

**CONTROL OF INSECTS INFESTING STORED PRODUCTS  
BY INSECTICIDE-TREATED BAGS**

---

**A Thesis  
Presented to  
the Faculty of the Graduate School  
University of Missouri**

---

**In Partial Fulfillment  
of the Requirements for the Degree  
Master of Science**

---

**by  
Costas Alexander Kouskolekas  
August 1958**

The undersigned, appointed by the Dean of the Graduate Faculty, have examined a thesis entitled **Control of Insects Infesting Stored Products by Insecticide-Treated Bags.**

presented by **Costas Alexander Kouskolekas**

a candidate for the degree of **Master of Science**

and hereby certify that in their opinion it is worthy of acceptance.

*Don C. Peters*  
*Harry E. Brown*  
*J. M. Poehlman*

### ACKNOWLEDGEMENTS

The writer wishes to express his gratitude and sincere appreciation to Dr. Don C. Peters for his personal help and continuous guidance throughout the experiments as well as for his most valuable aid in the preparation of the manuscript. Special thanks are due to Mr. Paul J. Spangler, who initiated the study, guided the first part of the research and permitted the use of his data.

The writer is particularly grateful to Dr. Philip C. Stone for making available the facilities of the Department, thus facilitating the completion of the study.

Sincere thanks are extended to Professor H. E. Brown for reading the thesis and for his very helpful suggestions and criticism.

## TABLE OF CONTENTS

	PAGE
INTRODUCTION . . . . .	1
CHAPTER	
I. THE PROBLEM AND GENERAL ASPECTS OF INSECT	
PENETRATION AND INFESTATION . . . . .	3
The Problem . . . . .	5
Statement of the problem . . . . .	5
Importance of the study . . . . .	5
General aspects of insect penetration and infestation . . . . .	6
Origin of infestation in farm storage . . . . .	6
Abilities of penetration . . . . .	6
Purpose of insect penetration . . . . .	7
Damage to stored grain by insects . . . . .	7
II. REVIEW OF THE LITERATURE . . . . .	9
III. MATERIALS AND METHODS . . . . .	24
Experiment with paper bags . . . . .	24
Experiments with cotton bags . . . . .	25
Test of the residual activity . . . . .	28
IV. RESULTS . . . . .	30
Experiment with paper bags . . . . .	30

CHAPTER	PAGE
Experiments with cotton bags . . . . .	30
Test of the residual activity . . . . .	41
V. DISCUSSION AND CONCLUSIONS . . . . .	47
VI. SUMMARY . . . . .	52
BIBLIOGRAPHY . . . . .	55

CHAPTER	PAGE
Experiments with cotton bags . . . . .	30
Test of the residual activity . . . . .	41
V. DISCUSSION AND CONCLUSIONS . . . . .	47
VI. SUMMARY . . . . .	52
BIBLIOGRAPHY . . . . .	55

LIST OF TABLES

TABLE	PAGE
I. Number of insects present in paper bags after two months of exposure . . . . .	31
II. Number of insects present in paper bags after four months of exposure . . . . .	32
III. Number of insects present in paper bags after six months of exposure . . . . .	33
IV. Number of insects present in paper bags after eight months of exposure . . . . .	34
V. Total infestation after ten months of exposure . .	35
VI. Number of insects present in closely woven bags after three months of exposure to infestation . .	37
VII. Total number of insects present in closely woven bags after two, three-month periods of exposure to infestation. . . . .	38
VIII. Number of insects present in loosely woven bags after three months of exposure to infestation . .	39
IX. Total number of insects present in loosely woven bags after two, three-month periods of exposure to infestation. . . . .	40

## TABLE

## PAGE

X.	Number of insects present inside treated bags five months after infestation. . . . .	42
XI.	Number of living insects present outside and inside the commercial flour bags three weeks after the insects were introduced. . . . .	43
XII.	Number of living insects present outside and inside closely woven bags one week after the insects were introduced. . . . .	44
XIII.	Number of living insects present outside and inside loosely woven bags one week after the insects were introduced. . . . .	45
XIV.	Number of living insects present outside and inside commercial flour bags one week after the insects were introduced. . . . .	46

## INTRODUCTION

Agricultural products in storage are often subject to serious attacks by insects. Insect damage to various stored materials constitutes an old problem and a considerable amount of research has been devoted to it. As Herford (1952) points out, reliable figures of world losses are difficult to obtain. According to conservative estimates five per cent of the cereal production of the world is destroyed in storage each year as a result of insect infestation; Cotton (1956) believes that ten per cent is a more realistic percentage. Cotton et al. (1945a) estimated the annual losses caused by insects to stored grain and milled products in the United States alone as 300 million dollars; other authors cited by Parkin (1956) set the current annual damage at 600 million dollars.

At the present time international attention is focused upon food production. The rapid increase of populations, the political crises in many parts of the world inducing a significant reduction in the production of cereals, and the change from the agrarian economy in various countries to the industrial type, contributes greatly to the above effect. However, more value must be placed upon food preservation. As Parkin (1956) states: "The importance of stored product entomology has not been appreciated largely because the

damage done is of an insidious nature and is often not detected until the commodity is about to be sold or consumed." As in the case of medicine, the application of preventive measures is a much more desirable and much less expensive way to avoid the damage. Consequently, great savings of stored products can be made by using relatively simple and cheap procedures of hygiene and insecticidal treatment.

The work reported in this paper is an attempt to find better ways to fight back the insects, as dramatically has been put by Despaul (1957), in their ceaseless struggle with mankind for a greater share of the earth's foods.

## CHAPTER I

### THE PROBLEM AND GENERAL ASPECTS OF INSECT PENETRATION AND INFESTATION

According to Cotton (1956), there are over forty species of insects infesting stored products. These species differ considerably in environmental requirements and general behavior from those attacking the crops in the field. Herford (1952) reports that although there are some groups, which are confined to certain categories of food, the majority are able to attack a very wide selection of products. This ability to develop satisfactorily in a vast range of different materials increases greatly their survival and distribution. These insects have adapted themselves to a diet of dried vegetable material (Cotton et al., 1945a) and some species really thrive in the absence of appreciable amounts of moisture. They are generally hardy and very prolific. Adult beetles can survive more than two years in unheated buildings (Despaul, 1957); in addition, they withstand long periods without food (Essig, 1945), a factor which favors their accidental distribution through modern transportation. The females produce a multitude of eggs and several generations

occur annually. As a rule they are protected from temperature fluctuations by the insulating properties of the products in which they live (Herford, 1952) and development without a resting period is insured. Due to their small size they are overlooked and their presence remains undetected until large populations have developed (Essig, 1945). Therefore, the sudden appearance and rapid spread of stored grain insect infestations is not surprising.

It is generally accepted that, once the infestation is under way, the stored product has already lost a part of its value. Various types of equipment have been used for storage, in order to prohibit any access by insects. Only metal and glass containers have provided complete protection; nevertheless, they are neither economical nor convenient for extensive use. The failure of cardboard, paper, synthetic and fabric containers to secure adequate prevention of insect penetration called for another approach to the problem. The incorporation of repellents or insecticides into the container seemed to be the most promising idea. However, the new aspect presented a serious drawback; the possibility of contamination of the stored product by some of the powerful chemicals used. Paper and cloth containers treated with various compounds have been tested for insect-proofness; none of the chemicals succeeded in satisfying all the requirements, with the possible exception of synergized

pyrethrins.

## I. THE PROBLEM

Statement of the problem. It was the purpose of this study (1) to investigate the control of stored-product insects with insecticide-treated paper and cotton bags; (2) to compare the effectiveness of different formulations of pyrethrins; (3) to test the relative toxicity and length of efficiency of various insecticides; (4) to determine the effectiveness of three botanical insecticides; (5) to evaluate the resistance to insect penetration of three types of cotton bags.

No attempt has been made to determine any contamination of the stored materials deriving from the insecticides used for impregnation of the bags.

Importance of the study. Agricultural products may be attacked by insects while in farm or commercial storage, during transportation and during the final shelving. Prevention of insect infestation will result in considerable reduction in damage. More extensive use of plant derivatives as insecticides will eliminate the hazards to man and warm-blooded animals derived from the utilization of powerful chemicals. The problem is of economic importance to the farmers, the storage enterprises, the manufacturers, the retailers and the consumers.

## II. GENERAL ASPECTS OF INSECT PENETRATION AND INFESTATION

Origin of infestation in farm storage. Infestation of grain on the farm may originate either in the field or in the storehouse. According to Herford (1952), in temperate regions the grain is relatively free from insect presence at the time of harvest. In tropical and sub-tropical countries, however, many storage pests fly from grain stores into the surrounding fields, with the result that the grain may be expected to be seriously affected when it is harvested. Infestation is due many times to the storing in places that were already infested. Cotton (1956) states that thorough cleaning of the storehouse before harvest is of utmost importance, since insects harbor in cracks and crevices filled with dust and old broken grain. Besides, insects migrate from their breeding places in barns and, subsequently, the near granaries become infested.

Abilities of penetration. All stored-product insects are considered as being good penetrators. There are, however, significant differences between the particular species. The ability of some species to penetrate packaging materials depends even upon the stage of development, as reported by

Gerhardt and Lindgren (1954a). This subject will be treated in more detail in the review of the literature.

Purpose of insect penetration. It is somewhat astonishing, perhaps, that insects do not penetrate for the sole reason of obtaining food. According to Despaul (1957), it is well established that insects attack packages which do not contain food; it has been demonstrated experimentally that they attack packages left in a room even though unpackaged and unprotected food is available to them. Search for food still remains their primary purpose of penetration; as secondary reasons, the search for dark areas as well as for protected places for oviposition are cited.

Damage to stored grain by insects. In a study by Cotton et al. (1953) the results of the destructive activities of stored-grain insects are presented. The quality and grade of the grain is reduced by the very presence of insects, cast skins, webbing and excreta. The weight is also reduced due to the remarkable feeding ability of the immature stages; therefore, the nutritional value of the grain is lowered. Infested grain may be declared unfit for human consumption. Many larvae feed almost exclusively on the germ; this feeding subsequently causes poor germination and results in higher requirements of seed supplies. The heat and

8.

moisture produced by the metabolic processes causes the grain to rot, mold and develop disagreeable odors. Finally, insect infestation by primary feeders opens the gates to the invasion of other insects and microorganisms.

## CHAPTER II

### REVIEW OF THE LITERATURE

Infestation of stored agricultural products by insects is an old phenomenon, probably as old as man himself. Man has always been conscious of the damage and has tried many ways to avoid the losses. Undoubtedly, it would be desirable to be able to rely on sanitation only. Cotton (1944) stresses sanitation as an imperative measure, by which prevention of infestation can be obtained. The fact that Gunderson (1956) kept untreated corn in good condition for one year by cleaning of the bins alone, illustrates that possibility. In practice, however, sanitation alone is very seldom sufficient and the use of protective measures is necessary.

Many types of packages have been used in order both to facilitate storage and to provide protection to cereal products. As Essig et al. (1943) point out, insect penetration of packaged foods is not a new problem but has been previously investigated by several workers. Parker (1913) observed that insects find their way in at the small holes present at the corners of unsealed packages and urged the use of a sealed paper carton. Most of the research, however, has been devoted to the subject since 1943, mainly due to

the increased transportation and distribution demands during World War II.

In an extensive study Essig et al. (1943) have investigated the resistance of various packaging materials. They have found that numerous factors influence the readiness of penetration: (1) the nature of the material, e. g. whether it is metallic, wooden, paper or synthetic; (2) the thickness of the package; (3) the presence of creases, folds, corners and scratches; (4) the treatment of the material with mechanical or chemical agents. Their interesting conclusions are presented as tentative:

(1) the penetration is favored by the presence of food; (2) insects with propensity for boring are the best penetrators; (3) at least one stage of the common pests was able to penetrate some materials, with the exception of the Saw-toothed grainbeetle, Orizaephilus surinamensis (L.); (4) none of the commercially used packaging materials tested is insect-proof.

Their results and conclusions have been supported by considerable experimental evidence.

Glass, wood and cellulose products including paper, fiberboard, cardboard and cellophanes have been tested by Linsley (1944). Waxed papers were readily penetrated and the results have been confirmed by Essig (1945). Waxed cartons have proved most satisfactory; abrasive papers have also been resistant and were penetrated only by the Cadelle, Tenebroides mauritanicus (L.), after nine months of ex-

posure. Among the most important requirements for an insect-proof package are noted the surface hardness, a minimum of folds and creases, thick walls and the absence of holes; Essig (1945) agrees completely. An asphalt-laminated paper tested has offered considerable resistance to penetration as reported both by Sweetman and Bourne (1944) and Essig (1945).

As mentioned before, the penetrating ability of an insect varies with the species. For one thing, the capacity depends upon the particular type of mouth parts. Insects having strong chewing mouth parts can cut through substantial wrappers. The Cadelle has been found by Cotton (1944) capable of cutting through a metal-foil-wrapped carton. Against less efficient insects the same author suggests a carton sealed and covered with a wet wrap. With the exception of the Cadelle and the Lesser grain borer, Rhyzopertha dominica (Fab.), most flour-infesting insects are not strong paper penetrators. They do enter, though, paper bags, as Cotton et al. (1945a) reported, through minute openings where the seals are not perfect or through the needle holes where the bags are sewed. Because of these reasons they suggest that all seams of paper bags should be cemented and sewed tops should be protected by strips of gummed tape. Fabric bags afford even less protection. Observations by the same

group of workers reveal that adult insects thrust their ovipositors through the meshes and lay their eggs directly in the products within the bags; besides, small-size adults and most larvae can crawl through the meshes and through needle holes along the seams and at the top or bottom where the bags are sewed.

The presence of food and a heavy insect population increases penetration, as concluded by Essig (1945). From the environmental factors the role of temperature is emphasized, since the stored-product insects are more or less adapted to extremes of humidity. Insect activity is correlated with changes in temperature between minimum and maximum, the maximum penetration occurring at seventy-five to eighty-five degrees F. In the same paper Essig also stated that optimum conditions for general activity of the insects are the optimum conditions for penetration and Cotton (1949) agrees with this conclusion.

During an experiment conducted by Gerhardt and Lindgren (1954b) various synthetic packaging films have been made up into bags and tested. Only a film containing aluminum foil has been relatively resistant, but not insect-proof. The Cadelle and the Lesser grain borer have been the best penetrators; the Saw-toothed grain beetle the least able.

In order to obtain complete exclusion of the insects

Laudani and Davis (1955) had to tape over all the needle punctures of the bags used for storage.

Some protection can be obtained by the use of multiple layers of paper and Arnold (1955) found that regular untreated multiwall bags are fairly resistant under normal conditions.

The remarkable ability of stored grain insects to induce infestation is depicted once more in the findings of Despaul (1957), who was working with cereal ration bars. The Confused flour beetle, Tribolium confusum Duv., was unable to penetrate the cellophane wrapping of the bars by boring through it; however, the beetles could flatten themselves sufficiently to slip under the folded ends of the wrapper and lay their eggs inside, thus establishing infestation.

The inadequacy of the commercially used containers to prohibit insect infestation led to another line of attack. Cotton et al. (1944) pointed out that the impregnation of the paper with suitable insect-proofing chemicals offers a means of preventing insects from boring into them. Almost simultaneously, Linsley (1944) suggested the incorporation of toxic chemicals into the paper as offering one of the most promising approaches to the problem.

Soft towel paper and Kraft paper were impregnated by

Cotton et al. (1944) with ten per cent D.D.T. solution in acetone. After exposure for two months to the attack of the Cadelle and the Lesser grain borer, the paper suffered no damage. The authors believe that D.D.T. may be found suitable for the impregnation of one of the plies of multi-wall paper bags or for incorporation into the coating liquor used in the preparation of coated Kraft paper for making single-wall bags.

Sabadilla used by Clark and Hoveland (1944) on paper cartons provided resistance for seventy-two days against penetration by cockroaches.

Kraft paper bags treated with five per cent D.D.T. in carbon tetrachloride offered greater resistance than cotton bags treated in like manner, as reported by Cotton et al. (1945b). Essig (1945) found that five per cent D.D.T. on fifty-pound Kraft paper gave protection for nine months; however, under 190° F. the effectiveness of the treatment was seriously reduced in six hours and mostly destroyed in twelve hours. Annand (1946) claimed that wrappings impregnated with D.D.T. were highly effective in preventing insect entrance into packages of cereals.

Bags made from fabric have also been tried extensively. Cotton bags impregnated with two and five tenths, five, and ten per cent D.D.T. solutions in carbon tetrachloride were

used by Cooper (1947) for an experiment. Impregnation was performed either by dipping or spraying. The treated bags were filled with corn and placed in contact with infested grain. Adequate protection was obtained for three months while all checks were infested. Further investigations carried on during subsequent years by the same author (1948, 1949, 1950) revealed that the ten per cent treatment had one and nine tenths per cent of the enclosed grain damaged after thirteen months and three and nine tenths per cent after eighteen months; the lighter treatments presented respectively higher percentages of infested grain. The infestation in the checks at the end of eighteen months attained eighty-nine and seven tenths per cent.

In a study by Butterfield et al. (1949) whole seeds were stored safely for one year in bags treated with one per cent D.D.T. while oily and broken seeds were not safe even for four months.

A great deal of research has been devoted to the control of insects by treated bags cooperatively by the Bureau of Entomology and Plant Quarantine and the Bureau of Agricultural and Industrial Chemistry of the U.S. Department of Agriculture.

Discussing the necessary properties of a good insect-resistant treatment for bags, Hilbert (1949) states that

such a treatment should be effective over several months of use, and should not contaminate the stored product nor be objectionable from the public-health standpoint.

Cotton et al. (1949) presented the results of a series of experiments with cotton bags impregnated with water dispersions of a one to ten pyrethrins-piperonyl butoxide mixture of such strengths that the cloth contained five, seven and five tenths, or ten mgs. of pyrethrins per square foot. The bags were filled with insect-free flour and exposed for seven months to continuous infestation. Satisfactory protection was afforded at all the above dosages tested. On the assumption that the pyrethrins deteriorate rapidly when exposed to light, an experiment was conducted with cloth bags containing ten mg. of pyrethrins per square foot, which were filled with flour and exposed to insect infestation in darkness, in indirect light and in direct sunlight. It was found that the insect repellency was retained under all conditions for seven months. In addition, it was demonstrated that treated bags, when stored for five months before they were used, were still effective.

Similar experiments established the value of the pyrethrins in keeping insects out of flour or other cereals packed in treated bags. According to Annand (1950), the treatment can also be applied to the cloth before the bags

are made or even to the warp yarn before the cloth is woven. The pyrethrins are of low order of toxicity to warm-blooded animals and the slight odor they give off is not objectionable. Baking tests conducted indicated that the quality of the stored flour was not affected (Brannan, 1950).

Work on the same line has also been done in Canada. Gardiner (1949) reported that cotton sacks treated with pyrethrum-piperonyl butoxide mixture at the rate of seventy-five mg. per square foot completely resisted insect entry for a period of eight months. Further tests (Gardiner, 1950) proved that the treatment was effective for over fifteen months.

Burlap bags impregnated with D.D.T. have been used for the storage of potatoes against the Potato tuberworm, Gnori-meschema operculella (Zeller). Hofmaster and Anderson (1948) obtained good results for ten months with five per cent D.D.T. Lloyd (1951) claimed complete protection with even five tenths of one per cent D.D.T. Hofmaster (1949) conducted large scale tests with burlap bags dipped in one, three, and five per cent D.D.T. solutions in xylene. The bags were filled with potatoes, placed in a large chamber and moths were released. All treatments gave a highly significant reduction in injury. The one per cent treatment gave poorer control and there was evidence of tunnels in the

potatoes; however, none of the larvae reached maturity. If pupae were introduced into the bags, eggs were not deposited by the emerged adults. Dudley et al. (1952) observed that if potatoes already infested with larvae were stored in treated bags, the adult moths were killed soon after they emerged.

The attention of sorghum breeders was also attracted to the use of treated bags in their breeding work. A small bag is regularly placed over the sorghum head in order to prevent cross pollination. This fact presents the disadvantage of increased insect activity within the bag due both to high humidity and the protection of the pests from parasites and predators. Dahms et al. (1951) found that by the use of sacks treated with Aldrin the Corn earworm, Heliothis zea (Boddie), was completely controlled. The same treatment proved to be effective against the Corn leaf aphid, Rhopalosiphum maidis (Fitch), as concluded by Hoyt (1954). D.D.T. when used for impregnation at the rate of 133 mg. per bag gave control of the Corn earworm, but increased Corn leaf aphid injury. There was little loss in toxicity if the bags were used six months after impregnation (Dahms et al., 1955).

Impregnated cotton bags filled with corn were tested by Jewett and Price (1951). While two and five tenths per

cent D.D.T. afforded little protection, ten per cent D.D.T. gave very good control against many stored-grain insects for twelve months and excellent protection from the Angoumois grain moth, Sitotroga cerealella (Oliv.), for six months.

Further work revealed that cotton and burlap bags treated with a mixture of pyrethrins and piperonyl butoxide give protection to stored grain for fourteen months (Hoyt, 1952). Fiberboard cartons sealed with an adhesive containing the same chemicals repelled insects for nine months. In order to evaluate the influence of formulations, Incho et al. (1953) applied three formulations of pyrethrins to Kraft paper: Wettable powder, oil solution and water emulsion. The wettable powder was effective and resisted penetration for one year; the other two showed a loss of activity at six months.

At the same time the newer insecticides were also tested. Lindane, Chlordane and Dieldrin gave long-time protection (Hoyt, 1954). According to Laudani and Davis (1955), Methoxychlor showed great promise as protective coating on bags. It exhibited a longer-lasting toxicity than the pyrethrins, but insects went through the needle holes of the treated sewn ends (Arnold, 1955).

Although the majority of the workers have expressed

their enthusiasm about the pyrethrins, some investigators were rather moderate in their statements. Kulash (1954) admits only some protection by storing grain in bags treated with five tenths of one per cent synergized pyrethrum.

Davis and Laudani (1955) placed in heavily infested rooms paper and cloth bags treated with synergized pyrethrum and filled with flour. The number of insect penetrations and the number of insects in the flour inside the bags were determined. Comparisons of effectiveness were based on these criteria. The paper bags provided protection for nine to twelve months; the cloth bags were effective for three to six months.

As a multiple insurance against insect penetration, bags with several walls have been also used. Arnold (1955) found out that multiwall paper bags having the outer ply coated with Pyrenone were completely resistant to all insects tested. Nine to twelve month protection can be expected with similar bags, as reported by Laudani and Davis (1955). The same authors observed that the pyrethrum deposits deteriorate rapidly and they believe that the great part of the protection provided by the pyrethrum treatment can be explained on the basis of repellency rather than toxicity. This belief based on experimental evidence had already been expressed by Laudani and Swank (1954), who

reported that the usual application rates of pyrethrum are too low to cause mortality after the first few days, but that there is a definite and long-lasting repellency.

Sivik and Kulash (1956) summarize the most important advantages that the use of treated bags for the protection of stored seed presents over other methods of control: (1) small amount of insecticide is applied; (2) all the seeds do not come in contact with the treated surface and in this way the possibility of undesirable odor and the deleterious effect on seed germination is lessened; (3) long period of protection is afforded without the necessity of retreating the seed.

Of course all bags will not be equally effective. As Cotton (1952) pointed out, the efficacy depends on the type of bag used. In a coarse bag it is rather difficult to impart any protective action, because the insects can get in without coming in contact very much with the treated fabric. If a closely woven material is available, the weave is so close that the insect has to make quite an effort to get into a bag of that type, and so it comes in contact with more of the chemical.

The efficiency of bags and packages has been questioned by various investigators. Paper and cloth bags were treated by Davis and Laudani (1955) with pyrethrum and Methoxychlor;

subsequent analyses indicated that the bags failed to have present the desired deposits of insecticide. Thomson (1950) expressed the possibility that the insect making the first penetration might pick up enough insecticide to be killed, but others could then safely pass through the hole.

By far the most important disadvantage in using treated bags for storage is the probability of contaminating the contents with the chemical utilized for the treatment. Large amounts of insecticide were absorbed by the foods, especially when fatty materials were packed in heavily impregnated bags and stored for long periods (Butterfield et al., 1949). After three months of storage of pyrethrins-treated bags filled with flour the piperonyl butoxide migrated into the contents (Hilbert, 1951). If in that case the contamination is considered harmless, in another case it may be extremely hazardous.

In several instances the insecticide present in the stored product exceeded the tolerance set by the Food and Drug Administration. Particularly in our time, when insecticides of high efficiency and persistence are available, we should be very careful. As Atkins and Greer (1953) said:

The extent to which the insecticides are transferred from the bags to their contents is of utmost importance, since, no matter how effective any treatment might be in preventing infestation, it can scarcely be looked upon as practical if it were obtained only at the cost of contaminating the stored product.

According to the same authors, the use of double layers of fabric with the insecticide impregnation limited to the outer layer would possibly prove useful both in limiting insect penetration and product contamination.

In practical application, taste repellents may be recommended where the use of insecticides is impractical or undesirable. It does not seem very probable to ever achieve the ideal repellent, which should be effective in low concentrations, stable and nonvolatile, colorless and odorless, low in toxicity to humans, nonreactive with machinery and economical (Block, 1951). However, it may be possible to substitute effective repellents for the insecticides in current use in order to accomplish our initial goal.

## CHAPTER III

### MATERIALS AND METHODS

Experiment with paper bags. Number 20 Kraft paper bags were treated with six concentrations of pyrethrins. Pyrenene O.F. 60-6 emulsifiable concentrate was provided by Fairfield Chemicals. One part of this concentrate mixed with twenty-nine parts of water gave an emulsion containing two tenths of one per cent pyrethrins. Both the amount of concentrate and the amount of water was varied accordingly to provide concentrations containing one tenth, two tenths, four tenths, six tenths, eight tenths and one per cent pyrethrins. The paper bags were treated by dipping in the different percentages of the insecticide and were subsequently dried at room temperature. Every treatment was replicated four times; untreated check bags were also used.

Shelled corn was used for this test. The corn was screened thoroughly, fumigated with carbon tetrachloride for twenty four hours and then well aired before being stored in the bags. Each bag was filled with one gallon of grain and the tops of the bags were folded down three times and then stapled tightly. The bags were placed at random

on infested corn. Several species of grain insects were found in the infested corn. These were the Saw-toothed grain beetle, the Confused flour beetle, the Cadelle, the Angoumois grain moth and the Indian meal moth, Plodia interpunctella (Hübner). The experiment was performed in a room where the temperature was recorded by a Friez Hygrothermograph and fluctuated between seventy and eighty degrees F. At the end of two, four, six, eight and ten months the bags were opened, the contents sifted and the number of insects present inside recorded by species. The number of holes on the bags was also recorded.

Experiments with cotton bags. Two types of bags were used: raw hem top, two and thirty-five hundredths of a yard osnaburg (closely woven) bags and raw hem top, two and eighty hundredths of a yard osnaburg (loosely woven) bags, purchased from Fulton Bag and Cotton Mills, Kansas City, Kansas. The bags were too large for experimental purposes. Consequently, they were cut in half lengthwise and resealed. The measurements of the bags after resewing were fifteen by six and one-half inches. Five treatments were applied to the bags, namely, five per cent D.D.T., two tenths of one per cent pyrethrins, approximately three per cent Ryania, five per cent Methoxychlor and twenty-

five hundredths of one per cent Rotenone.

In order to obtain the D.D.T. suspension, 378 gr. of Genitox S-50 (Allied Chemical and Dye Corporation, New York, New York) were mixed with one gallon of water.

The pyrethrins emulsion was obtained by mixing 130.3 ml. of Special Emulsifiable Pyrenone Concentrate T-647 (Fairfield Chemicals, Baltimore, Maryland) with one gallon of water.

Ninety-four and four tenths gr. of Ryanicide 100 per cent (S.B. Penick and Company, New York 8, New York) were used in a gallon of water. The quantity of Ryanicide was calculated on the basis of the material stored in each bag, the number of ml. of water absorbed by each bag and the rate of one lb. of insecticide per 1000 lbs. of seed recommended by the manufacturers. The quantity used would give to the bag the necessary coating to protect the 600 gr. of stored material.

378 gr. of Marlath (E. I. Du Pont de Nemours and Company Inc., Wilmington, Delaware) were mixed with one gallon of water to provide five per cent Methoxychlor suspension.

By mixing 189 gr. of Powdered Cube' Root (S.B. Penick and Company, New York) with one gallon of water, a suspension containing twenty-five hundredths of one per cent Rotenone was obtained.

A ten-quart bucket was used for the preparation of the various suspensions. The bags were dipped in the bucket and left for about ten minutes to be soaked. Subsequently the bags were hung on strings to be dried.

There were six replications of every treatment and type of bag including the control bags soaked only with water.

Each bag was filled with 600 gr. of shelled corn thoroughly sifted, fumigated with carbon tetrachloride and aerated for the removal of the fumigant vapor. The top of the bags was folded once and tied with string.

The bags were placed in the same infestation room used for the previous experiment. In order to obtain randomization, the pattern of a Latin Square six by six was followed for the placement of each type of bags on the infested corn. The infestation was increased this time by the presence of the Rice weevil, Sitophilus oryza (L.). The temperature was kept around eighty degrees F. by the use of a thermostat.

At the end of three and six months the bags were removed, the contents sifted and the number of insects inside each bag recorded.

A similar experiment was repeated using the same two types of bags and the same treatment. Each bag was filled with 500 gr. of shelled corn and 100 gr. of whole wheat

flour. The corn used was not fumigated but only thoroughly sifted. Each bag was placed in a separate gallon jar. Thirty Saw-toothed grain beetles, twenty Confused flour beetles and thirty Rice weevils were introduced into every jar.

Together with the two types of cotton bags, a third type, commercial flour sample bags, were also included in this test. These bags were treated with the same insecticides at half the previous concentrations. These treatments were also replicated five times. The flour bags were filled with 400 gr. of non-fumigated shelled corn plus seventy-five gr. of whole wheat flour. Each bag was placed in a gallon jar and thirty Saw-toothed grain beetles, twenty Confused flour beetles and thirty Rice weevils were also introduced in every jar.

The tops of the jar lids were partly replaced by a sixty-mesh screen to insure aeration. All jars were installed on shelves in the insect rearing room.

At the end of five months the bags were removed from the jars and their contents sifted. The number of insects in the jars and inside the bags was counted. Living and dead specimens were recorded separately.

Test of the residual activity. Upon the completion of the experiment in glass jars, the treated bags were used

in another test. The cotton bags were filled with 500 gr. of shelled corn and 100 gr. of whole wheat flour; the commercial flour bags were filled with 400 gr. of shelled corn and seventy-five gr. of whole wheat flour. Each bag was placed in a gallon jar. The treatments were replicated four times for each type of bag. Fifty Saw-toothed grain beetles, thirty Confused flour beetles and fifty Rice weevils were introduced in every jar. The jars were then placed in the insect rearing room.

One week after the insects were introduced in the jars, two replications of each type of bags were removed and the number of living insects in the jars and inside the bags counted. The remaining set of replications was examined in a like manner three weeks after the infestation was made.

## CHAPTER IV

### RESULTS

Experiment with paper bags. The results obtained after an exposure of two, four, six and eight months to stored-grain pests are presented respectively in Tables I, II, III, and IV. Table V shows the total infestation after ten months of exposure. A Chi Square analysis of the total infestation indicated no significant difference between treatments, but all treatments were significantly better than the control at the five per cent level.

Experiments with cotton bags. With the exception of the pyrethrins, the insecticides used for treating the bags were in the form of wettable powders. Both D.D.T. and Methoxychlor gave nice suspensions with water. The suspension needed to be agitated while the bags were soaking. The coating on the bags was heavy and uneven. When the bags were handled, the powder deposits spread around. Ryania and Rotenone did not give a good suspension. The coating on the bags was not even and there were spots with thick coating. The impregnation with Pyrenone was most satisfactory.

TABLE I  
 NUMBER OF INSECTS PRESENT IN  
 PAPER BAGS AFTER TWO MONTHS OF EXPOSURE

Treatments	Saw-toothed grain beetle	Confused flour beetle	Cadelle	Angoumois grain moth	Indian meal moth
.1% Pyrethrins	4	0	0	0	0
.2% Pyrethrins	0	0	0	0	0
.4% Pyrethrins	0	0	0	0	0
.6% Pyrethrins	0	0	0	0	0
.8% Pyrethrins	0	0	0	0	0
1.0% Pyrethrins	0	0	0	0	0
Control	3	38	0	3	0

TABLE II

NUMBER OF INSECTS PRESENT IN  
PAPER BAGS AFTER FOUR MONTHS OF EXPOSURE

Treatments	Saw-toothed grain beetle	Confused flour beetle	Cadelle	Angoumois grain moth	Indian meal moth
.1% Pyrethrins	0	1	0	0	0
.2% Pyrethrins	0	0	0	0	0
.4% Pyrethrins	0	0	0	0	0
.6% Pyrethrins	0	2	0	0	0
.8% Pyrethrins	0	2	0	0	0
1.0% Pyrethrins	0	2	0	0	0
Control	69	18	0	0	2

TABLE III

NUMBER OF INSECTS PRESENT IN PAPER  
BAGS AFTER SIX MONTHS OF EXPOSURE

Treatments	Saw-toothed grain beetle	Confused flour beetle	Cadelle	Angoumois grain moth	Indian meal moth
.1% Pyrethrins	3	3	0	0	0
.2% Pyrethrins	0	1	0	0	0
.4% Pyrethrins	0	0	0	0	3
.6% Pyrethrins	0	0	0	0	2
.8% Pyrethrins	0	3	0	0	1
1.0% Pyrethrins	0	0	0	0	1
Control	323	16	0	0	3

TABLE IV

NUMBER OF INSECTS PRESENT IN  
PAPER BAGS AFTER EIGHT MONTHS OF EXPOSURE

Treatments	Saw-toothed grain beetle	Confused flour beetle	Cadelle	Angoumois grain moth	Indian meal moth
.1% Pyrethrins	0	0	0	1	0
.2% Pyrethrins	1	0	0	0	0
.4% Pyrethrins	0	0	0	0	0
.6% Pyrethrins	0	0	0	2	0
.8% Pyrethrins	1	0	0	1	0
1.0% Pyrethrins	0	1	0	0	0
Control	14	11	2	62	16

TABLE V

## TOTAL INFESTATION AFTER TEN MONTHS OF EXPOSURE

Treatments	Saw-toothed grain beetle	Confused flour beetle	Cadelle	Angoumois grain moth	Indian meal moth	Total number of insects	Number of holes on bags
.1% Pyrethrins	7	4	0	1	0	12	10
.2% Pyrethrins	1	1	0	0	0	2	2
.4% Pyrethrins	0	0	0	0	3	3	3
.6% Pyrethrins	0	2	0	2	2	6	1
.8% Pyrethrins	1	2	0	4	1	8	0
1.0% Pyrethrins	0	3	0	0	2	5	1
Control	418	101	7	65	46	637	167

The results obtained in the first part of this experiment are presented in Tables VI, VII, VIII, and IX. Due to the low numbers and zeros in many of the replications the data in Tables VI and VIII were not analyzed statistically. The analysis of variance for Confused flour beetles, Saw-toothed grain beetles and Angoumois grain moths was carried out for the data summarized in Tables VII and IX. In Table VII the Confused flour beetle populations in Methoxychlor and D.D.T. were significantly higher than in the other treatments or the control. There were significantly more Angoumois grain moths in the controls of the closely woven bags, but there was no difference between treatments. In Table IX the significant differences in the Saw-toothed grain beetle and Angoumois grain moth populations were due only to the high numbers in the controls. The Confused flour beetle populations in loosely woven bags were significantly higher in the Methoxychlor-treated bags than in any of the other treatments. Only Rotenone and Pyrenone reduced the Confused flour beetles to a statistically significant degree below the checks.

When the experiment with the treated bags was repeated using infestations in individual jars the results in Table X, were obtained. There were holes on the commercial flour bags which were treated with Ryania and Rotenone and

TABLE VI

NUMBER OF INSECTS PRESENT IN CLOSELY WOVEN  
BAGS AFTER THREE MONTHS OF EXPOSURE TO INFESTATION

Treatments	Rice weevil	Confused flour beetle	Saw-toothed grain beetle	Cadelle	Angoumois grain moth	Indian meal moth
D. D. T.	2	12	0	2	2	1
Pyrenone	3	12	5	0	3	0
Ryania	2	4	6	0	2	1
Methoxychlor	1	11	2	0	0	1
Rotenone	0	5	5	1	9	0
Control	3	2	0	0	14	3

TABLE VII  
 TOTAL NUMBER OF INSECTS PRESENT IN CLOSELY WOVEN  
 BAGS AFTER TWO, THREE-MONTH PERIODS OF EXPOSURE TO INFESTATION

Treatments	Rice weevil	Confused flour beetle	Saw-toothed grain beetle	Cadelle	Angoumois grain moth	Indian meal moth	Total number of insects
D. D. T.	2	28	21	2	13	1	67
Pyrenone	3	14	15	0	4	1	37
Ryania	2	5	19	0	12	3	41
Methoxychlor	2	25	10	0	2	1	40
Rotenone	0	9	11	2	15	2	39
Control	3	2	7	0	189	32	233

TABLE VIII

NUMBER OF INSECTS PRESENT IN LOOSELY WOVEN  
BAGS AFTER THREE MONTHS OF EXPOSURE TO INFESTATION

Treatments	Rice weevil	Confused flour beetle	Saw-toothed grain beetle	Cadelle	Angoumois grain moth	Indian meal moth
D. D. T.	2	4	3	0	1	1
Pyrenone	4	1	1	1	6	1
Ryania	1	6	0	0	9	4
Methoxychlor	6	20	6	3	1	5
Rotenone	2	2	8	0	10	1
Control	2	4	24	0	22	2

TABLE IX

TOTAL NUMBER OF INSECTS PRESENT IN LOOSELY WOVEN  
BAGS AFTER TWO, THREE-MONTH PERIODS OF EXPOSURE TO INFESTATION

Treatments	Rice weevil	Confused flour beetle	Saw-toothed grain beetle	Cadelle	Angoumois grain moth	Indian meal moth	Total number of insects
D. D. T.	3	9	10	0	8	1	31
Pyrenone	4	3	5	1	9	1	23
Ryania	1	7	11	0	60	11	90
Methoxychlor	6	31	16	3	2	5	63
Rotenone	2	3	17	0	43	26	91
Control	2	13	145	3	897	17	1077

in the controls. The same treatments contained a large number of larvae of the Confused flour beetle. No statistical analysis was carried out on these data because of the large degree of variability between replications and the number of zeros. However, the biological significance of the control afforded by all the treatments except Rynia and Rotenone may be assumed as valid.

Test of the residual activity. Three weeks after the infestation was made, all insects were dead in the jars containing the closely woven and the loosely woven cotton bags. The number of living insects in the jars containing the commercial flour bags are reported in Table XI. The results of the one-week counts are presented in Tables XII, XIII and XIV. The number of zeros and the pronounced variability between replications made the application of a statistical analysis ineffectual. Nevertheless, the value of the results obtained must not be overlooked.

TABLE X

NUMBER OF INSECTS PRESENT INSIDE  
TREATED BAGS FIVE MONTHS AFTER INFESTATION

Treatments	Saw-toothed grain beetle			Confused flour beetle			Rice weevil		
	Closely woven bags	Loosely woven bags	Commercial flour bags	Closely woven bags	Loosely woven bags	Commercial flour bags	Closely woven bags	Loosely woven bags	Commercial flour bags
D. D. T.	0	0	0	0	0	0	0	0	0
Pyrenone	0	0	0	0	0	0	0	1	0
Ryania	1	0	117	2	0	114	1	0	621
Methoxychlor	0	0	0	0	0	0	0	0	27
Rotenone	0	1	2	0	1	624	0	0	268
Control	0	42	67	2	212	31	0	1	118

TABLE XI

NUMBER OF LIVING INSECTS PRESENT OUTSIDE  
AND INSIDE THE COMMERCIAL FLOUR BAGS  
THREE WEEKS AFTER THE INSECTS WERE INTRODUCED<sup>1</sup>

Treatments	Saw-toothed grain beetle		Confused flour beetle		Rice weevil	
	Outside the bag	Inside the bag	Outside the bag	Inside the bag	Outside the bag	Inside the bag
D. D. T.	0	0	0	0	0	0
Pyrenone	0	0	0	0	0	0
Ryania	0	0	0	0	0	0
Methoxychlor	0	0	0	0	0	0
Rotenone	0	0	1	8	0	0
Control	3	37	5	26	4	32

1. Fifty Saw-toothed grain beetles, thirty Confused flour beetles and fifty Rice weevils were introduced.

TABLE XII

NUMBER OF LIVING INSECTS PRESENT OUTSIDE  
AND INSIDE CLOSELY WOVEN BAGS ONE WEEK  
AFTER THE INSECTS WERE INTRODUCED <sup>1</sup>

Treatments	Saw-toothed grain beetle		Confused flour beetle		Rice weevil	
	Outside the bag	Inside the bag	Outside the bag	Inside the bag	Outside the bag	Inside the bag
D.D.T.	0	0	0	0	0	0
Pyrenone	0	0	1	0	0	0
Ryania	0	0	3	0	0	0
Methoxychlor	0	0	0	0	0	0
Rotenone	0	0	14	0	4	0
Control	45	0	53	0	45	0

1. Fifty Saw-toothed grain beetles, thirty Confused flour beetles and fifty Rice weevils were introduced.

TABLE XIII

NUMBER OF LIVING INSECTS PRESENT OUTSIDE  
AND INSIDE LOOSELY WOVEN BAGS ONE WEEK  
AFTER THE INSECTS WERE INTRODUCED<sup>1</sup>

Treatments	Saw-toothed grain beetle		Confused flour beetle		Rice weevil	
	Outside the bag	Inside the bag	Outside the bag	Inside the bag	Outside the bag	Inside the bag
D. D. T.	0	0	0	0	0	0
Pyrenone	0	0	1	0	0	0
Ryania	2	0	27	0	11	0
Methoxychlor	0	0	0	0	0	0
Rotenone	7	0	48	0	8	0
Control	42	0	51	0	61	0

1. Fifty Saw-toothed grain beetles, thirty Confused flour beetles and fifty Rice weevils were introduced.

TABLE XIV

NUMBER OF LIVING INSECTS PRESENT OUTSIDE  
AND INSIDE COMMERCIAL FLOUR BAGS ONE WEEK  
AFTER THE INSECTS WERE INTRODUCED <sup>1</sup>

Treatments	Saw-toothed grain beetle		Confused flour beetle		Rice weevil	
	Outside the bag	Inside the bag	Outside the bag	Inside the bag	Outside the bag	Inside the bag
D.D.T.	0	0	0	0	1	0
Pyrenone	0	0	7	0	0	0
Ryania	8	0	33	0	1	0
Methoxychlor	0	0	1	0	1	0
Rotenone	1	0	44	1	16	0
Control	19	4	22	21	6	15

1. Fifty Saw-toothed grain beetles, thirty Confused flour beetles and fifty Rice weevils were introduced.

## CHAPTER V

### DISCUSSION AND CONCLUSIONS

Successful results have been obtained with the paper bags treated with various concentrations of pyrethrins. It is interesting to notice that the Saw-toothed grain beetle was the first pest to enter the treatments. Although its penetrating ability is among the lowest for stored-product pests, its presence inside the bags can be explained on the assumption that the beetle found its way in through places where the seals of the bags were not perfect. The Confused flour beetles accomplished infestation at four months and the Indian meal moths at six months. The absence of the Cadelle in any treatment was probably due to the low number of beetles present in the infested corn. There was no significant difference between the protection afforded by the various concentrations of pyrethrins. The results showed that paper bags treated even with a very low percentage of pyrethrins offer significant protection from stored grain insects for at least ten months.

Most of the research done with treated cotton bags has been performed by using impregnated bags. The investigators used the pure form of the insecticides and a

solvent, such as acetone, carbon tetrachloride or xylene. In this way, solutions were obtained by which the bags were impregnated. The purpose of the work reported herein was to find a method of insect control, which would be convenient and simple enough to be used by the average farmer. This is the reason why wettable powders were chosen for the treatment of the bags.

Nevertheless, the wettable powders were somewhat inconvenient. The suspensions needed continuous agitation, or a thick precipitate would accumulate at the bottom of the can. The coating on the bags was uneven and heavy in many places. Handling of the bags would easily contaminate the surroundings with insecticide. To avoid as much as possible the above effect, half the concentrations were used with the commercial flour bags.

The first results obtained with the treated cotton bags were rather disappointing. Many treatments were more heavily infested than the controls. The bags treated with chlorinated hydrocarbons had surprisingly high numbers of Confused flour beetles. This was particularly true for Methoxychlor. It would almost appear to indicate attractant properties for Confused flour beetles at low dosages of Methoxychlor. The high numbers of the Angoumois grain moth present in the controls are not conclusive, since the

moths did not have to bore through the bags but could possibly accomplish infestation by ovipositing through the meshes of the fabric.

The possibility of uneven distribution of the insect populations in the layer of corn used as source of infestation was also encountered. In order to provide identical initial infestations to all replications, the experiment was repeated using infestations in individual jars. The two chlorinated hydrocarbons and the Pyrenone provided almost complete protection for five months. One replication of Methoxychlor contained all twenty-seven Rice weevils reported in Table X. The forty-two Saw-toothed grain beetles found in the control were from two replications and the other three replications were not infested; the same two replications contained all but one of the 212 Confused flour beetles. The commercial flour bags when treated with Rotenone or Rynania were not effective at all. It should not be forgotten, though, that these bags were treated with half the concentrations used for the treatment of the other two types of bags. All the replications of the commercial flour bags treated with Rotenone were highly infested. The populations of insects were well established inside these replications; the abundance of larvae and the holes present on the bags support this conclusion.

The same held true too for the replications treated with *Ryania*, but to a lesser extent; it should be taken into consideration that all 621 Rice weevils reported in Table X were found in one replication. The results suggest that the closely woven bags tested provide good protection even in the absence of insecticides; the loosely woven bags are somewhat resistant to penetration and the commercial flour bags are easily penetrated.

The third experiment was conducted in order to secure information on the length of effectiveness of the insecticides tested. The commercial flour bags were the only replications containing living insects inside. As these bags are easily penetrated, this was to be expected since the insects could not survive unless they obtained food and water which were present only inside the bags. Seven months after they were applied to cotton bags, the D.D.T., Pyrenone and Methoxychlor deposits exhibited an excellent residual activity against the species tested. Both *Ryania* and Rotenone produced little effect if any at all.

Lindgren et al. (1954) reporting on a similar experiment claimed that they obtained the maximum effect on mortality within ten days. In our experiments the best results were obtained at seven days.

The investigation of the insecticidal efficiency of

a chemical is a delicate task and may easily lead to erroneous conclusions, especially when the insecticide is studied in connection with groups of biological entities. Concluding the present work I would like to quote Parkin (1951), who calls attention on that point:

The insecticidal value of a chemical is a property which cannot be measured apart from a complex of modifying and interacting factors. It can be determined only in relation to a particular species. The larvae are sometimes more resistant than the corresponding adults. Even each stage exhibits considerable changes in resistance during its life. We cannot, then, generalize even to the extent of saying that a particular insecticide is effective against a particular species of insects. In addition, the concentration of the insecticide, the method of application, the period of exposure and the environmental conditions to which the insects are submitted before, during and after the application, must be taken into account. Finally, it should not be forgotten that practical conditions can rarely be adequately reproduced in the laboratory.

## CHAPTER VI

### SUMMARY

Number 20 Kraft paper bags were treated by dipping with one tenth, two tenths, four tenths, six tenths, eight tenths, and one per cent pyrethrin concentrations replicated four times; the bags were subsequently dried at room temperature. Each bag was filled with one gallon of insect-free corn, stapled tightly and placed at random on infested corn. The Saw-toothed grain beetle, the Confused flour beetle, the Cadelle, the Angoumois grain moth and the Indian meal moth were present in the infested corn. The number of insects inside the bags was recorded at two, four, six, eight, and ten months. The bags treated even with the lowest percentage of pyrethrins offered satisfactory protection from the species tested for ten months.

Two types of cotton bags, closely woven and loosely woven osnaburg bags were treated by dipping in concentrations containing five per cent D.D.T., two tenths of one per cent pyrethrins, three per cent Ryania, five per cent Methoxychlor and twenty-five hundredths of one per cent Rotenone. The bags were dried at room temperature. A third type of bag, commercial flour sample bags, were also

treated in like manner at half the previous concentrations. There were five replications of every treatment including the control bags soaked only with water. The osnaburg bags were filled with 500 gr. of thoroughly screened corn and 100 gr. of whole wheat flour. The commercial flour bags were filled with 400 gr. of thoroughly screened corn and seventy-five gr. of whole wheat flour. Each bag was placed in a separate gallon jar. Thirty Saw-toothed grain beetles, twenty Confused flour beetles and thirty Rice Weevils were introduced in every jar. The tops of the jar lids were partly replaced by a 60-mesh screen to insure aeration. The number of insects in the jars and inside the bags were counted at the end of five months. The D.D.T., Pyrenone and Methoxychlor provided almost complete protection for five months. The commercial flour bags treated with Ryania and Rotenone did not offer any protection. The closely woven bags as such provide good protection against insect penetration; the commercial flour bags are easily penetrated.

The same bags, which were used in the previous experiment, were prepared for infestation in the same way. Fifty Saw-toothed grain beetles, thirty Confused flour beetles and fifty Rice weevils were introduced in every jar. Counts of living insects in the jars and inside the

bags were made at one and three weeks after infestation. D.D.T., Pyrenone and Methoxychlor exhibited an excellent residual activity seven months after they were applied to the cotton bags. Ryania and Rotenone produced little effect if any at all.

## BIBLIOGRAPHY

- Annand, P.N. 1946. Encouraging results obtained with new and improved insecticides. U.S.D.A. Agr. Res. Adm. R. 1944/45 :122-132.
- \_\_\_\_\_, 1950. Cotton bags made insectproof. U.S.D.A. B.E.P.Q. R. 1948/49 :40-41.
- Arnold, K.A. 1955. Insect repellency in multiwalls. Mod. Packaging 28 (12) :120-121.
- Atkins, W.G. and E.N. Greer, 1953. The storage of flour in jute bags treated with insecticides. J. Sci. Food and Agr. 4 :155-160.
- Block, S.S. 1951. Protection of paper and textile products from insect damage. Indus. and Eng. Chem. 43 :1558-1563.
- Brannan, C.F. 1950. Insect-repellent cotton bags. US.D.A. R. Sec. 1949 :100.
- Butterfield, D.E., E.A. Parkin and M.M. Gale. 1949. The transfer of D.D.T. to foodstuffs from impregnated sacking. J. Soc. Chem. Indus. 68 :310-313.
- Clark, N. and N. Hoveland. 1944. Use Sabadilla for vermin-proofing paper cartons? Wis. Agr. Exp. St. B. 463 :73-74.
- Cooper T. P. 1947. D.D.T.-impregnated bags for protecting stored products from insects. Ky. Agr. Exp. St. R. 59 :37.
- \_\_\_\_\_, 1948. D.D.T.-impregnated bags for protecting stored corn from insects. Ky. Agr. Exp. St. R. 60 :40-41.
- \_\_\_\_\_, 1949. D.D.T.-impregnated bags for protecting stored corn from insects. Ky. Agr. Exp. St. R. 61 :27.
- \_\_\_\_\_, 1950. D.D.T.-impregnated cotton bags for protecting stored corn from insects. Ky. Agr. Exp. St. R. 62 :16.

- Cotton, R.T. 1944. Protection of stored and dried processed foods and seed supplies from insect attack. *J. Econ. Entom.* 37 :380-384.
- \_\_\_\_\_, 1949. Control of insects under corn storage conditions. Amer. Seed Trade Assoc. Hybrid Corn Division. Industry-Research Conf. R. 3 :47-56.
- \_\_\_\_\_, 1952. Control of insects in storage of hybrid seed corn. Amer. Seed Trade Assoc. Hybrid Corn Division. Industry-Research Conf. P. 7:35-44.
- \_\_\_\_\_, 1956. Pests of stored grain and grain products. Minneapolis: Burgess Publishing Co.
- \_\_\_\_\_, A.I. Balzer and H.D. Young. 1944. The possible utility of D.D.T. for insect-proofing paper bags. *J. Econ. Entom.* 37:140.
- \_\_\_\_\_, J. C. Frankenfeld and W.B. Strickland. 1945a. Insect-proof bags. U.S.D.A. C.720:72.
- \_\_\_\_\_, J.C. Frankenfeld and W.B. Strickland. 1949. Insect-proofing cotton bags. U.S.D.A. B.E.P.Q. E-783.
- \_\_\_\_\_, J.C. Frankenfeld, H.H. Walkden and R.B. Schwitzgebel. 1945b. Tests of D.D.T. against insect pests of stored seed. U.S.D.A. B.E.P.Q. E-641.
- \_\_\_\_\_, H.H. Walkden, G.D. White and D.A. Wilbur. 1953. Causes of outbreaks of stored grain insects. *Kansas Agr. Exp. St. B.* 359:6-8.
- Dahms, R.G., W.D. Guthrie and J.B. Sieglinger. 1951. Insecticide-treated bags protect sorghum heads. *What's new in Crops and Soils* 4(3):24.
- \_\_\_\_\_, J.B. Sieglinger and W.D. Guthrie. 1955. Methods of treating sorghum selfing bags for insect control. *J. Econ. Entom.* 48:568-572.
- Davis, D.F. and H. Laudani. 1955. The protection rendered against infestation by insecticide-treated flour bags in long-term storage tests. *Assoc. South. Agr. Workers* P. 52: 98-99.

- Despaul, J.E. 1957. Penetration of protective coverings by insects. J. Milk and Food Technology. 20(4):100-104.
- Dudley, J.E., B.J. Landis and W.A. Shands. 1952. Control of potato insects. U.S.D.A. F.B. 2040:38.
- Essig, E.O. 1945. Insects: their relation to packages and packaging materials. Mod. Packaging 18(11): 135-141.
- \_\_\_\_\_, W.M. Hoskins, E.G. Linsley, A.E. Michelbacher and R.F. Smith. 1943. A report on the penetration of packaging materials by insects. J. Econ. Entom. 36:822-829.
- Gardiner, J.G. 1949. Stored product insect investigations. Can. Min. Agr. R. 1948/49:101-102.
- \_\_\_\_\_, 1950. Stored product insect investigations. Can. Min. Agr. R. 1949/50:111-112.
- Gerhardt, P.D. and D.L. Lindgren. 1954a. Penetration of various packaging films by common stored-product insects. J. Econ. Entom. 47:282-287.
- \_\_\_\_\_, D.L. Lindgren. 1954b. Penetration of packaging films. Calif. Agriculturist 8(6):3-4.
- Gunderson, H. 1956. Effectiveness of synergized pyrethrins on shelled corn in Iowa. Entom. Soc. Amer. North Central Branch P. 11:28-29.
- Herford, G.V.B. 1952. The infestation of stored foodstuffs by insects. J. Sci Food Agr. 3:1-11.
- Hilbert, G.E. 1949. Insect-resistant treatment devised for cotton-bag fabrics. U.S.D.A. A.I.C. R. 1948/49: 5-6.
- \_\_\_\_\_, 1951. Insect-resistant flour bags tested by Industry and Army. U.S.D.A. A.I.C. R. 1949/50:9.
- Hofmaster, R.N. and L.D. Anderson. 1948. Potato tuberworm control in Virginia. J. Econ. Entom. 41:198-202.

- \_\_\_\_\_, 1949. Control of tuberworms in potato tubers. Va. Truck Exp. St. B. 111:1865-1872.
- Hoyt, A.S. 1952. Better protection from insects provided for stored grain. U.S.D.A. B.E.P.Q. R. 1950/51:23.
- \_\_\_\_\_, 1954. Insecticide residues protect fibers and fabrics for long periods. U.S.D.A. Agr. Res. Adm. R. 1952/53:252-253.
- Incho, H.H., Eileen J. Incho and N.W. Mathews. 1953. Insect-proofing paper. J. Agr. Food Chem. 1:1200-1203.
- Jewett, H.H. and W. A. Price. 1951. Protecting stored corn from grain insects by bags impregnated with D.D.T. Ky. B. 571.
- Kulash, W.M. 1954. Save stored grain from insect pests. N.C. Agr. Exp. St. B. 389:7.
- Laudani, H. and D.F. Davis. 1955. The status of federal research on the development of insect-resistant packages. T.A.P.P.I. 38:322-326.
- \_\_\_\_\_, G.R. Swank. 1954. A laboratory apparatus for determining repellency of pyrethrum when applied to grain. J. Econ. Entom. 47:1104-1107.
- Lindgren, D.L., H.E. Krohne and L.E. Vincent. 1954. Malathion and Chlorthion for control of insects infesting stored grain. J. Econ. Entom. 47:705-706.
- Linsley, E.G. 1944. Protection of dried packaged food-stuffs from insect damage. J. Econ. Entom. 37:377-379.
- Lloyd, G.W. 1951. Insecticide tests against the Potato tuberworm. J. Econ. Entom. 44:613-614.
- Parker, W.B. 1913. A sealed paper carton to protect cereals from insect attack. U.S.D.A. B. 15.
- Parkin, E.A. 1951. Biological tests of insecticides for stored product insects. J. Sci. Good Agr. 2:136-141.

\_\_\_\_\_, 1956. Stored product Entomology. Annual Revue of Entom. 1:223-240.

Sivik, F.P. and W.M. Kulash. 1956. Treated cloth bags to control the Rice weevil in corn. J. Econ. Entom. 49:64-65.

Sweetman, H.L. and A.I. Bourne. 1944. The protective value of asphalt-laminated paper against certain insects. J. Econ. Entom. 37:605-609.

Thomson, A.G. 1950. Infestation of packaged products checked by pest-proof wrap. Food Indus. 22:827.

University Libraries  
University of Missouri

Digitization Information for Theses and Dissertations project.  
Scanned from microfilm; no subsequent editing done.

Local identifier

Source information

Identifier	Microfilm reel# T1958-98-T1958-109
Format	Microfilm
Content type	Text
Notes	

Capture information

Date captured	2019
Scanner manufacturer/model	ScanPro 3000 /e-ImageData
Scanning software	PowerScan 3000(TM) v5.341
Optical resolution	600 dpi
Compression	LZW
Color settings	bitonal
File types	tiff
Notes	Scanned from microfilm; no editing done.

Derivatives - Access copy

Editing software	Photoshop
Resolution	600 dpi
Color	grayscale
File types	pdf
Notes	Converted from tiff to pdf using Adobe Acrobat Pro DC.