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THE WAX MOTH AND ITS CONTROL

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The wax moth (*Galleria mellonella* L.) is known under many names in different sections of the United States. Beekeepers know the insect as the " wax moth ", " bee moth ", " bee miller ", " wax worm ", " web worm ", and " wax miller." It is better known in the larval or worm stage than as the adult or moth and is therefore generally referred to as the " wax worm " or " web worm."

ECONOMIC IMPORTANCE AND SOURCES OF LOSS

No careful estimate has ever been made of the damage caused by the wax moth. The losses in Texas were at one time estimated at 5 percent, and in 1911 reports from 136 Texas beekeepers placed colony losses at from 5 to 95 percent, according to Texas Agricultural Experiment Station Bulletin 231. Losses in the Southern States are considerably higher than in the North because of the longer season of bee and moth activity. Moreover, apiary practices in the South, especially that of keeping empty combs on the colonies during long, slow honey flows, increase the opportunity for wax moth damage. The complete destruction of colonies, however, does not represent the total of wax moth damage, since combs in supers may be ruined even when the colony is of fair strength. This is particularly true when two or more hive bodies are placed on the colonies during slow flows, or late in the fall for storage.

Probably the most noticeable loss from wax moth injury is in combs in storage, especially if these combs are in a warm, protected place, and consists in the destruction of the combs by the larvae, which leave them a mass of webs and debris (fig. 1). In the North such losses are more common than the destruction of entire colonies.

The larvae of the wax moth cause a considerable amount of damage each year to comb honey. The eggs of the wax moth are probably laid on the comb or section boxes before the comb-honey supers are removed from the hives, but the damage usually occurs some time after the honey has been placed in storage. The damage consists of small, rather inconspicuous tunnels and borings through the thin wax cap of the honey cells. These small holes through the cappings cause the honey to leak out, which makes the affected section unmarketable. This type of damage is sometimes termed "weeping."

A rather indirect loss that might be charged to the wax moth is the winter loss of colonies in the Southern States. Owing to the necessity of preventing wax moth damage to stored combs after

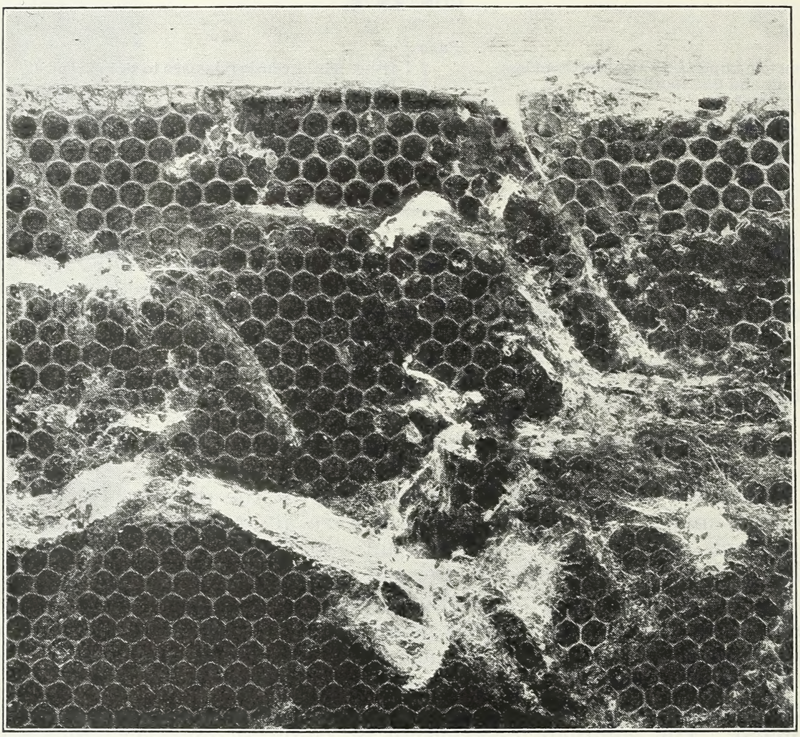

FIGURE 1.—Webs and tunnels made by larvae of the wax moth in a comb.

extracting, and the expense of storage room and treatment for such combs, many beekeepers store supers of these empty combs on the colonies during the winter. This gives added room for the bees to occupy during a warm spell, and a sudden change in temperature may chill or even kill them before they can return to the cluster. It also gives an opportunity for the dissipation of colony heat and thereby increases the quantity of food consumed by the bees, and, during long periods of cold or inclement weather, weak colonies or colonies short of stores may starve. In many such cases of starvation the wax moth destroys the combs before the beekeeper becomes aware of the death of the colony.

In any study of the economic importance of an insect, not only the loss but the benefit from the insect must be weighed. The wax moth is not an unmitigated evil. In the first place, the destruction of combs by the wax moth has not only tended to prevent the keeping of bees in box hives but has also tended to improve general beekeeping practices. The wax moth has also been an ally of the beekeeper by helping to destroy combs in bee trees or other inaccessible places, which might harbor germs of some of the brood diseases.

Since bees in box hives cannot be examined, requeened, or otherwise controlled, the colonies are likely to become weak, and under such conditions an invasion of the wax moth destroys the colony and the combs. Many States have laws to prevent the keeping of bees in box hives, and the wax moth has furthered the aim of this legislation by destroying such colonies in its spread. So thorough is the destruction of colony and combs in most box hives that, unless there are large stores of honey in the hives, bees are no longer attracted to them.

Particularly in the Southern States, where the honey flow is slow and extends over a long period, it has become a practice to give more super room at the beginning of the flow than the bees actually need. This is not the best practice if a large crop of honey is desired, and the destruction of such unprotected combs by the wax moth has been of direct benefit to beekeepers in forcing a change of method.

The destruction by wax moth larvae of combs in bee trees is probably a great aid in preventing the spread of bee disease through the robbing of honey by other bees and, in those areas where queen breeders and package shippers are located, the destruction of stray colonies has also been of real value. Since the germs of American foulbrood have been found in the excrement of wax moth larvae there is a theoretical possibility that the disease might be spread by this means, but actually there is no evidence to warrant pinning additional guilt on this pest.

The benefits of the wax moth are small, however, when compared with the losses of entire colonies and of stored combs, or the extra care and manipulation necessary to combat the insect.

HISTORY AND DISTRIBUTION

The earliest works on beekeeping contain references to the wax moth. Aristotle (384–322 B. C.), Virgil (70–19 B. C.), and Columella (middle of the first century, A. D.), all mention the wax moth as an enemy of the honeybee.

The range of foods that can be eaten by the larvae of the wax moth would suggest that it might at one time have had other foods than those obtainable in the hive, but at present wax comb in some form is practically its only food.

F. B. Paddock, who has made a study of the present-day distribution of the wax moth, was unable to determine the date of its introduction into the United States. From his distribution records some interesting inferences may be drawn: (1) The wax moth has been spread by man more than by the natural activity of the moth. The introduction of the moth into Sweden with beehives from Germany prior to 1750 and its introduction into Australia, New Zealand, and other island regions all point to the conclusion that the wax moth must have been aided in its distribution by man and by poor beekeeping methods. (2) The insect finds its most favorable conditions in the Temperate Zone. According to Paddock, the wax moth is present in Ontario, Canada, but has been unable to establish itself in Manitoba and British Columbia. The high altitudes of the Rocky Mountains are also free, but the wax moth can be found almost anywhere else in the United States where there are bees.

In the Southern States the wax moth does damage practically throughout the year, with the possible exception of December, January, and February; and during mild winters wax moths may appear even in January. It is probable that colonies are infested, at least with eggs, throughout the whole season of bee activity and that only in active colonies is wholesale damage prevented. In supers and hive bodies brought from the apiary and stored, larvae of all stages will be found, ordinarily within a week, unless the combs are treated. Under storage conditions, the lengths of the egg, larval, and pupal stages vary considerably, and the number of broods per year is largely determined by temperature and humidity. Distribution, under such conditions, is rapid because of the movement of combs and bee equipment, even without the active flight and dispersion of the adult moths.

LIFE HISTORY

THE EGG

The egg of the wax moth is small, white, somewhat elliptical, and rather inconspicuous (fig. 2). It measures about one fifty-fourth of an inch in greatest length and about one-sixtieth of an inch in greatest width. The size and shape vary somewhat, depending on the number of eggs laid in one spot and the character of the site in which they are laid.

At 75° to 80° F. the eggs hatch in from 5 to 8 days, but with low temperatures (50° to 60°) the period may extend to 35 days. Under apiary conditions the incubation period is probably almost entirely dependent on temperature.

The eggs of the wax moth are probably laid most frequently in the cracks between hive parts; that is, between supers, between hive body and bottom board, or between the super and cover. Egg masses have been found in cracks between the inner cover and top super of the hive, where they had been deposited by the female, apparently from the outside of the hive. Eggs are also laid inside the hive in more or less unprotected places. Under controlled conditions, when females were allowed access to combs, the eggs were found on the comb (fig. 2) along the edges of the frames and almost always in the portions of the hive farthest from the light. Egg masses in the hive are difficult to see and may often be overlooked.

THE LARVA

The young larvae, upon hatching, are very active and do not look like the familiar wax worms. Beekeepers have called them wood lice and have not connected the appearance of these forms with the damage from the worms, which they noticed later. They are often seen upon the inner covers of hives and in the cracks between supers and hive parts. They are less often observed within the hive, especially those with strong colonies, partly because they are very small and very active, and partly because they resemble the wax in color.

The young larvae attempt to burrow into the wax almost immediately after emergence from the egg. The first burrows are often incomplete and may be mere roughenings of the surface of the wax. After the first day, however, they make small tunnels between the cells and toward the midrib of the comb, in which the typical silken strands of the web may be found.

The growth of the larvae depends upon several factors, of which the quantity and quality of food and the temperature are most

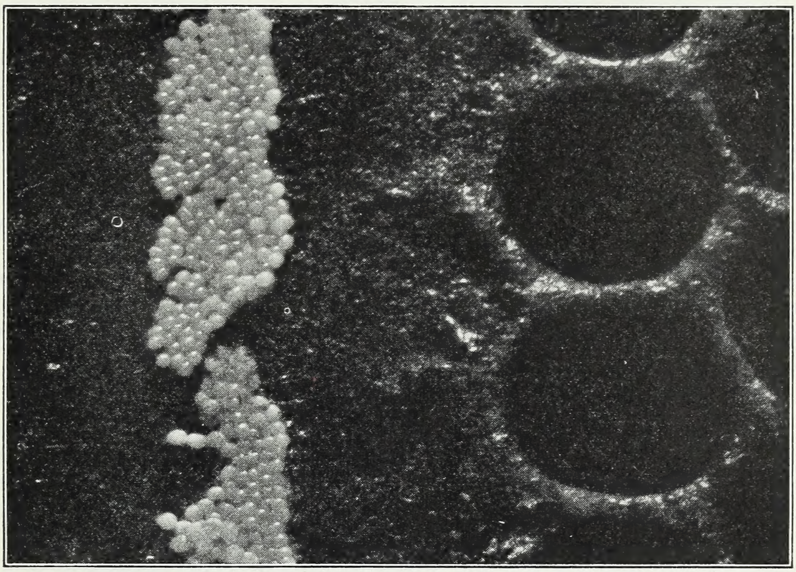

FIGURE 2.—Eggs of the wax moth laid on a comb. Greatly enlarged.

important. The length of the larval period, from the time of the hatching of the egg until pupation, has been found to range from 28 days to 4 months or even as long as 140 days or nearly 5 months. During this period the large larvae have grown from about one twenty-fifth of an inch to seven-eighths of an inch in length.

The food of the larvae is not confined to beeswax, and it is even probable that little pure wax is digested but rather that the larvae derive most of their nourishment from the impurities in the wax. Foundation, especially in frames, is seldom attacked and then usually only by the small larvae. In some cases newly emerged larvae have been seen chewing, or attempting to chew, other larvae which had been injured.

The larvae prefer the darker brood combs to the white extracting combs. In the brood combs the larvae confine their work mostly to the midrib and bases of the cells, and combs are often found with perhaps the outer one-fourth of the length of the cells untouched and the central portion, including the midrib, completely destroyed and replaced with a mass of web and refuse. Under such conditions the cells containing pollen are mostly avoided, although cells containing honey may be riddled. It is known, however, that larvae will eat pollen and develop on it. Wax moth larvae sometimes chew off the cappings of the cells containing sealed brood, and, while the bees may repair some of the damage, many cells will be left only partially closed.

Although larvae can develop on foundation, the mortality of such larvae is high, and the developmental period of those which survive is much longer than that of normally fed larvae, and the resulting adults are small and almost white. It is almost certain that damage reported by beekeepers in Louisiana as caused by the lesser wax moth (*Achroia grisella* Fab.) is caused by such poorly fed larvae of *Galleria mellonella*, since no specimens of the true lesser wax moth were observed during the author's studies. When the larvae are forced to exist on the lighter comb and the outer portions of the cells which have been left untouched by the previous broods, the damage done by them, such as the webbing and external feeding, and their later appearance greatly resemble the work and appearance of the lesser wax moth.

The optimum temperature for the development of the larvae is between 85° and 95° F., about that normally found in a beehive during the active season. At lower temperatures development is slower, but, unless the temperature falls below 60°, no other influence on the larva has been noted. At temperatures of 40° to 45° the larvae seem to become dormant, and no feeding or growth takes place.

THE PREPUPA

Before pupation the full-grown larvae spin a dense, tough, silken cocoon. Usually this cocoon is firmly attached to the side of the hive, to the frame, or other solid support, but in some cases the cocoons are found in the mass of tunnels and refuse of the wax of the frames or on the bottom of the hive (fig. 3). In many cases a hollow is chewed out of the wood of the hive or frame, and the cocoon is placed in this for added protection. Frames may be found in which holes have been bored completely through the end or top bars, and the cocoon and pupal case will be found inside these holes. This habit of the wax worm is responsible for a considerable part of the damage caused by the insect, since in heavily infested colonies not only the wax but also the frames are destroyed. In such cases particles of the wood borings are incorporated in the cocoon, which is then well disguised. The fully grown larvae migrate to considerable distances before the cocoons are spun, and pupal cases may be found beneath the hive and even on the more protected parts of the hive stand.

THE PUPA

Within the cocoon the larva changes to the pupa. The duration of the pupal stage within the cocoon ranges from 8 to 62 days, depending on temperature. As with many other insects, the pupal period allows the wax worm to pass through the fall and winter protected against climatic influence to a large extent. In the South, especially during warm winters, the adults may emerge at any time during the winter.

THE ADULT

The adult wax moths are about three-fourths of an inch in length and have a wing spread of about 1 to 1¼ inches in well-developed specimens. They are commonly seen in the resting position with their grayish-brown wings folded, rooflike, closely about them (fig. 4, *A* and *B*). The moths are not easily disturbed, but when molested they run rapidly before they take wing. The males are slightly smaller than the females and may be distinguished from them by the shape of the outer margin of the fore wing, which is smooth in the female but roundly notched in the male. The sexes

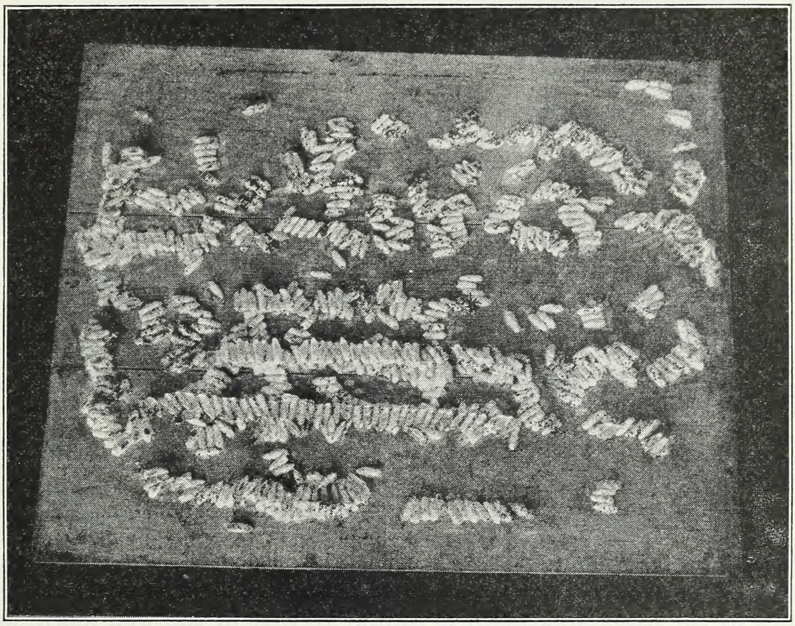

FIGURE 3.—Pupal cases, or cocoons, of the wax moth.

may also be distinguished easily by the palpi of the mouth parts, which are prominent in the female but absent in the male.

The moths vary widely in size and color, according to the type of food consumed by the larvae and to the length of time of development. Small, poorly nourished larvae, or those which, because of low temperatures or other factors, develop slowly, transform into small adults, sometimes less than half the normal size. Such small adults might easily be confused with the lesser wax moth. Larvae fed on dark brood combs transform into adults which may be dark gray to almost black, while larvae which survive on pure wax, or on foundation, transform into moths that are silvery white and smaller than those reared on brood comb.

The female starts depositing eggs from 4 to 10 days after emergence and continues depositing them as long as her bodily vitality lasts. Egg laying may be rapid at times, and as many as 102 eggs have been deposited by a female in 1 minute. The total number of eggs laid by a female varies to a considerable extent under laboratory conditions, but it is usually less than 300. The adults may live as long as 3 weeks.

NUMBER OF BROODS

It seems doubtful whether there are definite generations of the wax moth during different periods of the year in the Southern States. Rather it is probable that the moth is always present, that larvae in all stages, pupae, and adults may be found at any time, and that development goes on except during periods of low temperature.

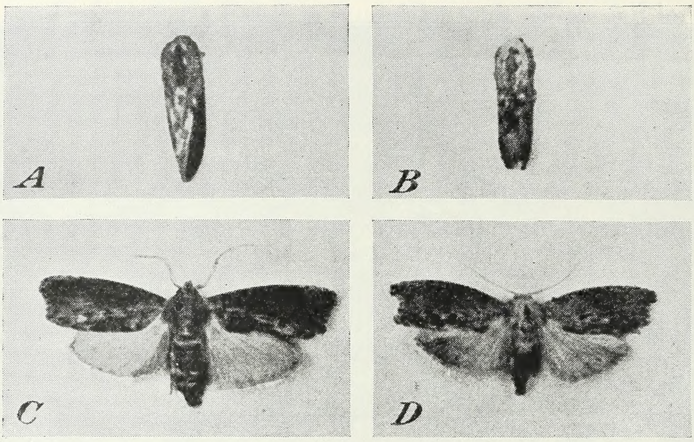

FIGURE 4.—Adults of the wax moth: *A* and *B*, With wings folded; *C* and *D*, with wings spread; *A* and *C*, females; *B* and *D*, males. Note the deep clefts in the tips of the fore wings of the male.

OTHER MOTHS CAUSING DAMAGE TO STORED COMBS

Mention has been made of the lesser wax moth, but this moth does not cause so much damage to stored combs as does the wax moth. The work of the lesser wax moth is similar to that of the wax moth, but the tunnels are smaller, the webs finer, and feeding and webbing are more confined to the outer surface of the combs. The Mediterranean flour moth (*Ephestia kuehniella* Zell.) is a pollen feeder rather than a wax feeder but does some damage to combs by boring tunnels through the midrib. This moth also tunnels into brood cells and consumes the food intended for the developing bee larvae. These moths, also, may be controlled by the methods given in this circular.

NATURAL CONTROL

The bees are the greatest and most effective natural enemies of the wax moths. They will, when the colony is strong, carry them bodily out of the hive, and there is no better insurance against the ravages of the pest than to have the combs populated with a strong colony headed by a vigorous queen.

A small red ant (*Monomorium* sp.), which seems to have a wide range of foods, has been quite effective in controlling the wax moth in laboratory experiments by feeding on resting wax moths during daylight, but it has not been observed attacking larvae in combs under apiary conditions. The ant seems more attracted to honey and pollen than to the wax moth in stored combs.

Comparatively little is known of the other insect enemies of the wax moth, and not much benefit can be expected from them.

Climatic conditions, particularly temperature, are effective in limiting the spread of the wax moth, and the rate of growth, and thereby the amount of damage done by the insect.

ARTIFICIAL CONTROL

CONTROL MEASURES UNDER APIARY CONDITIONS

Two phases of artificial control for the wax moth must be discussed, (1) the control measures for colonies under apiary conditions, and (2) control of the wax moth, or prevention of its damage, in stored equipment.

Under apiary conditions, the best control is in keeping colonies strong. Added to this should be cleanliness of hives—removal of propolis, bur combs, and refuse on the bottom board which provide protection for larvae of the wax moth. Even in strong colonies, developing larvae of the wax moth may often be found beneath the comb burs on the bottom board or in propolis and bur combs in the less accessible portions of the hives. Accidental loss of queens in such colonies late in the fall may mean the loss of colonies from wax moth damage before the first spring examination. Beekeeping practices and manipulations should be based on the assumption that the wax moth in some stage may be present in the hives at all times.

The box hive, or a hive in which the frames are not easily movable, gives the wax moth an opportunity to reproduce, and forms a breeding place from which other colonies may be attacked. From the standpoint of both productive beekeeping and wax moth control, such hives should be destroyed and replaced by modern equipment.

Control of the wax moth by trapping the adults at lights or by trap combs has not been successful. The adults are not attracted to lights and trap combs evidently are not more attractive.

CONTROL MEASURES IN STORED EQUIPMENT

For controlling the wax moth on equipment in storage, two methods of attack are possible. Some substance may be used which will kill the wax moth or some method adopted of repelling the adults so that eggs are not deposited on the stored equipment. Of the killing substances, fumigants (poisonous gases) have proved most satisfactory, but, with the exception of paradichlorobenzene, the gases do not remain in the supers long enough to have any distinct repellent action.

Fumigants for wax moth control are substances, whether liquid or solid, that form a killing gas that diffuses through the stored equipment and is taken in by the insect. Several different substances have been used with success against the wax moth, particularly paradichlorobenzene and carbon disulphide.

PARADICHLOROBENZENE

Paradichlorobenzene ("PDB") is a white crystalline substance which changes slowly into a gas. The gas is not unpleasant to smell, is noninjurious to people at the concentration obtained when used as directed, and is heavier than air. It is noninflammable and nonexplosive. It kills adults and larvae of the wax moth but is not effective against the eggs.

In fumigating with paradichlorobenzene, the supers should be stacked as tightly as possible and the cracks between supers covered with gummed paper strips (fig. 5). A generous handful of the crystals should be placed on the top of the frames of the top super and the cover put tightly in place. The crystals may be sprinkled directly on the top bars of the frames, as in figure 5, or put on a piece

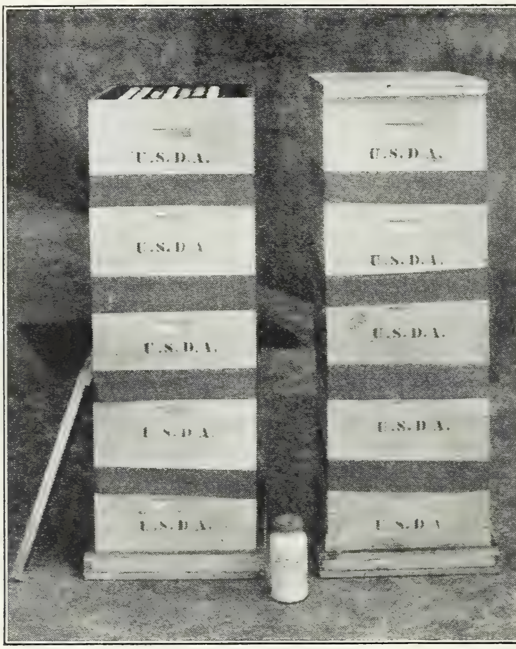

FIGURE 5.—Supers loaded with comb ready for fumigation. The joints are sealed with gummed paper tape, and the crystals of paradichlorobenzene have been sprinkled heavily over the top bars.

of paper laid on the top bars. Since the gas is nonpoisonous and not disagreeable, treatment may be made in ordinary storage without taking the infected material out of doors. At intervals during the storage season the covers of the stacks should be raised, and unless some are still present, more crystals added.

Paradichlorobenzene is at present as cheap as any of the materials mentioned in this circular, with the exception of sulphur, and is by far the easiest and least dangerous to use. The crystals last for some time, since they volatilize slowly, and not only kill the larvae and adults first present and the larvae as they hatch from the eggs, but repel moths from outside which might otherwise enter and start a fresh infestation. Paradichlorobenzene is most effective at temperatures above 70° F. and volatilizes more rapidly as the temperature rises. Inspections of stored materials should be made at intervals of 2 or 3 weeks, depending on the temperature of the storehouse and the prevalence of adult moths.

CARBON DISULPHIDE

Carbon disulphide has been a standard fumigant for wax moths and similar insects until recently, and with proper precautions is still satisfactory. As commonly sold commercially, it is a more or less yellowish, somewhat oily liquid that changes readily at ordinary temperatures into an ill-smelling gas. The liquid is about one-fourth heavier than water, and the gas is heavier than air. *It is highly inflammable, and the vapor is explosive when mixed with air in certain proportions, and therefore this chemical must not be handled around fire of any kind.* Preferably it should be used out of doors or in a well ventilated or open shed.

In using carbon disulphide the supers should be sealed in the same manner as for paradichlorobenzene. One ounce of liquid is sufficient for five supers, and more than this number of supers should not be placed in a single stack, since the weight of the gas carries it quickly to the bottom of the stack, and the top super may not be adequately fumigated. The stack should remain sealed for not less than 12 hours. Carbon disulphide is effective against larvae and adults but not against eggs; consequently, it may be necessary to repeat the treatment after any eggs have had time to hatch.

FUMIGANTS THAT ARE LESS EFFICIENT FOR WAX MOTH CONTROL

Other substances may be used for the control of the wax moth in stored equipment, but, as explained in the following paragraphs, they are not so efficient for this purpose as either paradichlorobenzene or carbon disulphide and are therefore not recommended.

The fumes from burning sulphur effectively control the larvae and adults of the wax moth but are ineffective against the eggs. Sulphur was one of the earliest of the substances used to control the wax moth in stored combs. The early method was to stack the supers over a pan of live coals over which was sprinkled powdered sulphur. About 2 ounces of powdered sulphur (flowers of sulphur) is sufficient for a stack of five supers. At least one empty super should be placed at the bottom of the stack so that the heat will not melt the combs. Present-day practice is to put the sulphur in a dish, wet it with denatured or wood alcohol, and ignite it directly. The work should be done in a well-ventilated room or out of doors, and precautions must be taken against ignition or overheating of the combs.

Calcium cyanide is effective against the larvae, pupae, and adults of the wax moth, but cannot be depended on to destroy the eggs. It is obtainable either as dust or as fine or coarse crystals. For use in fumigating bee equipment the crystals are preferable to the dust. In the presence of moisture (such as that found in the air) the crystals form a deadly gas, noninflammable and nonexplosive, *but extremely poisonous to people and animals. Care must be taken when using the substance, and the gas must not be breathed.* For use put one full tablespoonful of crystals on a sheet of paper and place the paper on the top of the frames in a super. Quickly place the other supers on top, using not more than five supers per stack, and tape the joints between supers with gummed paper tape. The fumigation should be done out of doors, or in a well-ventilated room.

Leave the stack for at least 12 hours before disturbing it, and air the supers well before storing them.

Carbon tetrachloride is effective against wax moths, but does not have enough penetrating power to kill larvae in cocoons or in thickly webbed refuse. It is a colorless liquid with a sweetish, disagreeable odor. The gas formed is heavier than that of carbon disulphide, and it is used in the same way. The gas is noninflammable and nonexplosive, but poisonous.

GENERAL DIRECTIONS AND SUMMARIZED INFORMATION ON THE USE OF FUMIGANTS

Use not more than five supers in a stack and seal the joints with gummed-paper tape to make the stack gas tight. With gases heavier than air, make sure that the base of the stack is tightly closed, since the gases sink to the bottom of the stack and may escape. A pad of newspapers placed beneath the stack will help to confine the gas.

Fumigate out of doors, if possible, or at least in a well-ventilated room. Read carefully the directions for using the selected fumigant and have everything in readiness before fumigation is begun, especially if cyanide is to be used.

CAUTION.—*Carbon disulphide gas is highly explosive, and any chance of ignition must be carefully guarded against. Both carbon disulphide and calcium cyanide and their gases are poisonous to people and to animals and must be stored and handled with extreme care.*

When using paradichlorobenzene, put the crystals directly on the top bars of frames of the top super, as shown in figure 5, or on a paper laid on the top bars, and renew them throughout the season whenever the crystals have disappeared.

As the other fumigants mentioned are not effective against reinfestation from hatching eggs, examinations must be made at intervals to see if any eggs have hatched, especially if the storage room is warm. If the temperature is above 70° F., repeat the treatment after 2 or 3 weeks. The stacks being fumigated must be kept sealed for at least 12 hours, and preferably for 24 hours.

Air the combs thoroughly before placing them on the hives.

Table 1 gives an outline for reference in fumigating against the wax moth.

CONTROL MEASURES IN STORED COMB HONEY

The control for wax moth damage to stored comb honey is the same as for other stored comb products. The supers should be removed from the colonies as soon as possible after the flow ceases and piled in tiers of not more than 8 to 10. All joints between supers should be covered with paper, and the bottom of the stack should be sealed to prevent leakage of gas. Paradichlorobenzene crystals should be sprinkled over the sections of each super as it is placed in the tier, as well as on the sections of the top super, since circulation of air is poor in such stacks. The treatment should be continued until the honey is graded and marketed. Carbon disulphide may be used according to the directions given, if desired.

TABLE 1.—*Summarized information concerning fumigants for the wax moth*

[Based on a stack of 5 supers (standard 10-frame)]

Substance	Characteristics of the gas	Quantity to be used	Approximate cost of first treatment (1934)	Length of treatment	Remarks
			Cents		
Paradichlorobenzene	Nonpoisonous to humans, noninflammable, nonexplosive.	3 ounces or 6 tablespoonfuls	4	Keep supply in stack throughout storage period.	Inspect supers at 2- to 3-week intervals.
Carbon disulphide	Poisonous to humans, highly inflammable, highly explosive.	1 ounce or 2 tablespoonfuls	4	Not less than 12 hours	Repeat once after 2 or 3 weeks.
Sulphur	Irritating	2 ounces [1]	3	do	Do.
Calcium cyanide	Extremely poisonous to humans, noninflammable, nonexplosive.	½ ounce or 1 tablespoonful	8	do	Do.
Carbon tetrachloride	Poisonous to humans, noninflammable, nonexplosive.	1 ounce or 2 tablespoonfuls	4	do	Do.

[1] The ordinary Mason-jar top holds about 1 ounce of sulphur flowers.

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