THE PERMANENCY AND EFFECT OF FOUR ORGANIC SYNTHETIC INSECTICIDES ON SELECTED WOOL FABRICS

by

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B. Sc. (H.Ec.), McGill University, Canada, 1944

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing and Textiles

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1948

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INTRODUCTION

Household and industrial losses due to destruction by the larvae of clothes moths and carpet beetles annually exceed two million dollars (7). Considering that a surprisingly small amount of manufactured fabric is treated against insect damage before it reaches the consumer and that there is a lack of permanent insecticides on the consumer market, this loss is not unexpected. It has been generally agreed by most authorities (2) that protection from such pests is more easily obtainable in the manufacturing processes. This fact, however, is no reason why permanent insect pest deterrents should not be available to the housewife for home use.

Fletcher (5), six years ago, proposed that the term "mothproofer" be replaced by "fabric pest deterrents" as fabric pests included both carpet beetles and clothes moths. This term was accepted by the American Association of Textile Colorists and Chemists (A.A.T.C.C.) and the American Standards for Testing Materials (A.S.T.M.). However, in most instances, it was found that the old term is still used.

Von Bergen and Mauersberger (21) included in their text the following description of an ideal fabric pest deterrent:

> The ideal moth-proofing agent should provide permanent protection, that is, its effectiveness should not be altered by frequent washings or drycleanings nor should it deteriorate with time or exposure to light or varying climatic conditions.

Results of a recent survey (10) showed that 80 per cent of the people interviewed desired more moth protected wearing apparel, furniture coverings and rugs, and were willing to pay the extra cost for such service. The Aresto-Moth process (19), developed recently, sprays DDT into articles which are being dry cleaned. Although this process is not permanent to dry cleaning or washing it is the beginning of protective services now being offered to the housewife for fabric pest control.

Insecticides are available in many forms such as sprays, dusts, fumigants, insecticidal cords, and aerosal bombs. These are grouped according to their reaction on the insect into three classes: stomach poisons, contact poisons and repellents. Many insecticides possess combinations of these reactions. The prevention of the attack lessens the loss or damage more effectively than killing the pest after the damage is seen (13). According to a recent survey (10), fabric pest deterrents which repel or kill the larvae on contact were preferred to stomach poison insecticides which required that the larvae feed before death occurred.

The importance of more research can be judged easily when one notes the extensive number of mothproofing patents recorded each year and the large amount of money that is being spent for the production of new insecticides (10). From the reports studied, it has been found that few insecticides are effective in the protection of wool fabrics against the larvae of carpet beetles and clothes moths. Consequently, this study was undertaken to determine the effect of four synthetic organic insecticides on the color and breaking strength of selected wool fabrics and to test the permanency of these compounds on the fabrics after exposure to light, after dry cleaning and after laboratory laundering.

REVIEW OF LITERATURE

Considerable research has been conducted on the subject of fabric pest deterrents. The extent of damage to cloth has been reported in a number of instances.

Patton (15) noted that animal fibers are not the only fibers attacked by larvae of clothes moths and carpet beetles. Nylon, finished completely or finished by a scouring process, had been damaged by carpet beetle larvae. He also reported that cotton cloth was similarly damaged. The nylon and cotton attacked were not digested but clipped and eaten by the larvae. Reumeuth (17) concluded that vegetable fibers as cotton, kapok and synthetic fibers of all kinds when mixed with wool, were clipped off by the larvae. Rayon stored between wool also was damaged. Larvae stored in cellophane bags clipped holes to escape from the bags. Clothes moth and carpet beetle larvae digested only keratin and casein, and when other materials were eaten they excreted them from the body unchanged.

According to Luttringhaus (8), the resistance of wool to larvae of clothes moths and carpet beetles was in proportion to the number of broken sulphur linkages. He also found that the digestive ferment present in the stomach of these larvae was specific for the sulphur linkages present in keratin.

Mosher (11) reported that although carpet beetles were not known until the early part of the nineteenth century, clothes moths were brought to the United States with the Pilgrim Fathers. Reference to these pests can also be found in the Bible (12), Isaiah LI, 8, in the Old Testament, "For the moth shall eat them up like a garment."

Concentrated efforts to protect articles and garments from ravages of these pests first began on a commercial basis, stated Clark (1), with the production of Eulan M in 1920. This was followed by a series of Eulan formulas. In 1934, Eulan CN was produced which was the first permanent compound for the protection of garments against clothes moths and carpet beetles. Luttringhaus (8) reported that this compound, applied in a warm acid dye bath, is guaranteed for the life of the article. In 1938, the J. R. Geigy Co. S. A. introduced Mitin FF, another permanent insecticide. Clark (1) noted that this compound can be applied in either a neutral or acid bath.

Few studies were found in the literature which dealt with the effect and permanence of the newer synthetic insecticides against the larvae of clothes moths and carpet beetles.

Synthetic insecticides are still in the experimental stage, consequently few studies were found on the protective value of those chosen for this work. DDT and Chlordan both have proved toxic to the larvae of clothes moths and carpet beetles (14). Mail (10), in a recent study, concluded that after dry cleaning DDT was no longer protective. Smith (19), in his article, stated that repeated washings removed the protective value of DDT against clothes moths and carpet beetles. No studies were found on the use of Hepta-Klor and Parathion as fabric pest deterrents.

At a meeting of the Wool Industries Association at Leeds, England (17), three methods of wool protection were discussed. Wool can be protected by the addition of a substance which makes it unpalatable to the larvae or which will poison them on eating. Storage in well-sealed containers with a volatile substance was another method mentioned. The third protective measure was periodic spraying of storage places and articles with fluid substances. It was pointed out that the permanence of the first method depended on the insecticide used. The other two methods were stated to be more useful in specific cases.

No studies were found which reported dipping the fabric in the solution as a method of applying the insecticide. Spraying DDT during dry cleaning was reported by Smith (19). Collins and Glasgow (3), using thermal DDT aerosols generated by a Todd Fog Applicator, concluded that this method can be successfully used in fumigating buildings where nonfood materials are stored. Another method, using a dispenser in which is contained a combustible cord incorporated with DDT, was studied by Pearsall and Wallace (16). When the cord was ignited, toxic vapors were given off. The larvae of the clothes moths were killed by the vapors but those of the carpet beetles were untouched although only light feeding was noticed after the use of the cord.

METHOD OF PROCEDURE

This work was limited to the use of wool fabrics since it is an accepted fact that insect pests readily feed on wool. Synthetic organic insecticides recently developed were used.

Fabrics Chosen

Four all-wool fabrics were selected for this study. These included one white, one tan, one light blue, and one navy blue so chosen as to permit a study of color change. Each fabric, two yards in length, was divided into six parts, one of which was held as control, one immersed in the solvent used in preparing the testing solution, and one immersed in each of the four insecticides. Samples of these fabrics are shown in Plate I.

Insecticides Chosen

The choice of insecticides used and the strength of each solution were determined from previous work done by the Department of Entomology of Kansas State College. The concentrations were expressed in percentage of weight per volume. These were 0.25 per cent for para, para' DDT and technical Chlordan, 0.1 per cent Hepta-Klor and 0.05 per cent technical Parathion. The solvent was Super-Sol (Pennsylvania Refining Company, Butler, Pa.). It was a practically odor-free solvent (average sp. gr. 0.764) which gave quick evaporation.

All solutions were prepared in the Department of Entomology and the fabrics were treated under their supervision.

Pure para, para' DDT (J. R. Geigy Inc., New York City, N. Y.) is chemically known as 2,2-bis-(-chlorophenyl)-1,1,1,-trichloroethane. DDT was first synthesized in 1874 by a German chemistry student Othmar Zeidler (20). Several years ago, Paul Muller, scientist of J. R. Geigy, Bask, Switzerland, also synthesized the product and noted its insecticidal properties. From his findings, Gesarol, used in agricultural control of certain insects and Neocid, the lousicide composition of DDT, were made available to the Armed Forces in 1942. First productions of DDT in the United States began in 1943 at the Cincinnati Chemical Works. Pure para, para' DDT,

EXPLANATION OF PLATE I

Fabrics used in this work

Fig. 1. White wool

Fig. 2. Tan wool

Fig. 3. Light blue wool

Fig. 4. Navy blue wool

PLATE I

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

as used in this work, is a white crystalline substance, odorless and readily soluble in oil solvents.

The synthetic compound, chemically known as 1,2,4,5,6,7,8,8-octochloro-4,7-methano-3_a,4,7,7_a-tetrahydroindane, was discovered by Dr. Julius Hyman (14). Octo-Klor (Julius Hyman and Company, Denver, Colorado) is the trade name of the sample used in this work. Technical Chlordan in the refined grade is a pale amber-colored, nearly odorless liquid, readily soluble in oil solvents. This company claimed that the toxicity for rats is the same for Octo-Klor as for DDT. In determining the L.D. 50 (lethal dose, 50 per cent mortality) for carpet beetle larvae, experiments showed Chlordan to be approximately three times that for DDT (14).

Hepta-Klor (Julius Hyman and Company, Denver, Colorado) is not in commercial production. An experimental sample was furnished by the company for these tests. It is possibly the most toxic of the materials present in technical Chlordan. In structure, this insecticide is believed to resemble Chlordan with one less chlorine atom. On certain insects, Hepta-Klor showed a greater toxicity than Chlordan by several times.

Parathion is the common name accepted for the insecticidal chemical O,O-diethyl,o-p-nitrophenyl thiophosphate (18). Thiophos 3422 (American Cyanamid Company, New York City) is the trade name of the sample used in these tests. It was the only one of the insecticides chosen for this work which did not contain chlorine. Parathion, an amber colored liquid, was readily soluble in oil solutions.

Analyses of Fabrics

All fabrics were analyzed for thread count, weight per square yard, breaking strength and colorfastness according to standards set up by Committee D-13 (4). The raveled-strip method (4) was used for breaking strength tests. The procedure used for judging color was modified to the extent that exposed samples were mounted on grey card-board, five inches by eight and one-half inches. The colorfastness of the original fabrics was obtained from previous work by the Department of Clothing and Textiles of Kansas State College.

Permanence of the insecticides was tested by exposing two-inch-square specimens to five larvae of the carpet beetle (Attagenus piceus Oliv.) for a period of 28 days (6). Treatment was considered satisfactory if after that time there was no visual damage and no living larvae were present. These tests were carried out by the Department of Entomology.

Preparation of Materials for Tests

The fabrics were divided into six parts, one part was saved for control, one part immersed in the solvent Super-Sol, and one part of each fabric was immersed in each of the four insecticides.

A specimen of each fabric, six inches by nine inches, was weighed then immersed in 500 cc of Super-Sol until saturated. Excess solvent was removed by hand squeezing until the specimens weighed approximately two and one-half times the original weight. After each piece was dipped into the solution, the amount of Super-Sol was made up to 500 cc before dipping the next specimen. The specimens were then dried for one week, after which each was cut into test specimens according to Diagram 1 presented in Plate II. One part was saved for a control, one part was exposed 40 hours in the Fade-Ometer and one used for a test of insect feeding.

Each insecticide solution was made up to one liter with the solvent Super-Sol. One specimen of each fabric, (white and tan, 12 inches by 54 inches and light blue and navy blue, 12 inches by 60 inches), was weighed then immersed in 500 cc of each of the insecticide solutions. Excess insecticide solution was removed by hand squeezing until the specimen weighed approximately two and one-half times its original weight. After each piece was dipped into the solution, the amount of insecticide solution used was recorded. The volume was made up to 500 cc each time before dipping the next piece. The specimens were then dried for one week after which they were cut according to Diagram 2 presented in Plate II.

EXPLANATION OF PLATE II

Diagrams for cutting specimens

Diagram 1. Specimen treated with Super-Sol

A - Control for Department of Entomology (2" x 9")

B - Exposed 40 hours in Fade-Ometer (2" x 9")

C - Control (2" x 9")

Diagram 2. Specimen treated with Insecticide

A - Control for Department of Entomology (2" x 12")

B - Exposed 40 hours in Fade-Ometer for color change (2" x 8")

C - Warp breaking strength (4" x 6½")

D - Warp breaking strength exposed 40 hours in Fade-Ometer (4" x 6½")

E - Filling breaking strength (4" x 6½")

F - Filling breaking strength exposed 40 hours in Fade-Ometer (4" x 6½")

G - Washing permanence test (2" x 3")

H - Fade-Ometer exposure permanence test (2" x 4")

J - Dry cleaning permanence test (12" x 1½")

PLATE II

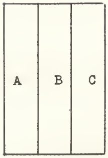

Diagram 1. Specimen treated with Super-Sol.

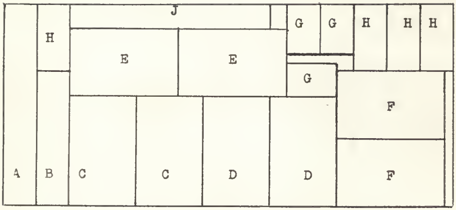

Diagram 2. Specimen treated with Insecticide.

Tests Performed

Color Change. The specimens immersed in the solvent and those immersed in each insecticide were compared with the original fabric for possible color change.

To determine the effect of the insecticide solutions on the colorfastness of the fabric, specimens of the treated fabrics were exposed for 40 hours at 100° F. in a FDA-R type of color Fade-Ometer. The colorfastness of the original fabrics was determined in previous work by comparing the untreated exposed specimens with the L 5 standard for color change, the results being expressed as "satisfactory" or "not satisfactory". Data are shown in Table 2.

The treated exposed specimens were compared with the corresponding untreated exposed specimen for color change and these results expressed as "same", "more" or "less" satisfactory than the untreated exposed specimens. These data are shown in Table 5.

Breaking Strength. Specimens of treated fabrics were tested to determine the effect of the insecticide on the breaking strength of the fabrics. The results are recorded in Table 6.

Specimens of treated fabrics were exposed to light for 40 hours in the Fade-Ometer. Tests were made to determine the effect of the insecticide solution on the breaking strength of exposed fabrics. These results are shown in Table 7.

Tests for Permanence of Insecticides. Insecticidal permanence of the chemical formulations to light exposure, dry cleaning, and laboratory laundering was determined by using standard testing procedures (3) and black carpet beetle larvae (*Attagenus piceus*). Larvae mortality and the amount of feeding were taken as a measure of the efficacy of the various insecticides. In general, the greater the larval mortality and the lower the feeding index (0 = no feeding; 1 = nap or slight feeding; 2 = medium feeding; and 3 = heavy feeding), the better the fabric was protected by the insecticide.

Specimens of the treated fabrics were exposed to insect larvae immediately after treatment. Results are shown in Table 9.

Specimens of the treated fabrics were exposed to insect larvae after exposure in the Fade-Ometer for 10, 20, 30, and 40 hours. These results are shown in Table 10.

Specimens were also tested for permanence after being dry cleaned one, two, and three times at a commercial plant. Specimens of the four fabrics treated alike were sewn together with strips of muslin between, before being dry cleaned. This was done to ensure similar treatment. The method used by the dry cleaning establishment consisted of running the cloth for 10 minutes in a mixture of Stoddard Solvent (Standard Oil Co.)

and Soltex (detergent, Riverside Mfg. Co.) and then rinsing in clear Stoddard solvent for five minutes. The material was then air dried and steam pressed. After each dry cleaning a portion was cut off and tested. These results are recorded in Table 11.

Other specimens were tested for permanence after one, two, and three laboratory washings in an automatic electric washing machine using 45 grams of grated bar soap for each washing. This amount provided a permanent suds for the washing time. The results are shown in Table 12.

DISCUSSION OF FINDINGS

The four all-wool fabrics that were used in this study were types suitable for construction of wearing apparel. All were purchased on the open market and as far as known had not been treated previously by any fabric pest deterrent. Preliminary experiments were done to determine if the untreated samples were subject to attack by larvae of carpet beetles. Results indicated heavy feeding in all cases.

The materials chosen were medium weight wools similar in construction and weight. The breaking strengths of all were comparable except the filling of the tan wool which was considerably lower than that of the others and the warp of the white wool which was much higher. After exposure in a Fade-Ometer for 40 hours, no appreciable change in the breaking strength was noted except for the navy blue warp which was slightly higher. Results are shown in Table 1. The navy blue fabric was the only one that proved to be satisfactory in color fastness as compared with the L 5 standard, Table 2.

The percentage of insecticide retained by the fabric was calculated from both the weight and volume of the insecticide solution actually absorbed by the fabric. Good agreement was observed between the data obtained by both methods. It is shown in Tables 3 and 4 that the concentration of the insecticide retained in the fabric is approximately twice that of the solution used. The 0.25 per cent solutions (p,p' DDT and Chlordan) resulted in approximately 0.5 per cent weight of the fabric impregnated, the 0.1 per cent solution (Hepta-Klor) in approximately 0.2 per cent weight of the fabric and the 0.05 per cent solution (Parathion) approximately 0.1 per cent weight of the fabric impregnated.

After the fabrics were air-dried for one week, they were examined for hand or feel, odor and color change. None showed any difference in texture from the original fabric. Only those treated with Chlordan exhibited a slight pine-like odor, however, it was not considered objectionable. Although the light blue wool "bled" slightly during the dipping process, no noticeable change in color was in evidence after the fabric was dry. The other samples indicated no color change from the untreated ones.

Table 1. Analyses of original fabrics.*

Wool fabric	Cond. weight per square yard (ounces)	Thread count: Warp	Thread count: Filling	Breaking strength in lbs. Unexposed: Warp	Unexposed: Filling	Exposed: Warp	Exposed: Filling
White	5.6114	57	43	29.0	16.0	30.0	17.0
Tan	5.4106	54	42	20.5	9.5	21.0	10.5
Blue	5.3782	42	27	15.0	12.0	18.0	14.5
Navy	6.7995	44	23	17.5	17.5	15.3	18.5

* Data taken from pervious work.

Table 2. Comparison of the color change of the untreated exposed specimens with the L 5 standard.*

Specimens exposed 40 hours in Fade-Ometer	
Untreated specimen	L 5 standard
White	unsatisfactory
Tan	unsatisfactory
Blue	unsatisfactory
Navy	satisfactory

* Data taken from previous work.

Table 3. Insecticide solutions absorbed by the wool fabric.

Insecticide	Wool cloth color	Original wt. (g) of wool cloth	Wt. (g) of wool plus insecticide solution	Wt. (g) of insecticide solution absorbed	Volume (ml) of insecticide solution absorbed
0.25% W/V p,p' DDT	White	83.50	209.75	126.25	175
	Tan	80.05	199.90	119.85	165
	Blue	93.75	235.40	141.65	185
	Navy	81.25	202.50	121.25	180
0.25% W/V Chlordan	White	81.65	205.10	123.45	166
	Tan	77.30	194.60	117.30	160
	Blue	100.35	250.03	149.68	203
	Navy	78.80	196.95	118.15	164
0.1% W/V Hepta-Klor	White	84.00	211.00	127.00	170
	Tan	80.00	200.00	120.00	165
	Blue	100.00	250.00	150.00	200
	Navy	83.00	210.00	127.00	180
0.05% W/V Parathion	White	84.00	212.00	128.00	180
	Tan	80.00	200.00	120.00	160
	Blue	101.00	253.00	152.00	205
	Navy	85.00	212.50	127.00	175

Table 4. Insecticide solutions absorbed as per cent weight of fabric.

Insecticide	Wool cloth color	Based on weight of solution absorbed	Based on volume of solution absorbed
p,p' DDT 0.25% W/V	White	0.495	0.525
	Tan	0.490	0.515
	Blue	0.493	0.493
	Navy	0.492	0.553
Technical Chlordan 0.25% W/V	White	0.494	0.509
	Tan	0.495	0.518
	Blue	0.486	0.506
	Navy	0.490	0.521
Hepta-Klor 0.1% W/V	White	0.198	0.202
	Tan	0.196	0.206
	Blue	0.195	0.200
	Navy	0.200	0.217
Technical Parathion 0.05% W/V	White	0.100	0.095
	Tan	0.098	0.100
	Blue	0.097	0.102
	Navy	0.098	0.103

Specimens of the treated samples were exposed in the Fade-Ometer for a period of 40 hours. In determining the effect of the insecticides upon the treated exposed fabric, the results from previous work as given in Table 2 were taken. Using these exposed specimens as controls, each was compared with its corresponding treated exposed specimens. The majority of the group who judged color change found that for all insecticides the treated white, blue, and tan wools were slightly less satisfactory than the untreated light exposed specimens. No change from the original light exposed specimen was noted for the navy blue wool. The results are shown in Table 5.

The breaking strengths of the original fabrics and these fabrics after treatment with the insecticides, as shown in Tables 6 and 7, indicated in all cases, except for navy blue warp, a slight increase in breaking strength after treatment. The effect of light exposure for the treated specimens resulted in a slight increase in breaking strength over that of the breaking strength of the same fabrics exposed to light but not treated with insecticides. All increases, however, were so slight as to be regarded as negligible.

Tests were made on specimens which had been treated with the solvent, Super-Sol. This was done to determine if the solvent possessed any insecticidal properties. Heavy feeding after 28 days' exposure to black carpet beetle larvae was noticed in three of the four fabrics, the fourth indicating slight feeding. These results are shown in Table 8. From this check test it was decided that the solvent showed negligible insecticidal properties.

Slight feeding was observed in most cases immediately after treatment with insecticides as seen in results given in Table 9. Such observations indicated that the insecticides chosen were effective immediately after treatment.

Exposure of the treated fabrics to the Fade-Ometer for periods of 10, 20, 30, and 40 hours, respectively, showed that light destroyed some of the effectiveness of the insecticides.

Table 5. Comparison of the color change of the treated exposed specimens with the untreated exposed specimens.

Specimens exposed 40 hours in the Fade-Ometer	White	Tan	Blue	Navy
Treated with Super-Sol	less	less	less	same
Treated with 0.25% p,p' DDT	less	less	less	same
Treated with 0.25% Chlordan	less	less	less	same
Treated with 0.1% Hepta Klor	less	less	less	same
Treated with 0.05% Parathion	less	less	less	same

Table 6. Breaking strengths (lbs.) of the original specimens and of the treated specimens.

Unexposed specimen	White		Tan		Blue		Navy	
	Pounds							
	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
Original fabric*	29	16	20.5	9.5	15	12	17.5	17.5
Treated with 0.25% p,p' DDT	31	18	24	14	20	16	17	20
Treated with 0.25% Chlordan	31	17	26	12	19	15	17	20
Treated with 0.1% Hepta Klor	32	16	25	13	21	15	16	19
Treated with 0.05% Parathion	31	17	24	13	20	14	17	21

* Data taken from previous work.

Table 7. Breaking strengths (lbs.) of the light exposed untreated specimens and the light exposed treated specimens.

Specimens exposed 40 hours in Fade-Ometer	White		Tan		Blue		Navy	
	Pounds							
	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
Untreated fabric*	21	10.5	30	17	18	14.5	15.5	18.5
Treated with 0.25% p,p' DDT	25	12	30	18	21	17	17	23
Treated with 0.25% Chlordan	24	13	31	17	20	16	17	21
Treated with 0.1% Hepta Klor	24	13	31	17	20	14	17	21
Treated with 0.05% Parathion	25	13	31	18	21	16	17	20

* Data taken from previous work.

Table 8. Feeding and mortality of carpet beetle larvae on fabrics after treatment with Super-Sol.

Insecticide	Wool cloth color	Days after larvae placed on fabric			
		14		28	
		% Mortality	Feeding	% Mortality	Feeding
Super-Sol check	White	0*	2*	0	3
	Tan	0*	2*	0	3
	Blue	0*	1*	0	1
	Navy	20*	2-3*	0	3

* Larval mortality and feeding observed 19 days after larvae placed on the fabric.

Key to table:
- 0 = no feeding
- 1 = slight feeding
- 2 = medium feeding
- 3 = heavy feeding

Table 9. Feeding and mortality of carpet beetle larvae on fabric immediately after treatment.

Wool cloth color	Days after larvae placed on fabric			
	14		28	
	% Mortality	Feeding	% Mortality	Feeding
White	20*	0*	40	0
Tan	0*	0*	60	0
Blue	20*	0*	60	0-1
Navy	20*	0-1*	60	0-1
White	0	2	0	2-3
Tan	0	0	0	2-3
Blue	20	1	40	0-1
Navy	0	0-1	0	0-1
White	0	1-2	0	1-2
Tan	0	1	0	0-1
Blue	0	0	0	0-1
Navy	0	0-1	0	0-1
White	20	0-1	100	0-1
Tan	20	0	80	0
Blue	20	0-1	80	0-1
Navy	0	0-1	100	0-1

* Larval mortality and feeding observed 19 days after larvae placed on fabric.

Key to table:
0 = no feeding
1 = slight feeding
2 = medium feeding
3 = heavy feeding

The results also indicated that each increasing 10 hours of exposure decreased the efficiency of the treatment. The least damage was done on specimens treated with p,p' DDT. Technical Parathion gave the next best protection, then Hepta-Klor and technical Chlordan. The data are recorded in Table 10.

Commercial dry cleaning decreased the effectiveness of the treatments as indicated by the damage done to the specimens. Results showed little difference from the first to the third dry cleaning. Technical Parathion gave the best protection, followed by Hepta-Klor, p,p' DDT and technical Chlordan. Results are shown in Table 11.

Fabric protection was affected by laboratory washings as shown in Table 12. With each successive washing further decreases in protection were noted. The results indicate the p,p' DDT was the most resistant to larvae after washing, then technical Chlordan, Hepta-Klor and technical Parathion. Results obtained from these tests indicate that all insecticidal materials resulted in a low larval mortality in the 28-day period. This is shown in Tables 9 to 12, inclusive.

Table 10. Feeding and mortality of carpet beetle larvae on fabrics after exposed in Fade-Ometer.

Insecticide	Wool cloth color	10 hours: Days after larvae placed on fabric				20 hours: Days after larvae placed on fabric				30 hours: Days after larvae placed on fabric				40 hours: Days after larvae placed on fabric			
		14		28		14		28		14		28		14		28	
		% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding
p,p' DDT 0.25% W/V	White	0*	0*	80	0	40*	0*	20	0	0*	0*	0	0	0*	1*	0	1
	Tan	0*	0*	0	0-1	0*	0*	0	0	0*	0*	0	0	0*	0*	0	0
	Blue	0*	1*	20	0-1	0*	1*	0	1-2	0*	2*	0	2	0*	1*	0	1-2
	Navy	40*	1*	40	0-1	20*	1-2*	20	3	0*	2-3*	0	3	0*	2-3*	0	3
Technical Chlordan 0.25% W/V	White	0	2	0	3	0	2	0	3	0	2-3	0	3	0	1-2	0	2
	Tan	0	2	0	2	0	1	0	2	0	1-2	0	2	0	1-2	0	2
	Blue	20	1	0	1	0	1	0	1	0	1	0	1-2	0	1-2	0	1-2
	Navy	0	2	0	3	0	0-1	0	0-1	0	3	0	3	0	3	0	3
Hepta-Klor 0.1% W/V	White	0	2	0	2-3	0	2-3	0	2	0	1-2	0	2	0	2	0	2
	Tan	0	2-3	0	3	0	3	0	3	0	2-3	0	3	0	3	0	3
	Blue	0	2	0	2	0	2	0	3	0	2-3	0	2-3	0	3	0	3
	Navy	0	0-1	0	2	0	3	0	3	0	3	0	3	0	3	0	3
Technical Parathion 0.05% W/V	White	40	0	80	0-1	0	2-3	0	2-3	0	1-2	0	3	0	3	0	3
	Tan	0	2-3	40	2-3	0	2	0	2-3	0	1-2	0	2-3	0	3	0	3
	Blue	0	1	80	1-2	0	2	0	2	0	2	0	2-3	0	2-3	0	3
	Navy	0	3	0	3	0	1-2	0	3	0	3	0	3	0	1	0	1-2

* Larval mortality and feeding observed 19 days after larvae placed on the fabric.

Key to table:
M = mortality
0 = no feeding
1 = slight feeding
2 = medium feeding
3 = heavy feeding

Table 11. Feeding and mortality of carpet beetle larvae on fabrics after commercial dry cleaning.

Insecticide	Wool cloth color	1st dry cleaning: Days after larvae placed on fabric: 14 % M	14 Feeding	28 % M	28 Feeding	2nd dry cleaning: Days after larvae placed on fabric: 14 % M	14 Feeding	28 % M	28 Feeding	3rd dry cleaning: Days after larvae placed on fabric: 14 % M	14 Feeding	28 % M	28 Feeding
p,p' DDT 0.25% W/V	White	0*	1-2*	0	3	-	2-3	0	3	0	0-1	0	0-1
	Tan	0*	0-1*	0	0-1	0	1	0	3	0	3	0	3
	Blue	0*	2*	0	2-3	0	1-2	0	2	0	1	0	2
	Navy	0*	2*	0	3	0	1	0	1	0	1	0	1
Technical Chlordan 0.25% W/V	White	0	2	0	3	0	0-1	0	3	0	1-2	0	3
	Tan	0	2	0	3	0	1	0	3	0	1	0	3
	Blue	0	1-2	0	1-2	0	1	0	1-2	0	1	0	2-3
	Navy	0	1	0	1	0	1	0	1	0	1	0	1
Hepta-Klor 0.1% W/V	White	0	1	0	2	0	0	0	0	0	1	0	2
	Tan	0	3	0	3	0	1	0	2	0	3	0	3
	Blue	0	2	0	2	0	1-2	0	2	0	1-2	0	2-3
	Navy	0	0-1	0	2	0	3	0	3	0	0-1	0	2
Technical Parathion 0.05% W/V	White	0	0	60	0-1	0	0	0	0	0	0	40	0-1
	Tan	0	0-1	0	0-1	0	0-1	0	1	0	0	0	1
	Blue	0	1	0	1	0	0-1	20	1	0	0-1	20	1
	Navy	0	1	0	3	0	1	0	1	0	0-1	0	1-2

* Larval mortality and feeding observed 19 days after larvae placed on the fabric.

Key to table:
M = mortality
0 = no feeding
1 = slight feeding
2 = medium feeding
3 = heavy feeding

Table 12. Feeding and mortality of carpet beetle larvae on fabrics after laboratory launderings.

Insecticide	Wool cloth color	1st wash: Days after larvae placed on fabric				2nd wash: Days after larvar placed on fabric				3rd wash: Days after larvae placed on fabric			
		14		28		14		28		14		28	
		% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding	% M	Feeding
p,p' DDT 0.25% W/V	White	0	0	0	0-1	0	0-1	0	0-1	0	1	0	1-2
	Tan	20	0-1	20	0-1	0	0-1	0	0-1	0	0-1	0	0-1
	Blue	0	1	0	1	0	1	0	1	0	1	0	1-2
	Navy	0	1	0	1-2	0	1	0	1	0	1	0	1
Technical Chlordan 0.25% W/V	White	0	1-2	0	2	0	1	0	3	0	2	0	3
	Tan	0	1	0	3	0	0-1	0	2	0	0-1	0	2
	Blue	0	1-2	0	1	0	1	0	1-2	20	1	0	1-2
	Navy	0	1-2	0	1-2	0	1-2	0	1	0	1	0	1
Hepta-Klor 0.1% W/V	White	0	1	0	1	0	2	0	2-3	0	1-2	0	2-3
	Tan	0	1-2	0	1-2	0	3	0	3	0	3	0	3
	Blue	0	1-2	0	2	0	3	0	3	0	1-2	0	1-2
	Navy	0	1-2	0	1-2	0	2	0	3	0	2	0	3
Technical Parathion 0.25% W/V	White	0	1-2	0	2	0	2-3	0	3	0	3	0	3
	Tan	0	2	0	1-2	0	2-3	0	3	0	3	0	3
	Blue	0	2	0	2	0	1-2	0	2	0	1-2	0	2-3
	Navy	0	1	0	2	0	2-3	0	3	0	2	0	3

Key to table:
M = mortality
0 = no feeding
1 = slight feeding
2 = medium feeding
3 = heavy feeding

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effect of four synthetic organic insecticides on the color and breaking strength of selected wool fabrics and to test the permanency of these compounds on the fabrics after exposure to light, after dry cleaning and after laboratory laundering.

No differences in the hand or color of the fabrics were noted after treatment with the insecticidal solutions.

Any differences which could have been attributed to the effect of the insecticidal treatment on the color or breaking strength of the treated fabrics when compared with the untreated fabrics were found to be negligible.

The following classification based upon visual evidence of feeding indicates to what extent each insecticide offered protection to the fabrics.

Specimens exposed to larvae immediately after treatment showed that p,p' DDT gave the greatest protection, technical Parathion second, Hepta-Klor third, and technical Chlordan fourth, in order of merit.

For permanence after being exposed in the Fade-Ometer at 100° F., p,p' DDT was found to give the greatest protection, followed by technical Chlordan, Hepta-Klor, and technical Parathion.

Technical Parathion showed the greatest protection after commercial dry cleaning, then Hepta-Klor, p,p' DDT and technical Chlordan.

The best fabric protection after laboratory laundering was given by p,p' DDT, followed by technical Chlordan, Hepta-Klor and technical Parathion.

ACKNOWLEDGMENT

Appreciation is expressed to Mrs. Katharine Hess, Associate Professor of Clothing and Textiles, and Dr. Paul A. Dahm, Assistant Professor of Entomology, for their guidance and help in directing this study.

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