SPECIAL REPORT
OF THE
STATE ENTOMOLOGIST
OF
MINNESOTA

TO THE GOVERNOR

THE MEDITERRANEAN FLOUR MOTH

FEBRUARY 29, 1904

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THE MEDITERRANEAN FLOUR MOTH.

Ephestia kuehniella, Zell.

His Excellency, S. R. Van Sant:

Many millers are asking for information as to how to rid their mills of this much dreaded pest, which has recently appeared in alarming numbers in this vicinity, apparently for the first time. I say apparently, for, although there is no record until the present time, of its presence near here, we have reason to believe that it has from time to time appeared in various parts of the state. Naturally if a mill is infested, the matter is not discussed, and this fact makes an outbreak all the more serious, for no pest calls more for co-operation in combating, and more general consultation and comparison of results of different treatments than the Mediterranean Flour Moth. The millers have every reason to dread this insect, since it sometimes completely stops the machinery of a flour mill, and when present always calls, sooner or later, for the expenditure of much effort and much money before a mill can be free from its depredations.

The fact that a mill is new is no safe-guard against contamination from returned sacks or the introduction of eggs of the pest in secondhand machinery coming from an infested mill. Nor is a clean mill exempt for the same reason, though regular cleanings have much to do with checking its increase.

In view of the seriousness of the situation and the lack of definite information upon this subject among many of our millers, who do not know the best means of fighting the moth, and in consideration of the fact that it is a pest which may appear sooner or later in any flour mill, the entomologist has felt justified in issuing at this time a special report upon the Flour Moth, fully illustrated, giving its life history, habits, and

chief sources of infection, the best remedies and means of prevention. Copies of this report will be mailed to all millers in Minnesota.

My predecessor, Dr. Lugger, had never included this pest in any of his bulletins. In April, 1900, he printed in the Northwestern Miller a popular account of the insect, with illustrations. In this article he advised fumigation with bisulphide of carbon, a process which millers do not apparently find satisfactory. Since that time considerable advance has been made in our knowledge of methods of control, which the present report aims to place before the millers of the Northwest. There have been some experiments on the part of the entomologist bearing upon the effect upon the insect and its eggs of exposure to certain temperatures for a definite length of time, upon the effect of liquid bisulphide of carbon, and of the gas, upon the eggs, and upon the effects upon the larvae of exposure to a known volume of the gas of C. S₂ for a definite time. The colored plate, excellently true to life, was made under the writer's direction, from actual specimens, as were the original photographs which appear in the body of the report. The best remedial and preventive measures have been obtained by recent interviews with practical millers, who have used said measures successfully, the writer taking the liberty to make certain suggestions as the result of some personal observations and knowledge of the insect's habits. It has seemed desirable also to append short descriptions of some other pests found in flour mills and granaries, most or all of which, when found in mills, are killed by the same treatment which has been found effectual against the flour moth.

Description of Moth, Larvae and Egg; Its Life, History and Habits.

This moth, named *Ephestia kuehniella*, by Professor Zeller in 1879 in honor of Professor Kuhn of the University of Halle, Germany, is from 2 ¹/₅ to 3 ¹/₅ of an inch long, measuring from 3 ¹/₅ of an inch to 1 inch from tip to tip of expanded wings. Its general color, when freshly emerged from pupa,

is blackish gray, the front wings being gray, spotted with black scales, and irregular, angular black lines crossing the wing near the tips. A characteristic W shaped black line will be noted crossing the wing about half way between the tip and base; see colored plate. Fig. 1 represents the moth enlarged three times. Fig. 2, the larva which produces the moth, also three times enlarged; Fig. 3, the pupa found in the cocoon, same enlargement; Fig. 4, the head and anterior segments of the larva to show details, enlarged six times; Fig. 5, the posterior segments to show de-

Fig. 1.—Mediterranean Flour Moth, three and three-fourths times enlarged. Original.

tails, enlarged six times; Fig. 6, the dorsal view of head and thoracic segments, showing details of shield, enlarged six times; Fig. 7, abdominal foot, twelve times enlarged, showing crown of hooks; Fig. 8, freshly made cocoon, formed in flour, showing larva within, three times enlarged; Fig. 9, one fore wing, showing venation, six times enlarged; Fig. 10, a hind wing, showing venation, six times enlarged; Fig. 11, a freshly laid egg, enlarged twenty-five times. The hind wings are thin, translucent and silvery. Both fore and hind wings are heavily fringed. All the above figures refer to the colored plate, not to the illustrations in text.

The females are a little larger than the males, but the coloration of the wings of both sexes is alike. The females have a characteristic habit, upon emerging from the pupa, of remaining for hours with tip of abdomen and head raised above the level of the rest of the body; see Fig. 10. Egg laying, which lasts several days, takes place, as a rule, immediately after copulation, each female averaging about 200 eggs. These eggs may be placed anywhere, in cracks, in flour, in spouts, purifiers or other machinery, in sacks containing flour or meal, in any place, in fact, to which the moth has access.

Fig. 2.—Larvae of Mediterranean Flour Moth, four times enlarged. Original.

The larva, sometimes called "the worm" (see colored plate, also Figs. 2 and 10 in the text), is about $1\frac{1}{25}$ of an inch when first hatched, from white to pink in color, with a reddish brown head; a few very small hairs are scattered over the body. The larval life is about forty days, and when full grown it measures from $1\frac{2}{5}$ to $3\frac{5}{8}$ of an inch in length. The color becomes more pronouncedly pink than in the young larva. We have noted in the laboratory that individuals vary in color, some even appearing to have a greenish tint. There are six true legs near the anterior end of the body, and four

pairs of rather long fleshy legs on the abdomen. With a lense one can see that each one of these abdominal legs is provided with a circle of small hooks at the end (Fig. 7, colored plate). There is also a pair of so-called caudal legs at the extreme posterior end of the larva.

Little blackish or brownish spots, each bearing one or two hairs, are formed over the body, three on a side in each segment. At the anterior and posterior ends, the spots which are lower down on the side are larger and more conspicuous than the others. One spot on each side, just back of the head, is formed by an incomplete ring, its circumference being broken toward the head. A careful study of the colored plate (Figs. 4 and 5), will help one in recognizing these details. Just back of the head (see Fig. 6 of colored plate), is a conspicuous reddish brown plate or shield, divided into two parts by a middle pale line.

The larva has a pernicious habit of secreting a silken thread wherever it goes. When traveling back and forth over a smooth surface this results in a sheet of silken tissue of considerable strength, much like that seen in Fig. 6 in text, which illustrates the work of the worms on a piece of bolting cloth covering a breeding jar in our laboratory. When, however, the larvae are crawling through flour or meal the result is, as many millers know to their cost, a mass of flour held together by countless threads, forming a webbing which clogs spouts, elevator legs and other machinery to such an extent frequently as to completely stop the work of the mill. (See Fig. 5 in text.)

This larva may find its way into a perfectly clean mill in returned sacks, unless said sacks are treated in some way before being placed in mill. Second-hand machinery from an infested mill may harbor larvae or eggs. When full grown, which takes, as we have said, about forty days, the larva crawls about restlessly until it finds a place to spin its cocoon, about 1/2 inch long, within which it transforms to a pupa (Fig. 8 of colored plate; see also *b* of Fig. 10). If this cocoon is spun in flour or meal it is matted with the fine particles, as shown in the colored plate. (See also Fig. 4 in text of report.) The pupa is reddish brown, a little less than 1/2 inch long, and about

1/10 of an inch wide. The last segment of the body of the pupa is provided with a few short hairs. The length of the pupal stage within the cocoon is evidently from ten to twelve days.

The time elapsing between laying of egg, hatching of same and transformation of larva into a pupa, and the emergence of the moth, is evidently between sixty and seventy days, or an average of nine weeks for one generation.

Fig. 3.—Egg of Mediterranean Flour Moth, fifty times enlarged. Original.

The egg, oval in shape, when first laid white and almost smooth, later becoming brownish and wrinkled, is just visible to the naked eye. The eggs hatch in nine or ten days. Two freshly laid eggs, measured in the laboratory, were each .6 millimeters long by .35 millimeters broad, or about 1/42 of an inch long by 1/63 of an inch broad. We figure one of these enlarged twenty-five times on colored plate (Fig. 11). Also same egg in text, Fig. 3, enlarged fifty times.

Eggs, as well as larvae, may be brought into a perfectly clean mill in infested material, thus sowing the seed of trouble; sacks, barrels, and second-hand machinery from some infested mill being the chief sources.

One female which we had under observation in the laboratory at St. Anthony Park began egg laying February 9th, continuing until and including February 14th, five days, laying during that period 247 eggs. Copulation lasts a long time and evidently one female may mate with several males, laying eggs between the different matings.

As regards the food habits of this insect; rice flour is a dainty dish for the larvae, as is flour made from buckwheat. Any infested mill which keeps flour in sacks before shipping may hear sooner or later from the consumer or retailer that "the flour is wormy." This is caused by the female moth pushing her ovipositor through the sack and laying her eggs in the flour inside. Crackers, germea, rolled wheat, oatmeal and corn meal are all said to suffer.

The moth is evidently a continuous breeder in warm localities, in warm mills for instance. It is a well known fact that cold retards and warmth hastens its development, millers sometimes taking advantage of the first point to keep the pest in check.

Fig. 4.—*a*, cocoon from below showing pupa through the thin silk attaching cocoon to some surface; *b*, same from above, enlarged—Riley & Howard in *Insect Life*.

Dr. Fletcher of Canada, says in connection with the outbreak there, that there are probably two normal broods, one in the spring, another in the autumn, but he thinks he raised as many as three distinct broods in a warm room during the winter. F. H. Chittenden, of Washington, claims that in the warmest weather in that locality, the life cycle occupies only five weeks. Prof. W. G. Johnson states, in contradiction to Mr. Chittenden's experience, that he has been unable to get a

full grown larva in less than five weeks from the time it emerged from the egg.

Preventive Measures.

Cleanliness:

Because a mill is clean or new is no reason why the moth cannot be introduced, if sacks containing eggs or larvae, or second-hand machinery from an infested mill are allowed to enter. At the same time, scrupulous cleanliness has much to do with immunity, for eggs and larvae are dislodged by processes involved in the term, and not allowed to develop.

Fig. 5.—Flour matted together by web spun by larvae, one-half natural size.—Lugger.

Every mill, it would seem, should, and many do, have cleaners or sweepers, whose sole duty it is to see that every floor and all machinery, purifiers, spouts and elevators are kept clean. Naturally such an employe or employes should have some knowledge of insects found in flouring mills.

Fumigation House:

The writer is convinced, from talking with millers who have had experience with this pest, that the chief source of contagion lies in receiving into the mill returned sacks, and also second-hand machinery from an infested mill, which may

harbor the eggs or larvae. Some mills, in order to avoid infection, will not take back old sacks. If a milling company must do this *such material should be thoroughly treated before being allowed in the mill.* A fumigation house, or room, might be constructed, where sacks or machinery could be fumigated. If sacks have been in transit for more than nine days, and during that time free from all sources of contagion, all eggs which may have been originally in the package have hatched, hence, one need not seek for a treatment which will kill them (the eggs), but only for such as will kill the worms which have hatched from the eggs. Carbon bisulphide is the best and safest fumigating material at our disposal, and could be well used in this instance. The gas generated by this liquid, when mixed with air, is highly explosive, and no lighted match or lamp, or lighted cigar or pipe should be brought near it. As it is definitely known just how much of this liquid is required to create a "death atmosphere," the cubical contents of this room, or better, house, should be accurately determined. From experiments tried with this gas by the writer, he would suggest one part of liquid for every one thousand parts of atmosphere. To determine, if possible, whether this strength of gas would penetrate to the center of the bale in killing quantity, the entomologist inclosed "worms," pupae, and moths in vials loosely stoppered with cotton. These vials were placed in a flour sack, which was tightly rolled up. This bundle was placed in a second flour sack, which in turn was tightly rolled, and the package placed in a burlap sack and rolled again. This compact bundle with the worms in the very center was then exposed for three days, in a tight iron box, to fumes of carbon bisulphide, one part of the liquid to 1,000 parts of atmosphere. This killed every "worm," pupa and moth. The fumigation house or room *must be absolutely tight to retain the gas.* The liquid should be placed in shallow trays, and the room closed for at least three days if the sacks are left in the bale. A longer time than that, under such conditions, would be highly desirable. If the worm cannot be reached in the bale by fumigation for three or five days with the above strength, millers should be

willing to open up the bales. This involves extra handling, and means added expense, but might be an imperative necessity, for *work not thoroughly done in this connection represents time and money thrown away*. After fumigation the house or room should be thoroughly aired before allowing a light of any kind inside.

Fig. 6.—Silk felt spun by larvae in crawling across bolting cloth on top of breeding jar; showing also larvae, pupa cocoons and moths somewhat reduced. Original.

The gas from bisulphide of carbon will sink through a mass of wheat in a large bin, and also through a chestful of woolen clothing, if in each case the liquid is placed in shallow dishes on top of the wheat, or clothing. It is probable, therefore, that it will penetrate a loose bale of sacks. Possibly heat alone might be profitably used in this connection.

Fig. 7.—Adjustable metal spout.—From W. G. Johnson's Report.

Cylindrical Metal Spouts:

L. C. Schroeder of Olean, N. Y., has invented and patented a metal spout, shown in Fig. 7, which is reported as giving satisfaction, since it presents a smooth surface within, and no corners, thus being a great improvement, as regards the flour moth, over the wooden spouts which afford such an excellent opportunity for the larvae and the laying of eggs. It is claimed that the metal spouts cost less than those made of wood. This principle, for reasons which will at once be obvious to practical mill men, cannot well be applied to the elevator legs, although it is said that the same party has patented a metal elevator leg.

Belt Brushes:

Since metal elevators cannot be economically introduced into our mills as they are now constructed, an excellent device for keeping the wooden elevators clean, if we are to believe statements of those who have used them, consists of an elevator brush as shown in Fig. 8, constructed as follows:

Fig. 8.—Elevator Brush.—From W. G. Johnson's Report.

"To make the brush, take a piece of 1 1/2-inch plank of the same dimensions as the elevator cups, and fasten bristles to three sides. The side A is fastened to the elevator belt with flat-headed D bolts running through the plank, as shown at B, B, the bolts being 1/4 or 3/8 of an inch. The bristles on the sides C, C, should be 3/4 of an inch long, but those at D should be longer, so that they will give a good brushing to the outer side of the elevator. The brush is easily made, and the miller can make it of any size to fit his elevators."

Co-operation:

Co-operation on the part of all millers, particularly where mills are in the same district, seems absolutely necessary. If one fumigates returned sacks, and goes to the expense of freeing his mill of this pest, all should. Otherwise, moths from the untreated mills are almost sure to enter a cleaned mill, rendering the work of the more careful miller, in this connection, of little value. Screening windows and doors might be resorted to, and form at least a partial protection, though occasioning additional expense. Observations at the Experiment Station indicate that the moth cannot pass through the mesh of ordinary wire mosquito netting (144 meshes to the square inch.)

Freezing:

This most excellent and inexpensive method is available for Minnesota millers during almost any winter. The spouts, elevator legs, purifiers and all machinery should be first freed from masses of webbed flour, etc., left open (this does not mean the unscrewing of the sides of the elevator legs or spouts), and then all windows thrown open for a period of four or five days, after which windows should be closed and heat turned on. The importance of exposure to heat after the freezing must not be underestimated. The owners of one infested mill stopped their machinery this winter, opened all machines, spouts and elevators to allow access of cold air, and then kept their windows open for a period of four days. This was done in a time of extremely severe weather, the thermometer ranging at the time from ten degrees below zero to thirty-two degrees below, the average temperature of the mill during that period being 5 degrees below zero. At the expiration of this period windows were closed and heat turned on. Some larvae ("worms") and moths collected, and subjected to examination for several days, did not revive, killed by the extreme cold, aided possibly by the sudden change from warm to cold and cold to warm. Eggs subjected to the above freezing, and kept under observation for fifteen days and over, did not hatch; nor did the weevils, and

other pests found with the Flour Moth, survive this treatment. These statements were made to the writer; they are not his observations.

However, while millers in Minnesota can secure at some time, during almost any winter, a temperature sufficiently low to kill by freezing, yet such a condition is not always present, even in Minnesota, when wanted (if outbreak occurs in early spring and summer for instance), and surely millers in the South could rarely, if ever, take advantage of this method. The bisulphide method (not fumigation) must of necessity have to be resorted to, when temperature conditions are not favorable for freezing.

In one or two mills subjected to this freezing process fire had to be kept in the basement, and a sufficiently low temperature could not be secured, the treatment in consequence resulting unsatisfactorily. See also results of experiments by the entomologist on page 14. In one mill, however, where the entire mill was exposed to severe cold for eight days or more, the process was an absolute success.

Observations and Results of Experiments by the Entomologist.

In the short time between the report of the recent outbreak of this moth and the placing of copy in the hands of the printer, the entomological department has been able to make some observations and try a few experiments in connection with its extermination, the results of which are here given.

Mating and egg laying; time elapsing between laying of egg and hatching of same.

Pairing is evidently protracted, one isolated pair under observation remaining *in copulo* four days. Ovipositing in one case lasted six days, a female beginning egg laying on February 9th and continuing until the 15th, on which date she died. During this time *the one female* laid 247 eggs. These eggs began hatching on the 18th, nine days after the first were laid, a recording thermometer registering an average temperature of 70 degrees Fahr. in the room during that time. Two freshly laid eggs were measured, each measuring .6 millimeters in length by .35 millimeters in breadth, or, in round numbers, $1/42$ of an inch long by $1/63$ of an inch in breadth.

The flight of the Moth: The question as to whether moths would fly from one mill to another suggested observations along this line. The insects if left to themselves did not fly in the morning. Late in the afternoon and in the evening after the light was turned on, an assistant reports them flying freely across the room, although not attracted to the lights, but rather avoiding them. Observations elsewhere indicate that they will fly at least 110 feet, and probably farther.

Can the Moth get through wire mosquito netting? Moths confined for several days in a cage made of wire netting, 144 meshes to the square inch, did not escape, dying within the cage.

Effect of liquid Carbon Bisulphide on eggs, larvæ, pupæ and moths: One contact for a few seconds with this liquid killed eggs, young and full-grown larvæ and moths. The pupæ were not killed immediately, but died later.

Effect of vapor of Bisulphide of Carbon on egg: Eggs exposed directly to this gas for a few hours did not hatch.

Effect of known low temperature on the eggs: Experiment in progress when this report goes to press.

Least volume of Carbon Bisulphide (CS_2) and least time of exposure necessary to kill full-grown larvæ and moths by fumigation:

Condition of Insect.	Strength of Gas.	Time Exposed.	Results.
Full-grown larvæ	1 Part liquid CS_2 to 1,500 parts atmosphere	1 hr. 40 min.	Killed.
Full-grown larvæ	1 Part CS_2 to 3,000 parts atmosphere.....	1 hr.	Killed.
Full-grown larvæ and moth.....	1 Part CS_2 to 6,000 parts atmosphere.....	2 hrs.	Killed.
Full-grown larvæ and moth.....	1 Part CS_2 to 12,000 parts atmosphere.	3 hrs.	Killed.

Effect of exposure of moths, eggs, larvæ and pupæ to known low temperatures for definite lengths of time.

- Lot No. 1. Exposed out of doors in breeding jar, for three days, to a temperature ranging from 18 degrees above to 12 degrees below zero. All killed.
- Lot No. 2. Placed in cold storage at 32 degrees for four days. Living at expiration of that time.
- Lot No. 3. Placed in cold storage at 14 degrees above zero for four days. A few worms survived.

- Lot No. 4. Placed in cold storage at 6 degrees for four days. One or two "worms" survived.
- Lot No. 5. Placed in cold storage at 1 degree above zero for four days. All killed.
- Lot No. 6. Placed out of doors for four days, temperature ranging from 18 above to 21 below zero. One or two worms survived.

It would seem, then, from the above, and from the experience of millers cited on page 13, that the "freezing process" to be thoroughly effective must be most thorough. Mills should be so constructed that all water pipes can be emptied, allowing all parts of the mill to get extremely cold. Further, since we know that a long continued even cold temperature is not always fatal to insects (note the hibernation of Minnesota insects, for example), but that exposure to cold and thawing alternately is fatal, we would suggest that millers in this work arrange to alternate the extremely cold temperature with warm, that is, after the first exposure to cold for a few days, allow the mill to become warm and follow this with another cold exposure. The above lots, Nos. 1 to 6, were masses of matted flour containing the worms, the latter being thus somewhat protected.

Spraying with Bisulphide of Carbon.

This method, which has been very successfully practiced, consists in forcing the liquid by a syringe made for the purpose into all the machinery infested, inside of spouts, etc. Parts of the mill or fittings which do not come in contact with grain or products made from same can be well treated with kerosene, squirting it into cracks between joists, and into cracks between joists and iron braces, into cracks about windows, along baseboards, and into cracks in floor, walls and ceilings. It is evident that this must be done most thoroughly to reach all eggs or worms concealed in such places. Fig. 9 represents a syringe used for spraying the bisulphide or kerosene. It may be made of iron pipe, of brass, or of tin. It is eighteen inches long, two inches in diameter, and will hold, at those measurements, about one quart. The rose is detachable, unscrewing from the barrel, and it (the rose) is filled on the end with many very small holes, as small as the finest needle, in order that the liquid may not be wasted. In filling the syringe the rose can be unscrewed and the end of the syringe immersed in the can holding the bisulphide, or, and this is much better, a little screw cap, not shown in the illustration, may be made on the side of the rose and the

liquid drawn in through that. This is by far the best plan, for when the rose is unscrewed and the liquid drawn into the syringe it necessitates the holding of the filled barrel upright in order to screw on the rose, under which circumstances the liquid will run out below, near the handle, unless the piston rod fits very snugly.

When the syringe is used with kerosene, the rose is unscrewed and a small nozzle with one aperture, considerably larger than the holes in the rose, put on in its place. This is used when treating cracks in floors, etc.

Fig. 9.

Before the work with carbon bisulphide or with kerosene is begun, elevator legs, spouts, purifiers and all infested machinery must be thoroughly cleaned, in other words freed from all matted flour. When the spouts are lined with tin, affording a retreat for the worms beneath the tin, the wooden sides must be removed to get at the culprits. Swabs of cotton waste or pieces of old sacks should be run through the elevators (stuffing these swabs into cups), taking off caps of elevators and having men, stationed at the top, take out the ascending swabs when they reach them, and put in other swabs in the descending leg. The elevator brush, Fig. 8, might be well used in this connection, or brushes made from the same material as the belting, frayed on three sides and riveted to cups. All conveyors should be taken out and thoroughly cleaned. Purifiers and reels and insides of conveyor boxes, all machinery in fact, should be thoroughly sprayed with carbon bisulphide after having been cleaned. The cloth tubes on dust machines should be burned. In treating elevator legs with carbon bisulphide, the same method can be used as in cleaning, described above, saturating the swabs with the liquid. A swab should take up about one pint of the liquid.

All this means the expenditure of time, and money for material. An ordinary sized mill may, in this process, use from 1,000 to 1,500 pounds of carbon bisulphide, or even more, to say nothing of the large amount of kerosene employed. We are reliably informed that bisulphide of carbon can be

purchased for 6 1/2 cents per pound of a dealer in New York City and St. Louis. This price does not include container, credit for which is allowed upon its return.

Caution: The gas generated by bisulphide of carbon is inflammable. Therefore, while it is being used and until the mill has been thoroughly aired after treatment, **no light of any kind should be allowed in the mill. A lighted cigar or pipe, lantern, or lighted match, if brought into the mill when filled with gas might cause an explosion.**

Effect of the Gas on Human Beings. This liquid can be safely handled by workmen in the mill if they will take the precaution to go at once into the open air when they feel any bad effects from inhaling the gas. The mill, during this process, should be tightly closed to make the work more effective, and in consequence is filled with fumes. If these fumes are inhaled by the men for some length of time without the precaution above mentioned of going frequently to the fresh air, temporary nausea and sickness may result, while prolonged exposure to dense fumes in a tight room might result very seriously. Nature, however, gives one warning in plenty of time to avoid danger. Then, too, in a case which came under the writer's observation, men working with the stuff became more or less immune, and one individual was hardly affected at all.

As is evident, the treatment of a mill in this way should be in charge of a reliable and competent man of intelligence, one fully posted as to the nature of the chemical his men are handling.

Methods Which Have Been Tried and Found Ineffective or Less Desirable than the Preceding.

Fumigation with Bisulphide of Carbon: Although this has been the common practice in the past, and is generally recommended in cases of attack of this insect, actual experience with its use does not bear out the recommendation, in that it does not appear to kill the moths or worms under the conditions which prevail in almost every mill. It may be effective against other insect pests with which flour mills are troubled,

thus giving rise, from published report, that it is effective also against the Mediterranean Flour Moth, but we know of at least three instances where it was tried in large mills and proved valueless.

The process consists in placing pans of carbon bisulphide on the different floors, using a definite amount of the liquid (about one part to every one thousand parts of atmosphere), first making the room as tight as possible, opening up all spouts, spindles and other apparatus in which the moth or its larva is found. The chief obstacle here is the almost utter impossibility of making the large rooms air tight. Then, too, as evidenced by the testimony of a Pennsylvania miller a few years ago: "When placed in plates it does not evaporate quickly enough to produce the death atmosphere required." This firm used three hundred soup plates half filled with bisulphide and distributed throughout the mill, besides saturating balls of cotton with the same and placing them in all reels and purifiers. The mill was left from Saturday night to Monday morning, and although thousands were found dead, many thousands more appeared from cracks and corners after a few days.

Sulphur: The burning of sulphur not practical, besides injuring the flour in sacks in the mills.

Steam: Not practical, requiring too elaborate preparation, and too frequent application; seriously injuring grain or flour, and rusting machinery.

Kerosene: Good for washing walls, machinery, floors, etc., where it cannot injure flour or grain. See reference to kerosene on pages 15 and 16.

Solution of Soda and Water: Used strong for washing inside of machines.

Buhach, or Persian Insect Powder: Has been burned in a mill with only partial success, and expensive.

Ammonia: Not successful.

Hydrocyanic Acid Gas: Coming quite generally into use. Placed in this list on account of danger of application unless in the hands of experienced parties. Deadly to all animal life. Prof. W. G. Johnson, author of "Fumigation Methods,"

says he has freed a number of mills of the Mediterranean Flour Moth by the use of this gas.

Corrosive Sublimate: Not desirable.

Limc: Whitewash to which a little glue has been added excellent for ceilings and walls; the tendency to rub off can be stopped, it is said, by adding a handful of common salt, and a half teacupful of lard to each gallon of wash, which should be thoroughly strained before being used.

Sulphuric Acid: Not recommended.

Tobacco: Not particularly effective, either as smoke or infusion.

Flour Paste: Compound of flour, water and vinegar and boiled by steam found to attract insects when paste was at a certain stage of fermentation. Moths fall into paste and perish. Too expensive, and has to be renewed every few days.

Vinegar and Water: Not desirable.

Molasses and Vinegar: Will attract and destroy some moths.

"Tanglefoot" or Sticky Flypaper: Something like the sticky mixture used to coat Tanglefoot Fly paper can be made without much expense. Hundreds of moths have been caught in a single night on sticky fly paper. The paper should be placed in such places as are frequented by moths for egg laying, notably on piles of sacks filled with flour, etc. It is evident that if one can catch many female moths before egg laying, the process is well worth the expense incurred, and is a desirable measure.

Coal Tar: Not desirable.

Coal Tar and Vaseline: Better than coal tar alone. This and preceding used in the same manner as "Tanglefoot."

Hand Picking: Not feasible.

Hay Ropes: A German miller is the authority for the statement that ropes of new mown hay placed about the mill in coils afford attractive retreats for the moth. These coils were burned with the contained moths each week.

High Temperature: Exposure to a temperature of 120 to 130 degrees Fahr. for two or three hours is claimed to be fatal

to the larva in the flour, and the same temperature for five or six consecutive hours is said to kill the eggs. This may prove of practical utility.

Natural Enemies of the Flour Moth.

Mr. Johnson describes in the American Miller for November, 1895, the discovery of one parasite in America, *Bracon hebetor*, Say. In Europe *Bracon brevicornis* and *Chremylus rubiginosus* are mentioned as parasites. Poultry, seemingly fond of the "worm," has been kept in warehouses with some good effect, though the hens appeared to tire of the diet. Mr. Johnson records the eating of a large number of pupae by a mouse, but no millers care to introduce mice into their mills for this purpose. Mice, as all entomologists know, readily eat insects, whether alive, or dead and pinned.

Tribolium confusum, a little brown beetle, a common pest in flour mills, and discussed in this connection elsewhere in the report, has been known to devour the pupae of the flour moth.

The so-called "bolting cloth beetle" (*Tenebroides mauritanicus*) of California eats larva and pupa of flour moth and larva and adult of *Tribolium*.

History of the Moth and Its Geographical Distribution.

The origin of this pest cannot be stated definitely. It is probable that it always has been a widespread species, but not arousing attention until, attracted by flour and related products in mills, it changed its habits and became prominent as a menace to the flour milling industry. When first named by Zeller it was supposed by him to have been introduced from America, and it was so stated, but it was found by him in an inland town of Germany, Halle, before he knew of it at any seaport, and the same thing could be said of its first officially reported appearance in France. One miller has said with emphasis that he knew of its occurrence in Paris as early as 1840, and another claims that it was in Constantinople in 1872, both statements, coming from different sources, affording additional proof that it is not of American origin, where it was

not officially reported until 1889 (Canada). There is evidence that it was in America a few years previous to this date, not however, until long after it was known in Europe. In 1885 it was declared to be a dreaded pest in many Mediterranean ports, though no statement was made as to how long it had existed in those places. It is reported from Chili, from Mexico, New Mexico, from the island of Jamaica, and in 1890 what was evidently this species was reported from South Africa. A practical miller who has since had experience with the pest in California, asserts that it was in Schleswig-Holstein, Germany, in 1858, although the first recorded observation from Germany is in 1877. Freight cars and ships may easily be the means of carrying it, either as egg, worm or moth, to regions remote from the scene of its earlier appearance.

It would be impossible to review in this publication the extensive literature upon this pest, nor is it necessary to list the bibliographical references. In order, however, to give an idea of its spread which is approximately correct, we list the following dates taken chiefly from Johnson's bibliographical list, and under each date insert the locality or localities where the moth appeared that year, as far as reported. In some instances, the outbreak may have been in the year preceding the report, but with these few exceptions, we believe the dates are correct.

1877.

Outbreak at Halle, Germany.

1879.

Outbreak of 1877 referred to and insect named by Zeller.

1884.

Belgium. Supposed then to have been introduced in an American cereal. Reported also on lower Rhine.

1885.

Reported at Bremervörde, Germany.

1886.

Appeared in England.

1887.

London. Trieste. In the 39th Annual Report of New York State Museum of Natural History, J. A. Lintner publishes his reply to an inquiry of the German consul general at New York City, asking for information about the Flour Moth. He states that he (Lintner) knew of no such insect in America. This is believed to be the first published statement in America regarding the pest.

1888.

T. D. A. Cockerell in the Entomologist for November, 1888, page 779, declares that certain larvae found in flour which came from America may have come from infested Trieste flour in the same warehouses.

1889.

First report of its occurrence in North America, in Canada. May have been present a few years earlier. Reported as being in very destructive numbers in England.

1890.

Still present in England and spreading. A pest reported from South Africa which, from its habit, must have been this insect.

1891.

Reported in Venezuela (or a closely allied species).

1892.

California. Island of Jamaica.

1893.

On the increase in California.

1894.

Still present in California. Reported from New York State, from North Carolina, and said to have been found in meal and bran from Mexico on exhibition in Chicago.

1898.

New York State. Pennsylvania. (Reported as having been present there for three years.) New outbreak in Canada.

1899.

Wisconsin.

1900.

Wisconsin.

1901.

Minnesota.

1903.

Minnesota.

The Flour Moth is found in Illinois, in Colorado and other states; it is, in fact, of very general distribution.

Fig. 10.—Mediterranean Flour Moth; *Ephestia kuehniella*, Zell.: a, larva; b, pupa; c, adult, enlarged; d, head and thoracic joints of larva; e, abdominal joint of same; still more enlarged; f, moth from side, resting; g, front wing, showing more important markings; h, venation of fore wing; i, venation of hind wing, somewhat enlarged. (a, b, c and c, Riley & Howard in *Insect Life*; d, f, g, h and i, after Snellen.)

SOME OTHER INSECTS FOUND IN FLOUR MILLS OR AFFECTING STORED GRAIN.

1

Many of the following insects are also found in flour mills, and are frequently spoken of collectively as "weevils," which term is also sometimes, though not often, applied to the Mediterranean Flour Moth. That this is a wrong appellation is evinced by the fact that only two of the insects listed below are true weevils. Treatment which is successfully directed against the Flour Moth will kill any of the following insects, when occurring in the mill treated.

The Granary Weevil.

Fig. 11.—*a, b, c*, different stages of the Granary Weevil (*Calandria granaria*), *d*, Rice Weevil (*C. oryza*).—F. H. Chittenden, Division of Entomology, U. S. Department of Agriculture.

Fig. 11 illustrates this species and its congener, the Rice Weevil. The hair lines by each show the natural size of the

insect. The female Granary Weevil punctures a grain of wheat with her snout and lays an egg in the opening, the larva after hatching feeding upon the interior of the kernel. There may be from four to six broods of the Granary Weevil during the year, depending on the temperature. It is estimated that one pair, under favorable circumstances, will produce six thousand descendants in a year. This beetle is of a shining brown color. It cannot fly. Its cousin, the Rice Weevil, is a dull brown, its back provided with four reddish spots. It has well developed wings. In the southern states this latter weevil is a serious pest.

The Angoumois Grain Moth.

Fig. 12.—Angoumois Grain Moth, *Sitotroga cerealella*: a, eggs; b, larva at work; c, larva, side view; d, pupa; e, moth; f, same, side view.—F. H. Chittenden, Division of Entomology, U. S. Department of Agriculture.

This pest is shown in Fig. 12. It is named from a province in France, where it has been known since 1736. It is claimed to have been found in America since 1728. More injurious in the South than in the North, it attacks not only wheat in the field and bin, but is partial to all the cereals. It is a brownish moth, resembling in a general way the Clothes Moth in size and appearance.

The Indian Meal Moth.

Fig. 13.—*Plodia interpunctella*: a, larva; b, pupa; c, adult male, enlarged; d, head and thoracic joints of larva, still more enlarged.—Riley and Howard in Insect Life.

This insect, resembling somewhat the Mediterranean Flour Moth, not only feeds upon grain, flour, meal and bran in mills, but is seen in stores and elsewhere, where it affects spices, herbs, roots, seeds, dried fruit, etc.

The larvæ or "worms" which produce these moths fasten together the kernels of grain, or the seeds or other material upon which they are feeding, with silken threads. These masses, fouled with their excrement, greatly impair the value of the in-

festes foodstuffs. It is said to have from four to six or nine broods annually, depending upon the temperature of the rooms where it is found. It is shown in its various stages in Fig. 13.

The Meal Snout Moth.

Fig. 14.—*Pyralis farinalis*: a, adult moth; b, larva; c, pupa in cocoon, twice natural size.—F. H. Chittenden, Division Entomology, U. S. Department of Agriculture.

This is a brownish moth, having darker brown patches at the outer edges of the front wings. Fig. 14 gives a very good idea of its appearance; the wavy white lines bordering the dark spots are characteristically striking. The larva makes tubes of silk, to which kernels of grain (if the worm is working in grain) adhere. (See Fig. 15.) Grain kept in dry and clean places is not likely to be affected.

Fig. 15.—Silken tubes covered with wheat made by larvae of *Pyralis farinalis*, half natural size.—Lugger.

The Confused Flour Beetle.

The accompanying figure (16) gives an excellent idea of this little pest, common enough in our flour mills. The beetle is dark brown, and practically omnivorous, attacking,

Fig. 16.—*Tribolium confusum*: a, beetle; b, larva; c, pupa, all enlarged; d, lateral lobe of abdomen of pupa; e, head of beetle showing antenna; f, same of *T. ferrugineum*, all greatly enlarged.—F. H. Chittenden, Division of Entomology, U. S. Department of Agriculture.

according to Chittenden, flour, baking powder, red pepper, beans, peas, rice chaff, ginger, slippery elm, nuts and seeds

of various kinds. We have found it attacking dried insects in our cabinets. Like the other insects under discussion, a high temperature invites more rapid reproduction than when the temperature is low. It is said to attack and eat the larvae of the Mediterranean Flour Moth.

The Slender-Horned Flour Beetle.

This insect is more common in the south, but deserves a place here. Indian corn is its special food. The beetle is brown, having on its head between its eyes, two small projections, readily seen in the illustration, Fig. 17. The Broad-

Fig. 17.—*Echocerus maxillosus*: a, larva; b, pupa; c, adult male, all enlarged.—F. H. Chittenden, Division of Entomology, U. S. Department of Agriculture.

horned Flour Beetle, and the Small-eyed Flour Beetle should be added here; the first more abundant on the Pacific coast, the second abundant and injurious in bakeries, feed stores and mills.

The Yellow Meal Worm.

This, Fig. 18, is one of our more common pests in Indian meal and found in almost any mill products allowed to accumulate in neglected places. The "worm" is round, smooth, waxy as to its surface, and nearly an inch long and yellow. The adult beetles fly and are attracted to lights. Another allied form common in America, but probably introduced from

Fig. 18.—*Tenebrio molitor*: a, larva; b, pupa; c, female beetle; d, egg with surrounding case; e, antenna; a, b, c, d, about twice natural size; e, more enlarged.—Chittenden, Division of Entomology, U. S. Department of Agriculture.

Europe or Asia, is the Dark Meal Worm. The Yellow Meal Worm or its beetle, or both, are said to make holes in bolting cloth.

The Saw-Toothed Grain Beetle.

Fig. 19.—*Sitona sorinamensis*: a, adult beetle; b, pupa; c, larva, all enlarged; d, antenna of larva, still more enlarged.—Chittenden, Division of Entomology U. S. Department of Agriculture.

Very commonly, though wrongly, called "weevil." It gets its name from the little teeth on each side of the thorax. (See

Fig. 19.) The beetle is reddish brown, and frequently very common in grain, also, according to Chittenden, feeding in flour, meal, dried fruits, seeds, breadstuffs, etc., and has been reported as having been found in starch, tobacco and dried meats. One or two other allied beetles we pass over as not being abundant enough to merit discussion here.

The Cadelle.

Fig. 20.—*Tenebroides mauritanicus*, Linn.: a, adult beetle with greatly enlarged antenna above; b, pupa; c, larva, all enlarged.—Chittenden, Division of Entomology, U. S. Department of Agriculture.

Sometimes called "The Bolting Cloth Beetle," living upon grain, is blackish, one-third of an inch long, and comes from a fleshy, whitish larva with a brown head. (See Fig. 20.) Both beetle and larva attack and eat other grain or flour insects which are met with. They are, therefore, not an un-mixed evil.

ACKNOWLEDGMENTS.

The two successful methods of combating the Mediterranean Flour Moth in mills, *freezing* and *spraying with C. S.*, were told me in detail by practical millers who had resorted to these processes with happy results. To these parties my thanks are due and cheerfully given. I have not hesitated to use information contained in W. G. Johnson's article on "The Mediterranean Flour Moth (*Ephesia kuehniella*, Zeller) in Europe and America," published as an appendix to the 19th report of the state entomologist of Illinois. From Farmers' Bulletin No. 45, United States Department of Agriculture, "Some Insects Injurious to Stored Grain," by F. H. Chittenden, statements were obtained bearing upon the habits and life histories of insects other than the Flour Moth found in flour mills and elevators. A number of Chittenden's illustrations have also been used.

The Booth Packing Company of Minneapolis very courteously allowed the use of their cold storage rooms in connection with experiments on the effects of different temperatures on the pest under discussion.

Acknowledgments are also due Director W. M. Liggett and yourself for recognizing the urgency of the situation, and enabling the Entomologist to place this information before the millers of the state quickly and in proper form.

Respectfully,

F. L. WASHBURN,

State Entomologist.

February 29th, 1904.

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