UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 707

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER August 26, 1918

RESULTS OF EXPERIMENTS WITH MISCELLANEOUS SUBSTANCES AGAINST BEDBUGS, COCKROACHES, CLOTHES MOTHS, AND CARPET BEETLES

By

E. W. SCOTT, Entomologist, Enforcement Insecticide Act
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CONTENTS.

INTRODUCTION.

In connection with the enforcement of the insecticide act of 1910, numerous substances entering into the composition of proprietary insecticides have been tested against many different insects, resulting in the accumulation of a large amount of data relative to the efficacy of such substances. This work is conducted at the Insecticide Board's Testing Laboratory, located at Vienna, Va., and directed by Dr. A. L. Quaintance, of the Bureau of Entomology.

This paper, the first of several to be published on the results of such tests, presents data on the efficacy of various substances, used alone and in combination, against bedbugs, cockroaches, clothes moths, and carpet beetles.

BEDBUGS.

METHODS OF TESTING.

The tests of various materials, in many cases of previously undetermined insecticidal value, against the bedbug (*Cimex lectularius* L.), are of two general types, (1) jar tests and (2) room tests. In the former 20 bedbugs were confined in a pint jar with paper scraps or excelsior to furnish hiding-places, and thoroughly dusted or sprayed with the material to be tested, after which the jars were covered with cheesecloth. At least two of these jars were used in each test. Records were taken at the end of 24 hours, and as often thereafter as was considered necessary. With each series of tests two similar jars, each containing 20 bedbugs and paper scraps or excelsior, were used as a check. If the mortality in these checks ran above 35 per cent the whole series was discarded, except in those cases where the mortality in the treated jars was 10 per cent or less. No food was furnished in any of these tests, but it should be noted that in many cases the experiments were continued for two weeks with a mortality of less than 10 per cent in the checks.

This method of testing, although admittedly very severe on the bugs, and not simulating natural conditions, was used primarily to ascertain whether the given insecticide material would kill the insects and was not intended to determine its exact value under practical conditions.

Experiments on a practical scale were made by thoroughly dusting badly infested rooms or beds with the material to be tested. In these experiments the room or bed was examined only once, usually four or seven days after treatment.

KILLING EFFECTS OF LIQUIDS AGAINST BEDBUGS.

HYDROCARBON OILS.

Twenty-seven different hydrocarbon-oil preparations, composed largely of oils of the nature of kerosene and gasoline mixed with varying amounts of nitrobenzene, phenols, essential oils, etc., were tested. All of these were found to be very effective, most of them killing 100 per cent of the treated insects within 24 hours.

As remedies against bedbugs, the oil sprays possess one very great advantage over other insecticides—their power of penetration. With powders and most liquids it is very difficult, if not impossible, to reach the bugs, which are generally hidden during the day in cracks and holes in the beds, behind wall paper and moldings, or in the bedding itself, and in these places they are readily reached by the heavier oils. These sprays possess the added advantage of de-

stroying the eggs whenever they come in contact with them, and here, also, their powers of penetration greatly increase their practical effectiveness.

The preparations composed largely of oils of the nature of gasoline were found, in jar tests, to be as effective as the kerosene sprays, but because of very rapid evaporation they are not as valuable under practical conditions as are those composed of a heavier oil, and it has been found that gasoline, at least under certain conditions, is not effective against bedbug eggs. (See p. 7.)

COAL-TAR CREOSOTE EMULSIONS.

Numerous tests with coal-tar creosote emulsions indicate roughly that the effectiveness of this class of materials depends on two factors: (1) The dilution, and (2) the amount of water present in the original emulsion. When used undiluted, these emulsions killed from 95 to 100 per cent in 24 hours, but when diluted 1 to 30 or more, in no case were all of the insects killed, although many of the tests were continued for seven days.

MERCURIC CHLORID.

Table I gives the results of tests with mercuric chlorid against bedbugs.

TABLE I.—*Results of tests with mercuric chlorid used as spray against bedbugs confined in jars.*

Test No.	Per cent mercuric chlorid.	Other ingredients.	Number used.	Duration of test.	Per cent dead.	Untreated, per cent dead.
				Days.		
1	0.23	Water	40	4	10	10
2	.50	do	80	8	39	15
3	1.00	do	120	4–8	20–53	7.5
4	1.09	Alcohol	120	5	70	30
5	1.35	Alum, salt, water	65	12	75–100	23
6	2.00	Water	80	8	58	15
7	4.00	do	80	8	77	0
8	5.72	Water, alcohol, phenol 1.44 per cent	40	6	45–95	13
9	6.00	Water	40	1	100	35

Table I shows that mercuric chlorid, even in a 2 per cent solution, is somewhat effective, and that a 6 per cent solution killed 100 per cent of the treated bugs within 24 hours.

As mercuric chlorid is a very violent poison, its use ordinarily would be attended with considerable danger, but in solution a small amount can be used effectively without serious danger of accidental poisoning. In solution it also can be more thoroughly applied and forced into cracks and holes, so that, on drying, it leaves a thin film of poison which will remain to kill any bugs not hit by the spray.

EXPERIMENTS WITH POWDERS AND OTHER MATERIALS.

PYRETHRUM.[1]

Tests with 28 different samples of pyrethrum have been made and all samples were found to be very effective against bedbugs in jar tests.

These tests also show that there is no practical difference in effectiveness between powder made from the buds, half-open flowers, half-closed flowers, and closed flowers, or between the cultivated and wild flowers. Tests made during 1912 with powders made from 1908, 1909, and 1910 crops of flowers showed no practical difference in their efficiency, which indicates that pyrethrum does not deteriorate materially in four years.

The actual effect of pyrethrum on bedbugs is to render the insects inactive almost at once, and, although slight movements of the legs and antennæ may continue for several days, the insects do not recover.

Under the conditions of jar tests five samples, consisting wholly or largely of pyrethrum stems, were found to be of comparatively little value. In the one-room test made with powdered stems they appeared to be absolutely ineffective. In this test a grossly infested bed was thoroughly dusted, and four days after treatment careful search failed to locate a single dead bug, either in the bed or on the floor. Many living bugs were found in cracks where the powder was still plainly visible, and some were seen crawling about with their backs still covered with it.

TOBACCO POWDERS.

A number of tests were made with tobacco powders against bedbugs dusted in jars, and it was found that powders containing as high as 3.41 per cent, 3.73 per cent, and 5.26 per cent nicotine did not kill all of the treated insects in 12 days.

HELLEBORE.

Not one of the seven different lots of hellebore tested was of value against bedbugs.

This would appear to indicate that hellebore is of no value as a contact insecticide, and this conclusion is greatly strengthened by the fact that it was found to be ineffective against 12 different species of other sucking insects.

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[1] A powder made by grinding to an impalpable powder the flower heads of a chrysanthemum, *Pyrethrum cinerariaefolium* and *P. roseum*. The manufactured product has been sold also as "buhach," Persian insect powder, and Dalmatian insect powder.

POWDERED MIXTURES CONTAINING MORE THAN ONE ACTIVE INGREDIENT.

A number of jar tests have been made with 20 miscellaneous powders containing small amounts of nicotine, naphthalene, pyrethrum, and various oils as active ingredients. These powders were more or less effective, depending on the amount of the active ingredients present.

MISCELLANEOUS MATERIALS.

The following materials were found to be more or less effective against bedbugs, killing from 80 to 100 per cent in jar tests:

Miscellaneous materials more or less effective against bedbugs.

Material.	Form of preparation.	Killed.
		Per cent.
Acetic acid	50 per cent solution	100
Ammonia water	Undiluted	80
Coal-tar oil, chlorinated	....do	100
Cottonseed oil	10 per cent mixture	93
Glycerol	Undiluted	100
Kerosene	10 per cent mixture	100
Linseed oil	....do	94
Nicotine (40 per cent, as sulphate)	1–32	80–90
Do	1–64	80–95
Pine needles, oil of	10 per cent mixture	100
Sabadilla seeds	Dust	100
Turpentine, crude wood	Undiluted	100
Mercuric chlorid	Dust	100

These data show little of interest, except the efficiency of sabadilla seeds (*Sabadilla officinalis* Brandt). These seeds or extracts are largely used in remedies for vermin on the human body, especially in the hair, but their use against bedbugs is rather unusual. In five tests they proved to be very effective, killing from 95 to 100 per cent in 48 hours.

Mercuric chlorid, used as a dust, killed all of the treated insects, but this material is too poisonous for general use in houses.

The following is a list of various materials which were found to be ineffective against bedbugs. The method of testing is indicated in parentheses.

Materials found ineffective against bedbugs.

Allspice (jar).
Alum (jar).
Angelica root (jar and room).
Arsenious acid (jar).
Borax (jar).
Boracic acid (jar).
Chamomile flowers (jar).
Colocynth pulp (jar).
Eucalyptus leaves (jar and room).
Formaldehyde (room, 8.87 per cent solution, sprayed twice, 1 part to 14 parts water).
Lead acetate (jar).
Paris green (jar).
Pepper, red (jar).
Quassia chips (jar and room).
Sodium bicarbonate (jar).
Sodium fluorid (jar and room).

The principal fact of interest in these data is that such violent stomach poisons as arsenious oxid and Paris green were found to be ineffective, as were also the milder sodium fluorid, lead acetate, borax, and boracic acid. These results show conclusively that bedbugs can be controlled only by an insecticide which acts directly on the body, and that none of the materials with which the insect comes in contact is taken into the stomach.

Although, in a few cases, these materials appeared to have some slight effect on the insects, the number killed was so small that they would be of no value under practical conditions.

PHOSPHORUS PASTES.

Two tests were made with pastes formed of sugar, water, and starchy material, and containing, in one case, 1.91 per cent and, in the other, 2.21 per cent of phosphorus. The first test was made in a room badly infested with bedbugs, and the paste was liberally smeared in the corners of the bedstead and in the cracks around the baseboards and moldings. Observations were made several days after treatment, and it was then evident that this material was of no value. Hundreds of living bugs were present, and the only dead ones seen were a very few that had become entangled in the paste and stuck fast.

In the second test the paste was smeared on pieces of paper and placed in a box containing 50 bedbugs. One week later examination showed that 90 per cent of the insects were still living and active.

FUMIGATION AGAINST BEDBUGS.

Results obtained in a limited number of tests made with sulphur as a fumigant show that it will kill bedbugs, and indicate that the necessary amount for effective use is at least 1 pound to 1,000 cubic feet of room space.

Not only is sulphur fumigation effective against the bedbugs themselves, but it has been found by several workers to kill the eggs also, which makes it a very satisfactory method of fighting this insect. This effectiveness against the eggs is of particular importance, since they are often deposited in inaccessible cracks and holes, or behind wall paper, where it is very difficult, or even impossible, to reach them with a dust or spray.

The following materials were found to be ineffective as fumigants against bedbugs when used at the rate indicated:

Paradichlorobenzene (8.5 pounds to 1,000 cubic feet).
Paraformaldehyde (2.25 pounds to 1,000 cubic feet).
Charcoal (1.64 pounds to 1,000 cubic feet).

TESTS AGAINST BEDBUG EGGS.

The eggs used in these experiments had been deposited on pieces of paper or cloth. These were thoroughly sprayed or dusted with the materials to be tested and then placed in jars covered with cheesecloth. Kerosene oil was the only material used which was found to be completely effective, not one of the eggs sprayed with this material hatching. The fact that the eggs sprayed with gasoline apparently hatched in a perfectly normal manner indicates that this material, although effective against bedbugs, vaporizes so rapidly that it does not penetrate the eggshell and reach the embryo, and that the evaporation is so complete that not enough oil remains, at the end of six days, to kill the newly hatched insects.

Mercuric chlorid, either as a dust or in a 1.35 per cent spray, appeared to have no effect on the eggs, as the young bugs emerged at approximately the same time as those from the untreated eggs. Where this material was applied as a dust, enough was present to kill all of the insects as soon as they had left the eggs, but the amount left by the 1.35 per cent solution apparently was not great enough to kill them.

SUMMARY.

1. The hydrocarbon oil sprays were found to be very effective against bedbugs, killing, in most cases, 100 per cent within 48 hours.

2. Coal-tar creosote emulsions were effective, when used undiluted, but their effectiveness fell very rapidly when they were diluted.

3. Mercuric chlorid, as a dust and in a 6 per cent water solution, was found to kill 100 per cent of the treated insects.

4. Pyrethrum was found to be very effective against bedbugs, while pyrethrum stems were of little or no practical value.

5. Tobacco powders, containing as high as 5.26 per cent of nicotine, were found to be of little or no value.

6. Hellebore was found to be absolutely ineffective against bedbugs.

7. Twenty miscellaneous powdered mixtures containing more than one active ingredient were tested and found to be more or less effective, depending on the amount of the active ingredients present.

8. Acetic acid, ammonia water, coal-tar oil (chlorinated), cottonseed oil, glycerol, kerosene, linseed oil, nicotine, oil of pine needles,—sabadilla seeds, turpentine and mercuric chlorid were found to be effective.

9. Twenty miscellaneous materials were found to be ineffective.

10. Sulphur fumigation, at the rate of 0.97 pound to 1,000 cubic feet of room space, was found to kill 100 per cent of the treated insects.

11. Three miscellaneous fumigants were found to be ineffective.

12. Phosphorus pastes proved to be of no value against bedbugs.

13. Kerosene was found to be effective, and gasoline and mercuric chlorid ineffective, against bedbug eggs.

COCKROACHES.

METHODS OF TESTING.

Two methods were employed in testing various materials against the common roach (*Blattella germanica* L.): (1) Badly infested rooms or kitchens were dusted or sprayed, and (2) cages were dusted or sprayed. The latter tests were made in wooden cages $11\frac{1}{2}$ inches long, $9\frac{1}{2}$ inches wide, and $2\frac{3}{4}$ inches deep, with top and bottom made of fine-mesh screen wire. For each test the entire interior of two or more of these cages was thoroughly dusted or sprayed with the substance to be tested. Twenty roaches, together with a small amount of bread for food and a few paper scraps to furnish hiding-places, were then added. At least two untreated cages, each containing 20 roaches with food and paper scraps, were used as a check with each set of tests. If the check showed a mortality of more than 20 per cent at the close of any series of tests, the experiment was discarded. However, it was rarely necessary to discard tests on this account, since the mortality of roaches confined in cages is almost negligible. Records were taken at the end of 24 hours, and as often afterwards as was considered necessary. The tests generally were closed at the end of one week, but in some cases observations were continued for longer periods.

It is considered that this method of testing, i. e., dusting or spraying the cage before inclosing the roaches, approximates the conditions that are met with in treating rooms, where only a very small proportion of the insects can actually be hit with a spray or powder, and therefore it is assumed that the real value of a given substance is determined by the number killed through coming in contact with it after it has been applied, rather than by the number killed through direct application. These cage tests, of course, are open to the objection that they are much more severe on the roaches than are the conditions which obtained in the room tests, since every part of the cage can be thoroughly treated, while many parts of a room will not be thoroughly sprayed or powdered, and many of the insects may not come in contact with the substance applied.

A limited number of fumigation tests were made in rooms or boxes. For the purpose of closely comparing the rapidity of the killing properties of two or more powders, tests were made by dipping the insects into the powder and placing them in empty vials where the effect of the substance could be noted.

ACTION OF MATERIALS ON ROACHES.

Upon careful study of the habits of roaches it has been found that these insects frequently cleanse their legs and antennæ. When any dirt or powder comes in contact with the appendages, these are at once drawn through the mouth parts of the insects and in this way cleaned. As a result, a certain amount of any powdered substance applied directly to a roach, or through which it may crawl, is thus taken into the mouth. In this way any poison, whether distasteful or not, finds its way into the stomach. Therefore it is not necessary to mix a stomach poison, in powdered form, with an attractive bait, since the chances are much greater that the poison will reach the stomach of the roach through its habit of cleansing itself than through the eating of the poisoned bait.

True contact poisons, as, for example, mineral-oil sprays, kill by coming in contact with the body. This may result (1) through direct application or (2) by coming in contact with the roach after it has been applied.

Certain substances, such as sodium fluorid, will act both as contact and as stomach poisons.

Substances also may kill through gases given off, as in the fumigation tests.

KILLING EFFECT OF POWDERED SUBSTANCES USED AS DUSTS AGAINST ROACHES.

SODIUM FLUORID.

In Table II are given the results of tests with sodium fluorid in kitchens and lunch rooms.

TABLE II.—*Results of tests with sodium fluorid against roaches in badly infested kitchens, bakeries, lunchrooms, milk-bottle exchanges, etc.*

Test No.	Per cent sodium fluorid.	Other ingredients.	Number used.	Duration of test.	Per cent killed.
1	100		Many	48 hours	100
2	100		do	do	100
3	100		do	do	100
4	100		do	do	100
5	50	Wheat flour, 50 per cent	do	do	100
6	50	do	do	5 days	98
7	50	Ground flint, 50 per cent	do	24 hours	100
8	50	do	do	48 hours	95

As will be noted in Table II, sodium fluorid, when used undiluted in badly infested kitchens and lunchrooms, kills practically every roach within 48 hours, and there is almost no reduction of this efficiency when it is used with equal parts of some inert substance, as flour or ground flint. The substitution of ground flint for wheat

flour did not decrease the effectiveness of sodium fluorid, and it is apparent also that the addition of a bait for the purpose of tempting the roach to eat the poison is not necessary. The insects are killed just as quickly through taking the fluorid into the system while cleansing the appendages as though eating poisoned bait.

In addition to the foregoing room tests, many cage tests were made in which sodium fluorid was mixed with lime or some other inert substance in varying proportions, ranging from 1 to 100 per cent. Under these conditions it was found that a mixture containing as low as 18 per cent of sodium fluorid killed all of the insects within 24 hours. Such low percentages as 5, 3, and 1 per cent were effective, but failed to kill 100 per cent, even when the tests were continued for 7 days.

Sodium fluorid proved the most effective of all the materials tested. While it acts primarily as a stomach poison, it may act also as a contact poison to a slight degree.

PYRETHRUM POWDER.

In tests of 22 different samples of pyrethrum powder (powdered flowerheads of *P. cinerariaefolium* and *P. roseum*) all were found to be very effective against roaches treated in cages, and no practical difference in value was found between the powders made from open, half-open, and closed flowers, or between the wild and cultivated flowers. Tests made during the winter of 1912 with pyrethrum powder from the crops of 1908, 1909, and 1910 showed no practical difference in their efficiency, thus indicating that this powder does not deteriorate materially in four years.

Pyrethrum stems, ground, were found to have no insecticidal value, and their addition to pyrethrum powder is certain to reduce its effectiveness.

The general effect of pyrethrum powder on roaches is to paralyze them and render them inactive almost at once, and, although slight movements of the legs and antennæ may continue for as long as 48 hours, a roach that has been thoroughly dusted will not recover.

Pyrethrum powder is not nearly as active against roaches as is sodium fluorid. Sodium fluorid may be diluted greatly and yet kill quickly, whereas pyrethrum powder when mixed with only a small percentage of inert matter kills very slowly. Therefore, in practice, it appears necessary to use unadulterated pyrethrum powder for effective results.

BORAX.

Borax, when used under average room conditions, was found to be partially effective, but can not be relied upon in cases of gross infestation.

Under the severe conditions attending the cage tests borax killed all of the treated roaches in from 4 to 7 days, when the amount of borax was not less than 12 per cent. With 10 per cent of borax or less, all were not killed in 7 days.

Borax as an insecticide acts very slowly, and satisfactory results against roaches, in most cases, can be obtained only when the material is repeatedly and persistently used.

Tests were made also to determine whether borax acts against roaches as a stomach poison or as a contact poison. In two tests bread which had been soaked in a saturated solution of borax was allowed to dry, and was then placed in the regular roach cages in large pieces, no other food being added. In the first of these tests all of the insects were dead at the end of 11 days, and in the other 70 per cent were killed in 16 days. In another test a mixture of 50 per cent borax and 50 per cent corn meal was moistened and allowed to dry in firm cakes, which were placed in the roach cage. In this test 75 per cent were killed in 16 days. In the untreated cages only 5 per cent were dead at the close of the experiment. Since, in these tests, there was very little opportunity for the borax to affect the roaches, except when taken internally with food, it would appear that the action of borax is primarily that of a stomach poison. This view is strengthened by the fact that borax was found to be ineffective against 8 species of sucking insects and effective against 7 species of chewing insects.

TOBACCO POWDERS.

In tests with nine different tobacco powders, in which the nicotine content ranged from 0.025 to 5.26 per cent, it was found that they were of no value against roaches. While nicotine is a stomach poison, it is evident that the roaches did not get enough of the powder, which carries only a small percentage of nicotine, to cause death.

PLASTER OF PARIS AND FLOUR.

Thorough tests were made of the method of killing roaches that has been quoted so often, namely, feeding the roaches a mixture of plaster of Paris and flour and furnishing them water to drink. The supposed effectiveness of this method is based upon the theory that the roach eats the mixture and then drinks the water, the plaster of Paris "setting" in the intestines and killing the roach.

A mixture of 25 per cent plaster of Paris and 75 per cent flour was fed to about 100 roaches on a table surrounded by a trough of water, the water being accessible to the roaches. Observations for nine days showed that none had been killed. This mixture was re-

placed with a mixture of 50 per cent plaster of Paris and 50 per cent flour, the roaches being allowed to remain on the table. Observations for 30 days showed that none had been killed, and they appeared as lively and healthy as when placed on the table. The presence on the table of innumerable roach droppings in the form of elongated white pellets of hardened plaster of Paris is conclusive evidence that the mixture was freely eaten, but that the plaster of Paris did not "set" until after it had left the intestines.

These tests demonstrate that the "plaster of Paris and flour treatment" is of no value against the common roach or "Croton bug," and would throw grave doubts upon its effectiveness against any other species of roaches.

MISCELLANEOUS POWDERS PARTIALLY EFFECTIVE AGAINST COCKROACHES.

Table III gives the results of tests with miscellaneous powders.

TABLE III.—*Results of tests with miscellaneous materials which were found to be effective against roaches.*

Test No.	Active ingredients.	Inert ingredients.	Kind of test.	Number used.	Duration of test.	Per cent killed.
					Days.	
1	Alum, 100 per cent		Cage	80	7	60–80
2	Arsenious oxid, 8.98 per cent	Sodium oxid and paper.	do	40	7	60–80
3	Arsenious oxid, 61.01 per cent	Sucrose, 35.28 per cent.	do	15	7	100
4	Arsenious oxid, 86.93 per cent	Talc, 13.07 per cent.	do	40	4–7	95–100
5	Arsenious oxid, 76.14 per cent, and barium carbonate, 22.89 per cent, mixture.	do	do	15	3	100
6	Barium carbonate, 100 per cent	do	do	40	3	100
7	Barium fluorid, 100 per cent	do	do	40	10–14	100
8	Do	do	Room	Many.	14	98–100
9	Boracic acid	do	do	Many.	7	50–60
10	Calcium fluorid, 100 per cent	do	Cage	20	7	95
11	Do	do	Room	Many.	14	95
12	Copper sulphate, 100 per cent	do	Cage	40	8	80–90
13	Hellebore (*Veratrum* sp.), 100 per cent.	do	do	120	7–14	85–100
14	Mercury bichlorid, 1.09 per cent	Ethyl and methyl alcohol.	do	140	7	30–65
15	Mercury bichlorid, 100 per cent	do	do	20	1	100
16	Mercury bichlorid, 5.72 per cent, and phenol, 1.44 per cent, mixture.	Water	do	40	8–14	100
17	Paradichlorobenzene, 100 per cent	do	do	40	2–7	100
[1] 18	Do	do	Room	40	2	48
[2] 19	Sabadilla seeds, powdered, 10 per cent.	Corn meal, 90 per cent.	Cage	80	19–34	70–100
20	Sodium silicofluorid, 100 per cent	do	do	100	5–7	75–100
21	Do	do	Room	Many.	14	67

[1] Fumigation.

[2] Furnished as food.

All of the materials given in Table III were active in varying degrees, killing from 48 to 100 per cent.

Although it would appear that several of these materials were satisfactorily effective, the fact that in the cage tests, in most cases, they required from 4 to 14 days to kill all of the treated roaches in

a given cage, shows that they act too slowly to commend themselves for general use. Barium carbonate and mercuric chlorid are the only materials that would appear to warrant further tests, and there is no indication that they will approach the effectiveness of sodium fluorid.

As only one of these mixtures (test No. 3) contained any substance that might serve as a bait, it is evident that their efficiency must be due to their being taken into the mouth by the roach when the appendages are cleaned. This conclusion is strengthened by the results of dipping tests, where roaches dipped in arsenic trioxid or sodium arsenite died in less than 48 hours.

It should be emphasized that arsenious oxid and mercury bichlorid are far too poisonous to human beings to be generally used as roach remedies under average dwelling conditions.

Hellebore, while poisonous to insects when taken internally, acts so very slowly that it can not be classed as a roach remedy.

In the test of paradichlorobenzene 8½ pounds of this material were exposed for 44 hours at a temperature of about 80° F. in a room the capacity of which was 846.5 cubic feet. The roaches were placed on the floor in two cages, and even this heavy fumigation, with the insects fully exposed, failed to kill 50 per cent.

MISCELLANEOUS POWDERS INEFFECTIVE.

The following list of various powdered materials tested, unadulterated, was found to be ineffective against roaches. Not less than 40 roaches were used in the cage tests, and the experiments were continued for at least a week. The room tests were made in badly infested rooms or kitchens and were generally continued for seven days. The method of testing is indicated in parentheses after the name of the material.

Miscellaneous powders ineffective against cockroaches.

Allspice (cage).
Angelica root (cage).
Anise seed (cage).
Barium sulphate (cage).
Calcium carbonate (cage and room).
Calcium hydroxid (room).
Calcium oxid (cage and room).
Calcium sulphate (cage and room).
Camphor (cage and room).
Cassia (cage).
Chamomile flowers (cage).
Charcoal (room).
Cloves (cage).
Colocynth pulp (cage and room).
Cornstarch (room).
Corn meal (room).
Dolomitic lime (cage).
Eucalyptus leaves (cage).
Ferric oxid (room).
Ferrous oxid (room).
Flint, ground (cage).
Fuller's earth (room).
Gypsum (cage and room).
Lead carbonate (cage and room).
Lime, air-slaked (cage and room).
Magnesium carbonate (room).

Miscellaneous powders ineffective against cockroaches—Continued.

Magnesium oxid (room).
Pepper, cayenne (cage).
Potato starch (room).
Quassia (cage and room).
Road dust (cage and room).
Rosin (cage).
Silica (room).
Sodium bicarbonate (cage and room).
Sodium carbonate (cage and room).
Sulphur, refined (room).
Sulphur sublimated (cage and room).
Wheat flour (room).

EXPERIMENTS WITH LIQUIDS AND PASTES.

KILLING EFFECT OF PHOSPHORUS PASTES.

Ten phosphorus pastes (proprietary), ranging from 0.14 per cent to 2.33 per cent, were tested against roaches in cages, but none of them proved effective. Several of them did kill from 50 to 90 per cent, but since, in most cases, the tests were continued for at least seven days, and in no case were all roaches killed in this time, it can be seen that these pastes, even under the most severe conditions and when no other food was available, were not effective to the extent that would be considered satisfactory.

In addition to the cage tests, two of the pastes were tested in badly infested kitchens, and were still less effective. A few dead roaches were found in the kitchens 24 hours after the application of the pastes, but in no case did it appear that more than 10 per cent had been killed, nor was the infestation greatly reduced. The pastes used in the kitchen tests, however, contained only 1.01 per cent and 1.34 per cent of phosphorus.

Under certain conditions, where all food can be kept from the roaches for several days and the phosphorus paste used liberally, it may give satisfaction. The senior writer observed the use of phosphorus paste against roaches, which, in the absence of other food, fed on certain of the young, tender plants in a greenhouse of the War Department. Two or three roaches were seen eating the paste, and the manager of the greenhouse claimed to get entirely satisfactory results from the use of this substance against this insect. This material, however, can not be relied upon for general use under average conditions.

HYDROCARBON OILS.

Numerous hydrocarbon-oil preparations, consisting essentially of oils of the nature of gasoline or kerosene, or some heavier oil, to which, in certain cases, had been added small amounts of nitrobenzene or phenols, were tested against roaches in cages. All of these sprays were found to be effective.

In considering the effectiveness of these oil sprays, due weight must be given to the fact that in cage tests the roaches are placed in the

sprayed cages before the oil has dried and that they are obliged to remain on, or near, surfaces that are well wet with the oil. Under room conditions many of the insects are hiding in cracks and crevices, and often escape being hit by the oil at the time of application. If they remain in hiding until the oil has dried, which may be from one to several hours, they escape death, but those venturing out before the oil has dried are killed by contact with it. Owing to the chance that many may escape contact with the oil, such sprays, while effective, are less satisfactory than sodium fluorid.

The addition of nitrobenzene or phenols does not appear to increase the effectiveness of the mineral oil.

COAL-TAR CREOSOTE EMULSIONS.

Tests were made with many coal-tar creosote emulsion preparations, undiluted, and in dilutions ranging from 1 part of the emulsion in 10 parts of water to 1 part of the emulsion in 100 parts of water. When applied undiluted the emulsion killed all of the roaches within 24 hours, but as the dilution was increased the effectiveness decreased rapidly, so that when the dilution was greater than 1 part emulsion to 20 parts of water the material proved only slightly effective, or ineffective.

Both cage and kitchen tests indicate that such emulsions should not be diluted more than 1 part in from 20 to 25 parts of water.

FUMIGATION AGAINST ROACHES.

SULPHUR.

Five tests were made with sulphur as a fumigant, the dosage ranging from 4 ounces to 55 ounces per 1,000 cubic feet. The number of tests was so small that no definite conclusions as to the effective strength are drawn. The tests showed, however, that roaches can be killed by sulphur fumigation, and indicate that the minimum amount of sulphur to be used for 1,000 cubic feet (10′ by 10′ by 10′) is about 9 ounces.

NICOTINE.

Nicotine, when used as a fumigant, was found to be of no value against roaches. A dosage of as much as 8 ounces of tobacco extract (40 per cent nicotine, as sulphate) to 1,000 cubic feet failed to kill them. A much greater strength than this would probably be effective, but the cost would be prohibitive.

SUMMARY.

1. Sodium fluorid was found to be the most rapid killer of roaches of all the substances tested. Only 24 hours were required to kill 100 per cent in cage tests, even when the material was diluted down to

18 per cent content. Practically 100 per cent were killed in treated kitchens by the use of a mixture containing 50 per cent of sodium fluorid.

2. Pyrethrum powder, pure, killed practically all of the roaches within 48 hours in cage tests. Its effectiveness was greatly reduced when slightly diluted.

3. Borax, unadulterated, and in combination with inert matter wherein there was less than 12 per cent borax, required from three to seven days to kill all of the roaches in cage tests, proving it to be very slow. Borax, used alone, was only partially effective in kitchen tests.

4. Phosphorus pastes were partially effective in cage tests and only slightly effective in room tests.

5. The various hydrocarbon-oil sprays, undiluted, killed from 80 to 100 per cent in treated cages.

6. Coal-tar creosote emulsions, undiluted, killed all in cage tests, but their effectiveness fell very rapidly when even slightly diluted with water.

7. Tobacco powders containing as high as 5.26 per cent of nicotine were found to be ineffective in cage tests.

8. The plaster of Paris and flour mixture was ineffective against roaches.

9. Alum, arsenious oxid, barium carbonate, barium fluorid, boracic acid, calcium fluorid, copper sulphate, hellebore, mercury bichlorid, paradichlorobenzene, sabadilla seeds, and sodium silicofluorid were found to be more or less active against roaches.

10. Thirty-eight miscellaneous materials were found to be ineffective.

11. Sulphur fumigation, at the rate of 9 ounces of sulphur to 1,000 cubic feet, was effective.

12. Nicotine fumigation, at the rate of 8 ounces of tobacco extract (40 per cent nicotine, as sulphate) to 1,000 cubic feet, was ineffective.

CLOTHES MOTHS.

SPECIES USED IN EXPERIMENTS.

There are two important species of clothes moths occurring in the United States, the webbing or southern clothes moth (*Tineola biselliella* Hum.) and the case-making clothes moth (*Tinea pellionella* L.). The former species was used exclusively in the experimental work on account of its abundance in Washington, D. C., its larger size, and the fact that it readily leaves its case when disturbed.

METHODS OF TESTING.

Against the adults.—Many cage tests were made against the adults in the laboratory, as follows: Twenty large, well-ventilated cages

were maintained, allowing 20 separate tests to be carried on at one time. Each cage was made of tulip, or what is commercially known as "whitewood," which, on account of its almost complete lack of odor and volatile oils, should be unobjectionable to moths. The inside dimensions of the cages were: Length, 3 feet; width, 2⅓ feet; depth, 10 inches. In the top a door, 3 feet by 1½ feet, covered with fine-mesh copper wire, provided means of entrance and ventilation, and at the back and at one side were screened apertures as further means of ventilation.

In each cage at the beginning of a test were placed three whitewood boxes, each 10 by 10 by 8 inches, fitted with sliding covers. A quantity of all-wool flannel, in pieces about 6 by 12 inches, was placed in each box. Flannel in two boxes was treated with the material being tested, while that in the third box was untreated and served as a check. The boxes containing the treated flannel were kept on one side of the cage; the untreated box on the other side, in order to minimize any chance of odors from the treated flannel affecting the untreated. The sliding covers were about three-fourths closed to exclude light and, at the same time, leave ample room for entrance of moths.

Finally, from 10 to 20 adult moths were placed in the large cage, the door quickly fastened, and the whole left in a quiet room. After a week or so more moths were often added to the cage, depending upon the available supply. The cage was fairly light; boxes fairly dark; and, as moths have a decided aversion to light, this condition tended to attract them to the boxes. The tests ran at least a month, sometimes longer, the purpose being to secure a maximum number of eggs hatched into larvæ large enough to be accurately counted. At the time results were recorded the number of dead moths, of living and dead larvæ, and of unhatched eggs was noted. The number of live larvæ found on the treated flannel, compared with the number found on the untreated flannel used as a check, determined the protective[1] value of the substance against moth infestation.

In addition to the cage tests, several room and trunk tests were made against the adults to approach more nearly practical conditions.

Against the larvæ.—The substance being tested was applied to the infested flannel in trunks, boxes, open battery jars, and closed bat-

[1] The word "protective," used in connection with these tests, is a rather broad term and is purposely used as such. At the time of testing the object was to determine whether materials used against moths as "repellents" had any so-called "repellent" effect upon the adult moth. Observations showed that, in the majority of cases where the effective remedies were used, adults were found to have entered boxes containing treated flannel, and often the number of dead ones there present, at the time of examination, equaled the number dead in boxes containing untreated flannel. It would appear, then, that the substances used did not act as repellents, but that moths entered boxes containing treated flannel and were either killed by the fumes or remained there until death occurred from other causes.

tery jars. Two lots of larvæ, treated, and one lot, untreated, made up each test. The usual duration of each test was one week, it being assumed that if the material used did not kill in that time it would be of no practical value.

Against the eggs.—Large pieces of flannel were placed in a jar containing many adult moths, and when the moths had deposited numerous eggs on the flannel it was taken out and cut into pieces in such a manner that each piece contained 10 or more eggs. The material to be tested was thoroughly applied to the pieces of flannel containing the eggs, and the treated flannel was then placed in open jars. An untreated lot, serving as a check, was used in each test. Observations were made at the end of 10 days to 2 weeks.

EXPERIMENTS AGAINST CLOTHES MOTHS.

NAPHTHALENE: EFFECT ON CLOTHES-MOTH ADULTS.

In two cage tests, as described, the flannel in the treated boxes was dusted with naphthalene flakes, and 10 adult moths were liberated in each cage. Examination made four weeks after treatment showed that the flannel in the treated boxes was entirely free from infestation by clothes-moth larvae, whereas the flannel in the untreated boxes was badly infested. Two other cage tests were made, in which naphthalene in the form of cakes or "bricks" was used, with the same result.

A room approximating 1,000 cubic feet was used for a "protective test" with naphthalene on a large scale. Three of the above-described small whitewood boxes containing flannel were placed in opposite corners of the room. About one-half pound of naphthalene flakes was placed in box No. 1; about one-fourth pound of naphthalene flakes in box No. 2; and one-fourth pound of naphthalene balls in box No. 3. Two boxes containing untreated flannel were used as checks. One hundred and forty adult moths were liberated in the room, which was made sufficiently tight to prevent their escape. At the end of $2\frac{1}{2}$ months all of the treated boxes were entirely free from infestation, while the untreated boxes contained many living larvæ.

A duplicate room test was made, one lot of treated flannel being placed in a closet in the room, and the closet door being allowed to remain open. Again, all treated flannel remained free from infestation, while on the untreated flannel 80 live larvæ were counted.

Several trunk tests were made. In the first series flannel, to which was added naphthalene flakes at the rate of one-fourth pound to 5 cubic feet, was placed in a trunk of average size. Forty adult moths were liberated in the trunk, and the lid closed. Examination at the end of eight weeks disclosed no larvæ on the flannel, and all of the adults dead. In an untreated trunk serving as a check, in which the

same number of adults were liberated, the flannel was badly eaten by larvæ, and a large number of live larvæ were present. In a duplicate test, in which naphthalene balls were used at about the same rate, the results were identical.

A second series of trunk tests was made, in which three trunks of average size were used, and adult moths were liberated in the trunks from time to time during the course of the experiments. In trunk No. 1 three-fourths pound of naphthalene flakes was scattered over the flannel and over the bottom of the trunk. Ten moths were added every two weeks, from May 7 to July 21, making a total of 70 moths used. Two months later (Sept. 20) examination developed that the flannel was unhurt, and no living adults, no larvæ, or eggs were found. In trunk No. 2 one pound of naphthalene balls was used, and moths were added as in trunk No. 1. The results were the same as obtained with the flake naphthalene. In the check (untreated) trunk the flannel was badly eaten at the close of the experiment, hundreds of live larvæ and 7 live adults being present.

To determine the rapidity with which adults are killed by confined fumes of naphthalene, a third series of trunk tests was conducted. Ten moths were placed in each of three tight trunks containing flannel and in each case a reasonable amount of naphthalene flakes was added. In from two to six days, all of the moths were dead.

NAPHTHALENE: EFFECT ON CLOTHES-MOTH LARVÆ.

Battery jars and trunks were used to test the effect of naphthalene on the larvæ. In the battery-jar tests jars of 216 cubic-inch content were used. From 10 to 20 larvæ, one-half to three-fourths grown, were placed upon a piece of all-wool flannel in each jar, and a liberal amount of naphthalene was applied to the entire piece of flannel. Two lots of larvæ, treated, and one lot, untreated, made up each test. The forms of naphthalene so tested were (1) one test of coarse flakes, (2) four tests of fine flakes, (3) one test of balls, and (4) one test of cake or brick. In each test the jars remained open. At the end of 7 days each of these substances was found to have killed from 85 to 100 per cent of the larvæ, and of the few remaining alive some were inactive. The flannel, in all cases, was undamaged.

In a second series of jar tests 10 half-grown larvæ were placed on flannel in each of five battery jars, which were tightly covered with heavy paper. To the 5 jars naphthalene flakes were added at the rate of 2, 4, 8, 20, and 40 grams, respectively, per cubic foot. At the end of one week the 2 and 4 gram applications had killed 90 per cent, and in every case all larvæ had been killed by the heavier dosages. In the untreated jars, serving as checks, only 5 per cent of the larvæ were dead. From observations on the effect of naphthalene on the

larvæ in these jar tests it was concluded that the naphthalene killed much more effectively and rapidly when the fumes were confined by covering the jars.

In trunk tests against larvæ fresh flannel and 25 larvæ, half-grown, were placed in a lantern globe, the two ends of which were covered with cheesecloth. This lantern globe was placed in a trunk of average size, in which naphthalene flakes at the rate of one-fourth pound to 5 cubic feet were sprinkled, and the lid closed. The use of the lantern globe was to prevent the naphthalene from coming in contact with the larvæ, so that any action noted on the larvæ would be from the effects of the fumes. Examination at the end of 32 days showed that all the larvæ were dead. The flannel was found to be very slightly eaten, showing that some of the larger larvæ had, no doubt, survived long enough to feed slightly. A duplicate test was made, in which naphthalene balls were used at about the same rate, with identical results. In an untreated trunk, serving as a check, to which the same number of larvæ had been added, were found many adult moths and more than a hundred larvæ, and the flannel was badly eaten.

The results of these tests indicate that the killing effect of the naphthalene is due principally to the fumes.

A second series of trunk tests was made, using three trunks of average size, in which larvæ were added at intervals during the course of the experiment. In trunk No. 1 three-fourths pound of naphthalene flakes was scattered over the flannel and the bottom of the trunk. Ten larvæ, half to full grown, were added every 2 weeks for 10 weeks, making a total of 50 larvæ used. Two months after the last lot of larvæ was added examination showed that none had pupated, there had been only very slight feeding on the flannel, and all had been killed.

In trunk No. 2 one pound of naphthalene balls was used, and larvæ were added from time to time as in the test with trunk No. 1. The results were the same as those obtained in the use of naphthalene flakes, except that there was no feeding on the flannel, which was due, no doubt, to the fact that a larger quantity of balls than flakes was used.

In the check trunk (trunk No. 3), at the close of the experiment, numerous moths and larvæ were found and the flannel was badly eaten.

NAPHTHALENE: EFFECT ON CLOTHES-MOTH EGGS.

Pieces of flannel about 1 inch square, containing 10 or more clothes-moth eggs, were thoroughly dusted with naphthalene flakes and placed in two open battery jars. Observations made 10 days later

showed that none of the eggs had hatched, while in an untreated jar 16 young larvæ and 2 unhatched eggs were found.

In a duplicate test, in which naphthalene balls were placed on the flannel, the results were identical.

From the results of the foregoing experiments it will be seen that naphthalene kills all stages of the clothes moth very effectively.

CAMPHOR.

Effect on clothes-moth adults.—Gum camphor, broken into small pieces, was used at the rate of about 5 ounces to 5 cubic feet, in a trunk containing flannel. Thirty moths were liberated in the trunk, and the lid closed. Examination made 32 days later showed no living adults and no larvæ, and the flannel had not been fed upon. Cage tests with this substance showed a variation in efficacy from 65 to 100 per cent as compared with the untreated flannel.

Effect on larvæ.—Twenty-five half-grown larvæ were placed on clean flannel in a trunk, and gum camphor was added at the rate of about 5 ounces to 5 cubic feet and the lid closed. Thirty-two days after treatment all of the larvæ were found to be dead, and the flannel had been slightly damaged from feeding.

Gum camphor scattered on infested flannel in an open jar killed 60 to 67 per cent of the larvæ in about 7 days.

Effect on eggs.—In two tests in open battery jars gum camphor killed all of the eggs, when sprinkled on pieces of flannel containing 10 or more eggs.

While camphor proved effective in varying degrees against the various stages of the clothes moth, close observations made during the course of the experiments show that it is much less active than the different forms of naphthalene.

RED-CEDAR CHEST.

Effect on clothes-moth adults.—A red-cedar chest of 10 cubic feet capacity was utilized. No record of the date of manufacture of the chest could be obtained. On May 6, 1915, 10 adult moths and a supply of flannel were placed in the chest. Ten more moths were added every two weeks until a total of 70 was reached. Two months after the last moths were added examination showed that all had been killed and that no eggs or larvæ were present.

Two years later (1917) 30 moths and a supply of flannel were added to the same chest. Observations made nine weeks after the experiment was started revealed no living adults, no eggs, and no larvæ. In a trunk, serving as a check, to which the same number of adults were added at the same time, more than 50 live larvæ were counted on the flannel at the close of the experiment.

Effect on larvæ.—The cedar chest above described was used also for a test against larvæ. In 1915 flannel was placed in this chest, and 10 one-half to three-fourths grown larvæ were added every two weeks until a total of 60 was reached. Examination made two months after the last addition of larvæ showed seven live larvæ; 36 larvæ had died and 17 had pupated. Of the 17 pupæ 2 died in the pupa stage and 15 emerged as moths, but died before any eggs were laid. The flannel had been fed upon considerably, but was not badly eaten.

Two years later (1917) this experiment was duplicated by adding 25 one-half to three-fourths grown larvæ at one time and allowing the experiment to run 33 days. The results were almost identical with those of the first experiment.

Effect on eggs.—A small piece of flannel containing many clothes-moth eggs was placed in the cedar chest described above. At the end of 23 days practically all of the eggs had hatched, but all of the resulting larvæ died almost immediately. A duplicate test was made, with identical results. The check flannel placed in a battery jar showed many eggs hatched and all larvæ alive.

The results of the foregoing tests indicate that adult clothes moths and young clothes-moth larvæ are killed when placed in a cedar chest, but that the larvæ one-half to full grown may live for a considerable length of time, and even, in some cases, reach the pupa stage and emerge as moths. It was observed in all tests that very little feeding was done.

RED CEDAR SHAVINGS AND CHIPS.

Effect of red-cedar shavings and chips on clothes-moth adults, larvæ, and eggs.—In cage tests cedar shavings and chips did not entirely prevent the moths from laying eggs on the treated flannel, yet they showed an apparent protective power when the treated flannel was compared with the untreated.

When cedar shavings and chips were thoroughly applied to larvæ more than one-fourth grown, they had no killing effect, but were somewhat effective against very young larvæ. Cedar chips burned in a fumigating box, at the rate of 2½ grams to 13 cubic feet, were not effective against larvæ.

Cedar chips proved ineffective in preventing the hatching of eggs.

Red-cedar leaves were entirely ineffective in killing larvæ and preventing moth infestation. The oil of cedar leaves, however, proved very effective for both purposes.

In addition to the above forms of cedar, very small boxes having an approximate content of 432 cubic inches (¼ cubic foot), made of freshly cut red-cedar lumber, were used for certain tests. Adult

moths were killed in from three to four days when confined in these boxes. From 18 to 25 days were required to kill 85 to 90 per cent of the half-grown larvæ when placed in the boxes.

PARADICHLOROBENZENE.

Effect on clothes-moth adults and larvæ.—Paradichlorobenzene killed only 30 per cent of the adult moths and none of the larvæ placed in a room of 846 cubic feet capacity. Eight and one-half pounds of paradichlorobenzene was exposed in 6 dishes for 21 hours, and during this time one-half pound of the material evaporated. A liberal amount of paradichlorobenzene scattered on infested flannel in an open jar killed all of the exposed larvæ in 20 hours.

In boxes, trunks, or closets this substance would, no doubt, be very effective, when used liberally, as indicated by its rapid killing effect against clothes-moth larvæ when confined in a small space; but owing to rapid evaporation its effectiveness would not last nearly as long as that of naphthalene.

PYRETHRUM POWDER.

Effect on clothes-moth larvæ and eggs.—Pyrethrum powder was found to kill 100 per cent of larvæ on infested flannel, even when used in proportions as low as 4 parts of pyrethrum powder to 96 parts of flour.

Two tests were made with pyrethrum powder against clothes-moth eggs. Whether or not the eggs were prevented from hatching has not been determined definitely. If any hatched, however, the resulting larvæ died immediately, since 16 days after treatment no larvæ were found and the flannel was not damaged.

While no test with pyrethrum powder was made against adult clothes moths, it is safe to say that the powder would kill the adults. Clothing thoroughly dusted with pyrethrum powder would be protected from larvæ resulting from any eggs that might be present.

HYDROCARBON OILS AND OIL EMULSIONS.

Effect on clothes-moth adults.—Various oils of the nature of kerosene have proved very effective in preventing infestation of larvæ, resulting from moths liberated in cages, as described on pages 16 and 17. However, flannels treated with oil emulsions at dilutions varying from 1 part of emulsion in 65 parts of water to 1 part of emulsion in 250 parts of water were not protected from infestation. It is necessary to use such emulsions either undiluted or only slightly diluted if satisfactory control is to be expected.

The vapors evolved from kerosene in a closed jar killed adult moths in 2½ hours, the experiment being so arranged that the moths were not in contact with the oil.

Commercial crude carbolic acid, used at the rate of 1 part of the acid to 10 parts of water, proved effective in protecting flannel from moth infestation.

Effect on larvæ.—Experiments with three different oils of the nature of kerosene, and one experiment with gasoline sprayed on pieces of flannel infested with larvæ, resulted in the killing of all larvæ in each case. Oil emulsions proved of little value, when diluted as much as 1 part of the emulsion to 65 parts of water, against larvæ, as well as against adults. Oil emulsions should be used either undiluted or only slightly diluted.

Commercial crude carbolic acid, used at the rate of 1 part of the acid to 10 parts of water, killed 85 per cent of the larvæ on badly infested flannel.

The vapors evolved by kerosene in a closed jar killed larvæ in 4½ hours, the experiment being so arranged that the larvæ were not in contact with the oil.

Effect on eggs.—Two pieces of flannel, each containing 10 or more clothes-moth eggs, were sprayed with gasoline, with the result that all of the eggs were killed. Also, 3 and 5 per cent solutions of commercial crude carbolic acid killed all eggs in similar tests.

SOAP.

Effect on clothes-moth larvæ.—Fish-oil soap, used at the rate of 1 pound of the soap to 12, 25, and 40 gallons of water, killed all of the larvæ when sprayed on infested flannel. Laundry soap in two tests, in which it was used at the rate of 1 pound to 10 gallons of water, killed all of the larvæ.

Effect on eggs.—Laundry soap was sprayed on eggs on flannel, the strengths used being 1 pound of soap to 10, 20, and 40 gallons of water. The strongest solution killed most of the eggs, but the two weaker solutions were entirely ineffective.

The above results with soap indicate that spraying or washing clothing with strong soap solution will free it from larvæ and eggs of the clothes moth.

NICOTINE EXTRACTS AND TOBACCO POWDER.

Effect on clothes-moth adults.—Flannel dusted with powdered tobacco leaves containing 4.56 per cent nicotine remained free from moth infestation in a single cage test, the untreated flannel, under the same conditions, becoming infested with 12 larvæ. Tobacco powders containing 0.4 per cent and 0.8 per cent of nicotine were not effective in preventing infestation in cage tests. Since the average tobacco powder found on the market contains a great deal less than

4 per cent of nicotine, this substance should not be depended upon for protection of clothing against moth attack.

No tests with nicotine extract were made to determine its value in protecting clothing from moth infestation in the presence of adults.

Effect on larvæ.—In Table IV are shown the results of 18 tests with several forms of nicotine in varying dilutions.

TABLE IV.—*Tests of the killing effect of nicotine solutions and tobacco powders against clothes-moth larvæ.*

Test No.	Nicotine, amount and form.	Dilution in water.	Treated.		Untreated.	
			Number of larvæ used.	Per cent dead.	Number of larvæ used.	Per cent dead.
1	13 per cent as extract	1 to 125	20	5	10	20
2	do	1 to 125	10	40	10	10
3	12 per cent as extract	1 to 32	20	20	10	20
4	do	1 to 32	20	10	10	10
5	do	1 to 32	20	5	10	40
6	40 per cent as sulphate	1 to 100	20	[1] 30	10	20
7	do	1 to 100	10		10	10
8	do	1 to 75	20	15	10	20
9	do	1 to 75	10	20	10	30
10	do	1 to 50	20	30	10	30
11	do	1 to 50	10	30	10	20
12	do	1 to 25	10	50	10	40
13	do	1 to 25	20	55	10	30
14	0.41 per cent in tobacco dust	Undiluted	20	5	10	
15	0.8 per cent in powdered stalks	do	20		56	6
16	3.14 per cent in powdered plant	do	20		50	8
17	3.38 per cent in powdered leaves	do	20	10	10	
18	4.56 per cent in powdered leaves	do	20	20	50	6

[1] Of those dead, 25 per cent probably drowned, as water was found in the jar.

It is seen that every form of nicotine, at the dilutions used, failed to kill an appreciable number of larvæ, and since the greatest strength used was 1 part of tobacco extract (40 per cent nicotine, as sulphate) to 25 parts of water, it is apparent that to kill a higher percentage the preparation would have to be used very slightly diluted or undiluted. This evidently would not be practical on account of the comparative cost and the danger of staining woolens.

Effect on eggs.—A nicotine-water solution (40 per cent nicotine), used at the rates of 1 part of the mixture to 25 and to 50 parts of water, killed all of the eggs on sprayed flannel. When the proportion of water was increased to 75 parts, 2 eggs hatched in one test and none in the other. The two larvæ resulting from the hatched eggs died almost immediately. When a dilution of 1 to 100 was used in 2 tests, one egg hatched in one test and two in the other, the resulting larvæ dying almost immediately. No greater dilutions were used, but the results indicate that when used at a much greater dilution than 1 to 100, the material would not be effective against the eggs. Owing to the expense of such a substance its use would be prohibitive.

MISCELLANEOUS MATERIALS.

Effect on clothes-moth adults.—Lavender flowers, cayenne pepper, and allspice are of no value in preventing moth infestation.

Cloves and oil of lavender were effective in protecting flannel from moth infestation.

Effect on larvæ.—Miscellaneous substances found to be effective against larvæ are as follows:

Alcohol (ethyl), 95 per cent solution used as a spray. Cloves, used as a dust. Sodium fluorid, used as a dust.

Miscellaneous substances found to be ineffective against clothes-moth larvæ are as follows:

Allspice (dusted).
Angelica root (dusted).
Borax (dusted).
Colocynth pulp (dusted).
Eucalyptus leaves (dusted).
Formaldehyde (sprayed 1 to 10).
Hellebore, white (dusted).
Lavender flowers (scattered on).
Lead carbonate (dusted).
Lead oxide (dusted).
Lime [air-slaked] (dusted).
Pyrethrum stems (dusted).
Quassia chips (dusted).
Sodium bicarbonate (dusted).
Sodium carbonate (dusted).

Effect on eggs.—Sulphur, salt, and borax were of no value in preventing hatching of clothes-moth eggs, when thoroughly sprinkled on infested flannel.

Formaldehyde killed the eggs when used undiluted and when diluted with 5 parts of water, but when used at the rate of 1 part to 10 parts of water eggs were not killed.

At 50 and at 70 per cent a solution of ethyl alcohol destroyed the viability of eggs, but at 30 per cent a solution was ineffective.

FUMIGANTS.

Effect on clothes-moth adults and larvæ.—In Table V are recorded the results of fumigation tests with miscellaneous materials.

TABLE V.—*Results of fumigation tests with miscellaneous materials against adults and larvæ of the clothes moth. Tests made in a fumigating house containing 360 cubic feet of space.*

Test No.	Name of material.	Amount.	Method of application.	Number used.		Percentage killed.	
				Adults.	Larvæ.	Adults.	Larvæ.
		Grams.					
1	Charcoal	265	Burned with forced draft	.....	10	.....	0
2	Formaldehyde	65	Evaporated over lamp	10	10	0	0
3	Paraformaldehyde	23	.....do.....	20	20	0	0
4	.....do.....	65	.....do.....	20	20	30	5
5	Sulphur	208	Burned with wick	15	10	100	20
6	.....do.....	243	Burned in retort	.....	10	.....	100
7	Sulphur and carbon, equal parts	228	.....do.....	20	20	50	0

As will be noted, sulphur burned in the form of a candle, at the rate of 208 grams to 360 cubic feet, killed all adults in 18 hours. The combination of sulphur and carbon in equal parts, when burned at the rate of 228 grams to 360 cubic feet, killed 50 per cent of the adults in 18 hours. Sulphur fumes killed larvæ in house fumigation when used at the rate of 243 grams to 360 cubic feet, but was ineffective at weaker strengths.

Formaldehyde in solution and in crystalline form (paraformaldehyde) failed to kill a majority of the adults and was of no value against larvæ.

HEAT.

Effect on clothes-moth larvæ.—The effect of heat on larvæ was tested by placing the infested flannel in an incubator. Ten larvæ were used in each case, with the results shown in Table VI.

TABLE VI.—*Effect of heat on clothes-moth larvæ.*

Length of exposure.	Degree of heat.	Result.
Minutes.	°*F.*	
6	128	All killed.
11	120	Do.
31	110	Do.
11	110	30 per cent killed.
31	105	20 per cent killed.

A single test made by exposing a piece of flannel containing many larvæ in the sun for six hours, the developing temperature ranging from 80° F. to 105° F., resulted in the death of all larvæ.

Effect on eggs.—The effect of heat on clothes-moth eggs was tested in the same manner as described above for larvæ, 10 or more eggs being present on each piece of flannel. See Table VII.

TABLE VII.—*Effect of heat on clothes-moth eggs.*

Length of exposure.	Degree of heat.	Result.
Minutes.	°*F.*	
6	128	All killed.
6	125	Do.
11	120	Do.
31	110	Do.
11	110	None killed.
31	105	Do.

A single test made by exposing for six hours a piece of flannel containing many clothes-moth eggs to the sun in the same manner as described for larvæ resulted in the killing of the eggs. The temperature of the flannel during the exposure rose from 80° F. to 105° F.

HOT WATER.

Effect on clothes-moth larvæ and eggs.—Both larvæ and eggs of the clothes moth were killed by dipping infested flannel for 10 seconds in water at a temperature of 140° F. When dipped for the same length of time in water at a temperature of 122° F., however, neither the larvæ nor the eggs were killed.

SUMMARY.

1. Naphthalene was uniformly effective in protecting woolens from clothes-moth infestation and in killing all stages of the insect.

2. Camphor, though more or less effective against all stages of the clothes moth, proved considerably less active than did naphthalene.

3. A red-cedar chest readily killed all adult moths and showed considerable killing effect upon young larvæ. It did not prevent the hatching of eggs, but killed all the resulting larvæ almost immediately.

4. Red-cedar chips and shavings, while not entirely effective in keeping the adult moths from laying eggs on the flannel treated, appeared to protect it from appreciable injury when used liberally. The chips and shavings showed practically no killing effect against eggs, or against the larvæ when over one-fourth grown.

5. Paradichlorobenzene was not effective against adults and larvæ in a room fumigation test of 21 hours duration, but killed larvæ effectively in battery-jar tests.

6. Pyrethrum powder readily killed clothes-moth larvæ.

7. Various mixtures of oils were effective in protecting clothing from infestation, when used undiluted or but slightly diluted, and killed 100 per cent of the larvæ when used undiluted.

8. Laundry soap killed both larvæ and eggs when used in strong solution.

9. Various tobacco extracts containing nicotine and tobacco powders, when used at reasonable strengths, proved of no value against this insect.

10. Lavender flowers, cayenne pepper, and allspice were ineffective and cloves and oil of lavender effective in protecting flannel from moth infestation.

11. Powdered cloves, sodium fluorid, and 95 per cent alcohol, undiluted, killed larvæ.

12. Allspice, angelica root, black pepper, borax, cayenne pepper, colocynth pulp, eucalyptus leaves, formaldehyde, hellebore, lead carbonate, lead oxid, lime, quassia chips, sodium bicarbonate, and sodium carbonate were of no value in killing clothes-moth larvæ.

13. Borax, salt, and sulphur did not kill clothes-moth eggs; 50 per cent and 70 per cent solutions of ethyl alcohol and a 16 per cent solution of formaldehyde killed the eggs.

14. Fumigation with sulphur proved effective in killing both adults and larvæ.

15. Heat killed both larvæ and eggs when they were exposed in an oven for 31 minutes at 110° F., and in less time at higher temperatures.

16. Hot water killed both larvæ and eggs when infested flannel was dipped for 10 seconds in water at a temperature of 140° F.

CARPET BEETLES.

SPECIES USED IN EXPERIMENTS.

There are two well-known species of carpet beetles in the United States, both injurious to woolen fabrics, but, in contrast to the clothes moths, generally attacking the heavier fabrics, such as carpets and blankets. One species is known as the "carpet beetle" or "black carpet beetle" (*Attagenus piceus* Oliv.) and the other as the "carpet beetle" or "buffalo bug" (*Anthrenus scrophulariae* L.). The former species, on account of its greater abundance in Washington, D. C., was used in the experimental work.

METHODS OF TESTING.

The methods used in testing the insecticide materials against the carpet beetle were essentially the same as used in the clothes-moth tests described on pages 16 and 18.

EXPERIMENTS AGAINST CARPET BEETLES.

NAPHTHALENE.

Effect on carpet-beetle adults.—Two cage tests with naphthalene flakes and two with naphthalene balls, 30 adult beetles being used in each test, resulted in complete protection of the treated flannel in all cases, while the untreated flannel was infested with from 5 to 13 living larvæ.

Two trunks containing flannel were used in tests against the adult beetles. In one trunk naphthalene flakes were applied at the rate of one-half pound to 13 cubic feet, and 40 beetles were added; in the other naphthalene balls were applied at the rate of one-half pound to 10 cubic feet, and 30 beetles were added. Four weeks after treatment all of the beetles were dead and no larvæ were present in the trunk treated with naphthalene flakes. No live adults, but 3 live and 2 dead larvæ, were found in the trunk treated with naphthalene balls, 8 weeks after treatment, and the flannel was not damaged. In an

untreated trunk there were several live larvæ, and the flannel was slightly damaged at the close of the experiment.

In 5 closed battery-jar tests, in which the adults were tightly confined with a small amount of naphthalene, they were killed in from 2 to 5 days.

Effect on larvæ.—Coarse naphthalene flakes, fine naphthalene flakes, and finely powdered naphthalene, dusted on larvæ infesting flannel, killed 90 to 95 per cent in open-jar tests.

In a closed trunk naphthalene flakes sprinkled on the bottom, at the rate of one-half pound to 13 cubic feet, killed, in 32 days, all of 25 larvæ placed on flannel in a lantern globe, the two ends of which were covered with cheesecloth to prevent the larvæ from coming in direct contact with the naphthalene. The flannel had not been noticeably injured. Naphthalene balls used against larvæ in the same manner, at the rate of one-half pound to 10 cubic feet, gave the same results. The check trunk showed 8 per cent of the larvæ dead and the flannel badly eaten.

These results indicate, as in the case of clothes moths, that the killing effect of naphthalene is due principally to the fumes liberated.

Effect on eggs.—In two open battery-jar tests with naphthalene flakes, applied to small pieces of flannel containing 10 or more eggs each, no eggs were found to have hatched at the end of 11 days. An average of 13 live larvæ was found on the untreated pieces of flannel.

In two similar tests, in which naphthalene balls were used, the results were identical.

Naphthalene was found to be very effective in protecting flannel from infestation by carpet beetles and in killing adults, larvæ, and eggs.

CAMPHOR.

Effect upon carpet-beetle adults.—In a cage test with gum camphor, in which 35 adults were used, no larvæ were found upon the treated flannel at the end of about one month, while 22 live larvæ were found upon the untreated flannel. In a duplicate test, in which 30 adults were used, 1 live and 2 dead larvæ were found at the end of 30 days.

Thirty adult beetles confined in a tight trunk containing one-half pound of camphor to 9 cubic feet were dead at the end of 30 days, and no larvæ were found to be present. In an untreated trunk 10 live larvæ were found at the end of 30 days, and the flannel had been slightly eaten.

Five closed battery-jar tests, in each of which 5 to 10 beetles were tightly confined with flannel treated with a small amount of camphor, resulted in the killing of 80 to 100 per cent in from 4 to 7 days.

Effect on larvæ.—A trunk test against larvæ was made, using camphor at the rate of one-half pound to 9 cubic feet. Twenty-five larvæ on flannel in a lantern globe were added. Observations showed, at the end of one month, that 72 per cent of the larvæ had been killed. In an untreated trunk only 8 per cent were dead in one month.

Camphor sprinkled over larvæ on flannel in open battery jars killed only a small percentage. In tests with the jars sealed, all the larvæ were killed in from 15 to 29 days, but none were killed in seven days. Only 15 per cent died in the untreated jars in 29 days.

Effect on eggs.—In two tests with camphor scattered on flannel containing 10 or more eggs, no larvæ were found to have hatched in 11 days, while an average of 13 live larvæ was found on the untreated pieces of flannel used as a check.

Camphor, although effective against the various stages of the carpet beetle, was not as uniformly efficient as was naphthalene. Since camphor kills more slowly and volatilizes much more rapidly than does naphthalene, its use is not recommended when naphthalene is available.

RED-CEDAR CHEST.

Killing effect on carpet-beetle adults, larvæ, and eggs.—Thirty adults and a large piece of flannel were confined in a red-cedar chest of 10 cubic feet capacity. At the end of 60 days examination showed that all adults were dead and that one live and more than 100 small dead larvæ were present. No noticeable injury had been done to the flannel.

Twenty-five half to full-grown larvæ, placed upon flannel, were confined in the chest for 60 days. At the end of that time none were found dead, and the flannel had been slightly eaten.

Two pieces of flannel, each containing 10 or more eggs, were inclosed in the chest for 23 days. At the end of that time examination showed 14 small dead larvæ on each piece of flannel. The flannel was not damaged. Although the cedar chest failed to kill the eggs, the newly hatched larvæ died almost immediately.

The cedar chest readily killed newly hatched larvæ, but failed to kill adults before eggs were laid and also did not kill one-half to full-grown larvæ. This cedar chest was the same one used in the clothes-moth test.

CEDAR CHIPS.

Effect on carpet-beetle adults.—Cedar chips were employed in three cage tests, about 30 adult beetles being used in each. Examination of the three tests 30 days later showed an average of 10 live larvæ on the treated flannel and an average of 16 live larvæ on the untreated.

Thirty adults, with a large piece of flannel, were inclosed in a trunk, to which had been added cedar chips at the rate of one-half pound to 9 cubic feet. At the end of 8 weeks all the adults were dead and no larvæ were present. The check trunk showed 10 live larvæ and the flannel slightly eaten.

Adults placed in closed battery jars with flannel treated with cedar chips resulted in the killing of 80 to 100 per cent in 7 days.

Effect on larvæ.—Red-cedar chips were placed in a trunk at the rate of one-half pound to 9 cubic feet. Twenty-five half to full-grown larvæ were added and the trunk closed immediately. At the end of 56 days no larvæ were dead, and the flannel was considerably eaten.

Effect on eggs.—Red-cedar chips were used in open battery jars against the eggs. After 9 days larvæ were observed on the flannel, but were not counted.

Apparently red-cedar chips were not very effective against the different stages of the carpet beetle. Clothing would be protected by the use of cedar chips only when used very liberally.

PYRETHRUM POWDER.

Effect on larvæ and eggs.—Pyrethrum powder was used in four tests against larvæ on flannel in open battery jars. An average of 27.5 per cent was killed in about a week.

Two tests were conducted with pyrethrum powder against larvæ on flannel in large-stoppered bottles. Of a total of 20 larvæ used, 90 per cent were killed in about one week. Fifteen per cent of the larvæ on untreated flannel in stoppered bottles died in the same time.

Two pieces of flannel, each containing 10 or more eggs, were placed in battery jars and dusted with the powder. At the end of 26 days no larvæ were found on the treated flannel, although the eggs may have hatched and the young larvæ have been killed almost immediately. An average of 13 live larvæ was found on the untreated pieces of flannel.

Pyrethrum powder proved considerably less effective against carpet-beetle larvæ than against clothes-moth larvæ.

HYDROCARBON OILS AND OIL EMULSIONS.

Effect on carpet-beetle adults, larvæ, and eggs.—A 10 per cent solution of carbolic acid showed moderate protective value against carpet-beetle adults in cage tests, while a 5 per cent solution proved ineffective.

Mineral oils and oil emulsions of the nature of kerosene killed all the larvæ when used undiluted. The oil emulsions proved effective

when diluted not more than 1 part to 10 parts of water. Against eggs, in two tests each, a 3, 5, and 10 per cent solution of crude carbolic acid appeared to prevent hatching.

SOAP.

Effect on carpet-beetle larvæ and eggs.—Fish-oil soap, used at the rate of 1 pound to 4 and 8 gallons of water, killed 100 per cent of the larvæ. When used at the rates of 1 pound to 10, 16, and 25 gallons, from 75 to 90 per cent were killed, while weaker solutions proved ineffective. Practically the same results were obtained by the use of laundry soap.

Laundry soap, used at the rate of 1 pound to 10 gallons of water, appeared to kill all carpet-beetle eggs in two tests. When used at the rates of 1 pound to 20 and 40 gallons of water it was not effective against the eggs.

NICOTINE SOLUTIONS AND TOBACCO POWDERS.

Effect on carpet-beetle larvæ.—Table VIII shows the results of tests with nicotine in various forms against the carpet-beetle larvæ.

TABLE VIII.—*Tests of the killing effect of nicotine solutions and tobacco powders upon carpet-beetle larvæ.*

Experiment No.	Nicotine, amount and form.	Dilution in water.	Number of tests.	Treated.		Untreated.
				Total number of larvæ used.	Average per cent dead.	Average per cent dead.
1	40 per cent nicotine as sulphate	1 to 10	2	20	100	6
2	do	1 to 25	2	20	60	6
3	do	1 to 50	2	20	20	6
4	40 per cent nicotine as extract in nicotine-water solution.	1 to 25	2	20	75	.....
5	do	1 to 50	4	40	47.5	.....
6	do	1 to 100	2	20	5	.....
7	12.5 per cent nicotine in nicotine-water solution.	1 to 125	3	30	70	10
8	11.6 per cent nicotine in nicotine-water solution.	1 to 32	8	80	72.5	4
9	4.56 per cent nicotine in tobacco dust	Undiluted	2	20	5	.....
10	0.41 per cent nicotine in tobacco dust	do	2	20	5	.....

As will be noted, it was necessary to use a tobacco extract (40 per cent nicotine, as sulphate) diluted at the rate of 1 part to 10 parts of water to kill all the larvæ. All weaker dilutions used failed to kill more than 75 per cent. It is therefore apparent that nicotine sprays are not to be recommended for carpet-beetle larvæ.

Powdered tobacco, containing 4.56 per cent of nicotine, which is considerably above the average percentage of nicotine content for such powders, was ineffective against the larvæ when used as a dust.

In addition to the foregoing tests tobacco powder containing 0.85 per cent nicotine was burned in a box at the rate of 6 ounces to 360 cubic feet. None of the 15 larvæ used in this box fumigation were killed in 19 hours. The strength was increased to 26 ounces to 360 cubic feet with the result that 20 per cent of the larvæ were killed.

Effect on eggs.—A solution containing 40 per cent nicotine extract, used at dilutions of 1 part mixture to 25 and 1 to 50, killed nearly all the eggs, while dilutions of 1 to 75 and 1 to 100 were not effective.

It appears from these tests that the various forms of nicotine are of no practical value against carpet beetles.

MISCELLANEOUS SUBSTANCES.

Effect on carpet-beetle adults.—Oil of cedar leaves effectively protected flannel from carpet-beetle infestation in laboratory-cage tests. Lavender flowers were ineffective in such tests. Formaldehyde fumigation ($2\frac{1}{3}$ ounces to 360 cubic feet) proved ineffective against adults.

Effect on larvæ.—Miscellaneous substances tested against carpet-beetle larvæ and found to be more or less effective are as follows:

Alcohol (ethyl), 50–95 per cent solutions.
Cloves (powdered).
Gasoline (undiluted).
Mercuric chlorid (1 pound to 50 gallons of water).
Sulphur (burned), $8\frac{1}{2}$ ounces to 360 cubic feet.

Miscellaneous substances found to be ineffective against larvæ are as follows:

Alcohol (ethyl) 20 to 40 per cent solutions (sprayed).
Allspice (dust).
Arsenious acid (dust).
Borax (dust).
Formaldehyde (fumigation).
Hellebore (dust).
Lavender flowers (dust).
Lime (dust).
Pepper, black (dust).
Sodium fluorid (dust).
Sulphur (dust).

Effect on eggs.—Solutions of ethyl alcohol at 30, 50, 70, and 100 per cent appeared to prevent the hatching of carpet-beetle eggs. A 20 per cent solution, however, was of no value.

Borax, gasoline, mercuric chlorid (1 pound to 50 gallons of water), and sulphur failed to prevent hatching of eggs.

HEAT.

Effect on carpet-beetle larvæ.—Tests of the effect of heat were conducted by placing 10 larvæ on flannel in an incubator for varying lengths of time. The results are shown in Table IX.

TABLE IX.—*Effect of heat on carpet-beetle larvæ.*

Length of exposure.	Degree of heat.	Results.
Minutes.	*° F.*	*Per cent killed.*
10	128	100
15	125	100
30	120	100
10	120	30
30	110	0
10	110	0
30	105	0

Effect on eggs.—Ten or more eggs on a piece of flannel were placed in an incubator for varying lengths of time. The results are shown in Table X.

TABLE X.—*Effect of heat on carpet-beetle eggs.*

Length of exposure.	Degree of heat.	Result.
Minutes.	*° F.*	*Per cent killed.*
11	130	100
11	128	50
19	125	100
16	125	100
31	120	0
11	120	0
31	110	0
11	110	0
31	105	0

To kill all larvæ, a temperature of 120° F. maintained for 30 minutes was required. Higher temperatures for less time were equally efficient. To prevent all eggs from hatching, it would appear, from these limited tests, that the length of exposure is more important than the temperature. A temperature of 125° F. for 16 minutes killed the eggs, while an exposure of 128° F. for 11 minutes failed to kill all the eggs.

Two pieces of flannel, each containing 10 or more eggs, were placed in the hot sun for three hours. The temperature on the flannel ranged from 109° F. to 120° F. Observations showed that none of the eggs so exposed hatched, while practically all the eggs on the unexposed flannel hatched.

HOT WATER.

Effect on carpet-beetle larvæ and eggs.—Flannel dipped for five seconds in water at a temperature of 140° F. resulted in the killing of both larvæ and eggs, while water at a temperature of 122° F. failed to kill either larvæ or eggs.

SUMMARY.

1. Naphthalene, against carpet beetles, as against clothes moths, proved effective in preventing infestation of clothing and in killing all stages of the insect.

2. Camphor was effective against the various stages of the carpet beetle, but killed much more slowly than did naphthalene.

3. A red-cedar chest killed adults and newly hatched larvæ, but had no effect on larvæ half grown or larger.

4. Red-cedar chips proved only moderately effective against carpet beetles.

5. Pyrethrum powder proved considerably less effective against carpet-beetle larvæ than it did against clothes-moth larvæ.

6. Various mixtures of mineral oils killed carpet-beetle larvæ, when used undiluted or but slightly diluted.

7. Laundry soap killed both larvæ and eggs when used in strong solutions.

8. Nicotine solutions and tobacco powders proved of no practical value against this insect.

9. Oil of cedar leaves was effective, and lavender flowers ineffective, in protecting flannel from carpet-beetle infestation.

10. Ethyl alcohol (50–95 per cent solutions), powdered cloves, gasoline, mecuric chlorid, and fumigation with sulphur (8½ ounces to 360 cubic feet) killed the larvæ effectively.

11. Ethyl alcohol (20 to 40 per cent solutions), allspice, arsenious acid, borax, formaldehyde fumigation, hellebore, lavender flowers, lime, black pepper, sodium fluorid, and sulphur were ineffective against the larvæ.

12. Ethyl alcohol (30, 50, 70, and 100 per cent solutions) killed carpet-beetle eggs, while borax, gasoline, mercuric chlorid, and sulphur failed to kill the eggs.

13. Heat killed the larvæ, when exposed in an incubator for 30 minutes at 120° F. A higher temperature was required to kill the eggs.

14. Hot water killed both larvæ and eggs, when the infested flannel was dipped for five seconds at a temperature of 140° F.

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