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NOTES ON *CRYPTOLESTES FERRUGINEUS* STEPH., A CUCUJID OCCURRING IN THE *TRICHOGRAMMA MINUTUM* PARASITE LABORATORY OF COLORADO STATE COLLEGE

By ELWOOD H. SHEPPARD

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Notes on *Cryptolestes Ferrugineus* Steph., a Cucujid Occurring in the *Trichogramma Minutum* Parasite Laboratory of Colorado State College*

By ELWOOD H. SHEPPARD

This work is divided into two parts: Part I is a consideration of the biology of *Cryptolestes ferrugineus* Steph.; part II is a consideration of the relation of the beetle to the *Trichogramma minutum* parasite work.

This problem attracted the attention of the writer because of the occurrence of *Cryptolestes ferrugineus*** in incubators used for rearing the Angoumois grain moth at Colorado State College of Agriculture and Mechanic Arts. *Trichogramma minutum* parasites are reared on eggs of this moth.

After a thorough study of literature, the writer has come to the conclusion that no work has previously been done on the life cycle of this insect. In fact, very little literature whatever can be found on it. A few references have been discovered in which the insect is simply reported as occurring, and even fewer have been found which shed some little light upon its habits in a very general way.

Cryptolestes ferrugineus belongs to the family Cucujidae. The insect was described by Stephens about 1845. According to Leng (4), *Cryptolestes* is a subgenus of *Laemophloeus*; Casey (1), however, objects to this classification. He maintains that in *Cryptolestes*, as represented by *ferrugineus* Steph., the tarsi are similar to *Laemophloeus*, but the anterior coxal cavities are even more broadly and completely inclosed by the sterna, there being merely a fine suture between each sidepiece and the median lobe. He concludes, then, that this character, in conjunction with the narrow, parallel form of the body and the absence of eopistomal suture, shows that *Cryptolestes* is not a subgenus of *Laemophloeus* but a very distinct and well-characterized genus. In literature, however, this insect is most often referred to as *Laemophloeus ferrugineus*.

Leng (4) lists *ferrugineus* Steph. and *testaceus* Payk as synonomous specific names for this species.

According to Wheeler (11), *Laemophloeus ferrugineus* Steph. is cosmopolitan. It has been reported from Britain in haystack

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**Determined by R. T. Cotton.

refuse and in granaries; it is rarely found under bark. It has been found in Germany in rice, bran middlings, and meal. It is often found in grain attacked by Calandra, in bran, flour, etc.

The writer wishes to express his appreciation of the kindly guidance and helpful criticism of Dr. George M. List, under whose direction this work was carried on.

PART I.—BIOLOGY OF *Cryptolestes Ferrugineus*

METHODS

An incubator equipped with a thermostat was used in the rearing of these insects. In this way the desired temperature of 83° F. was maintained. Since a high relative humidity is required, the incubator was further equipped with a large pan of water and an electric fan set in such a position as to pass a current of air directly over the water surface continuously.

Small glass vials with cotton stoppers, and hollow slides with cover glasses, were used for individual rearing cages. A more satisfactory type of cage, however, was developed later in the work. A three-quarters inch bone ring was placed on a glass slide and sealed with balsam. The interior was then black enameled. Over the top of the ring was placed a circle of clear celluloid with a small hole punched out of the center. This was also sealed on with balsam. By means of the opening provided it was possible to transfer larvae and food without the inconvenience of removing a cover glass. At the same time the larvae were found to be incapable of crawling out so long as the inner rim of the celluloid projected slightly over the bone ring. A great many of these cages were used in the rearing of larvae.

Still another type of cage used consisted of three-quarters inch glass tubing cut into quarter-inch lengths and sealed onto glass slides with balsam. Ordinary cover glasses were used with these cages. Such cages proved fairly satisfactory in rearing the larvae, although they were a little too large to be most efficient. The larvae insisted upon crawling up the sides of the cages and were therefore sometimes difficult to find.

A large supply of adult beetles was kept in petrie dishes in which were placed small squares of cardboard or blotting paper with tiny, knife-edge grooves cut half-way through. The eggs were carefully deposited in these by the females. By means of a tiny camel's-hair brush, eggs were transferred from there to the rearing cages.

STAGES OF THE LIFE CYCLE

THE EGG

DESCRIPTION.—The egg is small, slender, cylindrical in shape, and slightly rounded at both ends. It is about .65 mm in length and .24 mm across the widest portion. In color it is a beautiful translucent white.

INCUBATION PERIOD.—Eggs are deposited in small crevices. In about 5 days these eggs hatch when a temperature of 83° F. and a high relative humidity are maintained. Table 1 shows the incubation period of 30 eggs. It may be seen in the table that the incubation period is quite consistently 5 days. Out of the 30 eggs observed, three hatched in 4 days and one in 6 days. The other 26 all hatched in the usual 5-day period.

In all cases eggs transferred to steam-heated room conditions collapsed and failed to hatch, probably because of the low relative humidity.

TABLE 1.—*Incubation period of eggs at temperature of 83° F.*

Egg no.	Date deposited	Date hatched	Incubation period	Egg no.	Date deposited	Date hatched	Incubation period
1	Nov. 20	Nov. 25	5 days	16	Nov. 23	Nov. 28	5 days
2	Nov. 20	Nov. 25	5 days	17	Nov. 24	Nov. 29	5 days
3	Nov. 20	Nov. 25	5 days	18	Nov. 24	Nov. 29	5 days
4	Nov. 20	Nov. 24	4 days	19	Nov. 25	Nov. 30	5 days
5	Nov. 21	Nov. 26	5 days	20	Nov. 25	Nov. 30	5 days
6	Nov. 21	Nov. 26	5 days	21	Nov. 25	Nov. 30	5 days
7	Nov. 21	Nov. 27	6 days	22	Nov. 25	Nov. 30	5 days
8	Nov. 21	Nov. 26	5 days	23	Nov. 25	Nov. 30	5 days
9	Nov. 22	Nov. 27	5 days	24	Nov. 25	Nov. 30	5 days
10	Nov. 22	Nov. 27	5 days	25	Nov. 26	Dec. 1	5 days
11	Nov. 22	Nov. 27	5 days	26	Nov. 26	Dec. 1	5 days
12	Nov. 22	Nov. 27	5 days	27	Nov. 27	Dec. 1	4 days
13	Nov. 23	Nov. 28	5 days	28	Nov. 27	Dec. 2	5 days
14	Nov. 23	Nov. 28	5 days	29	Nov. 27	Dec. 2	5 days
15	Nov. 23	Nov. 27	4 days	30	Nov. 28	Dec. 3	5 days

THE LARVA

EMERGENCE.—When about ready to hatch the egg reveals quite clearly the segmentation of the larva within. A series of undulating movements, caudad forward, is set up by the larva, and very soon the eggshell is broken at the end by the pressure of the head capsule of the larva upon it. The larva continues its activity, more and more of the body being gradually exposed, until it is entirely free of the shell. The writer has observed hatching in many cases. Four to seven minutes are required for the process. As a rule, immediately upon hatching the larva walks rather rapidly away from the egg case, apparently in search of food.

DESCRIPTION.—The newly emerged larva is about .7 mm long, crystal white entirely, the head capsule and spine-like appendages of the last segment very soon becoming reddish-brown. It is cylindrical in shape, tapering a little at each end.

The full-grown larva, however, differs considerable in shape. The head and thoracic segments are quite narrow, but the segments of the abdomen are much broader and slightly longer. These segments become progressively broader posteriorly until the fourth segment of the abdomen, which is the widest. They then taper away again to the terminal segment, which is equipped with two spine-like appendages. The full-grown larva has a slightly margined appearance. Each abdominal segment bears two or more fine hairs on each side. The color of the larva is creamy white except the head capsule and terminal segment, which are reddish-brown. The full-grown larva is about 3.6 mm in length and .6 mm across the widest portion of the abdomen.

MOLTING.—With a controlled temperature of 83° F. and a high relative humidity, the larva molts four times, the last molt revealing the pupae. Table 2 gives the length of instars of 15 larvae, with head-capsule measurements of each instar.

TABLE 2.—*Length of instars and head-capsule measurement of 15 larvae.*

Larva No.	Length of 1st instar in days	Head capsule width 1st instar	Length of 2nd instar in days	Head capsule width 2nd instar	Length of 3rd instar in days	Head capsule width 3rd instar	Length of 4th instar in days	Head capsule width 4th instar	Total larval period in days
1	6	.16	11	.192	8	.24	8	.304	33
2	7	.161	9	.19	11	.237	8	.30	35
3	6	.156	10	.18	9	.22	9	.29	34
4	8	.163	9	.19	11	.23	9	.31	37
5	6	.15	10	.18	13	.21	8	.284	37
6	4	.161	13	.187	11	.24	7	.30	35
7	4	.16	14	.19	7	.23	9	.29	34
8	7	.155	14	.18	10	.22	7	.284	38
9	4	.148	5	.175	4	.21	5	.287	18
10	4	.15	4	.191	6	.24	8	.29	26
11	5	.16	3	.19	6	.24	5	.30	19
12	5	.161	4	.186	7	.235	8	.29	24
13	8	.16	8	.191	10	.24	13	.30	39
14	11	.153	7	.182	12	.23	11	.285	41
15	14	.16	7	.19	12	.24	8	.30	41
Average	6.6	.157	8.53	.186	9	.230	8.2	.294	32.33

LARVAL PERIOD.—At a temperature of 83° F. and a high relative humidity, the larval period was found to cover 32 to 37 days when the larvae were fed on corn meal. The nature of food used seems to have a pronounced effect upon the time required for larval development. Foods of animal origin, rather than vegetable origin, tend to shorten the larval period. Individuals fed on white flour require more time for development than those fed on corn meal. This may be due to the difference in texture. Such variation in the larval period may be observed in table 3.

TABLE 3.—*Relation between food of the larva and length of the larval period.*

Larva no.	Food used	Emergence date	Pupation date	Larval period
1	White flour	Oct. 21	Nov. 29	39 days
2	White flour	Oct. 22	Dec. 2	40 days
3	White flour	Oct. 24	Dec. 4	41 days
4	White flour	Oct. 25	Dec. 7	43 days
5	Corn meal	Nov. 3	Dec. 6	33 days
6	Corn meal	Nov. 3	Dec. 8	35 days
7	Corn meal	Oct. 27	Nov. 24	32 days
8	Corn meal	Nov. 4	Dec. 8	34 days
9	Corn meal	Nov. 7	Dec. 14	37 days
10	Corn meal	Nov. 9	Dec. 13	34 days
11	Dead larva	Nov. 29	Dec. 17	18 days
12	Ang. Gr. moth eggs	Nov. 29	Dec. 15	19 days
13	Ang. Gr. moth eggs	Nov. 30	Dec. 22	22 days
14	Ang. Gr. moth eggs	Nov. 27	Dec. 16	19 days
15	Own eggs	Nov. 25	Dec. 18	20 days

Another series of experiments was run on a much larger scale in a further attempt to determine the effect of larval food upon the time required for the development of the larvae. Eight hundred newly hatched larvae were started in 40 different cages on 40 different food rations. The temperature in this case was kept at 80°. This factor will account for the somewhat longer development periods. The results are shown in table 4.

It may be seen at once that the mortality was generally high throughout the cages. There were, undoubtedly, several factors causing this, but they proved to be very difficult to ascertain. In cases where the mortality is 100 percent, obviously there is something wrong with the food; but 50 percent is shown to be the lowest percentage of mortality in any of the cages, the others ranging from 50 to 100 percent mortality. So it would undoubtedly be incorrect to say that all the mortality is due to some deficiency in the food, since many foods were used which are known to be eaten by the larvae in their natural state and to be conducive to their development.

TABLE 4.—*Relation of larval food to length of larval period at 80° C.*

Cage	No. larvae started	Number died	Number matured	Percentage mortality	Lengths of larval period in days	Average length of larval period	Larval food
1	20	15	5	75	49, 50, 51, 54, 50	50.8 days	White flour
2	20	12	8	60	40, 40, 41, 41, 42, 43, 44, 45	42.0 days	White corn meal
3	20	14	6	70	38, 40, 40, 42, 44, 46	41.6 days	Yellow corn meal
4	20	20	....	100	....	.... ..	Cocoa
5	30	18	12	60	29, 29, 29, 30, 31, 32, 33, 33, 33, 34	31.4 days	Cadelle larvae
6	20	10	10	50	23, 23, 24, 24, 25, 25, 25, 25, 26, 28	24.8 days	Ang. moth eggs
7	20	20	....	100	....	.... ..	Ground rice
8	20	20	....	100	....	.... ..	Raisins
9	20	20	....	100	....	.... ..	Ground peanuts
10	20	20	....	100	....	.... ..	Ground coffee
11	20	20	....	100	....	.... ..	Powdered sugar
12	20	18	2	90	51, 54	52.5 days	Oatmeal
13	20	17	3	85	40, 43, 45	42.6 days	Bran
14	40	21	19	52	23, 24, 24, 25, 25, 25, 26, 26, 26, 26, 27, 28, 28, 28, 28, 28, 29, 29	26.3 days	Whole grain or wheat
15	10	6	4	60	29, 29, 32, 32	30.5 days	Y. C. M. & cadelle
16	20	20	....	100	....	.... ..	Whole milk
17	20	20	....	100	....	.... ..	Crude casein
18	20	20	....	100	....	.... ..	Ex. Starch
20	10	7	3	70	32, 34, 34	33.3 days	W. F. & Cad. Larvae
21	20	20	....	100	....	.... ..	C. Cas. & Ex. Starch
22	20	20	....	100	....	.... ..	Ex. Starch & Ash
23	20	20	....	100	....	.... ..	Ex. Cas. & Ash
24	20	20	....	100	....	.... ..	Cr. Cas. & Ash
25	20	20	....	100	....	.... ..	Ex. Cas. & Ex. Starch

TABLE 4.—*(Continued)*

Cage	No. larvae started	Number died	Number matured	Percentage mortality	Lengths of larval period in days	Average length of larval period	Larval food
26	20	20	....	100	....	.... ..	Larval Food
27	20	20	....	100	....	.... ..	Ex. Cas. & Ex. Starch & Ash
28	20	20	....	100	....	.... –	Cr. Casein
29	20	20	....	100	....	.... ..	Ex. Casein
30	20	17	3	85	42, 45, 46	44.3 days	W. C. M. & Cr. Cas.
31	20	17	3	85	41, 44, 46	43.6 days	W. C. M. & Ex. Cas.
32	20	13	7	65	26, 28, 29, 30, 30, 31, 32	29.4 days	Hollow Gr. of wheat
33	10	10	....	100	....	.... ..	Ex. Starch & Whole milk
34	10	10	....	100	....	.... –	Whole milk & ash
35	20	15	5	75	48, 48, 50, 52, 55	50.6 days	Whole flour & whole milk
36	20	18	2	90	52, 55	53.5 days	Wh. flour & Cr. Cas.
37	20	13	7	65	39, 39, 42, 42, 45, 45, 46	42.5 days	W. C. M. & Wh. milk
38	20	19	1	95	55	55 days	W. flour & Ex. Cas.
39	20	20	....	100	....	— –	Wh. kernels corn
40	20	20	....	100	....	.... ..	Wh. milk, Ex. Starch & ash

When newly hatched the larvae are very delicate and seem to need every advantage in order to gain a foothold in life. By far the highest mortality occurs in the first few days of existence. As a rule it was found that if a larva succeeded in passing the first molt it had a good chance of maturing, if protected from its enemies.

From the table we see that white flour shows 75 percent mortality and an average larval period of 50.8 days, while white corn meal shows only 60 percent mortality and an average larval period of only 42.0 days. Naturally, the question arises as to the reason for such variations. The higher protein content of corn meal is perhaps a contributing factor. It is also possible that the texture is of importance. Generally speaking, the foods of coarser texture seem to be more suitable to the needs of the larvae. The reason for this may be a strictly mechanical adaptability of the mouth parts. Possibly the larger particles retain more moisture which would likely aid in hastening the development of the larvae. In connection with this theory we find that the development period is shortened in the case of foods of animal origin, where the moisture content is higher than in the grains. The protein content is also higher in the case of foods of animal origin. It is also possible that the softness of the animal food which is in large pieces makes this type of food more available mechanically.

It is interesting to note that the larvae develop much faster in a whole grain of wheat than in the flour or meals. Perhaps this may be explained by the fact that some protein is retained in the grain which is lost in the flour. The larvae invariably bore into the softest portion of the grain at the germ end, and there they feed, gradually hollowing out a tiny cell just large enough for their development.

It is the opinion of the writer that some of the perspiration moisture of the larvae is retained in this tiny cell, and this hastens the development of the insect. The grain is soft in this portion, making it easily available mechanically, and it has a high moisture content. The larva goes into the pupal stage within this little cell and emerges from the grain as an adult.

From the table we see that the larval periods range from an average of 24.8 days, when the larvae were fed on Angoumois grain moth eggs, to an average of 55.0 days, when the larvae were fed on white flour plus extracted casein. The other average larval periods, when various foods were used, range between these two extremes as shown in the table.

When considering the value of a food as a larvae developer, the mortality rate must naturally be taken into consideration, as well as the average length of the larval period. In order to show the relative values of the various foods, the percentage mortality of the larvae in each cage has been added to the average length of the larval period. In this way the lower numbers represent foods most conducive to larval development, whereas the foods represented by higher numbers are less conducive to larval development. According to this plan, the various foods used are listed as follows:

Angoumois grain moth eggs	74.8
Whole grains of wheat	78.3
Yellow corn meal plus Cadelle larvae	90.5
Dead Cadelle beetle larvae	91.4
Hollow grains of wheat (which have been infested with Angoumois grain moth)	94.4
White corn meal	102.0
White flour plus Cadelle larvae	103.3
Yellow corn meal	111.6
White corn meal plus whole milk	107.5
White flour plus whole milk	125.6
White flour	125.8
Bran	127.6
White corn meal plus extracted casein	128.6
White corn meal plus crude casein	129.3
Oat meal	142.5
White flour plus crude casein	143.5
White flour plus extracted casein	150.0

According to these numbers, then, which show the relative standings of the different foods and food combinations, Angoumois grain moth eggs are most conducive to larval development; and white flour plus extracted starch shows the least value in this respect of any of the foods upon which any of the larvae succeeded in developing. All foods not listed above show a mortality of 100 percent in the table.

FEEDING HABITS.—Larvae die within less than 24 hours after emergence without food. They have been observed feeding on white flour almost immediately after the egg has hatched. According to observations, they feed readily upon white flour, bran, corn meal, broken grains of wheat, whole grains of wheat, broken kernels of corn, their own eggs, eggs of the Angoumois grain moth, pupae of the Angoumois grain moth, larvae of the Angoumois grain moth which have been injured or have died, their own larvae under the same conditions, larvae of the Cadelle beetle under the same conditions, and their own pupae. As a rule they seem to prefer the foods of animal origin.

It is obvious, then, that the larvae are quite cannibalistic, since they feed upon both their own eggs and their own pupae.

THE PUPA

About 2 days before pupation the larva becomes decidedly inactive and contracted. The pupa is usually naked, a beautiful translucent white in color except for the compound eyes, which are dark brown. Legs, wings, and antennae are folded neatly against the body. This is a curiously contracted, angular-appearing stage and is small compared with the larva. The pupa is about 1.92 mm in length and .76 mm across the widest portion.

The pupa is quite active when disturbed. It is always found pupating face downward on the bottom of the cage; when turned over it soon regains its original position.

At a temperature of 83° F. and a high relative humidity, about 5 days are required for the pupal period. Table 5 gives the pupal period of 30 individuals.

On the fourth day of pupation the color changes to a light tan, gradually becoming darker until the emergence of the beetle.

TABLE 5.—*Showing pupal period at temperature of 83° F.*

Pupa no.	Pupation date	Emergence date	Pupal period	Pupa no.	Pupation date	Emergence date	Pupal period
1	Dec. 2	Dec. 7	5 days	16	Dec. 8	Dec. 13	5 days
2	Dec. 2	Dec. 7	5 days	17	Dec. 8	Dec. 13	5 days
3	Dec. 2	Dec. 7	5 days	18	Dec. 8	Dec. 13	5 days
4	Dec. 2	Dec. 7	5 days	19	Dec. 8	Dec. 13	5 days
5	Dec. 2	Dec. 7	5 days	20	Dec. 8	Dec. 13	5 days
6	Dec. 2	Dec. 8	6 days	21	Dec. 9	Dec. 14	5 days
7	Dec. 4	Dec. 9	5 days	22	Dec. 9	Dec. 14	5 days
8	Dec. 4	Dec. 9	5 days	23	Dec. 11	Dec. 16	5 days
9	Dec. 4	Dec. 9	5 days	24	Dec. 11	Dec. 16	5 days
10	Dec. 4	Dec. 9	5 days	25	Dec. 12	Dec. 17	5 days
11	Dec. 6	Dec. 11	5 days	26	Dec. 13	Dec. 17	4 days
12	Dec. 6	Dec. 11	5 days	27	Dec. 13	Dec. 18	5 days
13	Dec. 6	Dec. 11	5 days	28	Dec. 15	Dec. 20	5 days
14	Dec. 6	Dec. 12	6 days	29	Dec. 16	Dec. 21	5 days
15	Dec. 8	Dec. 13	5 days	30	Dec. 16	Dec. 21	5 days

THE ADULT

DESCRIPTION.—When the beetle first emerges, it is a medium tan in color. In about 4 or 5 days it assumes its natural color of a dark reddish-brown. The mature insect is a small, very much compressed beetle 1.6 to 2.2 mm in length. The body is of a slender form, with parallel sides. The males as a rule seem to be somewhat larger bodied than the females, and are furnished with slightly more filiform antennae. The last three segments of the 11-jointed antennae, however, are enlarged in both males and females.

A more complete description is given as follows: Beetles depressed, elongate; antennae 11-jointed, elongate, last three segments slightly enlarged, nearly as long as elytra; scutellum distinct; elytra rounded at tip and covering the abdomen, emarginate, striate, punctate, slightly longer than head and thorax together; front coxal cavities widely separated; anterior coxal cavities broadly and completely inclosed by the sterna, merely a fine suture between each sidepiece and the median lobe; front coxae rounded, not prominent; hind coxae nearly contiguous, transverse; abdomen with five free ventral segments, equal in length; legs rather short; femur large; tibia slender, terminated by two spurs; tarsi four-jointed; eyes rather small, set back on head near front margin of thorax; labrum large, transverse, rounded in front; head and thorax finely punctured, the latter narrowed behind, sides curved sinuate near hind angles which are sharp and prominent. Length 1.6 to 2.2 mm.

PREOVIPOSITION PERIOD.—A preoviposition period of 10 days was observed in one case and a period of 15 days in another.

COPULATION.—Usually beetles are not found copulating in light, open places. One pair was observed in copulation for about 10 minutes, the female eating peacefully during this time. Suddenly another male started biting the copulating pair near the point of contact, and after a few seconds they separated. Several other beetles appeared, and there followed a general milling about.

OVIPOSITION.—Eggs are deposited singly in small crevices. Oviposition has often been observed by the writer. A typical case follows: The female beetle wandered about over the strip of blotting paper, inserting the ovipositor here and there as though in search of a suitable place for the egg. Finally a tiny knife-edge slit in the paper was decided upon, and the ovipositor was extended far into the crevice, the weight of the body being thrown back on the last pair of legs, and the front part of the body being raised from the surface of the paper. Excessive movements of the head and antennae followed. This position was maintained for 3 minutes. Somewhat convulsive movements of the ovipositor accompanied the laying of the egg. Suddenly, then, the beetle resumed its normal position on the surface of the paper and nervously scurried this way and that, soon retiring under the paper. Upon examination an egg was found in the crevice.

It was found that the food of the adult has a direct bearing upon the number of eggs deposited. In order to determine exact variations of this nature, 60 pairs of beetles were put in each of five cages, each cage containing a different kind of food, as shown in table 6. Daily observations were made over a period of 36 days. The results are shown in table 6.

TABLE 6.—*Relation of food of adults to oviposition.*

Cage A—Sixty pairs fed on dead Cadelle beetle larvae exclusively.
Cage B—Sixty pairs fed on white corn meal exclusively.
Cage C—Sixty pairs fed on white flour exclusively.
Cage D—Sixty pairs fed on Angoumois grain moth eggs exclusively.
Cage E—Sixty pairs fed on extracted starch exclusively.

Date	Number of eggs deposited				
	Cage A	Cage B	Cage C	Cage D	Cage E
3/23	9	5	0	9	0
24	13	7	0	15	0
25	17	23	0	12	0
26	12	19	1	18	0
27	13	20	1	12	0
28	15	18	2	15	0
29	9	7	0	12	0
30	13	10	0	18	0
31	15	11	0	21	0
4/ 1	7	6	0	15	0
2	9	7	0	12	0
3	8	5	0	15	0
4	6	4	1	18	0
5	10	5	0	15	0
6	7	3	0	21	0
7	10	3	1	12	0
8	9	2	0	15	0
9	8	2	0	18	0
10	10	1	0	15	0
11	12	4	0	21	0
12	9	2	0	9	0
13	13	6	1	20	0
14	7	2	0	6	0
15	10	4	0	15	0
16	11	3	0	9	0
17	5	2	0	12	0
18	8	1	0	3	0
19	3	4	0	12	0
20	5	1	0	3	0
21	4	3	0	9	0
22	7	2	0	9	0
23	5	2	0	9	0
24	4	1	0	5	0
25	3	4	0	7	0
26	5	2	0	5	0
27	4	2	0	4	0
Total no. of eggs deposited	315	203	7	446	0

As the table shows, the beetles fed on corn meal show a higher oviposition record for the first few days than any of the others. After the sixth day, however, both cages A and D (beetles fed on dead Cadella beetle larvae and Angoumois grain moth eggs, respectively) show a higher record than cage B, which fell off rather rapidly. The beetles fed on Angoumois grain moth eggs proved to be the most consistent egg layers, depositing a total of 446 eggs during the 36-day period. Beetles fed on dead Cadella beetle larvae rated second, depositing a total of 315 eggs. Beetles fed on white flour deposited only seven eggs during the 36 days, and those fed on extracted starch deposited none. Mortality was high in the case of white flour and 100 percent in the case of extracted starch.

FEEDING HABITS.—The adult beetles feed readily on white flour, bran, corn meal, broken grains of wheat, broken kernels of corn, their own eggs, eggs of the Angoumois grain moth, larvae of the Angoumois grain moth which have been injured or have died, their own larvae under the same conditions, and their own pupae, according to observations. The beetles have not been observed feeding on dried fruits. Five out of twelve adults were kept alive for 11 months on white flour alone. At times they seem to prefer the animal food, but at other times they leave it for the grain or meal. They are very often associated with other insects. Their craving for animal food is undoubtedly one reason for such associations.

OTHER HABITS.—At temperatures around 75° F. and below the beetles are extremely gregarious and inactive, huddling together in small masses in the corners of the cages.

When warmed by an intense light the beetles sometimes use their wings in attempted flight. In no case, however, have they succeeded in clearing the rim of a petrie dish which is one-half inch in height.

According to observations, these beetles are decidedly photonegative and thigmo-positive.

LENGTH OF LIFE CYCLE

All beetles in table 7 were reared under carefully controlled conditions of temperature and relative humidity. The temperature was kept constant at 83° F. and the relative humidity at approximately 65 percent.

It has already been shown that the length of the larval period is to a noticeable degree dependent upon the nature of the food consumed by the larva. When larvae were fed on eggs of the Angoumois grain moth, the life cycle was found to require a period of only 29 to 32 days. Approximately the same was found to be true when dead larvae of the Cadelle beetle and *C. ferrugineus* eggs were used for larval food. When larvae were fed on corn meal, however, the period required for the completion of the life cycle was increased to 42 to 47 days. Forty-nine to fifty-three days were found to be required when white flour was used for food. Table 7 gives data on the life cycles of 15 beetles.

TABLE 7.—*Length of life cycle at 83° F.*

No.	Larval food	Egg stage	Larval stage	Pupal stage	Entire life cycle
1	White flour	5 days	39 days	5 days	49 days
2	White flour	5 days	40 days	5 days	51 days
3	White flour	5 days	41 days	5 days	51 days
4	White flour	5 days	43 days	5 days	53 days
5	Corn meal	5 days	33 days	5 days	43 days
6	Corn meal	5 days	35 days	5 days	45 days
7	Corn meal	5 days	32 days	5 days	42 days
8	Corn meal	5 days	34 days	5 days	44 days
9	Corn meal	5 days	37 days	5 days	47 days
10	Corn meal	5 days	34 days	5 days	44 days
11	Dead Cadelle larvae	5 days	18 days	5 days	28 days
12	Angoumois gr. moth eggs	5 days	19 days	5 days	29 days
13	Angoumois gr. moth eggs	5 days	22 days	5 days	32 days
14	Angoumois gr. moth eggs	5 days	19 days	5 days	29 days
15	Own eggs	5 days	20 days	5 days	30 days

IMPORTANCE OF HIGH RELATIVE HUMIDITY

It has been found by the writer that a high relative humidity is essential for oviposition. The same seems to be necessary to the hatching of the egg and to proper larval development. At the beginning of this work the writer made many attempts at rearing the beetles under steam-heated room conditions and in incubators which maintained a constant temperature, but no success was met until the relative humidity was increased.

Van Emden (10) has made observations in this connection. To quote from this writer, "The bodies of pests of stored products have a higher moisture content than that of their food, and to conserve it they spin shelters to reduce the loss of perspiration moisture. The species that are not so adapted require more moisture for development and often occur as secondary pests. *Laemophloeus ferrugineus* Steph. is an example of this."

NATURAL ENEMIES

Natural enemies observed are the Gamasid mite (*Seiulus pomi* Parst.), a tiny black hymenoptera (*Cephalonomia waterstoni* Gahan), and the Cadelle beetle.

Seiulus pomi has often been observed feeding upon both the egg and the pupa of *C. ferrugineus*.

Cephalonomia waterstoni seems to delight in grabbing a larva of *C. ferrugineus* between its mandibles, scurrying about with it for a while, and then feeding upon it. Larvae seem to become somewhat paralyzed almost immediately after falling into the clutch of the mandibles of this hymenoptera. These tiny predators are capable of carrying full-grown larvae of *C. ferrugineus.*

Cephalonomia waterstoni has also been observed feeding upon eggs of *C. ferrugineus.* An interesting note here is that in no case has *Cephalonomis* been observed feeding upon eggs or larvae of the Angoumois grain moth.

PART II.—RELATION OF BEETLE TO *Trichogramma Minutum* PARASITE WORK

As has already been mentioned, *Cryptolestes ferrugineus* infests the incubators used for rearing the Angoumois grain moth at Colorado State College. Since eggs of the grain moth are used in rearing the *Trichogramma minutum* parasite of the codling moth, it is obvious that the feeding habits of the beetle prove detrimental to the progress of the parasite work. For, as has already been stated, both larvae and adults feed readily upon eggs of the moth.

It should be recalled here that, as has already been shown, the larvae of *Cryptolestes ferrugineus* develop faster when fed on eggs of the Angoumois grain moth than when fed on any other food experimented with, unless it be larvae of the Cadelle beetle. Another interesting fact that has already been brought out is that adult females of *Cryptolestes* show a higher oviposition record when fed on Angoumois grain moth eggs than when given any other ration. It is clear, then, that the existence of the grain moth is conducive to increased numbers of the beetle in the incubators.

Table 8 gives the daily record of moth eggs eaten by an isolated pair of *C. ferrugineus.* From these figures it is obvious that, with a large number of beetles present, a great many eggs would be consumed in a short time.

From emergence until the time of pupation one larva fed on Angoumois grain moth eggs exclusively consumed, or partially consumed, 35 eggs; while another larva under the same conditions consumed, or partially consumed, 50 eggs.

Both larvae and adults of the beetle have been found to feed upon pupae of the grain moth. Because of this it is thought that a great many of the moths never pass the pupal stage.

TABLE 8.—*Angoumois grain moth eggs consumed daily for a period of 60 days by an isolated pair.*

Date	Eggs con-sumed	Date	Eggs con-sumed	Date	Eggs con-sumed	Date	Eggs con-sumed	Date	Eggs con-sumed
10/15	13	27	30	8	22	20	33	12/2	20
16	15	28	16	9	20	21	23	3	19
17	35	29	10	10	17	22	20	4	19
18	10	30	17	11	34	23	13	5	29
19	18	31	28	12	20	24	10	6	31
20	30	11/1	15	13	16	25	27	7	34
21	12	2	13	14	15	26	20	8	25
22	15	3	36	15	10	27	15	9	24
23	19	4	15	16	14	28	14	10	20
24	24	5	10	17	23	29	19	11	16
25	20	6	30	18	18	30	27	12	10
26	16	7	31	19	30	12/1	24	13	15

Although both larvae and adults feed readily upon dead or crippled larvae of the grain moth, they have never been observed attacking normal, live larvae.

Temperature and relative humidity conditions in the grain moth incubators are ideal for the development of the beetle. The necessity of preserving the moths renders control measures difficult.

The beetles develop within grains of wheat which have already been punctured by the larvae of the grain moth, in whole grains which have not been punctured, or in the loose refuse in the bottom of the incubators. The broken grains of wheat are one of the chief sources of food for both larvae and adults.

A considerable majority of beetles taken from the incubators were found, upon examination of the genetalia, to be females. Of 100 beetles examined, only 25 percent were males.

SUMMARY

Eggs of *Cryptolestes ferrugineus* hatch in from 4 to 6 days at a temperature of 83° C. and a high relative humidity. The larval period requires 20 to 45 days or more, depending to a great extent upon the larval food. The larva molts four times, the last molt revealing the pupa. The food of the larva has been found to have a pronounced effect upon the length of the larval period. Larvae without food die within less than 24 hours after emergence. They feed upon a wide variety of grains and animal foods. The larvae are cannibalistic in that they feed upon both their own eggs and their own pupa. The pupal period requires 4 to 6 days at a temperature of 83° C.

A preoviposition period of 10 days was observed in one case and a period of 15 days in another.

The feeding habits of the adults are much the same as those of the larvae. The number of eggs deposited by the females is to great extent dependent upon the type of food available.

The length of the complete life cycle was found to vary from 28 to 53 days at a temperature of 83° C.

It has been found that a high relative humidity is essential to oviposition, hatching of the egg, larval development, and pupation.

Natural enemies observed are the Gamasid mite (*Seiulus pomi* Parst.), a hymenoptera (*Cephalonomis waterstoni* Gahan), and the Cadelle beetle.

Conditions in the Angoumois grain moth incubators are ideal for the development of the beetle. Eggs of the Angoumois grain moth as food produced the fastest larval development of the beetle and the highest oviposition record.

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