture 14% Temperature 68°

TABLE VI

INSECTICIDAL EFFECTS OF VARIOUS DUSTS IN WHEAT ON DIFFERENT INSECTS AFTER THREE DAYS' EXPOSURE

		Mortality Percentage			
Formulations	Dosage	Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
Malathion 10%	1/1000	100	100	100	100
	1/10000	97	80	80	100
Dow ET-14 10%	1/1000	97	95	85	100
	1/10000	70	60	30	97
Dipterex 10%	1/1000	97	95	95	100
	1/10000	33	25	25	60
C & C 7744 10%	1/1000	80	75	80	100
	1/10000	60	60	35	100
Ryania (pure)	1/500	77	75	65	100
	1/1000	45	50	45	40
Methoxychlor	1/1000	77	70	70	100
	1/10000	16	25	25	33
Check	untreated	0	0	0	9

Room Tenperature 71°F. Moisture of Grain 14%

TABLE VII

INSECTICIDAL EFFECTS OF VARIOUS DUSTS IN WHEAT ON DIFFERENT INSECTS AFTER SIX DAYS' EXPOSURE

Formulations	Dosage	Mortality Percentage Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
Malathion 10%	1/1000	100	100	100	100
	1/10000	100	100	100	100
Dow ET-14 10%	1/1000	100	100	100	100
	1/10000	90	85	65	100
Dipterex 10%	1/1000	100	100	100	100
	1/10000	75	70	65	100
C & C 7744 10%	1/1000	100	100	100	100
	1/10000	55	60	55	100
Ryania (pure)	1/500	97	100	85	100
	1/1000	70	75	65	80
Methoxychlor	1/1000	100	100	85	100
	1/10000	28	25	30	53
Check	untreated	0	5	0	9

Room Temperature 71°F. Moisture 14%

TABLE VIII

SHOWING INSECTICIDAL VALUE OF MALATHION, DOW ET-14, C & C 7744 DUSTS IN CORN AFTER ONE DAY'S EXPOSURE AGAINST DIFFERENT INSECTS

Formulations	Dosage	Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
		Mortality Percentage			
Malathion 10%	1/1000	90	90	85	100
Dow ET-14 10%	1/1000	58	65	85	100
C & C 7744 10%	1/1000	63	70	75	100
Check	untreated	0	0	0	9

TABLE IX

SHOWING EFFECTS OF DIFFERENT DUSTS AGAINST INSECTS IN CORN AFTER THREE DAYS' EXPOSURE

Formulations	Dosage	Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
		Mortality Percentage			
Malathion 10%	1/1000	100	100	100	100
Dow ET-14 10%	1/1000	97	95	100	100
C & C 7744 10%	1/1000	75	80	70	100
Check	untreated	3	0	0	12

Temperature 72°F.   Moisture in Grain 12.11%

TABLE X

SHOWING INSECTICIDAL VALUE OF MALATHION, DOW ET-14, AND C & C 7744 AGAINST DIFFERENT INSECTS IN CORN AFTER SIX DAYS EXPOSURE

Formulations	Dosage	Mortality Percentage Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
Malathion 10%	1/1000	100	100	100	100
Dow ET-14 10%	1/1000	100	100	100	100
C & C 7744	1/1000	100	100	100	100
Checks	untreated	3	2	0	9

Room Temperature 72°F. Moisture Contents 12.11%

TABLE XI

EFFECTS OF MALATHION, DOW ET-14 AND C & C 7744 INSECTICIDAL DUSTS IN GRAIN SORGHUMS AGAINST DIFFERENT INSECTS

	Exposure Period							
	One Day Mortality Percentage				Three Days Mortality Percentage			
Formulation & Dosage	Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle	Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
Malathion 10% at 1/1000	85	85	90	100	100	100	100	100
Dow ET-14 10% at 1/1000	52	55	60	100	100	95	95	100
C & C 7744 10% at 1/1000	52	65	72	100	70	65	80	100
Checks (untreated)	0	0	0	3	0	0	0	9

Temperature 69°F. and 72°F. Moisture content 11.9%

TABLE XII

EFFECTS OF MALATHION, DOW ET-14 AND C & C 7744 DUSTS AGAINST DIFFERENT INSECTS IN GRAIN SORGHUMS AT SIX DAYS' EXPOSURE

Formulation & Dosage	Mortality Percentage Rice Weevil	Granary Weevil	Confused Flour Beetle	Sawtoothed Grain Beetle
Malathion 10% at 1/1000	100	100	100	100
Dow ET-14 10% at 1/1000	100	100	95	100
C & C 7744 10% at 1/1000	97	90	95	100
Checks (untreated)	3	0	0	12

Room Temperature 70°F. Moisture of Grain 11.9%

TABLE XIII

EFFECTS OF VARIOUS CHEMICALS IMPREGNATED ON JUTE BAGS ON DIFFERENT INSECTS AFTER ONE DAY

Treatment	No. of Insects found in each bag after 24 hours exposure							
	Rice Weevils				Confused Flour Beetles			
	Dead *	Alive	%Repel-lency '	%Protec-tion †	Dead	Alive	%Repel-lency	%Protec-tion
R 11 1%	2	0	96	100	1	0	98	100
R 55 1%	0	3	95	95	0	0	100	100
R 441 1%	3	0	95	100	3	0	94	100
Perthane 1%	3	2	91	96	0	0	100	100
Pyrenone 1%	1	1	96	98	5	0	90	100
Malathion 1%	4	1	91	98	1	0	98	100
Lindane 1%	8	2	82	96	3	1	92	98
Methoxychlor 1%	10	4	74	93	0	3	94	94
Dipterex 1%	0	10	82	82	0	5	90	90
Check	0	54			0	50		

* Numbers of dead and alive insects represent the total of three replicates for each chemical.

' The % repellency was arrived at by comparing the total number of the dead and living insects with the number in the check.

† The % protection was determined by comparing the number of the living with the corresponding check.

TABLE XIV

EFFECTS OF DIFFERENT CHEMICAL IMPREGNATED ON JUTE BAGS ON VARIOUS INSECTS AFTER 2 MOS.

Treatment	No. of Insects found in each bag after 24 hours exposure							
	Rice Weevils				Confused Flour Beetles			
	Dead	Alive	%Repel-lency	%Protec-tion	Dead	Alive	%Repel-lency	%Protec-tion
R 11 1%	1	0	98	100	0	1	98	98
R 55 1%	0	0	100	100	0	0	100	100
R 441 1%	0	0	100	100	0	1	98	98
Perthane 1%	2	2	90	95	0	0	100	100
Pyrenone 1%	0	0	100	100	1	3	91	93
Malathion 1%	1	0	98	100	2	2	91	97
Lindane 1%	4	2	85	98	3	1	91	98
Methoxychlor 1%	1	4	88	90	0	3	93	100
Dipterex 1%	8	2	75	95	2	3	89	93
Check	0	40			0	45		

TABLE XV

EFFECTS OF VARIOUS CHEMICALS IMPREGNATED ON JUTE BAGS ON INSECT INFESTATION AFTER TWO MONTHS

	No. of Insects found in each bag after 72 hours exposure							
	Rice Weevils				Confused Flour Beetles			
Treatment	Dead	Alive	%Repellency	%Protection	Dead	Alive	%Repellency	%Protection
R 11 1%	0	1	97	97	0	1	98	98
R 55 1%	0	1	97	97	0	2	96	96
R 441 1%	1	0	97	100	0	2	96	96
Perthane 1%	0	1	97	97	0	2	96	96
Pyrenone 1%	1	2	92	94	1	2	93	96
Malathion 1%	12	3	67	92	9	1	78	98
Lindane	4	2	83	94	2	2	91	96
Methoxychlor 1%	2	2	89	94	1	5	87	88
Dipterex 1%	7	3	72	92	3	10	71	78
Check	0	35			0	45		

TABLE XVI

GERMINATION DATA OF THE TREATED GRAINS

Grain	Date of Treatment	Date of Test	Germination Percentage of Seed treated with C7744 10% at 1/1000	Diptерex 10% at 1/1000	Dow ET-14 10% at 1/1000	Malathion 10% at 1/1000	Methoxychlor 10% at 1/1000	Ryania pure at 1/500	check
Wheat	Dec. 20, 1956	March 20, 1957	57	56	57	57	57	61	50
Corn	Feb. 15, 1957	March 1957	41		41	42			42
Grain Sorghum	Feb. 15, 1957	March 1957	40		45	38			40

The corn and sorghum grains were treated with only malathion, Dow ET-14 and C 7744 and their germination was tested.

Fig. 1. Adjusting the Moisture Contents of Grains.

Fig. 2. Mixing an Insecticide with the Grain on the Standard Ball Mill.

Fig. 3. Cultures of Different Test Insects in the Rearing Cage.

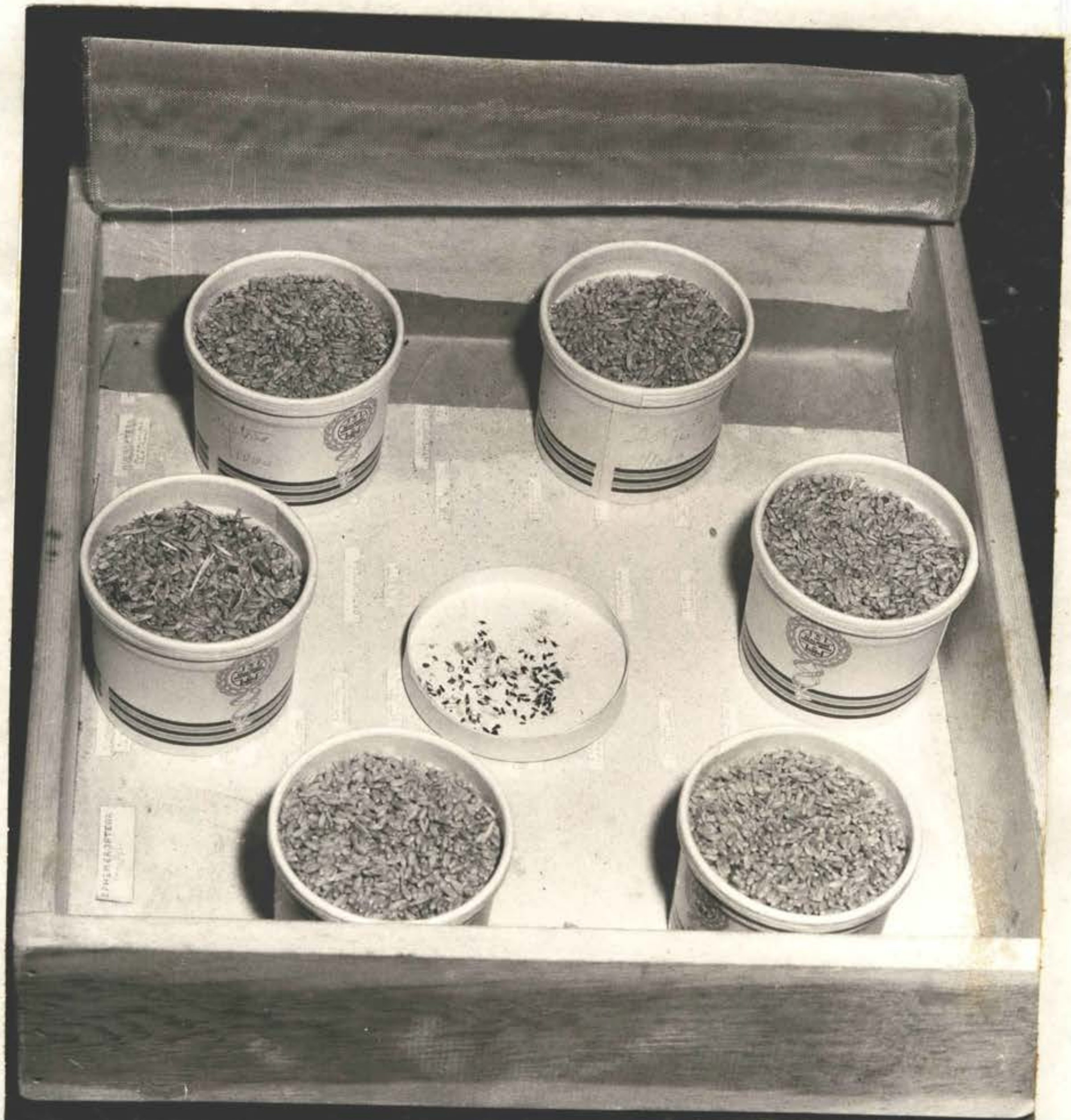
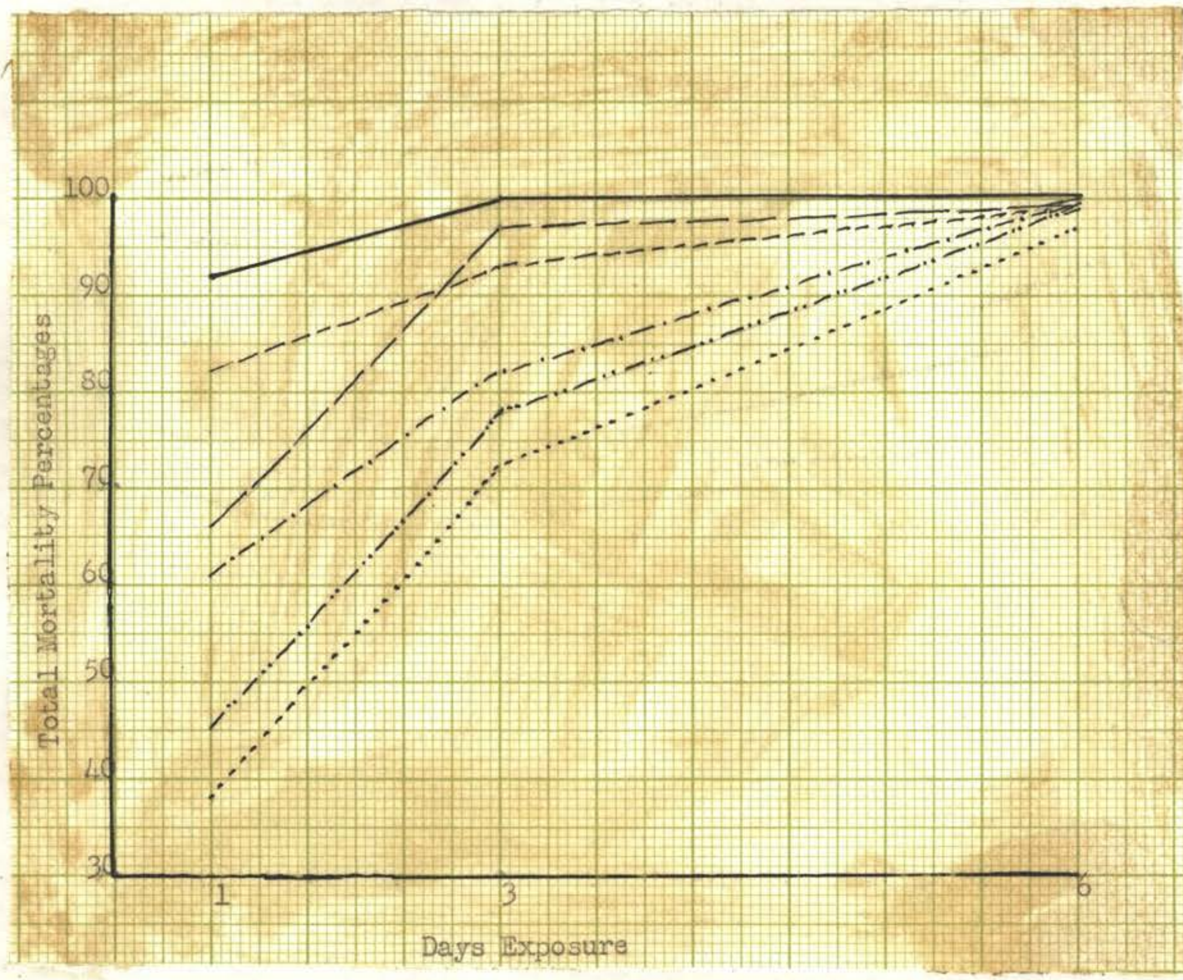


Fig. 4. Arrangement of Repellency Tests.

FIGURE VI

TOTAL MORTALITY OF TEST INSECTS EFFECTED BY
INSECTICIDAL DUSTS AT HIGHER DOSAGE LEVEL



Malathion
Dow ET-14
Dipterex
C & C 7744
Ryania
Methoxychlor

VITA

Niadar Singh Mali

Candidate for the Degree of

Master of Science

THESIS: EVALUATION OF SOME NON-HAZARDOUS INSECTICIDES AND REPELLENTS FOR THE CONTROL OF STORED GRAIN INSECT PESTS.

MAJOR FIELD: Entomology

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