(Papers read by title)

STUDIES ON THE LIFE-HISTORY OF TWO KANSAS SCARABÆIDÆ (COLEOP.)¹

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INTRODUCTION

The study of the two species under consideration, *Cyclocephala villosa* Burm. and *Anomala binotata* Gyll., is a continuation of the life-history investigations of Kansas white grubs. The synonymical status of *Cyclocephala villosa* Burm. is in question because of its similarity to *Cyclocephala immaculata* Oliv. In a large series of specimens, intermediate forms show a gradation from one species to the other. Horn (1871, p. 337) separated *C. villosa* from the synonymy of *Melolontha angularis* Knoch where it had been previously placed. If *C. immaculata* and *C. villosa* are found to be synonymous, *immaculata* should take precedence because of priority. However, the writer chooses to call the species *villosa*² on the authority of Swenk (1911, p. 285) who states that *villosa* is the most abundant species in Nebraska, an adjoining state.

With *Anomala binotata* Gyll., three species, *unifasciata* Say, *marginella* Lec., and *luteipennis* Lec., have been united by Horn (1884, p. 164), the latter being a variety with the elytra not as rough, more shiny and without the usual spots.

CYCLOCEPHALA VILLOSA Burm.

GENERAL CONSIDERATIONS.—The genus *Cyclocephala* contains some of our common and most injurious white grubs. Forbes (1891b, p. 40) reports the grubs of *C. immaculata* infesting grass-land, corn on sod, roots of corn, and young oats. Titus (1905, p. 14) found them at the roots of grass and sugar-cane stubble, and Riley (1870, p. 307) recorded them in strawberry beds. Davis (1916, p. 264) states: "*Cyclocephala immaculata* is frequently found in compost heaps and in cultivated fields, and may obtain its full growth on decaying matter alone or may become a serious field pest, damaging crops similar to those attacked by *Lachnosterna* grubs." Under the name *C. villosa*,

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² Specimens sent to J. J. Davis were determined as *Cyclocephala villosa* Burm.

Swenk (1913, pp. 86-87) reports the larvæ doing severe damage to winter wheat in Nebraska. He says: "The same condition was common in many fields in the southeastern part of the country, namely, that the plants had commenced dying about the first of September and in the next month had died out completely or at least had only a scattered sickly stand remaining. The soil in these fields was fairly alive with the *Cyclocephala* larvæ. Over fifty were turned out in a space less than two feet square and not all of them were secured." The writer has taken the grubs in corn, wheat, and oat fields, in grass of lawns, and sod of orchard and pasture land. Meager accounts are found in the literature of the life-history of *C. immaculata*. The following observations on *C. villosa* were made in Kansas during the past two seasons:

THE EGG.—The eggs are pearly white and nearly round, being slightly longer than wide. When freshly laid, they are about 1.2 mm. wide and 1.7 mm. long. They continue to increase in size as development proceeds, but gradually lose their oval shape until a nearly round form is assumed, at which time they are about 2.1 mm. in diameter. An average measurement of thirty eggs, chosen at random from eggs of various stages of growth, was found to be 1.7 mm. wide and 1.95 mm. long. Eggs are laid in the ground, generally in small clumps of soil. The exact number of eggs laid by an individual female has not been definitely determined. Three females, mated in rearing cages, afterwards laid 21, 16, and 10 eggs apiece. In each case, these females had been collected at lights and may have mated and laid eggs previously. Table I shows the number and time of egg laying by these individuals, and the interval between mating and oviposition.

TABLE I—OVIPOSITION RECORD

No.	Date Mated	Number of Eggs Laid							Number of Days between Mating and Oviposition
		July 18	July 21	July 24	July 29	Aug. 3	Aug. 5	Total	
1	July 5	..	6	4	..	..	..	10	16
2	July 12	..	8	3	5	..	..	16	9
3	July 12	3	2	..	4	10	2	21	6

In life-history cages, egg laying by females collected at lights began, in 1916, on July 3, and, in 1917, on July 11. In each instance, the period of oviposition extended over 31 and 44 days, respectively. Individuals becoming adults after July 20, 1917, began to lay eggs August 1, 1917. Table II shows the variation in the length of the egg stage for the two seasons.

THE LARVA.—Previous to hatching, the body segments and the brown mandibles of the young larva can be discerned through the

TABLE II.—INCUBATION PERIOD

Date	No. Eggs Hatching	Minimum Days	Maximum Days	Average Days
1916	51	9	23	13
1917	56	13	25	18

shell of the egg. When hatched, the grub is about 2 mm. long and, except for the mandibles, is entirely white. In a few hours the entire head begins to darken until it has assumed its final brownish color. The grubs when full grown are about 23 mm. long and 6 mm. through their widest part, and are creamy white in color. In their characteristic doubled-over position, they appear about one-half as long or about 12 mm.

The grubs of this genus are distinguished from those of *Lachnosterna* by the absence of the median longitudinal double row of mesad pointing spines on the last abdominal segment of *Lachnosterna* and by a transverse anal slit which in *Lachnosterna* is V-shaped. According to Davis (1916, p. 266) the *Cyclocephala* grubs resemble those of *Cotalpa*, with which they are more apt to be confused.

As the time of pupation approaches, the grubs shed the meconial mass in their alimentary tract and appear to shrivel up somewhat, cease feeding, and become generally inactive, forming the prepupal stage. Table III gives the length of the complete larval stage as it occurs in Kansas.

TABLE III.—DEVELOPMENT OF GRUBS FROM HATCHING TO PUPATION

Serial No.	Hatched	Became Prepupa	Pupated	Length of Prepupal Stage (days)	Complete Time of development (days)
	1916	1917	1917		
1895	July 15	June 23	June 30	7	350
1896	July 15	June 26	July 1	5	351
1898	July 16	July 6	July 12	6	361
1899	July 16	June 28	July 5	7	354
1902	July 16	June 27	July 5	8	354
1903	July 17	July 10	July 16	6	364
2246	July 22	July 5	July 11	6	354
2247	July 22	June 28	July 5	7	348
2356	July 23	June 26	July 5	9	347
2361	July 24	June 26	July 1	5	342
2945	July 27	June 23	July 1	8	339
3036	Aug. 1	July 1	July 8	7	341
3038	Aug. 1	June 26	July 5	9	338
3040	Aug. 2	June 30	July 7	7	339
3041	Aug. 2	June 26	July 3	7	335
3042	Aug. 2	July 7	July 13	6	345
3083	Aug. 2	July 9	July 16	7	348
				Average 6	347

The average time of complete development for 17 individuals was 347 days, with a minimum of 335 days and a maximum of 364 days. The prepupal stage has an average length of 6 days, with a minimum

of 5 days and a maximum of 9 days. In 1916, the first larvæ hatched July 15 and, in 1917, July 24. The winter is passed as a larva and the following summer the grubs transform to pupæ. Grubs were fed from the time of hatching to the prepupal stage on germinating grains of wheat, except during the winter when they were in a dormant condition. The larvæ were found infesting corn, wheat, and oat fields, as well as sod of lawns, orchards and pastures.

THE PUPA.—The pupa is about 17 mm. long and 8 mm. wide. When freshly transformed, it is creamy white with a faint trace of brown on the legs, wings, head, thorax, and tip of abdomen. Gradually, the pupa darkens to a reddish brown. It lies, as a rule, in the old larval moult which splits at the time of pupation from the epicranial suture backwards over the dorsum of the grub.

In 1916, pupation began in soil cages on May 27 and continued until the middle of July. In 1917, pupation did not begin until June 30, and lasted until August 6. Pupæ were collected in the fields during late June, checking closely with the time of pupation in life-history cages. Table IV gives the length of the pupal period of 13 individuals reared from eggs.

TABLE IV—LENGTH OF PUPAL STAGE

Serial No.	Pupated	Became Adult	Length of Stage	Sex
1895	1917 June 30	1917 July 21	21	♂
1896	July 1	July 21	20	
1899	July 5	July 23	18	
1902	July 5	July 22	17	
2246	July 11	July 27	16	
2356	July 5	July 21	16	
2381	July 1	July 20	19	
3036	July 8	July 26	18	
3038	July 5	July 23	18	
3040	July 7	July 25	18	
3041	July 3	July 22	19	
3042	July 13	July 28	15	
3083	July 16	Aug. 2	17	
			Average 17	

The average time of development was 17 days, with a minimum of 15 days and a maximum of 21 days. The average of 33 other individuals reared from grubs collected in the fields was 16 days, with a minimum of 8 days and a maximum of 24 days.

THE ADULT.—Newly emerged adults have a pale creamy tinge which soon darkens to a normal dull yellow color. They are from 11 to 14 mm. long and 6.8 mm. wide and have the surface sparsely covered with fine hairs. The elytra and thorax are somewhat finely punctuate. Males are distinguished from the females by an enlargement of the fifth joint of the anterior tarsi and a somewhat longer antennal club.

The adults fly at night and are strongly attracted to lights. The

first appearance of the beetles at lights was June 12, in 1916, and June 29, 1917. In the first instance, a maximum flight was reached near the last of June, while, in 1917, the maximum was attained near the middle of July. The flight during both years extended to near the middle of August. Mating takes place in the daytime and in life-history cages was several times observed on the surface of the soil. The male uses the enlarged tarsal joint to clasp the female on the edge of the elytra behind the legs. Unlike the position assumed in *Lachnosterna*, the females of *villosa* do not remain motionless but will move about carrying the males on their backs. If disturbed while mating, they hasten to burrow into the soil. The food of the adults has not been definitely determined. None were taken on trees among daily collections made last summer. A few individuals were collected at night on the common pigweed (*Amaranthus* sp.) upon which they were apparently feeding.

To summarize, the life cycle of *C. villosa* is one year. Adults appear at lights in June, July, and early August. Eggs, which are laid in soil, hatch after 9 to 25 days. The larva passes the winter in hibernation. The larval stage was found to average 347 days. The pupal stage varied in length from 8 to 24 days.

ANOMALA BINOTATA Gyll.

GENERAL CONSIDERATIONS.—In the adult stage, this species is known as a leaf-eater. In the grub stage, its depredations are not so familiar. However, they are thought to feed on living rootlets (Davis, 1916, p. 265) and may often occur in sufficiently large numbers to damage crops. Webster (1891, pp. 345-346) records adults feeding on strawberry blossoms and later (1892, p. 197) on blossoms of blackberries in large numbers. He also cites an instance of a fly (*Laphria tergissa*) capturing and flying away with a beetle of this species in its grasp. Luger (1899, p. 175) lists *binotata* in his work on insects injurious to fruit-producing plants. Johnson (1900, p. 84) records three instances of the beetle feeding on foliage of pear and apple trees. Chittenden (1902, p. 100) states that *binotata* is one of the vine-chafers injurious to grapes, strawberries, and locust, and later (1903, p. 732) adds that they were injurious to roses in 1902. Pettit (1908, p. 122) recommends spraying with arsenites after having found the beetles injuring young apple foliage. Hart (1911, pp. 73-75) records more observations on this species than any American writer. He noted from 30 fields in which pupæ and adults were found, 29 of them had been in oats. A note before the writer shows that out of 126 beetles maturing from larvæ collected in fields, 115 individuals were taken in oat fields. The remainder were from wheat and corn land. Felt

(1913, p. 106) found the beetles in strawberries being shipped into New York, and Swenk (1913, p. 87) mentions the insect as a minor wheat pest in Nebraska where he found them in large swarms alighting on wheat and trees and shrubs of all kinds.

THE EGG.—The eggs of this species are pearly white and have a distinct shining luster. They are slightly longer than wide, being somewhat oval in appearance. When freshly laid, they are about 1.6 mm. long and 1.2 mm. wide. As development progresses, the eggs increase in size until they attain an average size of about 2.5 mm. long and 2.0 mm. wide. Oviposition occurs during the early part of June, the eggs being laid in the soil. A number of eggs found in life-history cages on June 15, but which had been laid some few days previous, hatched from 7 to 11 days later. Shortly before hatching, the brown tips of the mandibles and faint outlines of the body of the embryo larva can be seen through the egg shell.

THE LARVA.—The young larvæ upon hatching are about 2.5 mm. long and are entirely white except for the tips of the mandibles which are brown. When full-grown, they are about 20 mm. long and 7 mm. wide at the thorax. They taper toward the posterior end and are creamy white with a pale yellow, finely reticulated head. The spiracles are likewise pale yellow in color. The posterior ventral segment bears a triangular patch of short hairs with a centrally located longitudinal double row of prostrate spines. Dorsally, this particular segment bears longer and much finer hairs. The other dorsal segments are covered with short, brownish, bristle-like hairs interspersed with finer and longer hairs. Concerning these grubs Davis (1916, p. 266) writes: "The grubs of *Anomala*, *Listochelus*, and *Phytalis* are very close to those of *Lachnosterna* and we are at present unable to satisfactorily distinguish between grubs of these four genera except by direct comparison, but no doubt substantial characters will be found when we have obtained a sufficient number of grubs of the first three mentioned genera." The first larvæ hatched on June 22. The length of the larval stage, inclusive of the semi-pupal stage, was found to average 83 days, with a minimum of 80 days and a maximum of 86 days.

When near pupation the grubs shed their meconium and appear to become shorter and broader. This is the initiation of the so-called prepupal stage. Faint traces of black waste matter are still to be seen in the alimentary tract. The posterior abdominal segment appears much depressed and greatly wrinkled. This condition is likewise found to a lesser degree in the penultimate segment. The prepupa lies coiled on its back and when disturbed wriggles about on its side, alternately straightening and coiling the body. The length of the prepupal stage varies from 6 to 10 days with an average of 7 days.

Grubs were reared from the egg to prepupa in common salve boxes by feeding them germinating grains of wheat, the roots of which apparently offered sufficient sustenance. Larvæ were collected abundantly in oat land and doubtlessly fed upon the roots of oats. They were also found in wheat and corn fields but not in such large numbers.

THE PUPA.—The transformation from the larva to the pupa leaves the newly formed individual, as a rule, within the old larval moult from which it has just emerged. At first it is creamy white but soon changes to a dark yellow until just before the end of the period the head, thorax, wings, legs, and last abdominal segments assume a still darker hue. The pupæ are from 14 to 16 mm. long and from 6 to 7 mm. wide. Movement results from raising and lowering the abdomen. They are easily distinguished from the pupæ of *Lachnosterna* by the absence of the long protuberances at the tip of the abdomen and their much smaller size. In life-history cages, pupæ were collected as early as August 24, but the majority of the individuals were found soon after September 1 and continued to be present throughout the entire month. Pupæ collected in the fields during the month of September served as a check on the cage observations. The average length of the pupal stage for 126 individuals was 16 days, with a minimum of 13 days and a maximum of 22 days.

THE ADULT.—Horn (1884, p. 158) describes *Anomala binotata* as follows:

"Form moderately robust, piceous; thorax dark bronze, shining; elytra yellowish testaceous, the suture and margin narrowly bordered, and usually on each side two piceous spots. Head rather densely punctured. Clypeus scarcely broader at base, the margin narrowly reflexed. Thorax narrowed in front; sides arcuate, disc convex, sparingly punctured, toward the sides more densely and with a larger foveate puncture. Scutellum bronzed. Elytra, with stria, of coarse punctures, somewhat confused in the sutural region, three of the intervals very slightly more elevated. Pygidium rather densely rugulose, and with short hairs. Body beneath coarsely, not densely punctured, pectus, coxal plates and sides of abdomen hairy. Length .40-.44 inch; 10-11 mm.

"The claw joint of the anterior tarsi is distinctly toothed beneath. The anterior claw is flexed at base, the tip cleft, the upper portion quite slender, and a little shorter than the lower. The anterior claw of the middle tarsus is cleft at tip, the two portions nearly equal."

The adults of this species are notably injurious to the blossoms and foliage of fruit-producing plants. They fly by day, often at dusk and infrequently at night, being attracted to lights. They begin to mature by September 6 but remain in their pupal cells until the following spring. According to Hart (1911, p. 73) mating occurs on the surface of the soil where the females attract the males, after which the females enter vertical burrows in the soil presumably to deposit eggs. Males can be distinguished from the females by the antennal club which is

longer than the funiculus in the male and about equal in length to the funiculus in the female.

Birds are known to feed on the adults of this species. McAtee (1908, pp. 26 and 44) reports cardinals and rose-breasted grosbeaks feeding on *Anomala binotata* and Beal (1912, pp. 17 and 54) cites the kingbird and yellow-bellied fly catcher. The writer found one specimen in the stomach of a toad taken in a corn field in May.

To summarize, the adults of *Anomala binotata* are injurious to fruit-producing plants and the grubs are minor pests of corn, wheat and oats. The winter is passed as an adult. Eggs are laid in the spring and soon hatch, producing larvæ whose average time of development was found to be 83 days. The pupal stage lasts on an average 16 days. The adults transform in the fall and remain in their pupal cells until the following spring, thus completing a one-year life cycle.

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NOTES ON THREE SPECIES OF APPLE LEAF-HOPPERS

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While connected with the New York (Geneva) Agricultural Experiment Station the writer had opportunity to make observations on the life-histories and habits of three important leaf-hoppers attacking apple.

The three species of leaf-hoppers, *Empoasca mali* LeBaron, *Empoasca unicolor* Gillette, and *Empoa rosæ* Linnæus, which are discussed in this paper, are quite similar in general appearance. Especially is this true of the two species of *Empoasca* and the nymphs of all three species.

DISTINGUISHING CHARACTERISTICS

The nymph of *Empoa rosæ* may be distinguished by its white color, as well as by the contour of the anterior margin of the vertex. The

Fig. 5. Heads of leaf-hopper nymphs, showing comparative structures and sizes; a, *Empoa rosæ*, b, *Empoasca mali*, c, *Empoasca unicolor*.

nymphs of both the other species are green, and by this character may be separated from the preceding form with little difficulty. The two *Empoasca* nymphs are very closely similar, and are very easily confused. The nymph of *Empoasca unicolor* differs most distinctly from that of *E. mali* in the contour of the anterior margin of the vertex and there is also a difference in the coloration of the two species.

The adult of *Empoa rosæ*, like the nymph, is recognized by its white