BIOLOGY OF THE FLOUR BEETLES, TRIBOLIUM CONFUSUM DUV. AND T. FERRUGINEUM FAB.[1]

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INTRODUCTION

The flour beetles have long been known to be among the more serious pests of flour, meal, and other cereal products. Numerous references in the literature give ample evidence of their importance as destroyers of these foodstuffs. However, owing probably to the rather long adult life of these insects and the difficulties in observing the immature stages, no thorough work has been done on their life history. Several suppositions of early authors regarding the life cycle have been copied and recopied until now these statements, often erroneous, are accepted as facts. The following preliminary account is a summary of rather extensive experiments on these two species commenced by the writer in the latter part of 1929.

DIFFERENTIATING CHARACTERS OF ADULTS

The two species *Tribolium confusum* Duv. and *T. ferrugineum* Fab. are so similar in size, color, shape of body, and habits that they are continually confused, even by experienced entomologists. The distinguishing characters are so constant, however, that once these are learned there can never be any doubt as to their identity. The character found most useful by the writer for distinguishing the two species is the size of the eyes on the ventral surface of the head. In *T. ferrugineum* the width of each eye is approximately equal to the distance separating them on the underside of the head. In *T. confusum* the eyes, viewed from below, appear small, the width of each eye being approximately only one-third that of the distance separating them. This character can be used for the identification of living specimens, whereas the character usually given—i. e., the sudden enlargement of the last three joints of the antennae in *T. ferrugineum* and the gradual enlargement in *T. confusum*—is almost useless for identifying living specimens because the antennae are usually in motion. Another differentiating trait, useful for field identification but rather unreliable, is that when placed on a flat surface under a strong light *T. ferrugineum* often attempts to fly, and sometimes makes short flights of a few feet, while *T. confusum* never makes any attempt at flight.

Careful measurements of 50 adults show them to be somewhat smaller than the measurements usually given. *Tribolium confusum* is found to average 3.47 mm in length and 1.07 mm in width through the prothorax. These measurements are almost identical with those

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given by Brindley, [2] but are considerably smaller than those of Chapman [3] and other authors. *T. ferrugineum* averages 3.32 mm in length and 1.03 mm in width through the prothorax.

ORIGIN, HABITAT, AND DISTRIBUTION

The origin of insects infesting stored products is difficult to determine because they are widely distributed by commerce and most of them have long been cosmopolitan pests. In the case of *Tribolium ferrugineum* a hint as to its probable origin is given by Blair,[4] who refers to it under the name *T. castaneum* Hbst. He shows that in India this species is commonly found in the wild state under bark and in wood. It is also found in such situations in North America and elsewhere, but not at all frequently. It is an insect of subtropical climates, and very likely India is its original home. This view is strengthened by the fact that, in the same article, Blair has described a very closely related species, *T. indicum*, from the same country and with the same habitat, which does not occur in stored products.

As to the original habitat of the genus, there can be no reasonable doubt that before the advent of civilized man it lived under bark and in old logs. Here it was probably a scavenger, but this can not be definitely proved. Almost without exception, the beetles of the subfamily Ulominae, of which Tribolium is a member, occur either as pests of stored products or else under the bark of trees and in rotting logs. It seems evident that all the members of this group originally lived in the latter habitat and have recently adopted the flour-feeding habit. Two species of Tribolium, *T. madens* Charp. and *T. indicum* Blair, are found almost exclusively in such situations, and the two flour pests *T. confusum* and *T. ferrugineum* are themselves occasionally found there.

These two species are known to be cosmopolitan, occurring throughout the world in stored cereal products. Temperature seems to influence their distribution somewhat. *Tribolium ferrugineum* is essentially an insect of warm climates, being seldom taken north of the fortieth parallel. *T. confusum*, on the other hand, seems to prefer cooler climates and is most abundant in the northern part of the United States.

FOOD

A wide variety of foodstuffs are attacked by Tribolium, a list of which is given by Chittenden.[5] Practically any kind of flour, meal, breakfast food, and cracked grain is attacked, and much damage is done to dried insect specimens in collections. The writer has found these pests as much to be feared in insect collections as the dermestids. They are also known to breed in certain spices. Three other preferred foods which seem to have received little or no mention are chocolate, raisins, and various nuts, especially Persian (English) walnuts, on which the larvae develop very rapidly.

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[2] BRINDLEY, T. A. THE GROWTH AND DEVELOPMENT OF EPHESTIA KUEHNIELLA ZELLER (LEPIDOPTERA) AND TRIBOLIUM CONFUSUM DUVAL (COLEOPTERA) UNDER CONTROLLED CONDITIONS OF TEMPERATURE AND RELATIVE HUMIDITY. Ann. Ent. Soc. Amer. 23: 741–757, illus. 1930.

[3] CHAPMAN, R. N. THE CONFUSED FLOUR BEETLE (TRIBOLIUM CONFUSUM DUVAL). Minn. State Ent. Rpt. 17: 73–94, illus. 1918.

[4] BLAIR, K. G. THE INDIAN SPECIES OF PALORUS, MULS. (COLEOPTERA: TENEBRIONIDAE) AND SOME ASSOCIATED BEETLES. Indian Forest Rec. 14 (5): 1–20 (133–152), illus. 1930.

[5] CHITTENDEN, F. H. INSECTS AFFECTING CEREALS AND OTHER DRY VEGETABLE FOODS. Chapter 8, in The Principal Household Insects of the United States. U. S. Dept. Agr., Div. Ent. Bul. (n. s.) 4: 112–131, illus. 1896.

OVERWINTERING

In heated flour mills, warehouses, etc., Tribolium breed the year around and all stages can be found at any time during the year. In unheated flour mills this is not the case. Some authors have stated that these beetles do not live over winter in unheated mills but that these mills are reinfested in the spring from neighboring heated mills. An inspection of several unheated flour mills in Maryland and northern Virginia during February, 1931, revealed many adults of *T. confusum* in a semidormant condition, but no living larvae or pupae. As the adults usually live a year, or over, it is evident that in unheated flour mills in this territory the winter is passed in the adult stage and breeding begins with the approach of spring. In the Gulf States breeding probably continues the year around, while in the extreme Northern States and Canada the species may not be able to survive the winter except in heated buildings. *T. ferrugineum* seems to be less resistant to cold than *T. confusum*.

LONGEVITY

It has been known that Tribolium adults are long-lived, but no actual tests have previously been made to determine the maximum length of life. Estimates have ranged from three months to a year or more. As many of the adults under observation by the writer are still alive, no definite statement can yet be made as to the maximum length of life except that it is considerably longer than is generally supposed. Of 50 individuals of *T. confusum* emerging nearly 24 months previous to this writing (January, 1932), 13 are still alive and active. *T. ferrugineum* appears to be somewhat shorter lived than *T. confusum*, but 5 individuals out of an original 60 are still alive after 23 months.

OVIPOSITION

Of all phases of the life history of Tribolium, oviposition seems to have received the least attention. Only two investigators, Chapman and Brindley, appear to have done any work on the oviposition of these insects, and they have been concerned only with the number of eggs laid per day by young females and have made no attempt to determine the total number of eggs laid or the length of the oviposition period. Inasmuch as the oviposition period may last for more than a year and it is almost impossible to locate the eggs in the flour, it is not surprising that more work has not been done along this line.

In the experiments made by the writer 25 pairs of each species were segregated on emergence and placed in different foods under different conditions of temperature and humidity. Small vials, lightly stoppered with cotton, were used as containers. A single pair of adults was placed in each vial and moved to another vial every day. Various methods of locating the eggs were tried, but it was found that the method, first advocated by Chapman, of counting the larvae rather than the eggs was more accurate. As approximately 90 per cent of the eggs hatched, the actual number of eggs laid is about one-ninth greater than the figures given, which concern viable eggs only.

Table 1 gives the average duration of the egg-laying period and the average number of eggs laid for each group of females used in the experiments.

TABLE 1.—*Summary of data concerning oviposition of Tribolium confusum and T. ferrugineum*

T. CONFUSUM

Temperature	Food	Females	Average oviposition period	Average eggs laid	Average eggs laid per day
		Number	*Days*	*Number*	*Number*
27° C.	Whole-wheat flour	6	214	521	2.43
	Bran	6	263	333	1.26
	Oatmeal	2	136	141	1.04
	White flour	3	325	187	.58
Room	Whole-wheat flour	7	280	744	2.66

T. FERRUGINEUM

27° C.	Whole-wheat flour	6	171	438	2.56
	Middlings	3	102	246	2.41
	Bran	3	147	235	1.60
Room	Whole-wheat flour	3	160	518	3.24
	Corn meal	3	228	500	2.19
	Middlings	2	143	302	2.11
	Oatmeal	3	245	123	.50
	White flour	2	73	19	.26

The longest oviposition period observed was that of a female of *Tribolium confusum* in whole-wheat flour at room temperature. This female laid viable eggs for 432 days. The longest period for *T. ferrugineum* was 308 days, for a female that was kept in oatmeal at room temperature. The greatest number of viable eggs laid was 976, by a female of *T. confusum* also kept in whole-wheat flour at room temperature. The greatest number of viable eggs laid by *T. ferrugineum* was 956; this individual was kept in corn meal at room temperature. The number of eggs laid per day is not large. In no case were more than 13 viable eggs laid in one day by a single female, and the average was only 2 or 3 per day. Under optimum conditions Brindley [6] records 18 eggs in one day and a much higher daily average than is indicated here.

Mating was observed rather frequently among the pairs of adults in the experiment. The writer's records show that the female may continue to lay viable eggs for as long as five months after being separated from the male.

THE EGG STAGE

The eggs are usually laid singly, directly in the flour, but occasionally they are found attached to the sides of the container. They are coated with a sticky substance which causes the flour to adhere to them. The length of the incubation period varies considerably with the external conditions. Fifty eggs of *Tribolium ferrugineum* kept in an incubator at 27° C. hatched in an average period of 5.5 days. Forty eggs kept at room temperature averaged 8.6 days. Here the temperature ranged from 18.5° to 28.5° and averaged 22°, while the humidity ranged from 22 to 43 per cent and averaged 32 per cent.

The incubation period for *Tribolium confusum* is slightly longer. Forty eggs kept in an incubator at 27° C. hatched in an average period of 6.8 days. Of these, 17 kept in continuous light averaged 6.5 days,

[6] Brindley, T. A. Op. cit.

and 23 kept in continuous darkness averaged 7 days. Forty eggs kept at room temperature required on an average 12.8 days to hatch. In this case the temperature ranged from 14.5° to 26° and averaged 21°, while the relative humidity ranged from 24 to 51 per cent and averaged 34 per cent.

THE LARVAL PERIOD

Chapman[7] and Brindley[8] found six larval instars in *Tribolium confusum*. Through continued observation the writer has determined that there is no fixed number of larval molts, but that the number ranges from 6 to 11 or more and is normally 7 or 8 instead of 6. This variation is due both to external conditions, such as food, temperature, and humidity, and to individual characteristics entirely apart from external influences.

The number of larval instars was determined by actual count of the number of times individual larvae molted before pupation. Over 100 eggs of both species of Tribolium were placed in individual containers and observed each day until the individuals emerged as adults. Varying conditions of food, temperature, and humidity were used. After each molt the exuviae could be seen in the small vial used as a container and were immediately removed and recorded.

Table 2 gives a summary of experiments to determine the number and duration of the larval instars under various conditions.

[7] Chapman, R. N. Op. cit.

[8] Brindley, T. A. Op. cit.

TABLE 2.—*Summary of data on the larval period of Tribolium confusum and of T. ferrugineum*

T. CONFUSUM

Temperature	Food	Larvae	Average duration of each larval instar [a]											Entire larval period
			First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth	Eleventh	
		Number	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
27° C.	Middlings	4	1.6	4.5	4.0	4.2	4.5	4.5	6.5	5.0(1)				31.0
	Bran	11	2.2	5.7	6.5	6.4	6.5	6.6	6.7	7.3(7)	8.0(1)			45.7
	Oatmeal	5	2.0	5.8	6.8	8.2	8.0	13.2	8.4	9.4	8.0(1)	7.0(1)		64.6
	White flour	8	2.0	4.9	7.5	7.5	12.0	16.5	14.2(5)	19.7(3)				89.0(3)

T. FERRUGINEUM

27° C.	Bran	7	2.0	4.4	4.0	4.1	4.1	6.1	7.0(4)					28.9
	Whole-wheat flour	7	1.7	4.3	4.0	4.1	4.3	4.9	6.1	7.0(1)				30.4
	Corn meal	8	2.0	4.6	5.0	4.0	4.5	6.1	7.6(5)	7.0(1)				31.9
	Middlings	7	2.0	4.7	4.3	4.0	4.3	6.0	7.0(4)	7.3(3)				32.6
	Oatmeal	7	1.9	5.6	7.9	8.9	10.6	11.1	9.5(6)	10.7(6)	8.5(2)	9.0(1)		68.2(4)
	White flour	7	2.0	5.6	5.9	9.4	18.0	21.7(3)	17.0(1)	26.0(1)	14.0(1)			87.5(2)
Room	Middlings	7	2.3	7.9	6.0	4.9	4.6	7.6	12.7(3)	14.0(1)				40.4
	Whole-wheat flour	6	2.2	8.3	6.5	4.8	4.5	7.2	11.0(5)	13.0(2)				46.8
	Bran	4	2.7	9.2	6.5	5.3	5.3	6.0	12.5	6.0(1)	11.0(1)			51.5
	Corn meal	7	2.6	10.6	8.3	6.3	7.0	8.9	10.1	10.7(6)	9.0(1)			64.9
	White flour	4	2.3	8.5	9.0	14.2	21.5	20.5	14.0	21.0(2)	20.0(1)			79.8(3)
	Oatmeal	3	2.7	10.0	12.0	11.3	12.7	12.0	8.3	8.0	9.7	11.7	15.7	114.0

[a] Numbers in parenthesis indicate number of individuals passing through any molt if less than original number.

There is considerable variation in the length of the larval period due both to the kind of food and to the temperature. Whole wheat flour, middlings, bran, and corn meal are all acceptable foods. Growth is very slow in white flour and many of the larvae die before reaching the adult stage. Under certain conditions Persian walnuts have been found to be very favorable for larval development, some of the shortest life cycles being recorded with this food. A constant temperature of 27° C. proved to be much more suitable for development than ordinary room temperatures. In Table 2 the room temperatures were those found in the laboratory at Washington, D. C., during April and May.

There is considerable individual variation but practically no overlapping of the measurements of an individual of one instar with those of the next. The following tabulation shows the average widths of the head capsules of 40 larvae of *Tribolium confusum* of the different instars:

Instar	Width (mm) of head capsule	Instar	Width (mm) of head capsule
First	0.175	Sixth	0.459
Second	.197	Seventh	.585
Third	.249	Eighth	.619
Fourth	.311	Ninth	.655
Fifth	.387		

THE PUPAL PERIOD

When ready to pupate, the mature larva comes to the surface of the food in which it has been working and, after a short prepupal period, transforms to the naked pupa, lying in or on the surface of the food without protection of any kind. The vacated pupal cells of the Mediterranean flour moth are often found to contain several Tribolium pupae.

The average duration of the pupal period was found to be as follows:

Thirty-one *T. confusum* pupae kept at 27° C. in continuous darkness emerged as adults in from 7 to 12 days, with an average of 8.74 days.

Forty-three *T. confusum* pupae kept at 27° C. in continuous light emerged as adults in from 6 to 9 days, with an average of 7.86 days.

One hundred and twelve *T. ferrugineum* pupae kept at 27° C., for the most part in continuous darkness, had a pupal period of from 6 to 9 days, with an average of 7.14 days.

Thirty-two *T. ferrugineum* pupae kept at room temperature during the early summer had a pupal period of from 5 to 14 days, with an average of 8.5 days.

It is during the pupal period only that the sexes can be distinguished. Chapman [9] gives a good illustration of the differences in the terminal segment of the abdomen. On the female there is a pair of appendages in addition to the regular terminal cerci, while the terminal segment of the male appears to have only a disklike depression on this segment.

PARASITES

The flour beetles seem to be comparatively free from parasitic enemies. Two mites, *Acarophenax tribolii* Newstead and Duval and *Pediculoides ventricosus* Newport, and a bethylid, *Rhabdepyris zeae* Waterston, have been recorded as attacking Tribolium, but none seem to be very effective in controlling these pests.

[9] Chapman, R. N. Op. cit.

SUMMARY

The flour beetles *Tribolium confusum* Duv. and *T. ferrugineum* Fab. are among the more serious pests of flour and other cereal products. They attack practically any kind of flour, meal, breakfast food, or cracked grain, many kinds of spices, and various nuts, chocolate, and raisins. They are also serious pests in insect collections.

The size of the eyes on the ventral surface of the head is the best character for distinguishing the two species.

The winter is passed in the adult state in the central and northern parts of the United States. Adults of both species may live two years or even longer.

The oviposition period of *T. confusum* may last as long as 14 months, the average being about 9 months. That of *T. ferrugineum* is slightly less. A female of either species usually lays 400 to 500 eggs during this time; in some cases nearly 1,000 eggs have been laid by a single female.

The average incubation period at 27° C. is 6.8 days for *T. confusum* and 5.5 days for *T. ferrugineum*.

The number of larval instars ranges from 6 to 11, with an average of 7 or 8. The larval period at 27° C. ranges from 27 to 90 days according to the food. It is slightly longer for *T. confusum* than for *T. ferrugineum*. Whole-wheat flour, middlings, bran, corn meal, oatmeal, and white flour, arranged in the order of their acceptability, are the foods used in the experiments. Measurements of the head capsule in larvae of *T. confusum* are given.

The pupal period at 27° C. averages 8.2 days for *T. confusum* and 7.1 days for *T. ferrugineum*. Lower temperatures lengthened all stages considerably.

Enemies of the flour beetles include two mites and a bethylid.